3 Fwd_ Review process for sea level_storm surge p....pdf

From:	Beavers, Rebecca
To:	John Dennis
Cc:	Cat Hawkins Hoffman; Patrick Gonzalez
Subject:	Fwd: Review process for sea level/storm surge project
Date:	Wednesday, August 03, 2016 10:44:28 AM

Hi John:

This sea level/storm surge projections dataset is somewhat unique for NPS & we are at the point we need to establish the internal NPS review process. Can we set a time to discuss?

Some background information is in the following email from PI- Dr. Maria Caffrey. Patrick Gonzalez has been the WASO contact on this 3 year NRFS project.

Thank you!

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/adaptation.htm

---------- Forwarded message ----------
From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
Date: Wed, Aug 3, 2016 at 10:22 AM
Subject: Review process for sea level/storm surge project
To: Rebecca Beavers <rebecca_beavers@nps.gov>

Rebecca,

I'm currently finishing up my draft report for my sea level and storm surge project and am starting to look ahead to how this should all be reviewed. I expect that the findings for this project have the potential to impact a lot of management decisions for the 118 coastal park units involved in this study. I've already received a lot questions and requests to share my data from folks working on other NPS projects for things like:

- Foundation documents
- State of the parks reports
- The Western Carolina project
- DAB projects

I'm also scheduled to present on this in the CCRP webinar series later in the fall. I anticipate that I will have the first draft of the report to you by Friday (8/5). The GIS data is all ready to review right now. Doug Wilder made a online viewer for reviewers: (b) (5) [redacted]

The individual GIS files can also be accessed through the NPS FTP site that I will send along to you in another email (the FTP site won't let me attach a link here).

How would you like to proceed with reviewing everything?

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

8 Re_ First draft is done!.pdf

From:	Beavers, Rebecca
To:	Babson, Amanda
Cc:	Caffrey, Maria
Subject:	Re: First draft is done!
Date:	Friday, August 19, 2016 7:39:23 AM

Hi Amanda:

After I & (& you, as well, if you have the time) review this report for typos & initial changes- the science team will get first review of this document. Your request for Franks Hays should be be a sample application for this report and related communication products.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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On Fri, Aug 19, 2016 at 7:34 AM, Babson, Amanda <amanda_babson@nps.gov> wrote:

> Thanks! Looks like you've done exactly what I was looking for (Fig. 4 and then the p. 14 section). I look forward to looking deeper.
> Amanda
>
> On Thu, Aug 18, 2016 at 4:38 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Before you start doing extra work, I am linking you to draft products that maria would also provide to you if she were in the office.
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>> http://www.nps.gov/subjects/climatechange/adaptation.htm
>>
>> ---------- Forwarded message ----------
>> From: **Maria Caffrey** <maria.caffrey@colorado.edu>
>> Date: Fri, Aug 5, 2016 at 7:59 PM
>> Subject: First draft is done!
>> To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Yay!!!

You can access it here: https://www.dropbox.com/sh/dwbd3uudowu4io1/AADjesLINuPviKbzRo3VcXa9a?dl=0

It's the file called "Sea Level Change Report Draft_August 2016.docx"

I'm sure it still has a bunch of typos all over it (I'm kinda delirious right now from writing it at the moment), so I will go back and check it for typos when I get back, but you're welcome to check it out and let me know if I'm missing anything significant.

See you in a few weeks.

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Boulder, CO 80309

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9 initial report review.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria; Caffrey, Maria
Subject:	initial report review
Date:	Tuesday, August 23, 2016 11:28:55 PM

Welcome back. It's great to see this info coming together.

My initial comments are uploaded to: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\report

We can discuss on Thursday or Friday.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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11 Sea level and storm surge report.pdf

From:	Caffrey, Maria
To:	Amanda Babson; Patrick Gonzalez
Cc:	Rebecca Beavers
Subject:	Sea level and storm surge report
Date:	Friday, September 02, 2016 3:05:20 PM
Attachments:	Sea Level Change Report Draft for Review_September 2016.docx Reviewer comments_insert last name here.xlsx

---

Amanda, Patrick,

Here is the draft report. I have included an excel spreadsheet for your comments so I don't have to try and combine four versions of track changes from everyone (I'll be emailing Rob and Steve for their comments separately). Please try to get your reviews back to me by 9/16/16.

Have a great labor day weekend!

Maria Caffrey, PhD

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NPS Geologic Resources Division http://nature.nps.gov/geology
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11 1 Attachment Sea Level Change Report Draft for Review_Sept.pdf

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Change in the National Park Service: Sea Level and Storm Surge Projections for 118 National Park Service Units

Natural Resource Data Series NPS/XXXX/NRDS—2016/XXX

ON THIS PAGE
Driftwood washed up on the shoreline of Redwood National Park.
Photograph courtesy of Maria Caffrey, University of Colorado.

ON THE COVER
Fort Point National Historic Site and the Golden Gate Bridge, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

Sea-Level Change in the National Park Service

Sea Level and Storm Surge Projections for 118 National Park Service Units

Natural Resource Data Series NPS/XXXX/NRDS—2016/XXX

Maria A. Caffrey[1], Rebecca L. Beavers[2], Cat Hawkins-Hoffman[3]

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NT: More authors will be added. Pending their approval.

September 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Climate Change Response Program website (http://nps.gov/orgs/ccrp/index.htm), and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

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NPS XXXXXX, September 2016

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Photo 1. Point Reyes National Seashore. Photo credit: Maria Caffrey.

Abstract/Executive Summary

Photo 2. Basement flooding in the visitor center at Rosie the Riveter WWII Home Front National Historical Park. This photograph was taken approximately 12 years after the establishment of the park. Photo credit: Maria Caffrey.

Changing relative sea levels and potential increasing storm surges due to anthropogenic climate change present many challenges to land managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service to combine, compare, and contrast different sea-level change projections from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios using National Oceanic and Atmospheric Administration (NOAA) storm surge models. This report covers how these models are used to protect coastal units that have recently recovered from storm damage, such as the Statue of Liberty in New York. Both the IPCC and NOAA have established their own climate change scenarios, however this research will be the first to combine these results to show how storm surge could propagate in the future using bathtub models. These scenarios result in significantly different inundation outcomes. In addition to using multiple sea level and storm surge scenarios; multiple time horizons (2030, 2050 and 2100) were studied. The National Capital Region is expected to experience the highest average rate of sea level change by 2100, although the coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is also expected to experience the highest storm surges based on historical data and NOAA storm surge models.

These results have far reaching implications for adaptation and mitigation strategies for lands managed by the National park Service.

Acknowledgments

This project was funded using funds from the NPS Servicewide Comprehensive Call (FY2013–2015) and was augmented by funds from the Natural Resource Stewardship and Science Directorate's Geologic Resources Division and Climate Change Response Program. We would like to thank the members of the communication advisory team (Lynda Bell, Ann Gallagher, Will Elder, Janet Cakir, Stanton Enonmoto, Matt Holly, Shawn Norton, Larry Perez, and Ryan Stubblebine) and science advisory team (Amanda Babson, Patrick Gonzalez, Steve Nerem, and Rob Thieler) for their time and input into this project.

We would also like to thank the Susan Teel and Caroline Rohe at Gulf Islands National Seashore for their assistance designing two waysides. Likewise, we also thank Julie Whitbeck, Aleutia Scott, Kristy Wallisch, and Stacy Meyers for helping design, review, and install a wayside at Jean Lafitte National Historical Park and Preserve. Elizabeth Rogers and Kathy Krause helped design a wayside for Fire Island National Seashore.

We would also like to thank xxx for their assistance in editing and reviewing this document.

List of Terms

The following list of terms are defined here as they will be used in this report.

Flooding: The temporary impoundment of water on the land.
Inundation: The permanent impoundment of water on what had once been dry land.
Isostatic rebound: A change in land level caused by a change in loadings on the Earth's crust. The most common cause of isostatic rebound is the loading of continental ice during the Last Glacial Maximum in North America. The North American land surface is still moving after the melting of this continental ice in an effort to return to equilibrium with its original pre-loading state.
National Park Service unit: Property owned or managed by the National Park Service.
Relative sea level: Where the water level can be found compared to some reference point on land. This term is most frequently used in discussion of *changes* in relative sea level. A change in relative sea level could be caused by a change in water volume or a change in land level (or some combination of these two factors).
Sea level: The average level of the seawater surface.
Sea-level change: This term is frequently used in reference to *relative* sea-level change. This is the product of two main factors, 1) an increase in the volume of ocean water, and 2) a change in land level. These two factors can be broken down further into other drivers that will be discussed in greater detail in other sections. This term is sometimes mistakenly confused with the term *sea-level rise*.
Sea-level rise: An increase in sea level. This is the result of an increase in ocean water volume caused principally by melting continental ice and thermal expansion. This term is not to be confused with increasing *relative* sea level, which can also be caused by decreasing land levels.

Introduction

Global sea levels are rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), the onset of anthropogenic climate change has significantly increased the rate of global sea-level rise (Grinsted et al. 2009, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). As human activities release carbon dioxide (CO_2) into the atmosphere we can expect the Earth's atmosphere to continue to warm over the next century (IPCC 2013, Mearns et al. 2013, Melilo et al. 2014). As the atmosphere warms we anticipate sea levels to also rise; however, the rate of warming depends on a number of factors that have been categorized by the Intergovernmental Panel on Climate Change (IPCC) into four different representative concentration pathways (RCPs; Meinshausen et al. 2011). These RCPs are newly defined climate change scenarios that were first introduced in the IPCC's most recent climate change report (IPCC 2013) and will form the basis of this report. The aim of this report is to discuss how anthropogenic climate change will impact our coastal zone via sea-level change and storm surge. As temperatures change, sea levels will rise due to a number of factors that will be discussed in greater detail; however, while sea levels are incrementally rising we can also expect periods of coastal flooding caused by coastal storms and hurricanes to exacerbate the growing problem of coastal inundation (see list of terms).

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion of damage to public and private infrastructure (Tollefson 2013). While the amount of damage from this storm might seem to be extreme, we can expect a 1/100 year storm surge to cost $2–5 billion and a 1/500 year storm surge to cost $5–11 billion (Aerts et al. 2013). Looking ahead to the future we can expect storms to become more intense (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea-level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline.

Peek et al. (2015) estimated that the cost of sea-level rise in 40 National Park Service units could be in excess of $40 billion if these units were exposed to one-meter of sea-level rise. The aim of this report is to examine 118 coastal park units to; 1) quantify precisely how much sea-level rise they can expect over the next century based on the latest IPCC (2013) models, and 2) how could storm surge generated by hurricanes could also impact these parks.

Format of This Report

This report is separated into five sections: introduction, methods, results, discussion, and conclusion. Results per park will be presented alphabetically by region. The 118 park units studied for this project cover six administrative regions: the Northeast, Southeast, National Capital, Intermountain, Pacific West, and Alaska. Funding for this project did not include projected changes in lake levels, although we recognize that interior waterways and lakes, especially the Great Lakes, are also vulnerable to climate change. Further explanation on how to access the data from this project can be found in the methods sections and accompanying appendices.

Frequently Used Terms

Definitions of the most basic terms used in this report can be found on page viii. However, some terms require some greater explanation for their use. We are following the advice of Flick et al. (2012) in differentiating between the terms *flooding* and *inundation*. While many choose to use these terms interchangeably, we use the term flooding to describe the temporary placement of water on land. This is usually the result of storm activity and other short-lived events, such as periodic tidal action, and will therefore be used here in reference to the effects of a storm surge on land. Inundation is used to refer to the gradual permanent submergence of land that will occur due to sea-level rise.

Furthermore, the terms sea-level rise and sea-level change are also used differently. Sea-level rise refers only to rising water levels resulting from an increase in global ocean volumes. In most parts of the United States this increase in water volume will lead to increasing relative sea levels. However, in some parts of the country relative sea level is *decreasing* due to isostatic rebound. Figure 1 shows current sea level trends based on tide gauge records for United States that span at least 30-years of data.

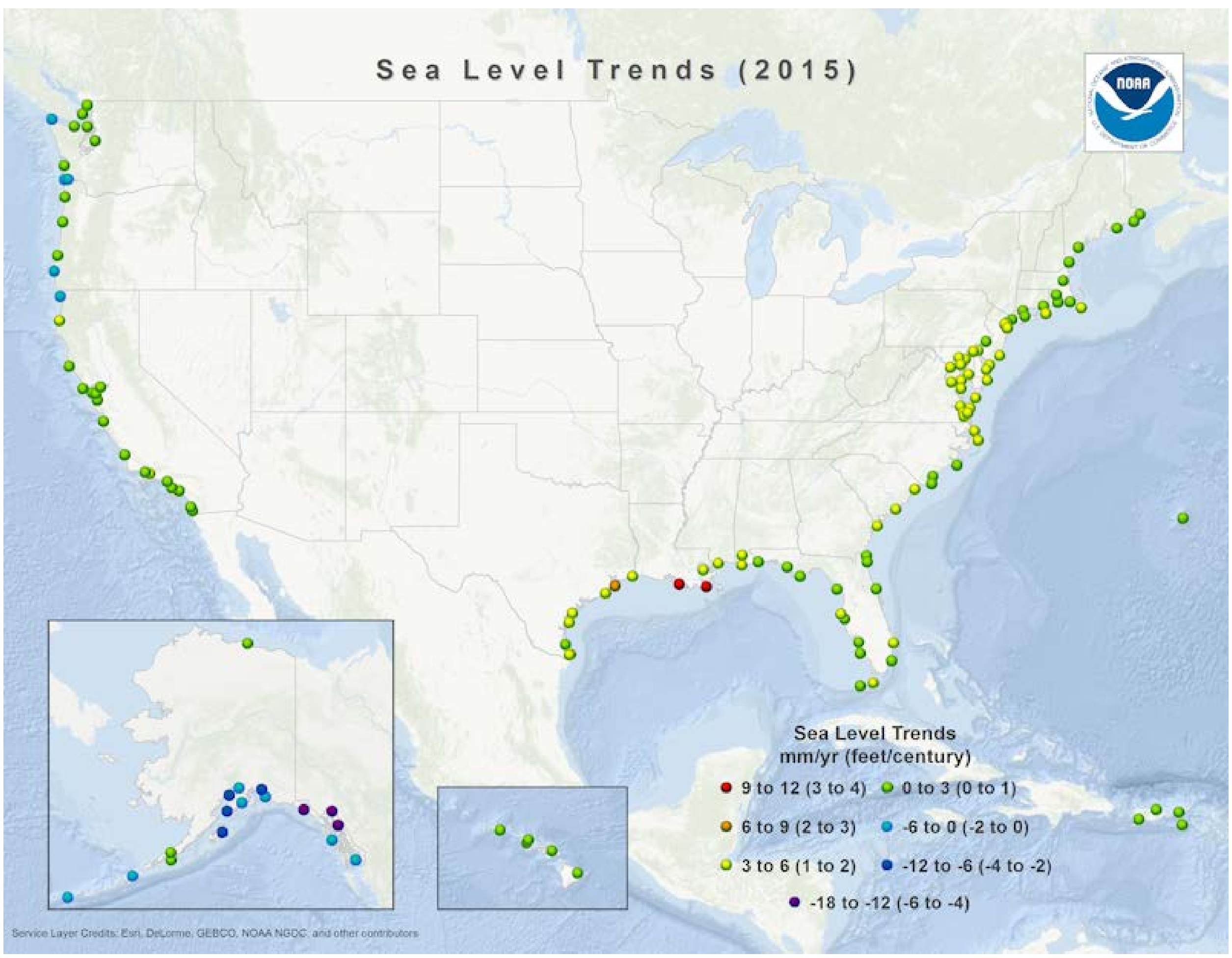


Figure 1. Sea level trends for the United States based on Zervas (2009). Trends are calculated for 2015 relative to global mean sea level. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change.

Yellow to red dots are experiencing greater than the global average (primarily driven by regional subsidence) and blue to purple dots are stations that are experiencing less than the global average (due to isostatic rebound or other tectonically-driven factors). Source: https://tidesandcurrents.noaa.gov/sltrends/slrmap.htm

The Southeast Region of Alaska is experiencing a decrease in relative sea level. Alaska's crust is still rebounding following the melting of large volumes of ice that had been stored on land for centuries to millennia. Alaska is also very tectonically complex with a large number of faults that contribute to this crustal motion. Even though the volume of water in this region is increasing, the rate of sea-level rise is not enough to keep up with the rate of land-based movement resulting in a decrease in relative sea level. Whether the rate of land-based motion will continue throughout this century will be discussed in further detail in other chapters; however, this is why we use the term *sea-level change* as a more inclusive term that better reflects regions that will experience a decrease in relative sea level (at least in the early part of this century) as well as those that will have to deal with increasing relative sea levels.

Methods

This report reflects the work of a three-year project that began in 2013. 118 National Park Service units were selected after consultation with regional managers who identified which units they considered to be vulnerable to sea level change and/or storm surge (Appendix C). Funding for this project required the following:

1. Calculate rates of sea level change over multiple time horizons for each park unit.
2. Estimate potential exposure to storm surge using the National Oceanographic and Atmospheric Administration (NOAA) Sea, Lakes, and Overland Surge from Hurricanes (SLOSH) Model.
3. Create waysides communicating about the impact of climate change in the coastal zone for three National Park Service units.

A wayside is an exhibit designed to be installed outside for visitors to find out more information about a particular subject (https://www.nps.gov/hfc/products/waysides/). Four waysides were created for three National Park Service units: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore. These parks were selected after consulting with regional managers who recommended units that they felt had a need for a communication product and had communication staff who were available to work with staff at the University of Colorado in the design. The finished wayside designs are in Appendix D. Each wayside design is different because each wayside was customized to reflect the messaging and/or themes of each unit.

Sea-Level Rise Data

Sea-level rise is the product of a number of factors at work. As humans activities release more CO_2 and other greenhouse gases into the atmosphere, mean global temperatures will increase (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). Rising global temperatures cause ice located on land and in the sea to melt. While the melting of sea ice is problematic from an oceanographic perspective (primarily because it will alter water temperatures and salinity), it is the melting of ice that is currently stored on land that will have the greatest impact on global sea levels.

Melting sea ice is not a cause of sea-level rise. Water level does not change when sea ice (ice wholly contained within water and not supported by land) melts. The phase shift of water from ice to liquid water does not displace an additional volume of water.

However, the melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise. As ocean waters warm the density of these waters will also change causing thermal expansion. Thermal expansion is responsible for approximately 39% of sea level rise while melting ice contributed a further 47% from 1993 to 2010 (IPCC 2013). Other factors that also need to be considered are listed in Table 1.

Table 1. Observed global mean sea level budget (mm/yr) over multiple time horizons (IPCC 2013).

Source	1901–1990	1971–2010	1993–2010
Thermal expansion	—	0.08	1.1
Glaciers except in Greenland and Antarctica[a]	0.54	0.62	0.76
Glaciers in Greenland	0.15	0.06	0.10[b]
Greenland ice sheet	—	—	0.33
Antarctic ice sheet	—	—	0.27
Land water storage	-0.11	0.12	0.38
Total of contributions	**—**	**—**	**2.8**
Observed	**1.5**	**2.0**	**3.2**
Residual[c]	0.5	0.2	0.4

[a]Data until 2009, not 2010.
[b]This is not included in the total because these numbers have already been included in the Greenland ice sheet.
[c]This is calculated as observed global mean sea level rise – modeled glaciers – observed land water storage. See table 13.1 in IPCC (2013) for more details.

Sea level rise projections for this project follow a *process-based model* approach. This process-based approach generates data based on the underlying processes that are responsible for sea level rise. This is in contrast to *semi-empirical* models that use observations in combination with any number of other variables or theoretical considerations, which in some cases include expert elicitations (surveys or interviews with other professionals to gauge their opinion) (Rahmstorf 2010, Orlic and Pasaric 2013). The IPCC cites a number of semi-empirical projections in their most recent report (IPCC 2013), but they choose to use coupled atmosphere-ocean general circulation models (AOGCM). AOGCMs are able to simulate the processes of change rather than relying on statistical inferences that make up the semi-empirical approach. AOGCMs are considered a process-based technique, although some variables may have been derived using semi-empirical methods (IPCC 2013).

Local sea-level rise numbers for 2050 and 2100 were taken directly from the IPCC (2013) downscaled AOGCM regional climate model (RCM). Many park units also require estimates for shorter time horizons that fit more closely with the expected lifetime of various projects, so sea level rise projections for 2030 were calculated using IPCC RCM data for each sea level rise driver shown in Table 2 downscaled to 2030 for each RCP. All projections results are relative to the period 1986–2005 (see Appendix C for further discussion).

Table 2. Median values for projections of global mean sea level and its contributions in meters for 2100 (IPCC 2013).

	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Thermal expansion	0.15	0.20	0.22	0.32
Glaciers	0.11	0.13	0.14	0.18
Greenland ice sheet surface mass balance[a]	0.03	0.05	0.05	0.10
Antarctic ice sheet surface mass balance	-0.02	-0.03	-0.03	-0.05
Greenland ice sheet rapid dynamics	0.04	0.04	0.04	0.05
Antarctic ice sheet rapid dynamics	0.08	0.08	0.08	0.08
Land water storage	0.05	0.05	0.05	0.05
Sea level rise	0.44	0.53	0.55	0.74
Greenland ice sheet	0.08	0.09	0.09	0.15
Antarctic ice sheet	0.06	0.05	0.05	0.04
Ice-sheet rapid dynamics	0.12	0.12	0.12	0.14

[a]Changes in ice mass derived through direct observation and satellite data.

The standard error (σ) for each site estimate was not calculated because it was beyond the scope of this project. However, it can be calculated using the following equation and data available from the IPCC (2013 supplementary material):

Eq 1. $$\sigma_{tot}^2 = \left(\sigma_{steric/dyn} + \sigma_{smb\_a} + \sigma_{smb\_g}\right)^2 + \sigma_{glac}^2 + \sigma_{IBE}^2 + \sigma_{GIA}^2 + \sigma_{LW}^2 + \sigma_{dyn\_a}^2 + \sigma_{dyn\_g}^2$$

Where: *steric/dyn* = the global thermal expansion uncertainty plus dynamic sea surface height; *smb_a* = the Antarctic ice sheet surface mass balance uncertainty; *smb_g* = the Greenland ice sheet surface mass balance uncertainty; glac = glacier uncertainty; *IBE* = the inverse barometer effect uncertainty; *LW* is the land water uncertainty; *dyn_a* = Antarctica ice sheet rapid dynamics uncertainty; and, *dyn_g* = Greenland ice sheet rapid dynamics uncertainty.

Initial data were exported as GeoTIFF files that could be manipulated in ArcGIS as simple bathtub models. A weighted average by shoreline was calculated for park boundaries that overlapped more than one data cell. A standard bathtub model approach was used to show the effects of sea level rise on top of mean higher high water. Areas of inundation and flooding are denoted in the maps in the blue. Additional low-lying areas that could be potentially inundated or flooded are shown in green

(Figure 2). These low-lying areas do not appear to have any inlet or other pathway for water, although they should still be considered vulnerable to exposure to either groundwater seepage or potential flooding via breaching. The lack of high-resolution DEMs and time constraints prevented us from attempting a dynamic modeling approach (see limitations below). Maps were created to illustrate inundation all park units for 2050 and 2100 under RCP4.5 and RCP8.5.

Figure 2. An example of how areas of inundation appear in ArcGIS. In this example for the Toms Cove area of Assateague National Seashore, areas of inundation (RCP4.5 2050) are shown in blue. Other low lying areas that are blocked from inundation by some impediment are shown in green.

Storm Surge Data

NOAA SLOSH data estimate potential storm surge height (NOAA 2016). The NOAA SLOSH model is comprised of the following three products (P-Surge, MEOW, and MOMs) that utilize three different modeling approaches (probabilistic, deterministic, and composite) to estimate storm surge.

P-Surge (also known as the tropical cyclone storm surge probabilities product) uses a probabilistic approach by examining past events to estimate the storm surge generated by a cyclone that is present and within 72-hours of landfall. It statistically evaluates National Hurricane Center data (calculated in part using a deterministic approach) including the official projected cyclone track and historical forecasting errors. It also incorporates astronomical tide calculations and variations in the radius of maximum wind into this estimate. These rates of motion variables are then fit to a Cartesian or polar (depending on the location) grid (Jalesnianski et al. 1992).

The Maximum Envelope of Overwash Water (MEOW) calculates flooding using past P-Surge data to create a composite estimate of the potential storm surge generated by a hypothetical storm. This product generates a worst-case scenario based on a hypothetical storm category that includes forward speed, trajectory of the storm when it strikes the coastline, and initial (mean vs. high) tide level that will also incorporate any historical uncertainty from previous landfall forecasts.

The final SLOSH product is the MOM (Maximum of MEOWs) model. MOM is a further composite approach that uses the forward speed, trajectory, and initial tide level data that is also used by MEOW to create a worst-of-the-worst scenario (or “perfect storm”). Storms are simulated for 32 regions (also known as operational basins, Figure 3) defined by NOAA. Data was imported into ArcGIS using the SLOSH display program. Maps were generated showing storm surge for all possible Saffir-Simpson hurricane categories for each site. While most sites had data for Saffir-Simpson hurricane categories 1–5, a few sites, such as Acadia National Park, were missing the highest category. NOAA did not model this scenario because it is considered extremely unlikely at a location that far north in the Atlantic Ocean.

SLOSH MOM was used to estimate potential storm surge in 79 coastal park units. Unfortunately MOM data do not exist for the remaining 39 units, so we supplemented this with data from Tebaldi et al. 2012 wherever possible. Tebaldi et al. (2012) used 55 long-term tide gauge records to calculate potential sea level and storm surge estimates. We used the current 50-year and 100-yr return level data from their paper for any parks near to a tide gauge. Unfortunately we were unable to use either Tebaldi et al. (2012) or SLOSH MOM data for the Alaskan, Guam, and American Samoa park units.

Figure 3. An example of the extent of an operational basin shown in NOAA’s SLOSH display program. The black area is the full extent of the operational basin for Chesapeake Bay.

Storm surge models were combined with the mapped sea level rise data to get a rough idea of how these regions could be exposed to flooding occurring later in the century on top of inundation. We used historical hurricane data from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010) to ascertain the highest Saffir-Simpson category hurricane to strike within 10 miles of each park unit. We then used the MOM estimate for a storm surge one category higher than anything that had struck the park historically (based data spanning 1842–2014; Appendix E, Table E3). By using one storm category higher than historical data we hoped to approximate what could happen as storms are expected to be more intense due to anthropogenic climate change in the future (Emanuel 2005, Webster et al. 2005, Mendelsohn et al. 2012). However we would recommend caution in using these combined maps for any detailed planning due to the limitations that will be discussed further in the following section of this report.

Limitations

While every effort has been made to use the best available data and techniques, all projects of this nature have limitations that should be clearly delineated to ensure that these data are interpreted correctly.

Every effort has been made to incorporate any parks, such as Harriet Tubman Underground Railroad National Monument, that were established after work began, although some maps might be missing due to lack of available boundary data in new units.

We used a bathtub modeling approach to map the extent of sea level rise and storm surge over every unit. Bathtub modeling simply simulates how high up or inland water will go under different climate scenarios. It does not take into account changes in topography or other environmental or manmade systems that will occur in response to encroaching water. While bathtub models are the most widely used technique for modeling inundation, it is also a more passive technique of simulating how sea level rise will impact a landscape (Storlazzi et al. 2013). Dynamic models could model changes in flow around buildings or estimate how topographic features such as dune systems will migrate in response to inundation and flooding; but dynamic models also vary in their methods, which can be a severe limitation if trying to standardize data for comparison and management.

Even though SLOSH MOM has the widest geographic storm surge coverage of any model in the US, storm surge data are not available for every part of the coastline. Every effort has been made by this project to bridge any gaps where SLOSH MOM does not exist. While the Tebaldi et al. (2012) data cover the California, Oregon, Washington, and southern Alaskan coastlines, it does not give any information for the northern Alaskan, American Samoan, or Guam coastlines. These coastlines are vulnerable to storm surge but we could not find data that we were satisfied were accurate enough to be included in our mapping efforts. Furthermore, combined sea level and storm surge maps are only intended as a rough guide of how flooding by storm surge on top of permanent inundation due sea level rise and should be used with caution. As more of the coastline becomes inundated we can expect coastal flooding to also change accordingly. The SLOSH model is a probabilistic approach that uses previous storms to estimate future storm surge. It cannot take into account any changes in future basin morphology that could affect the fluid dynamics and propagation of coastal flooding.

SLOSH MOM is modeled using mean sea level (0 m NAVD88) and what NOAA terms “high tide” (which is not tied to the local tidal datum, but is actually a round number based on the average high tide for the region that was modeled). Jalesnianski et al. (1992) estimate surge estimates to be accurate +/- 20%, although Glahn et al. (2009) discuss how others have found the P-Surge model to be more accurate than originally estimated. All of these things must be kept in mind when using these numbers for mapping.

Land Level Change

It is important to include changes in land level while interpreting changes in sea level. The IPCC (2013) does not include changes in relative sea level in their calculations of sea-level change. Our sea level rise results do not include how changes in land level will change over time. Land level change is an important variable when calculating relative sea level. Land levels have changed over time in response to numerous factors. Changes in various land-based loadings, such as ice sheets during the last glacial maximum, on the continents has been a significant cause of land level change in the U.S. Post-glacial isostatic rebound is the result of this pressure placed on the Earth’s crust by the ice sheets and is still causing land levels to change. Land level can also be altered by other factors such tectonic shifts particularly along Alaska and continental U.S. Pacific coastline. The aforementioned drivers can often prompt either a relative increase or decrease in land level depending on location. Other factors such as aquifer drawdown and the draining of coastal swamps can create decreases in relative land level.

Quantifying how land levels are changing is difficult given the paucity of data available prior to modern satellite data. This data need will be relieved by the release of a NASA study on land-based movement in 2017 (Nerem per. comm.). This NASA report will provide numbers for land-based movement across the country. These numbers should be incorporated with the sea-level rise numbers in this report once they are released in 2017. These numbers can be combined with the numbers in this report in the following equation (after Lentz et al. 2016):

Eq. 2 $$aE = E_0 - e_i + R$$

Where; ae is the adjusted elevation, E_0 is the initial land elevation, e_i is the future sea level for either 2030, 2050, or 2100, and R is the current rate of land movement due to isostatic adjustments.

In the interim, tide gauges can provide data regarding changes in land level, but should be used cautiously. We have listed tide gauge data for the rate of change in land level for tide gauges nearest to all units for this study in Appendix E; however, only Fort Pulaski National Monument and Fort Point National Historic Point have a long-term tide gauge on site. This lack of nearby long-term data can limit the accuracy of these numbers if they are applied to sea level change projections for almost all other parks units. Land level changes were only reported for long-term tide gauges that had at least thirty years of data in order to ensure a statistically robust dataset. Based on these limited records we estimate that seven park units are currently experiencing decreasing relative sea levels (Figure 4; Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords

National Park, Lake Clark National Park, Sitka National Historical Park), although we cannot be certain of this number given that many of park units are some distance from a tide gauge. We expect the release of the NASA data (Nerem per comm.) to help refine these estimates.

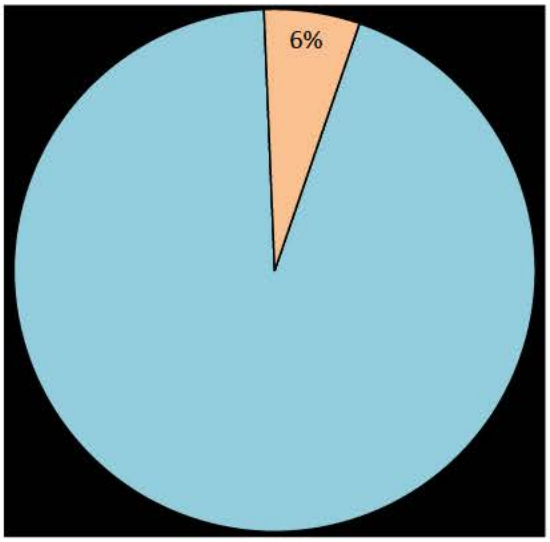


Figure 4. The estimated percentage of park units that currently experience decreasing relative sea levels (orange) versus those with increasing relative sea level (blue).

It is strongly recommended that you discuss the applicability of these land level numbers with a natural resources manager or similar expert to ensure that the nearest tide gauge to your project site is appropriate. In selecting an appropriate tide gauge to use a number of variables must be taken including oceanographic setting, length of the record, completeness of data, and geography of the coastline. A decision was made by the science team for this project to not set a threshold for how close a park unit should be to a long-term tide gauge based on the aforementioned considerations.

Where to Access the Data

All GIS data from this project will be uploaded on www.irma.gov for archiving by park. Non-GIS users can access the data discussed in this report using our online map viewer at:

(b) (5) [redacted]

A website discussing this project is available at the following address:

https://www.nps.gov/subjects/climatechange/sealevelchange

The raw IPCC (2013) data can be downloaded using the following link:

http://ipcc.ch/report/ar5/wg1/docs/ar5_wg1_ch13sm_datafiles.zip

Results

Sea level and storm surge maps are in Appendices A and B. A full list of the 118 park units used for this study can be found in Appendix D along with a table listing sea level rise projections per park unit. Following the methods outlined above we found that sea level rise will average between 0.45m (RCP2.6) and 0.67 m (RCP8.5) by 2100. However, this number masks how these data will vary geographically. Figure 5 describes these data in more detail by breaking down sea level estimates by region. The error bars in Figure 5 denote the standard deviation for each average per region, which further reveals how these numbers can vary. A high standard deviation and range signals that sea level estimates vary between units, whereas a low standard deviation and small range are be expected in smaller regions where sea level rise estimates do not cover such a large geographic area.

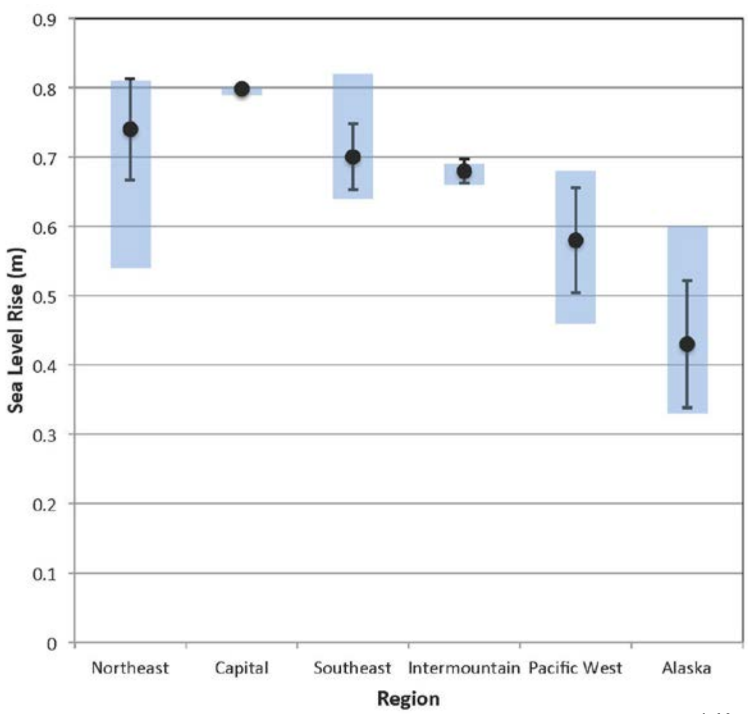


Figure 5. Projected future sea level by region for 2100 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region. These averages do not include the impact of land movement.

Based on the averages per region we found that the shoreline within the National Capital Region is expected to experience the highest sea level rise (0.80 m RCP8.5 2100), although this number does not include changes in land level over the same time interval. The shoreline near Wright Brothers National Memorial in the Southeast Region has the highest overall projected sea level rise (0.82 m RCP8.5 2100). Glacier Bay Preserve and Klondike Gold Rush National Historical Park are tied for lowest projected sea level rise at 0.33 m using RCP8.5 for 2100. The Alaska Region also has the highest standard deviation among park units. The National Capital Region conversely has very little standard deviation due to the compact nature of the region that meant that all of the parks units listed fell within the same raster cell. This is not to say that all of the parks will experience exactly the same amount of sea level rise, but that the IPCC model projected that sea levels could rise up to an average 0.80 m (RCP8.5) above waterline for that region by 2100. These differences among the National

Capital parks is illustrated in our sea level rise maps which will be discussed in further detail in the National Capital section of this report.

Comparing RCP8.5 data for 2030 and 2050 (Figures 4 and 5, respectively) shows the National Capital Region tied with the Northeast Region in 2030 based on average projected sea level rise, however the National Capital Region ranks highest in 2050. The Alaska Region ranks lowest for all three time intervals followed by the Pacific Northwest region, Intermountain Region, and Southeast Region. The Northeast Region comes ranks second highest for 2050 and 2100.

Figure 6. Projected future sea level by region for 2030 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region.

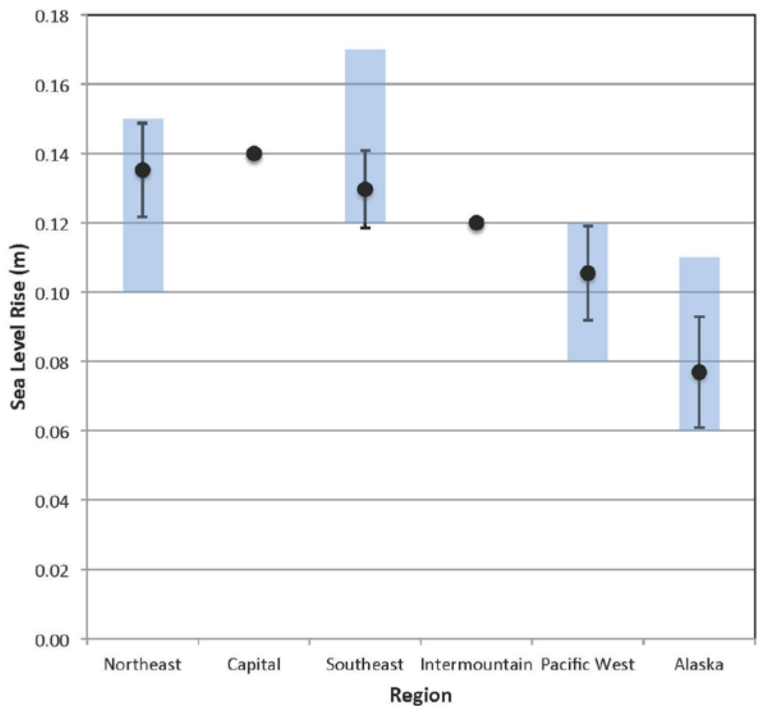
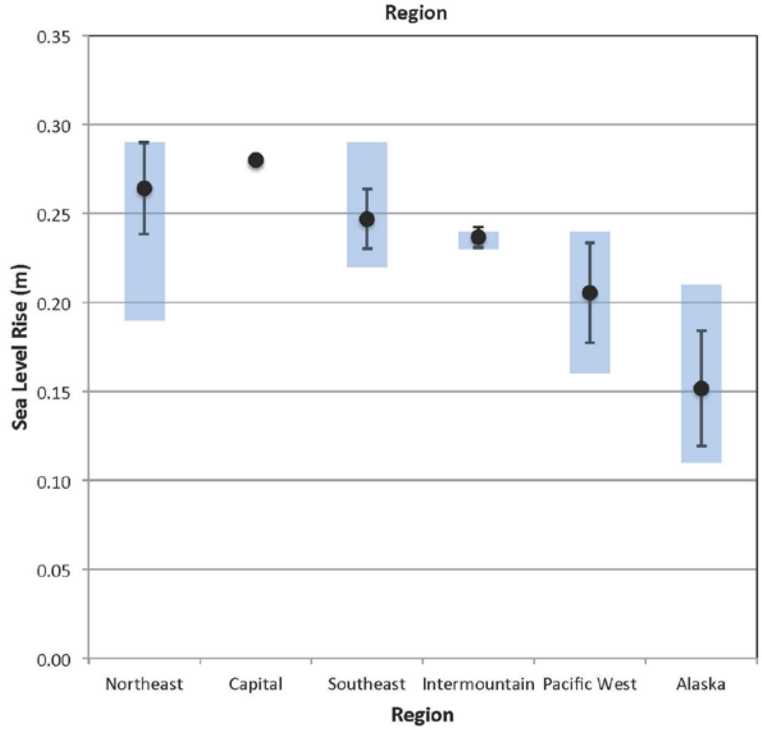


Figure 7. Projected future sea level by region for 2050 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region.



Storm surge was mapped for 79 park units. Storm surge data were combined with sea level rise projections to approximate how much area could be exposed to flooding on top of inundation. We used data for one storm category higher than the highest historical storm for our combined maps. Table E3 in Appendix E lists the highest historical storm for each park unit. 31 park units did not have a historical storm path travel within 10 miles of their boundaries, so a Saffir-Simpson hurricane 1 was simulated for these locations. The lack of a historical storm does not mean that these parks are not subject to strong storms. It may merely be that these parks are in regions that either do not have extensive historical records or they experience strong storms that are classified differently, such as nor'easters.

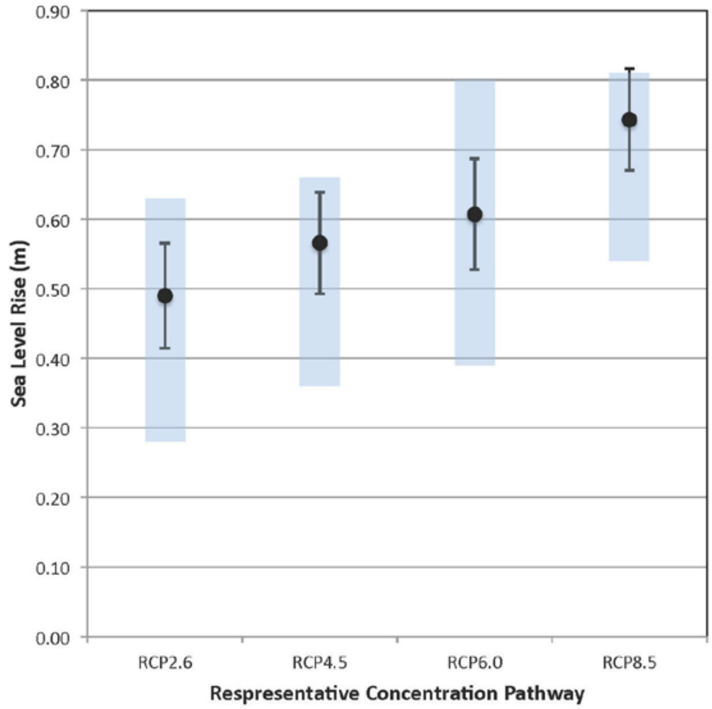
The Southeast Region has the strongest historical storms (average of highest recorded storm categories = 2.79), followed by the Intermountain Region (average = 2.33), National Capital Region (average = 1.90), and the Northeast (average = 1.03). None of the historical data intersected with the 10 miles buffers around the Alaska region parks. The Pacific West Region has experienced some tropical depressions, particularly in Hawaii, but most of their storm surges are driven by other phenomena, such as midlatitude cyclones or extreme tides (sometimes colloquially referred to as a king tide). The strongest (highest winds) and most intense (lowest pressure at landfall) recorded historical storm to have impacted a park unit was the "Labor Day Hurricane" that passed within 10 miles of Everglades National Park in 1935. However, while this storm may have been the highest intensity storm it is certainly not the most damaging or costly storm in National Park Service history.

Northeast Region

Figure 8 shows how the range of sea level projections for the Northest Region for 2100. It is projected to average between 0.49 m (RCP2.6) and 0.74 m (RCP) of sea level rise by the end of the century. Colonial National Historical Park, Fort Monroe National Monument, and Petersburg National Battlefield are all tied for the coastline with the highest projected sea level rise in 2050 and 2100. They are also tied along with Edgar Allen Poe National Historic Site, Fort McHenry National Monument and Historic Shrine, Independence National Historical Park, and Thaddeus Kosciusko National Memorial as parks near coastline with the highest projected sea level rise for 2030. However, while these parks may have ranked highly, so caution should be used when analyzing these results. Many of these parks do not have coastline and so these projections are based on sea level rise for the coastline adjacent to these parks. The maps in Appendix A show how these projected numbers will impact each of these parks. Colonial National Historical Park, Fort McHenry, and Fort Monroe National Monument are the only park units that contain coastline with their boundaries.

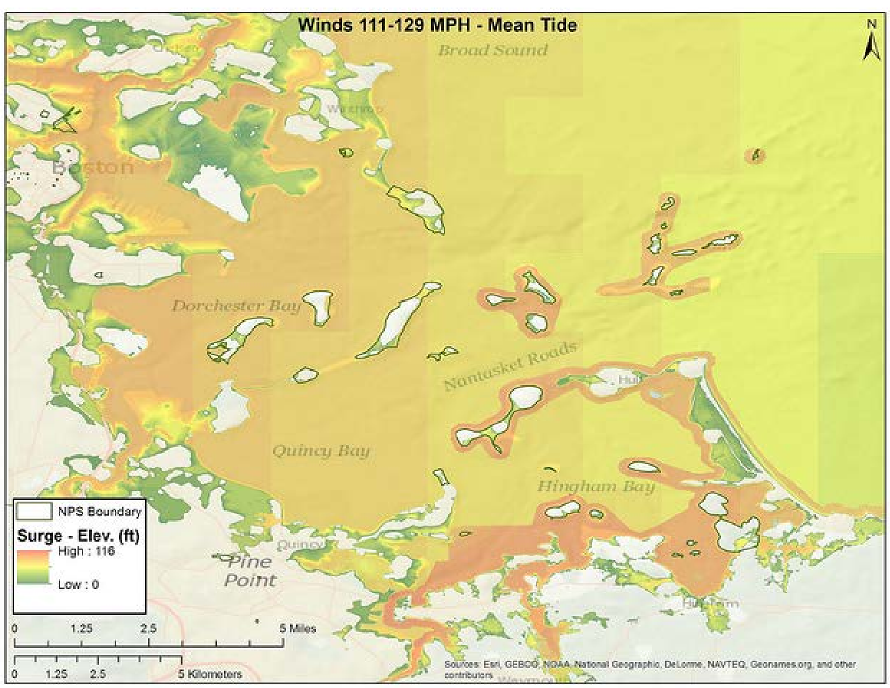
Acadia National Park had the lowest projected rates of sea level rise for 2030 (0.08–0.10 m), 2050 (0.14–0.19 m), and 2100 (0.28–0.54).

Figure 8. Projected future sea level by 2100 for the Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each category.



The highest recorded storm to have travelled within 10 miles of any of the 29 parks units identified for study was an officially unnamed hurricane in 1869 known colloquially as Saxby's Gale that was classified as a Saffir-Simpson 3 hurricane. The storm path passed Boston National Historical Park and Roger Williams National Memorial. Figure 9 shows the estimated extent of a storm surge from category 3 hurricane striking Boston Harbor Islands National Recreation Area at mean tide.

Figure 9. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at mean tide near Boston Harbor Islands National Recreation Area.



Southeast Region

The southeast region can expect to have some of the more intense (highest Saffir-Simpson storm category) storm over this century. Historically, the region has the highest intensity storms; although Everglades National Park has recorded a category 5 hurricane within 10 miles of its boundary, Figure 10 shows how it would only need to be struck by category 2 hurricane to completely flood the park.

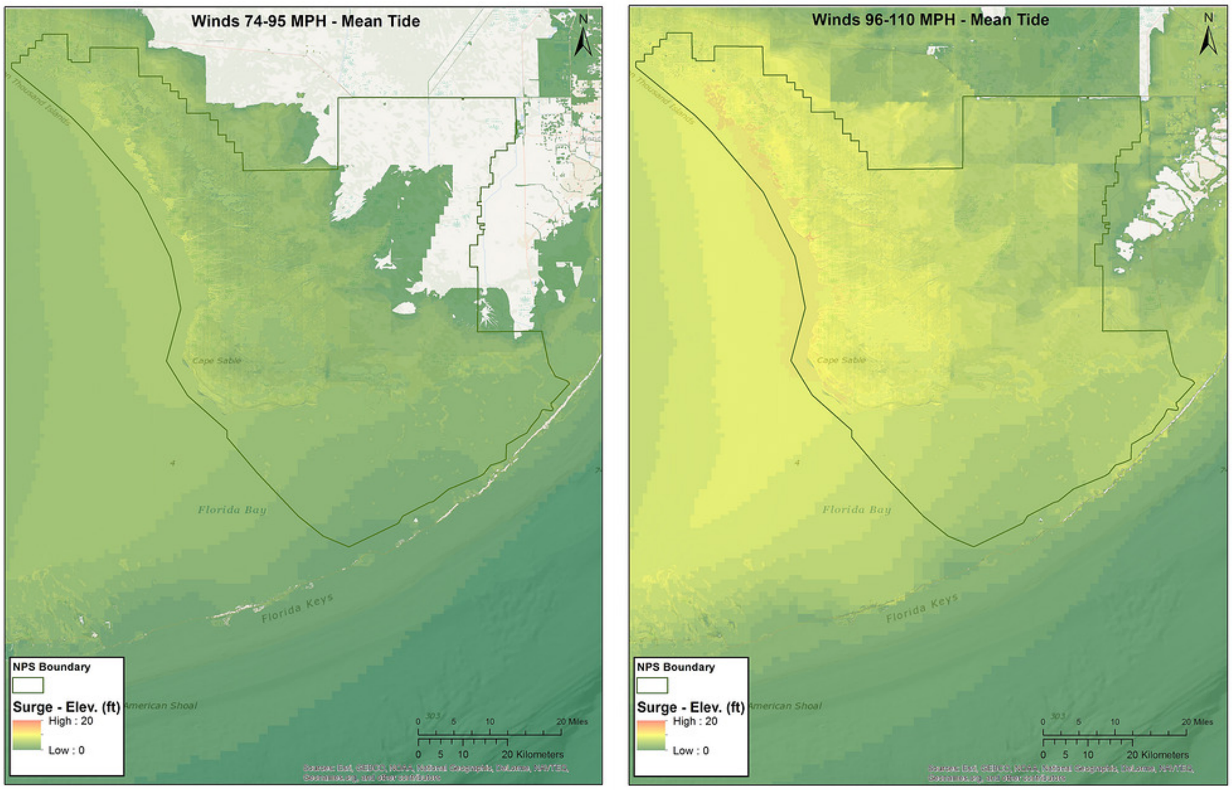


Figure 10. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide.

Combining such large storm surges with sea level rise highlights how exposed many of the Southeast Region park units are. It should also be considered that sea level rise projections do not include changes in land level. We recommend waiting for the forthcoming NASA report (Nerem per comm.) on land level before applying any numbers for planning; however, using table E1 from Appendix E as a rough guide changing land level for parks near tide gauges can be evaluated. The Eugene Island, Louisiana tide gauge's current rate of sea level rise is the highest in the country at 9.65 mm/yr owing in part to the large rate of subsidence in the region (Figure 1). Using the nearest tide gauge to Jean Lafitte National Historical Park and Preserve (Grand Isle, Louisiana, gauge 8761724) we can estimate that land will subside by 7.60 mm/yr. Applying this estimate of subsidence (using a baseline of 1992) to our RCP8.5 projections, the park could experience approximately 0.41 m of *relative* sea level rise by 2030 followed by 0.69 m by 2050 and 1.50 m by 2100.

Our projections list Wright Brothers National Memorial's nearest coastline as having the greatest sea level rise by 2100 (0.82 m RCP8.5), but given the elevation of the park, this will still not inundate a large area of the memorial. However this could be more of a problem if this rise in water level is combined with other factors, such as a storm surge. The park will be almost completely flooded if a category 2 or higher hurricane strikes on top of the inundation from sea level rise.

Nearby Cape Hatteras and Cape Lookout National Seashores are projected to experience up to 0.79 m and 0.76 m, respectively (RCP8.5) of sea level rise by 2100. Both of the aforementioned units have shoreline as part of their boundaries, which means these rises in sea level will result in large areas of inundation. While these national seashores may rank slightly lower than Wright Brothers National Memorial for sea level rise, they serve as example of how caution must be used when using these numbers to assess which park units are most vulnerable to sea level rise. Other factors, such as percent of exposed land, changes in land movement, and adaptive capacity must also be taken into account for vulnerability analysis (Peek et al. 2015).

National Capital

National Capital Region has very little variability in projected sea level rise because all of the park units selected for study are all adjacent to the same section of coastline that was modeled. Their proximity also explains why they all share the same storm history. Despite these similarities, the way these numbers will impact each individual park unit will vary based on the topography of Washington D.C. The strongest storm to ever pass within 10 miles of the National Capital Region parks was as Saffir-Simpson category 2 hurricane that struck the city in 1878. While 1878 storm caused relatively little damage, we can expect a significantly larger amount of damage if a similar storm struck the city again. Figure 11 shows the extent of flooding created a Saffir-Simpson category 2 hurricane. A storm surge measuring more than 3 m could travel up the Potomac River causing large amounts of flooding.

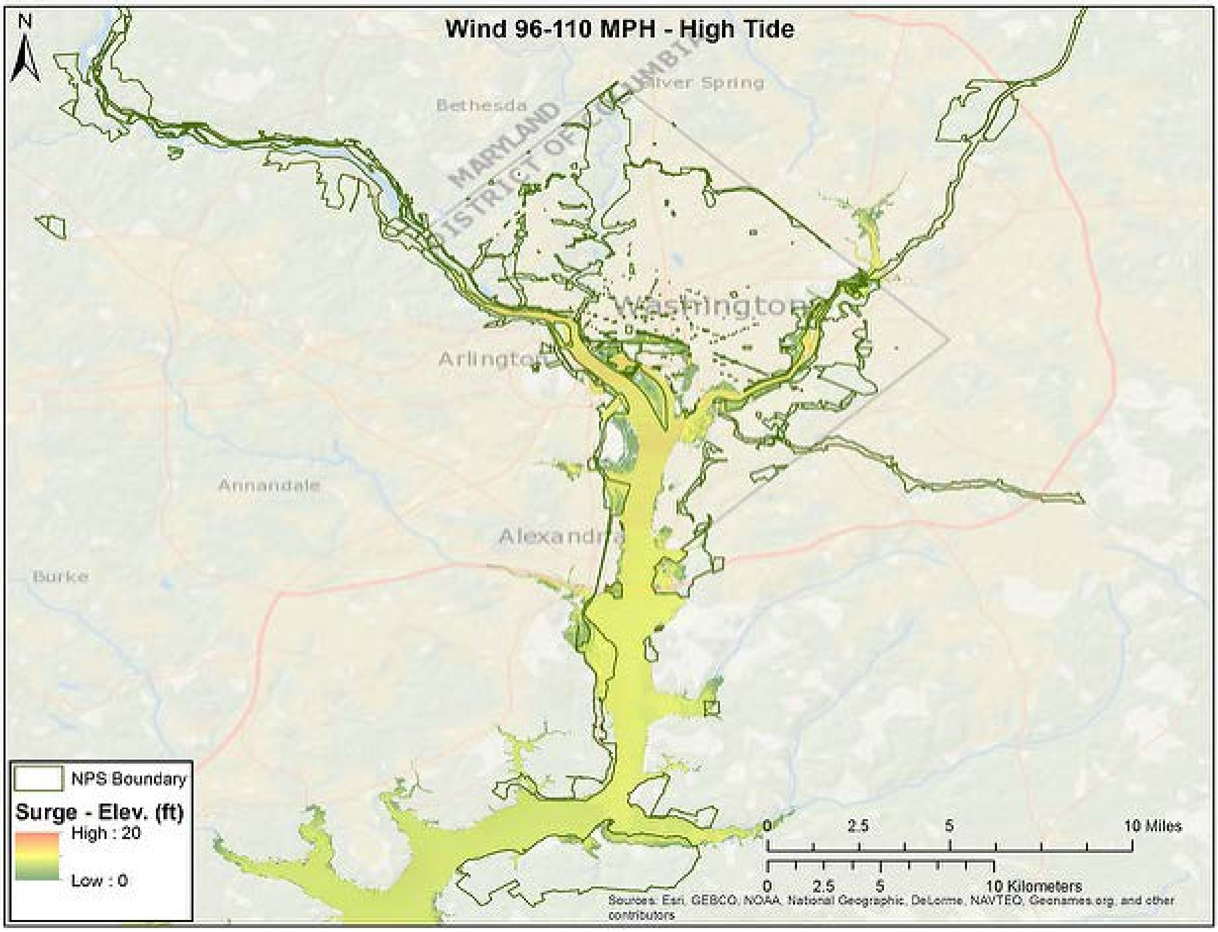


Figure 11. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide.

IPCC/SLOSH models showed either storm surge or sea level rise (or some combination of the two) impacting every park nominated for study with the exception of Harpers Ferry National Historical Park. Our mapping efforts revealed that Harpers Ferry National Historical Park located approximately 149 m above sea level is unlikely to experience any impacts of sea level rise due to its elevation and is unlikely to be damaged by storm surge from a hurricane from its relatively protected location behind several dams along the Potomac and Shenandoah Rivers. Harpers Ferry is potentially vulnerable to other climate change impacts, such as changing temperatures and precipitation.

Sea level rise alone is not expected to spread very far into Washington D.C., although a large section on the east side of Theodore Roosevelt Island will be inundated. However, storm surge flooding on top of this sea level rise would have widespread impacts.

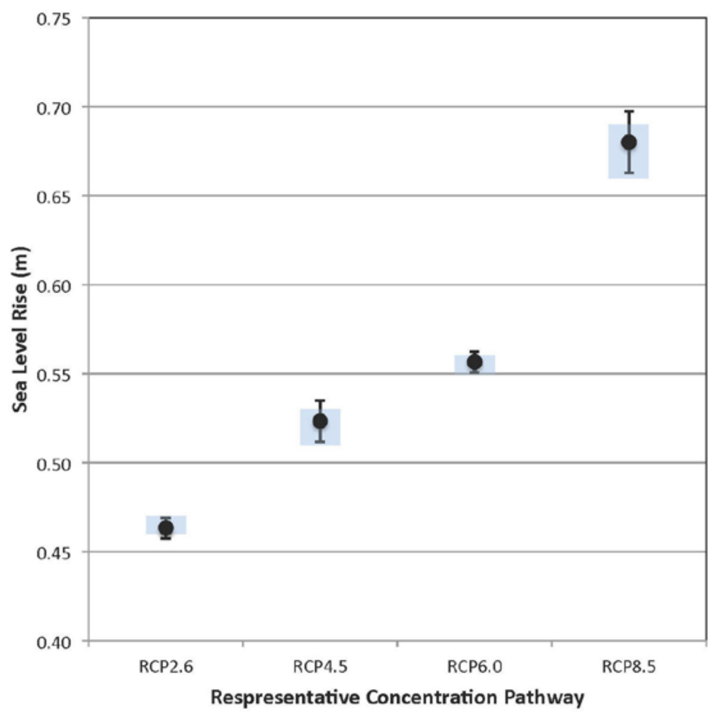
Intermountain Region

The Intermountain Region covers mostly inland park units stretching from Texas to Montana. Only three park units in Texas could be nominated for a study of this nature: Big Thicket National Preserve, Palo Alto Battlefield National Historical Park, and Padre Island National Seashore. Padre

Island National Seashore is likely to experience the greatest effects of sea level and storm surge out of the three park units. Sea level is projected to rise 0.46–0.69 m (RCP2.6–8.5, Figure 12) by 2100. The same amount of sea level rise is projected for the shoreline near Palo Alto Battlefield National Historical Park, but it is not expected to stretch inland enough to reach the park. Palo Alto Battlefield National Historical Park has no history of being within 10 miles of any hurricane, making the site unlikely to be flooded by storm surge. SLOSH MOM models for the park unit show that that the region would have to have either a Saffir-Simpson category 4 hurricane striking at high tide or a category 5 hurricane striking at any tide in order for the park to experience any storm surge. Whereas Figure 13 shows how Padre Island National Seashore located on the shoreline to the east of Palo Alto Battlefield National Historical Park has been within 10 miles of a category 4 hurricane. SLOSH MOM data show that another category 4 hurricane that would likely flood almost the entire island if it struck again.

There is some potential for storm surge to travel up the Neches River and flood the southernmost part of Big Thicket National Preserve, although storm surge defenses in Beaumont, Texas to the south of the preserve are likely to buffer it from any surge. It is more likely that a hurricane would cause flooding over a wider area of the park via precipitation.

Figure 12. Projected future sea level by 2100 for the Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each category.



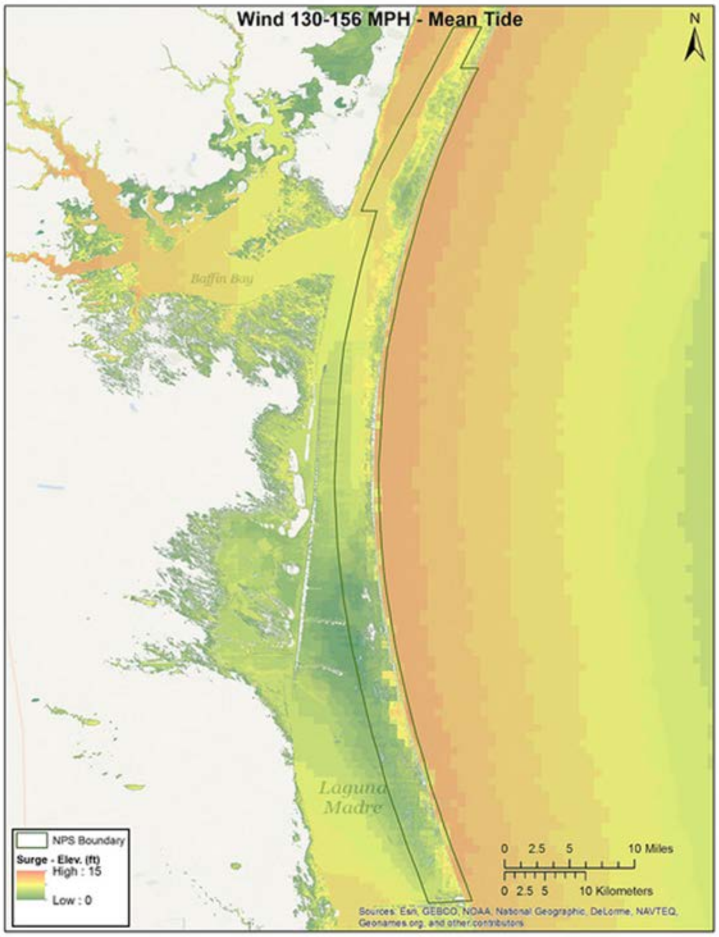


Figure 13. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore.

Pacific West Region

The Pacific West Region identified 24 park units that could be vulnerable to sea level rise and/or storm surge. These units are located over a large area comprising California, Oregon, Washington, Hawaii, American Samoa, and Guam. The average projected sea level rise ranges between 0.40–0.58 m (RCP2.6–8.5) by 2100 for the whole region; however, there is a large standard deviation between these numbers (0.04–0.08 for RCP2.6–8.5, respectively) that belies how the park-specific projections vary across the region. War in Pacific National Historical Park in Guam has the highest projected sea level rise at 0.68 m (RCP8.5) by 2100. War in Pacific National Historical Park is also tied for highest projected sea level rise with almost all of the Hawaiian park units in 2030 and 2050.

At the other end of the spectrum the park units located around Washington's Olympic Peninsula (Ebey's Landing National Historical Reserve, Olympic National Park, and San Juan Island Historical Park) rank lowest for projected sea level rise. Sea level is projected to rise much more slowly in this region reaching a maximum 0.46 m (RCP8.5) by 2100. This is a region that is subject to tectonic shifts as well as continuing land movement due to isostatic rebound that further complicate sea level projections. Long-term tide gauge records at Neah Bay, Washington (gauge 9443090) and Tofino, Canada (gauge 822-116) show relative sea levels as currently decreasing while tide gauges in Port

Angeles, Washington (gauge 9444090), Victoria, Canada (gauge 822-101), and Seattle, Washington (gauge 9447130) show it to be increasing (Zervas 2009). Our projections show sea level in this region to rise throughout this century, although the release of the forthcoming NASA report (Nerem per comm.) could shed more light on this matter.

Modeling for storm surge is complicated by the lack of hurricanes to have stuck many of the parks in this region. Instead we chose to use data from Tebaldi et al. (2012) that includes anomalous surges that could be created by storms as well as other factors (sometimes referred to as king tides). Based on the Tebaldi et al. (2012) data, La Jolla, California (gauge 9410230) has the lowest 100-year storm surge measuring 0.95 m and Toke Point, Washington (gauge 9440910) has the highest 100-year storm surge (1.96 m) in the Pacific West Region. Tebaldi et al. (2012) did not analyze storm data for Hawaii, Guam, or American Samoa, although IBTrACS (Knapp et al. 2010) does have hurricane records for these areas. Only tropical depressions have been recorded within 10 miles almost all of the selected Hawaiian park units (Haleakala National Park, Hawaii Volcanoes National Park, Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puukohola Heiau National Historic Site, and World War II Valor in the Pacific National Monument).

Alaska Region

The Alaska Region has the lowest average projected sea level rise (0.28–0.43 m by 2100) compared to the five regions described above. Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park in southeastern Alaska share the lowest projected sea level rise (0.33 m RCP8.5 2100) while Bering Land Bridge National Preserve on the west coast of the state has the highest projected sea level rise (0.60 m RCP8.5 2100).

Figure 1 shows how current relative sea levels vary across the state. Land levels are rapidly rising in the southeast of the region due to isostatic rebound and other tectonic shifts. Current rates of relative sea level change in Skagway, Alaska are the lowest in the country; decreasing at an average rate of 17.59 mm/yr (Zervas 2009). The net result of these increasing land levels is decreasing relative sea levels for at least the early part of this century. Despite melting ice and other factors outlined in Table 1 that are adding to our ocean waters volume, the amount of rising water is not sufficient to keep up with the land level. Seven park units (Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park) have been identified as potentially having decreasing relative sea levels based on the nearest tide gauge data to each of these parks. None of these parks have long-term tides gauges that have data spanning at least thirty years. A great strength of using the IPCC (2013) process-based model approach is that, unlike many other semi-empirical models, it does not rely on long-term tide gauge records to statistically predict future sea levels. However, our sea level projections do not at this time include changes in land level. The numbers we supply here are for how much we can expect the water volume to rise near to each of these park units. Table E1 shows how land levels are changing at long-term tide gauges across the country. However, given that all of these park units are located far from a tide gauge and that the region is relatively geologically complex, we would not recommend using the land movement numbers from the nearest tide gauge for any of the Alaskan parks.

Storm surge is also very difficult to model for this region. Historically, many of the parks had sea ice along the coastline that helped protect these parks from storm surge. Consequently NOAA do not have SLOSH MOM models for this region. IBTrACS data (Knapp et al. 2010) show a few storm paths that have moved towards the region, but these types of storms typically do not make landfall once they move over colder waters. Alaska does hold the record for the highest intensity (lowest central pressure) storm (Duff 2015). A downgraded super typhoon, Nuri, struck Adak Island, Alaska in 2014 with recorded winds gusting up to 122 mph. It is unfortunately impossible to determine an average or peak historical storm surge without adequate tide gauge data.

Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/yr, although this rate accelerated over the later part of the century. Slangan et al. (2016) found that the release of anthropogenic greenhouse gases has been the primary driver of global sea level change since 1970 as the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/yr (Cazenave et al. 2014, Fasullo et al. 2016).

The IPCC (2013) expects this rate will increase and predicts global average sea levels to increase by 0.40–0.63 m (RCP2.6–8.5) by 2100. We used regional sea level projections from the IPCC (2013) generated for 2050 and 2100 in combination with our own downscaled projections for 2030 to estimate how much sea level rise 118 coastal national park units could experience in the future. Our are projections are based on the new representative concentration pathways (Meinshausen et al. 2011, Figure 14) and use a process based model approach.

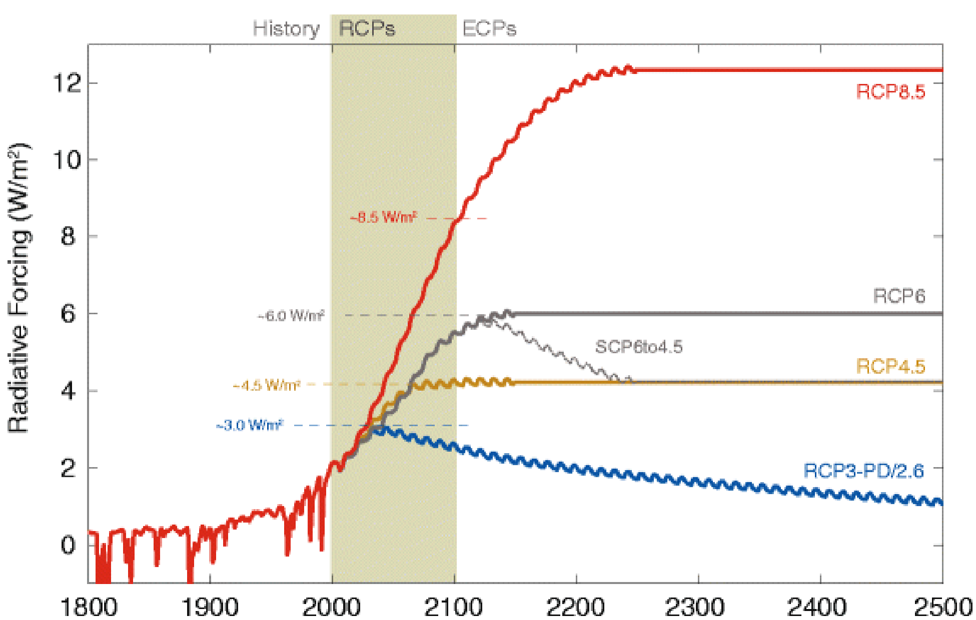


Figure 14: Radiative forcing for each of the Representative Concentration Pathways (RCPs). RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011.

There are numerous academic articles that use mostly semi-empirical models (Rahmstorf 2007) to estimate sea level rise for a number of regions across the U.S. The IPCC (2013) lists a number of semi-empirical sea level estimates, all of which create estimates of future sea level that are higher than the IPCC (2013) approach. The differences to these approaches can be attributed to a number of factors. For example, some of the older papers may have higher sea level estimates because they are based on the older IPCC SCRES scenarios (e.g. Vermeer and Rahmstorf 2009, Grinsted et al. 2010, Jevrejeva et al. 2010). Other papers may augment their sea level projections with "expert elicitations" where experts are polled on how much they think sea level (or a related factor) could rise in the future (e.g. Bamber and Aspinall 2013, Jevrejeva et al. 2014, Horton et al. 2014). Others have published articles criticizing the IPCC sea level estimates as being too conservative or underestimating rates of future sea level change (e.g. Kerr 2013, Horton et al. 2014). These criticisms were addressed by Church et al. (2013) and so they will not be discussed in detail here. Recent analyses by Clark et al. (2015) further supports the findings of the IPCC.

A key strength of these methods has been that this research applies a unified approach to identify how sea level change will impact all coastal park units across the National Park System, rather than relying on sea level data generated for specific regions. Our analyses revealed that the National Capital Region is projected to be the region to experience then greatest increase in sea level (not taking into account changes in land level). This rise will impact each of the region's units in different ways depending on the elevation of the individual unit, but it could be catastrophic if combined with a storm surge from a storm such as the category 2 hurricane in 1878.

At the individual park level IPCC projections reveal the sea level along the coastline adjacent to Wright Brothers National Memorial could rise up 0.82 m (RCP8.5) by 2100, which could lead to significant flooding if combined with a storm surge. The Southeast Region as a whole is generally susceptible to inundation and flooding due to its low-lying nature in many places, particularly in the Cape Hatteras/Cape Lookout National Seashores region. Our sea level rise maps highlight how much all of these park units will be impacted.

However these estimates do not factor in changing land levels. We are expecting the latest state-of-the-art land level estimates to be released by NASA in 2017. In the meantime we can roughly estimate relative sea level change for a small number of parks based on current rates of subsidence gathered from nearby long-term tide gauge data. We expect Jean Lafitte National Historical Park and Preserve to have the greatest relative sea level increase based on the current rate of land movement. Our sea level projections agree with current sea level trends that the southeast Alaska region is experiencing the least amount of sea level rise of anywhere in the National Park System.

Sallenger et al. (2012) discussed how storm surge combined with sea level rise could create a 1000-km long "hotspot" along the North Atlantic coast from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. Our projections also found that to be the case. We mapped future inundation caused by sea level change combined with flooding caused by a storm measuring one storm category higher than historical for each park unit, assuming an intensification of future storm surge (Webster 2005, Mingfang 2015). We found that almost all of the coastal park units would be flooded under these conditions.

It is unknown exactly to what degree future storm surge will impact the Alaskan park units. Storm accurate long-term (>30 years) surge data do not exist for the Alaska region. Even if such data did exist it would be not be analogous to future conditions in the regions as sea ice that had previously protected the shores for many of the western Alaska park units melts to reveal an easily erodible coastline (Frey et al. 2015). The warming of ocean waters in the Gulf of Alaska and Pacific Ocean could also make it more conducive for more storms like Typhoon Nuri to travel north without losing as energy as they once did.

The Pacific West Region shows a lot of variability among parks. A recent report by Golden Gate National Recreation Area (2016) goes into detail regarding what some of these park units are doing to plan for climate change. The National Research Council report for California, Washington, and Oregon (2012) has been cited frequently as a resource on sea level rise in the region, but it does not cover the entire administrative region that is managed by the Pacific West Region. War in Pacific National Historical Park in Guam ranks first as having the highest projected sea level rise amongst the units administered by the Pacific West Region.

Island park units in general are especially exposed to the impacts of sea level change and storm surge. Many of the barrier island parks, such as Fire Island National Seashore, Assateague National Seashore, Palo Alto Battlefield National Historical Park, Gulf Islands National Seashore and Cape Hatteras National Seashore are all projected to experience sea level rises over 0.69 m by 2100 (RCP8.5). This sea level rise combined with storm surge could be especially difficult for isolated island park units, such as the Caribbean park units, National Park of American Samoa, and War in Pacific National Historical Park where access to aid in the event of a natural disaster may not be immediately available.

Conclusions

Projections of sea level change and storm surge due to anthropogenic climate change in 118 coastal park units administered by the National Park Service are presented in this report. Historical storm surge data showed the Southeast Region to have experienced the most intense hurricanes, which could lead to even greater storm surges in the future if storms become stronger (Webster 2005, Mingfang 2015). Sea level rise is projected to generally be greatest in the National Capital Region, although some low-lying parks, such as Everglades National Park and park units in the Outer Banks of North Carolina and Gulf Coast will continue to be challenged by this issue.

Sea level and storm surge will vary geographically, resulting in unique challenges for adaptation and management. It is important to acknowledge that sea level change will impact some parts of Alaska differently to the rest of the country. Northwest Alaska can expect relative sea levels to increase over time, while southeast Alaska relative sea levels will likely continue to decrease over the first part of this century followed by an increase in relative sea level by the end of the century.

This project is an important first step in assessing how changes in sea level and storm surge due to anthropogenic climate change will impact our national park units. By combining projected sea level with storm surge data we can start to examine how these two separate variables can exacerbate the impact of each other over time. It is clear that more research can be done on these complex issues to assess how these changes will impact individual parks as well as the wider regions. Looking ahead, these data have applications for a number of future projects related to both natural and cultural resources as well as the planning and management of infrastructure.

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Appendix A

Sea-level change Maps

The following maps were created by this project to illustrate the impact of storm surge for all of the parks that have SLOSH data. These maps were created by this project using NOAA data. For further information regarding our methods refer to methods section on page 4. Digital versions of these maps will be available at www.irma.gov

and [redacted]

[Maps will be inserted after they have been reviewed]

Appendix B

Storm Surge Maps

The following maps were created by this project to illustrate the impact of storm surge for all of the parks that have SLOSH data. These maps were created by this project using NOAA data. For further information regarding our methods refer to section xxx. Digital versions of these maps will be available at www.irma.gov and https://www.flickr.com/photos/125040673@N03/albums/with/72157663665097941. Maps are arranged alphabetically by unit name.

[Maps will be added after they have been reviewed]

Appendix C

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with regional managers. Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.

Q. Who originally identified which park units should be used in this study?

A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. Where did you use data used by Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to help plug some of these gaps in our data network for park units in California, Oregon, Washington, and southern Alaska.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012). The following parks used Tebaldi et al. (2012) data: Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into that region.

Q. Why are the storm surge maps in NAVD88?

That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on projections for some parks?

The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America. It uses a fixed value for the height of the sea level. While this is a popular datum for mapping, it has the limitation that it is based on the tidal benchmark for Rimouski, Canada. As you move further away from this benchmark you can expect actual sea level to differ from the reference benchmark. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

All parks are different, as are all projects. Your choice of scenario may depend on many different factors. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. 2009. Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). The standard error of the IPCC is explained in greater detail in the chapter 13 supplementary material in AR5 (IPCC 2013).

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent an average storm surge number. As described above there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, El Niño and La Niña years will impact sea level. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of man-made structures, such as levees and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. Permanent inundation will change the way waves propagate within a basin in the future. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www.nhc.noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bath tub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact Rebecca Beavers for assistance. It may be possible to downscale projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing between sources.

Q. What are other impacts from sea-level rise that parks should consider?

A. Impacts from sea-level rise could include, but are not limited to, destroyed cultural resources, damage to above ground infrastructure, difficulty accessing buried infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems.

Appendix D

Waysides

The following pages show the final designs for waysides that were installed in parks as part of the funding for this project. Gulf Islands National Seashore received two waysides that were received in 2015. Jean Lafitte National Historical Park and Preserve and Fire Island National Seashores waysides were installed in 2016.

See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the snow white beaches, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Each year, erosion, storms, coastal development, and rising sea level shrink the nesting beach habitat of sea turtles. When a female sea turtle is ready to lay her eggs, she will try to return to the same sandy beach every two to three years. Will her nesting home still be here?

Please join the National Park Service in protecting these beaches, so that you and your children may watch her hatchlings return to lay their eggs.

The road at Fort Pickens gets overwashed with storm waves. As the sea level rises, these events are becoming more common

See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the historic forts, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Fighting the Rising Sea

Each year, erosion, storms, shipping channels, and rising sea level are changing the shoreline of the barrier islands. The National Park Service and Corp of Engineers work together on renourishment projects to rebuild the coastline around historic Fort Massachusetts. The fort is often battered by waves, putting the structure in jeopardy.

Please join the National Park Service in protecting our seashore, so that you and your children may continue to enjoy these historic places.

Sinking Land, Rising Water

This is the Barataria Basin, built of soil washed to this area by the Mississippi River. This soil is still compacting and sinking, a process called subsidence. Most of the Barataria Preserve is less than two feet above sea level, and its subsidence rate is nearly half an inch a year.

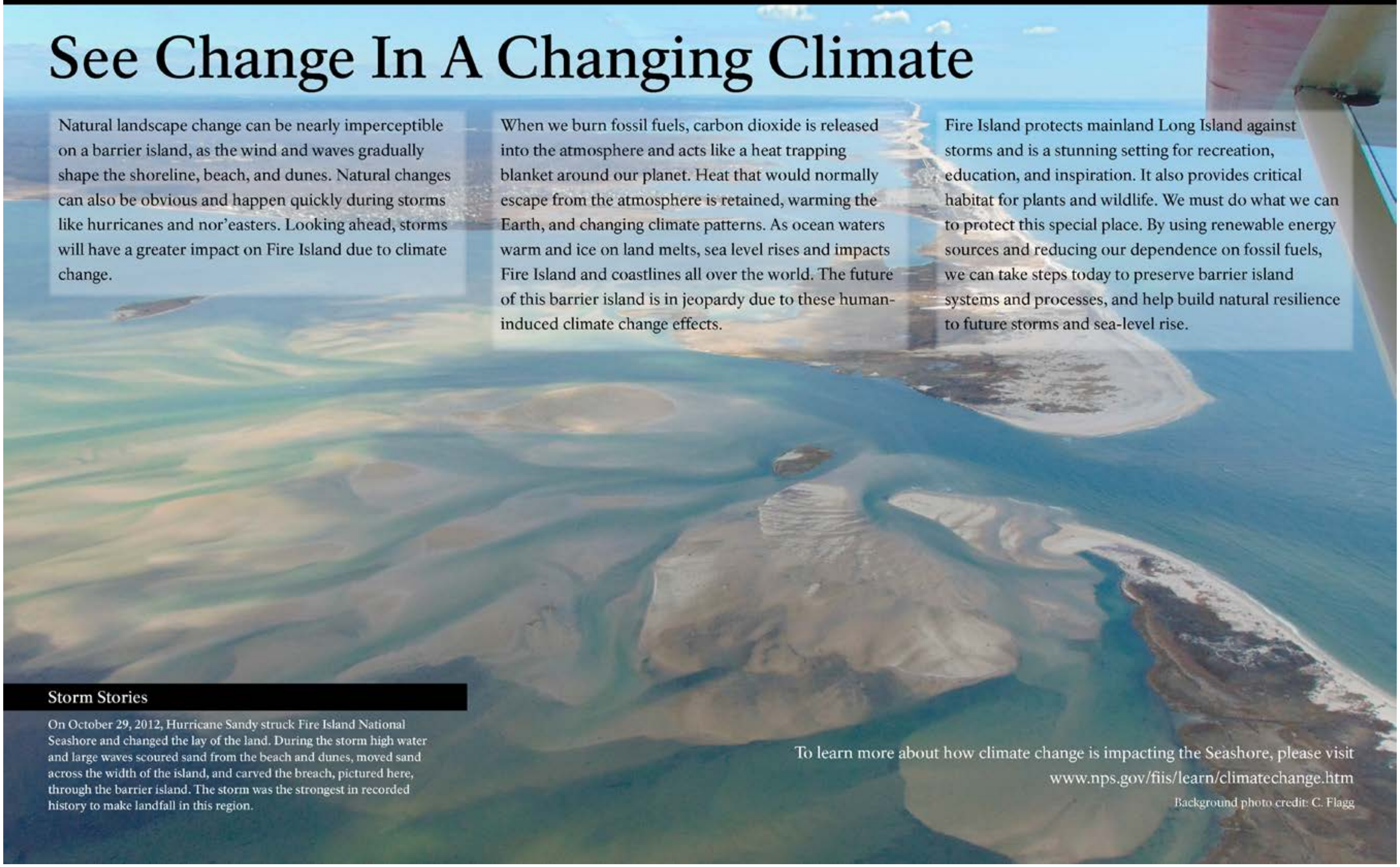
Meanwhile, glaciers and polar ice sheets are melting and our warming climate is heating oceans everywhere, making their waters expand just like water does when you heat it on the stove. Everywhere on the planet, the oceans are a little higher every day.

The combination of the Barataria Basin's sinking land and global sea level rise means that the ocean is creeping in faster here than almost anywhere else in North America.

- Floods are becoming more frequent and lasting longer
- Coastal wetlands are disappearing as land sinks and water rises
- Less land is available to buffer Gulf of Mexico storms
- Storm and flooding threats to homes, communities, and infrastructure like highways, ports, and energy facilities are increasing
- Salt water from the Gulf is moving into freshwater wetlands, killing the plants that hold the land together
- Death of plants, animals, and microbes that cannot tolerate increased flooding or salt water

The photo shows two feet of flooding on Barataria Boulevard after Hurricane Isaac in August 2012. The map shows predicted consequences of 18 inches of sea level rise in the preserve; blue areas would be flooded and brown areas would remain land.

See Change In A Changing Climate



Natural landscape change can be nearly imperceptible on a barrier island, as the wind and waves gradually shape the shoreline, beach, and dunes. Natural changes can also be obvious and happen quickly during storms like hurricanes and nor'easters. Looking ahead, storms will have a greater impact on Fire Island due to climate change.

When we burn fossil fuels, carbon dioxide is released into the atmosphere and acts like a heat trapping blanket around our planet. Heat that would normally escape from the atmosphere is retained, warming the Earth, and changing climate patterns. As ocean waters warm and ice on land melts, sea level rises and impacts Fire Island and coastlines all over the world. The future of this barrier island is in jeopardy due to these human-induced climate change effects.

Fire Island protects mainland Long Island against storms and is a stunning setting for recreation, education, and inspiration. It also provides critical habitat for plants and wildlife. We must do what we can to protect this special place. By using renewable energy sources and reducing our dependence on fossil fuels, we can take steps today to preserve barrier island systems and processes, and help build natural resilience to future storms and sea-level rise.

Storm Stories

On October 29, 2012, Hurricane Sandy struck Fire Island National Seashore and changed the lay of the land. During the storm high water and large waves scoured sand from the beach and dunes, moved sand across the width of the island, and carved the breach, pictured here, through the barrier island. The storm was the strongest in recorded history to make landfall in this region.

To learn more about how climate change is impacting the Seashore, please visit www.nps.gov/fiis/learn/climatechange.htm

Background photo credit: C. Flagg

Appendix E

Data Tables

Table E1. The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (yrs)[†]	Rate of Subsidence (mm/yr)
Northeast Region				
Acadia National Park	Bar Harbor, ME (8413320)	N	60	0.750
Assateague Island National Seashore[‡]	Lewes, DE (8557380)	N	88	1.660
Boston Harbor Islands National Recreation Area	Boston, MA (8443970)	N	86	0.840
Boston National Historical Park	Boston, MA (8443970)	N	86	0.840
Cape Cod National Seashore	Woods Hole, MA (8447930)	N	75	0.970
Castle Clinton National Monument	New York, The Battery, NY (8518750)	N	151	1.220
Colonial National Historical Park	Sewells Point, VA (8638610)	N	80	2.610
Edgar Allen Poe National Historic Site	Philadelphia, PA (8545240)	N	107	1.060
Federal Hall National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
Fire Island National Seashore	Montauk, NY (8510560)	N	60	1.230
Fort McHenry National Monument and Historic Shrine	Baltimore, MD (8574680)	N	105	1.330
Fort Monroe National Monument[‡]	Sewells Point, VA (8638610)	N	80	2.610
Gateway National Recreation Area*[‡]	Sandy Hook, NJ (8531680)	N	75	2.270
General Grant National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
George Washington Birthplace National Monument[‡]	Solomons Island, MD (8577330)	N	70	1.830
Governors Island National Monument[‡]	New York, The Battery, NY (8518750)	N	151	1.220
Hamilton Grange National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
Harriet Tubman Underground Railroad National Monument	Cambridge, MD (8571892)	N	64	1.900
Independence National Historical Park	Philadelphia, PA (8545240)	N	107	1.060
New Bedford Whaling National Historical Park	Woods Hole, MA (8447930)	N	75	0.970
Petersburg National Battlefield[‡]	Sewells Point, VA (8638610)	N	80	2.610
Roger Williams National Memorial	Providence, RI (8454000)	N	69	0.300

Sagamore Hill National Historic Site	Kings Point, NY (8516945)	N	76	0.670
Saint Croix Island International Historic Site‡	Eastport, ME (8410140)	N	78	0.350
Salem Maritime National Historic Site	Boston, MA (8443970)	N	86	0.840
Saugus Iron Works National Historic Site	Boston, MA (8443970)	N	86	0.840
Statue of Liberty National Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
Thaddeus Kosciuszko National Memorial	Philadelphia, PA (8545240)	N	107	1.060
Theodore Roosevelt Birthplace National Historic Site	New York, The Battery, NY (8518750)	N	151	1.220

Southeast Region				
Big Cypress National Preserve	Naples, FL (8725110)	N	42	0.270
Biscayne National Park‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
Buck Island Reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Canaveral National Seashore	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620
Cape Hatteras National Seashore*‡	Beaufort, NC (8656483)	N	54	0.790
Cape Lookout National Seashore	Beaufort, NC (8656483)	N	54	0.790
Castillo De San Marcos National Monument‡	Mayport, FL (8720218)	N	79	0.590
Charles Pinckney National Historic Site	Charleston, SC (8665530)	N	86	1.240
Christiansted National Historic Site‡	San Juan, Puerto Rico (9755371)	N	45	-0.202
Cumberland Island National Seashore‡	Fernandina Beach, FL (8720030)	N	110	0.600
De Soto National Memorial	St. Petersburg, FL (8726520)	N	60	0.920
Dry Tortugas National Park‡	Key West, FL (8724580)	N	94	0.500
Everglades National Park*‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
Fort Caroline National Memorial‡	Fernandina Beach, FL (8720030)	N	110	0.600
Fort Frederica National Monument‡	Fernandina Beach, FL (8720030)	N	110	0.600
Fort Matanzas National Monument‡	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620
Fort Pulaski National Monument	Fort Pulaski, GA (8670870)	Y	72	1.360
Fort Raleigh National Historic Site‡	Beaufort, NC (8656483)	N	54	0.790
Fort Sumter National Monument‡	Charleston, SC (8665530)	N	86	1.240
Gulf Islands National	Dauphin Island, AL	N	41	1.220

Seashore*‡	(8735180) Pensacola, FL (8729840)	N	84	0.330
Jean Lafitte National Historical Park and Preserve‡	Grand Isle, LA (8761724)	N	60	7.600
Moores Creek National Battlefield‡	Wilmington, NC (8658120)	N	72	0.430
New Orleans Jazz National Historical Park‡	Grand Isle, LA (8761724)	N	60	7.600
Salt River Bay National Historical Park and Ecological Preserve‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
San Juan National Historic Site	San Juan, Puerto Rico (9755371)	N	45	-0.020
Timucuan Ecological and Historic Preserve‡	Fernandina Beach, FL (8720030)	N	110	0.600
Virgin Islands Coral reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Virgin Islands National Park‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Wright Brothers National Memorial‡	Sewells Point, VA (8638610)	N	80	2.610

National Capital Region				
Anacostia Park	Washington, DC (8594900)	N	83	1.340
Chesapeake and Ohio Canal National Historical Park	Washington, DC (8594900)	N	83	1.340
Constitution Gardens	Washington, DC (8594900)	N	83	1.340
Fort Washington Park	Washington, DC (8594900)	N	83	1.340
George Washington Memorial Parkway	Washington, DC (8594900)	N	83	1.340
Harpers Ferry National Historical Park	Washington, DC (8594900)	N	83	1.340
Korean War Veterans Memorial	Washington, DC (8594900)	N	83	1.340
Lincoln Memorial	Washington, DC (8594900)	N	83	1.340
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Washington, DC (8594900)	N	83	1.340
Martin Luther King Jr. Memorial	Washington, DC (8594900)	N	83	1.340
National Mall	Washington, DC (8594900)	N	83	1.340
National Mall and Memorial Parks	Washington, DC (8594900)	N	83	1.340
National World War II Memorial	Washington, DC (8594900)	N	83	1.340
Piscataway Park	Washington, DC (8594900)	N	83	1.340
Potomac Heritage National	Washington, DC	N	83	1.340

Scenic Trail	(8594900)			
President's Park (White House)	Washington, DC (8594900)	N	83	1.340
Rock Creek Park	Washington, DC (8594900)	N	83	1.340
Theodore Roosevelt Island Park	Washington, DC (8594900)	N	83	1.340
Thomas Jefferson Memorial	Washington, DC (8594900)	N	83	1.340
Vietnam Veterans Memorial	Washington, DC (8594900)	N	83	1.340
Washington Monument	Washington, DC (8594900)	N	83	1.340

Intermountain Region				
Big Thicket National Preserve‡	Sabine Pass, TX (8770570)	N	49	3.850
Palo Alto Battlefield National Historical Park‡	Port Isabel, TX (8779770)	N	63	2.160
Padre Island National Seashore*	Padre Island, TX (8779750)	N	49	1.780

Pacific West Region				
Cabrillo National Monument	San Diego, CA (9410170)	N	101	0.370
Channel Islands National Park‡	Santa Monica, CA (9410840)	N	74	-0.280
Ebey's Landing National Historical Reserve‡	Friday Harbor, WA (9449880)	N	73	-0.580
Fort Point National Historic Site	San Francisco, CA (9414290)	Y	110	0.360
Fort Vancouver National Historic Site‡	Astoria, OR (9439040)	N	82	-2.100
Golden Gate National Recreation Area	San Francisco, CA (9414290)	N	110	0.360
Haleakala National Park*‡	Kahului, HI (1615680)	N	60	0.510
Hawaii Volcanoes National Park*‡	Hilo, HI (1617760)	N	80	1.470
Kaloko-Honokohau National Historical Park‡	Hilo, HI (1617760)	N	80	1.470
Lewis and Clark National Historical Park	Astoria, OR (9439040)	N	82	-2.100
National Park of American Samoa	Pago Pago, American Samoa (1770000)	N	59	0.370
Olympic National Park*‡	Seattle, WA (9447130)	N	109	0.540
Point Reyes National Seashore‡	San Francisco, CA (9414290)	N	110	0.360
Port Chicago Naval Magazine National Memorial‡	Alameda, CA (9414750)	N	68	-0.780
Pu'uhonua O Honaunau National Historical Park*‡	Hilo, HI (1617760)	N	80	1.470
Puukohola Heiau National Historic Site*‡	Hilo, HI (1617760)	N	80	1.470
Redwood National and State	Crescent City, CA	N	74	-2.380

Parks	(9419750)			
Rosie the Riveter WWII Home Front National Historical Park*	Alameda, CA (9414750)	N	68	-0.780
San Francisco Maritime National Historical Park	San Francisco, CA (9414290)	N	110	0.360
Santa Monica Mountains National Recreation Area	Santa Monica, CA (9410840)	N	74	-0.280
War in the Pacific National Historical Park	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
World War II Valor in the Pacific National Monument[‡]	Honolulu, HI (1612340)	N	102	-0.180

Alaska Region				
Aniakchak Preserve*[‡]	Unalaska, AK (9462620)	N	50	-7.250
Bering Land Bridge National Preserve[‡]	No data	No data	No data	No data
Cape Krusenstern National Monument[‡]	No data	No data	No data	No data
Glacier Bay National Park*[‡]	Juneau, AK (9452210)	N	71	-14.620
Glacier Bay Preserve*[‡]	Juneau, AK (9452210)	N	71	-14.620
Katmai National Park[‡]	Seldovia, AK (9455500)	N	43	-11.420
Kenai Fjords National Park[‡]	Seward, AK (9455090)	N	43	-3.820
Klondike Gold Rush National Historical Park[‡]	Skagway, AK (9452400)	N	63	-18.960
Lake Clark National Park[‡]	Seldovia, AK (9455500)	N	43	-11.420
Sitka National Historical Park[‡]	Sitka, AK (9451600)	N	83	-3.710
Wrangell – St. Elias National Park[‡]	Cordova, AK (9454050)	N	43	3.450
Wrangell – St. Elias National Preserve[‡]	Cordova, AK (9454050)	N	43	3.450

[†]Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

[‡]It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway 2.6	4.5	6.0	8.5
Northeast Region					
Acadia National Park	2030	0.08	0.09	0.09	0.10
	2050	0.14	0.16	0.16	0.19
	2100	0.28	0.36	0.39	0.54
Assateague Island National Seashore[§]	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Boston Harbor Islands National Recreation Area	2030	0.11[‡]	0.11	0.11[‡]	0.11
	2050	0.19[‡]	0.20	0.20[‡]	0.22
	2100	0.37[‡]	0.45	0.50[‡]	0.62
Boston National Historical Park	2030	0.11[‡]	0.11	0.11[‡]	0.11
	2050	0.19[‡]	0.20	0.20[‡]	0.22
	2100	0.37[‡]	0.45	0.50[‡]	0.62
Cape Cod National Seashore[§]	2030	0.13	0.15	0.13	0.15
	2050	0.23	0.27	0.23	0.29
	2100	0.45	0.51	0.57	0.69
Castle Clinton National Monument*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Colonial National Historical Park	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81
Edgar Allen Poe National Historic Site*	2030	0.16[‡]	0.15	0.15[‡]	0.14
	2050	0.27[‡]	0.27	0.27[‡]	0.28
	2100	0.54[‡]	0.62	0.68[‡]	0.79
Federal Hall National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Fire Island National Seashore[§]	2030	0.14	0.14	0.14	0.14
	2050	0.25	0.26	0.25	0.27
	2100	0.50	0.58	0.62	0.76
Fort McHenry National Monument and Historic Shrine	2030	0.16[‡]	0.15	0.15[‡]	0.14
	2050	0.27[‡]	0.27	0.27[‡]	0.28
	2100	0.54[‡]	0.62	0.68[‡]	0.79
Fort Monroe National Monument	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Gateway National Recreation Area	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
General Grant National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
George Washington Birthplace National Monument	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Governors Island National Monument	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Hamilton Grange National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Harriet Tubman Underground Railroad National Monument	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Independence National Historical Park*	2030	0.16‡	0.15	0.15‡	0.14
	2050	0.27‡	0.27	0.27‡	0.28
	2100	0.54‡	0.62	0.68‡	0.79
New Bedford Whaling National Historical Park*	2030	0.13	0.13	0.12	0.13
	2050	0.22	0.23	0.22	0.25
	2100	0.45	0.53	0.55	0.70
Petersburg National Battlefield*	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81
Roger Williams National Memorial*	2030	0.13	0.13	0.12	0.13
	2050	0.22	0.23	0.22	0.25
	2100	0.45	0.53	0.55	0.70
Sagamore Hill National Historic Site	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Saint Croix Island International Historic Site	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.26	0.26	0.27
	2100	0.52	0.59	0.64	0.76
Salem Maritime National Historic Site	2030	0.11‡	0.11	0.11‡	0.11
	2050	0.19‡	0.20	0.20‡	0.22
	2100	0.37‡	0.45	0.50‡	0.62
Saugus Iron Works National Historic Site	2030	0.11‡	0.11	0.11‡	0.11

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Saugus Iron Works National Historic Site	2050	0.19‡	0.20	0.20‡	0.22
	2100	0.37‡	0.45	0.50‡	0.62
Statue of Liberty National Monument	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Thaddeus Kosciuszko National Memorial*	2030	0.16‡	0.15	0.15‡	0.14
	2050	0.27‡	0.27	0.27‡	0.28
	2100	0.54‡	0.62	0.68‡	0.79
Theodore Roosevelt Birthplace National Historic Site*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77

Southeast Region					
Big Cypress National Preserve§	2030	0.13	0.13	0.12	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.46	0.54	0.55	0.69
Biscayne National Park	2030	0.14‡	0.13	0.12	0.12
	2050	0.24‡	0.23	0.21	0.24
	2100	0.47‡	0.53	0.53	0.68
Buck Island Reef National Monument	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
Canaveral National Seashore	2030	0.14‡	0.13	0.13‡	0.12
	2050	0.25‡	0.24	0.24‡	0.24
	2100	0.50‡	0.54	0.59‡	0.68
Cape Hatteras National Seashore	2030	0.15‡	0.15	0.15	0.14
	2050	0.26‡	0.28	0.28	0.28
	2100	0.53‡	0.63	0.68	0.79
Cape Lookout National Seashore§	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.27
	2100	0.53	0.61	0.65	0.76
Castillo De San Marcos National Monument	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
Charles Pinckney National Historic Site*	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Christiansted National Historic Site	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
Cumberland Island National Seashore	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
De Soto National Memorial	2030	0.14	0.13	0.13	0.13

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	**4.5**	**6.0**	**8.5**
De Soto National Memorial	2050	0.24	0.24	0.23	0.25
	2100	0.48	0.56	0.57	0.72
Dry Tortugas National Park[§]	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.24
	2100	0.47	0.54	0.56	0.69
Everglades National Park[§]	2030	0.13	0.13	0.12	0.17
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.54	0.68
Fort Caroline National Memorial	2030	0.14	0.13	0.13	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.56	0.56	0.70
Fort Frederica National Monument	2030	0.14	0.13	0.12	0.12
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.54	0.54	0.69
Fort Matanzas National Monument	2030	0.14	0.13	0.13	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.56	0.56	0.70
Fort Pulaski National Monument[§]	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Fort Raleigh National Historic Site	2030	0.15[‡]	0.15	0.15	0.14
	2050	0.27[‡]	0.28	0.28	0.28
	2100	0.53[‡]	0.63	0.68	0.79
Fort Sumter National Monument	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Gulf Islands National Seashore[§]	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.48	0.55	0.57	0.70
Jean Lafitte National Historical Park and Preserve[†§]	2030	0.14	0.13	0.13	0.12
	2050	0.24	0.23	0.23	0.24
	2100	0.48	0.54	0.56	0.68
Moores Creek National Battlefield*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.27
	2100	0.53	0.61	0.65	0.76
New Orleans Jazz National Historical Park*	2030	0.14	0.13	0.13	0.12
	2050	0.24	0.23	0.23	0.24
	2100	0.48	0.54	0.56	0.68
Salt River Bay National Historic Park and Ecological Preserve	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
San Juan National Historic Site	2030	0.12	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.22
	2100	0.43	0.49	0.50	0.64

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Timucuan Ecological and Historic Preserve	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
Virgin Islands Coral Reef National Monument	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.51	0.64
Virgin Islands National Park§	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.51	0.64
Wright Brothers National Memorial*	2030	0.15‡	0.16	0.16	0.15
	2050	0.27‡	0.29	0.28	0.29
	2100	0.53‡	0.65	0.70	0.82

National Capital Region					
Anacostia Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Chesapeake & Ohio Canal National Historical Park§	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.62	0.66	0.79
Constitution Gardens*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Fort Washington Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
George Washington Memorial Parkway§	2030	0.15‡	0.15	0.15‡	0.14
	2050	0.26‡	0.27	0.26‡	0.28
	2100	0.53‡	0.62	0.66‡	0.79
Harpers Ferry National Historical Park*§	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.62	0.66	0.79
Korean War Veterans Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Lincoln Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Martin Luther King Jr. Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
National Mall*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
National Mall & Memorial Parks*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
National World War II Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Piscataway Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Potomac Heritage National Scenic Trail	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
President's Park (White House)*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Rock Creek Park	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Theodore Roosevelt Island Park	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Thomas Jefferson Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Vietnam Veterans Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Washington Monument*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80

Intermountain Region					
Big Thicket National Preserve*	2030	0.14[‡]	0.12	0.12[‡]	0.12
	2050	0.23[‡]	0.23	0.22[‡]	0.23
	2100	0.47[‡]	0.51	0.55[‡]	0.66
Palo Alto Battlefield National Historical Park*[§]	2030	0.13	0.13	0.13	0.12
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.56	0.69
Padre Island National Seashore[§]	2030	0.13	0.13	0.13	0.12
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.56	0.69

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway 2.6	4.5	6.0	8.5
Pacific West Region					
Cabrillo National Monument	2030	0.10	0.10	0.09	0.10
	2050	0.17	0.17	0.17	0.19
	2100	0.35	0.40	0.41	0.53
Channel Islands National Park§	2030	0.11	0.11	0.10	0.10
	2050	0.20	0.19	0.18	0.20
	2100	0.39	0.44	0.46	0.57
Ebey's Landing National Historical Reserve	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46
Fort Point National Historic Site	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
Fort Vancouver National Historic Site*	2030	0.12	0.11	0.11	0.10
	2050	0.21	0.20	0.19	0.19
	2100	0.42	0.45	0.47	0.55
Golden Gate National Recreation Area§	2030	0.11	0.10	0.10	0.10
	2050	0.19	0.18	0.17	0.19
	2100	0.37	0.42	0.43	0.54
Haleakala National Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Hawaii Volcanoes National Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Kalaupapa National Historical Park§	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.66
Kaloko-Honokohau National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Lewis and Clark National Historical Park§	2030	0.12	0.10	0.10	0.10
	2050	0.20	0.19	0.18	0.19
	2100	0.40	0.44	0.46	0.53
National Park of American Samoa	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.52	0.65
Olympic National Park§	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Point Reyes National Seashore[§]	2030	0.11	0.10	0.10	0.10
	2050	0.19	0.19	0.18	0.19
	2100	0.38	0.43	0.45	0.55
Port Chicago Naval Magazine National Memorial	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
Pu'uhonua O Honaunau National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Puukohola Heiau National Historic Site	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.51	0.52	0.67
Redwood National and State Parks	2030	0.12	0.11	0.10	0.10
	2050	0.20	0.19	0.18	0.20
	2100	0.40	0.44	0.46	0.56
Rosie the Riveter WWII Home Front National Historical Park	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
San Francisco Maritime National Historical Park	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
San Juan Island National Historical Park	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46
Santa Monica Mountains National Recreation Area[§]	2030	0.12	0.11	0.10	0.11
	2050	0.20	0.20	0.19	0.20
	2100	0.40	0.45	0.46	0.58
War in the Pacific National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.22	0.24
	2100	0.44	0.51	0.54	0.68
World War II Valor in the Pacific National Monument[§]	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.52	0.67

Alaska Region					
Aniakchak Preserve[§]	2030	0.09[‡]	0.09	0.09	0.09
	2050	0.15[‡]	0.17	0.16	0.18
	2100	0.31[‡]	0.38	0.40	0.51
Bering Land Bridge National Preserve[§]	2030	0.11	0.11	0.10	0.11

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
	2050	0.18	0.19	0.18	0.21
	2100	0.37	0.44	0.45	0.60
Cape Krusenstern National Monument[§]	2030	0.10	0.10	0.10	0.10
	2050	0.17	0.18	0.17	0.20
	2100	0.35	0.42	0.43	0.58
Glacier Bay National Park[†§]	2030	0.07	0.06	0.06	0.06
	2050	0.11	0.11	0.11	0.12
	2100	0.23	0.25	0.28	0.34
Glacier Bay Preserve[†]	2030	0.06	0.06	0.06	0.06
	2050	0.11	0.11	0.11	0.11
	2100	0.22	0.24	0.27	0.33
Katmai National Park[§]	2030	0.09	0.08	0.08	0.08
	2050	0.15	0.15	0.15	0.16
	2100	0.31	0.34	0.37	0.47
Katmai National Preserve[†§]	2030	0.09	0.08	0.08	0.08
	2050	0.15	0.15	0.14	0.16
	2100	0.30	0.33	0.34	0.45
Kenai Fjords National Park[†§]	2030	0.09[‡]	0.08	0.08[‡]	0.08
	2050	0.15[‡]	0.14	0.14[‡]	0.15
	2100	0.30[‡]	0.33	0.34[‡]	0.44
Klondike Gold Rush National Historical Park*[†§]	2030	0.06[‡]	0.06	0.06[‡]	0.06
	2050	0.11	0.11	0.11[‡]	0.11
	2100	0.22	0.24	0.27	0.33
Lake Clark National Park*[†]	2030	0.08	0.08	0.07	0.08
	2050	0.14	0.14	0.13	0.15
	2100	0.29	0.32	0.33	0.43
Sitka National Historical Park[†]	2030	0.08	0.07	0.07	0.07
	2050	0.14	0.14	0.13	0.14
	2100	0.28	0.31	0.33	0.41
Wrangell - St. Elias National Park[§]	2030	0.07	0.06	0.06	0.07
	2050	0.12	0.12	0.11	0.12
	2100	0.23	0.26	0.8	0.35
Wrangell – St. Elias National Preserve*[§]	2030	0.07	0.06	0.06	0.06
	2050	0.12	0.12	0.11	0.12
	2100	0.23	0.26	0.29	0.35

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table E3. IBTrACS data (Knapp et al. 2010) was used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Park Unit	Highest Recorded Hurricane Within 10 mi
Northeast Region	
Acadia National Park	Hurricane, Saffir-Simpson category 1
Assateague Island National Seashore	Hurricane, Saffir-Simpson category 1
Boston Harbor Islands National Recreation Area	Hurricane, Saffir-Simpson category 2
Boston National Historical Park	Hurricane, Saffir-Simpson category 3
Cape Cod National Seashore	Hurricane, Saffir-Simpson category 2
Castle Clinton National Monument	Hurricane, Saffir-Simpson category 1
Colonial National Historical Park	Tropical storm
Edgar Allen Poe National Historic Site	Extratropical storm
Federal Hall National Memorial	Hurricane, Saffir-Simpson category 1
Fire Island National Seashore	Hurricane, Saffir-Simpson category 2
Fort McHenry National Monument and Historic Shrine	Tropical storm
Fort Monroe National Monument	Tropical storm
Gateway National Recreation Area	Hurricane, Saffir-Simpson category 1
General Grant National Memorial	Hurricane, Saffir-Simpson category 1
George Washington Birthplace National Monument	Extratropical storm
Governors Island National Monument	Hurricane, Saffir-Simpson category 1
Hamilton Grange National Memorial	Hurricane, Saffir-Simpson category 1
Harriet Tubman Underground Railroad National Monument	Tropical storm
Independence National Historical Park	Extratropical storm
New Bedford Whaling National Historical Park	Extratropical storm
Petersburg National Battlefield	Hurricane, Saffir-Simpson category 2

Roger Williams National Memorial	Hurricane, Saffir-Simpson category 3
Sagamore Hill National Historic Site	Hurricane, Saffir-Simpson category 2
Saint Croix Island International Historic Site	Hurricane, Saffir-Simpson category 2
Salem Maritime National Historic Site	Hurricane, Saffir-Simpson category 1
Saugus Iron Works National Historic Site	Hurricane, Saffir-Simpson category 1
Statue of Liberty National Monument	Hurricane, Saffir-Simpson category 1
Thaddeus Kosciuszko National Memorial	Extratropical storm
Theodore Roosevelt Birthplace National Historic Site	Hurricane, Saffir-Simpson category 1

Southeast Region	
Big Cypress National Preserve	Hurricane, Saffir-Simpson category 4
Biscayne National Park	Hurricane, Saffir-Simpson category 4
Buck Island Reef National Monument	Hurricane, Saffir-Simpson category 2
Canaveral National Seashore	Hurricane, Saffir-Simpson category 2
Cape Hatteras National Seashore	Hurricane, Saffir-Simpson category 3
Cape Lookout National Seashore	Hurricane, Saffir-Simpson category 3
Castillo De San Marcos National Monument	Hurricane, Saffir-Simpson category 3
Charles Pinckney National Historic Site	Hurricane, Saffir-Simpson category 4
Christiansted National Historic Site	Hurricane, Saffir-Simpson category 4
Cumberland Island National Seashore	Hurricane, Saffir-Simpson category 4
De Soto National Memorial	Hurricane, Saffir-Simpson category 1
Dry Tortugas National Park	Hurricane, Saffir-Simpson category 4
Everglades National Park	Hurricane, Saffir-Simpson category 5
Fort Caroline National Memorial	Hurricane, Saffir-Simpson category 2
Fort Frederica National Monument	Hurricane, Saffir-Simpson category 1
Fort Matanzas National Monument	Hurricane, Saffir-Simpson category 1
Fort Pulaski National Monument	Hurricane, Saffir-Simpson category 2
Fort Raleigh National Historic Site	Hurricane, Saffir-Simpson category 2
Fort Sumter National Monument	Hurricane, Saffir-Simpson category 4

Gulf Islands National Seashore	Hurricane, Saffir-Simpson category 4
Jean Lafitte National Historical Park and Preserve	Hurricane, Saffir-Simpson category 2
Moores Creek National Battlefield	Hurricane, Saffir-Simpson category 1
New Orleans Jazz National Historical Park	Hurricane, Saffir-Simpson category 2
Salt River Bay National Historic Park and Ecological Preserve	Hurricane, Saffir-Simpson category 4
San Juan National Historic Site	Hurricane, Saffir-Simpson category 3
Timucuan Ecological and Historic Preserve	Hurricane, Saffir-Simpson category 2
Virgin Islands Coral Reef National Monument	Hurricane, Saffir-Simpson category 3
Virgin Islands National Park	Hurricane, Saffir-Simpson category 3
Wright Brothers National Memorial	Hurricane, Saffir-Simpson category 2

National Capital Region	
Anacostia Park	Hurricane, Saffir-Simpson category 2
Chesapeake & Ohio Canal National Historical Park	Hurricane, Saffir-Simpson category 2
Constitution Gardens	Hurricane, Saffir-Simpson category 2
Fort Washington Park	Hurricane, Saffir-Simpson category 2
George Washington Memorial Parkway	Hurricane, Saffir-Simpson category 2
Harpers Ferry National Historical Park	Extratropical storm
Korean War Veterans Memorial	Hurricane, Saffir-Simpson category 2
Lincoln Memorial	Hurricane, Saffir-Simpson category 2
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Hurricane, Saffir-Simpson category 2
Martin Luther King Jr. Memorial	Hurricane, Saffir-Simpson category 2
National Mall	Hurricane, Saffir-Simpson category 2
National Mall & Memorial Parks	Hurricane, Saffir-Simpson category 2
National World War II Memorial	Hurricane, Saffir-Simpson category 2
Piscataway Park	Hurricane, Saffir-Simpson category 2
Potomac Heritage National Scenic Trail	Hurricane, Saffir-Simpson category 2
President’s Park (White House)	Hurricane, Saffir-Simpson category 2

Rock Creek Park	Hurricane, Saffir-Simpson category 2
Theodore Roosevelt Island Park	Hurricane, Saffir-Simpson category 2
Thomas Jefferson Memorial	Hurricane, Saffir-Simpson category 2
Vietnam Veterans Memorial	Hurricane, Saffir-Simpson category 2
Washington Monument	Hurricane, Saffir-Simpson category 2

Intermountain Region	
Big Thicket National Preserve	Hurricane, Saffir-Simpson category 3
Palo Alto Battlefield National Historical Park	No recorded historical storm
Padre Island National Seashore	Hurricane, Saffir-Simpson category 4

Pacific West Region	
Cabrillo National Monument	Tropical depression
Channel Islands National Park	No recorded historical storm
Ebey's Landing National Historical Reserve	No recorded historical storm
Fort Point National Historic Site	No recorded historical storm
Fort Vancouver National Historic Site	No recorded historical storm
Golden Gate National Recreation Area	No recorded historical storm
Haleakala National Park	Tropical depression
Hawaii Volcanoes National Park	Tropical depression
Kalaupapa National Historical Park	Tropical depression
Kaloko-Honokohau National Historical Park	Tropical depression
Lewis and Clark National Historical Park	No recorded historical storm
National Park of American Samoa	No recorded historical storm
Olympic National Park	No recorded historical storm
Point Reyes National Seashore	No recorded historical storm
Port Chicago Naval Magazine National Memorial	No recorded historical storm
Pu'uhonua O Honaunau National Historical Park	No recorded historical storm
Puukohola Heiau National Historic Site	Tropical depression

Redwood National and State Parks	No recorded historical storm
Rosie the Riveter WWII Home Front National Historical Park	No recorded historical storm
San Francisco Maritime National Historical Park	No recorded historical storm
San Juan Island National Historical Park	No recorded historical storm
Santa Monica Mountains National Recreation Area	No recorded historical storm
War in the Pacific National Historical Park	No recorded historical storm
World War II Valor in the Pacific National Monument	Tropical depression

Alaska Region	
Aniakchak Preserve	No recorded historical storm
Bering Land Bridge National Preserve	No recorded historical storm
Cape Krusenstern National Monument	No recorded historical storm
Glacier Bay National Park	No recorded historical storm
Glacier Bay Preserve	No recorded historical storm
Katmai National Park	No recorded historical storm
Katmai National Preserve	No recorded historical storm
Kenai Fjords National Park	No recorded historical storm
Klondike Gold Rush National Historical Park	No recorded historical storm
Lake Clark National Park	No recorded historical storm
Sitka National Historical Park	No recorded historical storm
Wrangell - St. Elias National Park	No recorded historical storm
Wrangell – St. Elias National Preserve	No recorded historical storm

NPS XXXXXX, September 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
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Fort Collins, CO 80525

www.nature.nps.gov

11 2 Attachment Reviewer comments_insert last name here.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

12 Re_ REQUEST_ peer review manager for sea level_....pdf

From:	Gross, John
To:	Beavers, Rebecca
Cc:	Cat Hawkins Hoffman
Subject:	Re: REQUEST: peer review manager for sea level/ storm surge projections report & data series
Date:	Friday, September 02, 2016 5:03:39 PM

Hi Rebecca,

If you handle this like you've done in the past (i.e., you do 99% of the work ...) then I'd be happy to read through the materials and do that last 1%.

Cheers,
johng

On Fri, Sep 2, 2016 at 2:52 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi John:
>
> Maria Caffrey, Patrick, Amanda, and I met this week; we are the non- external component of the sea level /storm surge project's science team. In 1-2 weeks, Maria Caffrey will submit a report and GIS data for NPS NRSS review. This will likely be published as 2 items: a NRR and data series.
>
> We are at the point that we need a CCRP peer review manager (other than one of us). I highly recommended you, and Cat gave her OK to ask you via correspondence w/ Patrick ;-)
>
> Since you have done this role with me before, you know I will help as appropriate to reduce the time required by you. We also have Amanda stepping up to help, too.
>
> Will you serve as the peer review manager for these 2 items: a NRR and data series?
>
> Thank you!
>
> -rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
> http://www.nps.gov/subjects/climatechange/adaptation.htm
>
> 2016 National Park Service CENTENNIAL | FIND YOUR PARK

--
John Gross, PhD
Climate Change Ecologist, NPS

13 Re_ Sea level and storm surge project draft report.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Cc:	Rob Thieler
Subject:	Re: Sea level and storm surge project draft report
Date:	Monday, September 12, 2016 10:52:38 AM

Thanks for fitting in a quick review, Rob. (b) (6) [redacted]

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
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On Mon, Sep 12, 2016 at 10:46 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Rob,
>
> Thanks so much for sending me this. I'll make sure to expand on the things you suggest. Sorry it was all rather short notice.
>
> (b) (6) [redacted].
>
> Cheers,
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
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>
> On Mon, Sep 12, 2016 at 10:43 AM, Rob Thieler <rthieler@usgs.gov> wrote:
>
>> Maria,
>>
>> Sorry to have missed the call. The invite came while I was (b) (6) [redacted], and when we came back (b) (6) [redacted]. Suffice to say I've been running to catch up. But unfortunately this request is one where the train leaves me behind.
>>
>> I gave the report a really, really quick glance over. A couple things that you may want to add:

) more discussion of a) why the IPCC SLR projections are used (beyond just the process model rationale, e.g., are they more spatially comprehensive than other options), and b) how these projections and their uncertainties compare to more recent work (e.g., Kopp et al. 2014 Earth's Future; 2016 PNAS), as well as the projections used in the third National Climate Assessment. Much as I use and admire the work of IPCC, their projections weren't out a week before people started looking for the next thing. (For better or worse, almost seems like SLR projections have gone into 24-hour news cycle mode.) Obviously you have to choose something, but it bears explaining and comparing what you chose in a bit more depth.

) comparison of the storm MEOW/MOM approach to recent extreme water level work, e.g., Sweet and Park 2014 Earth's Future; Hall et al. 2016 for DOD https://www.serdp-estcp.org/News-and-Events/News-Announcements/Program-News/DoD-Report-on-Regional-Sea-Level-Scenarios). Also, how this compares to similar work by UCS (http://www.ucsusa.org/sites/default/files/attach/2016/07/us-military-on-front-lines-of-rising-seas_all-materials.pdf). Point being that there are an increasing number of these studies and there is increasing potential for brand, data, and most importantly, conclusion confusion (esp in situations where you have a studied military installation near/next to a studied NPS unit).

Hope this little bit helps. Holler if you want suggestions for external reviewers. But authors of the aforementioned reports would be a good place to start.

Best,
-rt

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From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Date: Friday, September 2, 2016 at 5:19 PM
To: Rob Thieler <rthieler@usgs.gov>
Subject: Sea level and storm surge project draft report

Hi Rob,

Sorry you couldn't make our call this week. The good news is that I've put together a draft of my final report. I was wondering if you have time to look it over? Patrick has asked that I send a copy of this to each science team member for your initial review before I send it out for wider review by the regions and external reviewers. We are also sending the GIS data out for separate review by GIS specialists. We are planning on issuing the GIS data in a separate publication.

So sorry for the short notice. Would it be possible for you to look it over and get back to me by 9/16? If not, I can always add you as a reviewer when it goes out for wider review, but I thought you might want to check it out before I send it to too many people.

I have attached the report along with an excel file for your comments. It will be easier to compile the comments if they are in a table format rather using four versions of track changes. Thanks for your help on this.

Have a great labor day weekend.

Maria Caffrey, PhD

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14 SLR statement; IUCN; Patrick’s brief.pdf

From:	Gross, John
To:	Caffrey, Maria; Rebecca Beavers
Subject:	SLR statement; IUCN; Patrick"s brief
Date:	Tuesday, September 13, 2016 12:29:22 PM
Attachments:	DeConto RM Pollard 2016 Antarctic ice and SLR Nature.pdf Boetsch DF etal 2008 MD CC impact assessment.pdf

Maria and Rebecca,

Very nice visiting with you about the report and associated data. From a very selfish perspective, your work is going to be extremely useful to me and others in CCRP so full steam ahead! And more broadly (and perhaps more immediately), the information is going to be even more helpful to people in facilities and operations. So I'll do everything I can to help you polish this and push it out the door.

On SLR: I also agree totally with what Patrick put in his brief, but he completely failed to address the concern I have, which is that IPCC has very explicit requirements about the information and data that it allows to be considered in e.g. estimating SLR or other climate increases. My concern is that we are very rapidly increasing our knowledge of ice and ocean dynamics, both through the analysis of existing observations, and we are now observing changes and dynamics that were not apparent at the time the last IPCC projections were produced. Attached are a couple papers that support my (perhaps incorrect) impression that newer studies are mostly supporting SLR projections greater than IPCC. (BTW, Boetsch et al. has an exceptionally nice explanation of why bay surges will increase even more than SLR. I had absolutely no appreciation or understanding of this, and even I could present it to park staff after reading the report).

I hoped Patrick would address the differences between IPCC and other (mostly newer) projections. I'm not so much interested in how IPCC did their projections, but really would like an expert assessment or synthesis of the suite of SLR projections and whether the newer projections of greater SLR rates are credible and broadly supported by the community of scientists with suitable expertise.

And.. here's the URL for the partly-laid-out version, and below the statement that I made and that I'm wondering if you think is OK/correct/could be improved.

URL for guide: http://www.georgewright.org/iucn_cc_bpg_arc

Statement (PAs = protected areas)

Sea level rise is important for many PAs, and it is thus may be an important variable to include in climate scenarios. The IPCC Working Group 1 report (2013, Chapter 13) includes regional-scale sea level rise projections. Some recent analyses have estimated greater rates of sea level rise than those reported by IPCC, particularly studies with new information of ice sheet dynamics (DeConto et al., 2016). Both high and low estimates can be used in scenarios to represent the range of projections for sea level increases.

Cheers,
johng

On Tue, Sep 13, 2016 at 11:48 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Hi John,
>
> Here is the file I mentioned in our meeting today.
>
> Cheers,
>
> Maria Caffrey, PhD
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John Gross, PhD
Climate Change Ecologist, NPS

14 1 Attachment DeConto RM Pollard 2016 Antarctic ice and SLR .pdf

ARTICLE

doi:10.1038/nature17145

Contribution of Antarctica to past and future sea-level rise

Robert M. DeConto[1] & David Pollard[2]

Polar temperatures over the last several million years have, at times, been slightly warmer than today, yet global mean sea level has been 6–9 metres higher as recently as the Last Interglacial (130,000 to 115,000 years ago) and possibly higher during the Pliocene epoch (about three million years ago). In both cases the Antarctic ice sheet has been implicated as the primary contributor, hinting at its future vulnerability. Here we use a model coupling ice sheet and climate dynamics—including previously underappreciated processes linking atmospheric warming with hydrofracturing of buttressing ice shelves and structural collapse of marine-terminating ice cliffs—that is calibrated against Pliocene and Last Interglacial sea-level estimates and applied to future greenhouse gas emission scenarios. Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500, if emissions continue unabated. In this case atmospheric warming will soon become the dominant driver of ice loss, but prolonged ocean warming will delay its recovery for thousands of years.

Reconstructions of the global mean sea level (GMSL) during past warm climate intervals including the Pliocene (about three million years ago)[1] and late Pleistocene interglacials[2–5] imply that the Antarctic ice sheet has considerable sensitivity. Pliocene atmospheric CO_2 concentrations were comparable to today's ($\sim$400 parts per million by volume, p.p.m.v.)[6], but some sea-level reconstructions are 10–30 m higher[1,7]. In addition to the loss of the Greenland Ice Sheet and the West Antarctic Ice Sheet (WAIS)[2], these high sea levels require the partial retreat of the East Antarctic Ice Sheet (EAIS), which is further supported by sedimentary evidence from the Antarctic margin[8]. During the more recent Last Interglacial (LIG, 130,000 to 115,000 years ago), GMSL was 6–9.3 m higher than it is today[2–4], at a time when atmospheric CO_2 concentrations were below 280 p.p.m.v. (ref. 9) and global mean temperatures were only about 0–2 °C warmer[10]. This requires a substantial sea-level contribution from Antarctica of 3.6–7.4 m in addition to an estimated 1.5–2 m from Greenland[11,12] and around 0.4 m from ocean steric effects[10]. For both the Pliocene and the LIG, it is difficult to obtain the inferred sea-level values from ice-sheet models used in future projections.

Marine ice sheet and ice cliff instabilities

Much of the WAIS sits on bedrock hundreds to thousands of metres below sea level (Fig. 1a)[13]. Today, extensive floating ice shelves in the Ross and Weddell Seas, and smaller ice shelves and ice tongues in the Amundsen and Bellingshausen seas (Fig. 1b) provide buttressing that impedes the seaward flow of ice and stabilizes marine grounding zones (Fig. 2a). Despite their thickness (typically about 1 km near the grounding line to a few hundred metres at the calving front), a warming ocean has the potential to quickly erode ice shelves from below, at rates exceeding 10 m yr^{-1} °C^{-1} (ref. 14). Ice-shelf thinning and reduced backstress enhance seaward ice flow, grounding-zone thinning, and retreat (Fig. 2b). Because the flux of ice across the grounding line increases strongly as a function of its thickness[15], initial retreat onto a reverse-sloping bed (where the bed deepens and the ice thickens upstream) can trigger a runaway Marine Ice Sheet Instability (MISI; Fig. 2c)[15–17]. Many WAIS grounding zones sit precariously on the edge of such reverse-sloped beds, but the EAIS also contains deep subglacial basins with reverse-sloping, marine-terminating outlet troughs up to 1,500 m deep (Fig. 1). The ice above floatation in these East Antarctic basins is much thicker than in West Antarctica, with the potential to raise GMSL by around 20 m if the ice in those basins is lost[13]. Importantly, previous ice-sheet simulations accounting for migrating grounding lines and MISI dynamics have shown the potential for repeated WAIS retreats and readvances over the past few million years[18], but could only account for GMSL rises of about 1 m during the LIG and 7 m in the warm Pliocene, which are substantially smaller than geological estimates.

So far, the potential for MISI to cause ice-sheet retreat has focused on the role of ocean-driven melting of buttressing ice shelves from below[16,18–20]. However, it is often overlooked that the major ice shelves in the Ross and Weddell seas and the many smaller shelves and ice tongues buttressing outlet glaciers are also vulnerable to atmospheric warming. Today, summer temperatures approach or just exceed 0 °C on many shelves[21], and their flat surfaces near sea level mean that little atmospheric warming would be needed to dramatically increase the areal extent of surface melting and summer rainfall.

Meltwater on ice-shelf surfaces causes thinning if it percolates through the shelf to the ocean. If refreezing occurs, the ice is warmed, reducing its viscosity and speeding its flow[22]. The presence of rain and meltwater can also influence crevassing and calving rates[23] (hydrofracturing) as witnessed on the Antarctic Peninsula's Larson B ice shelf during its sudden break-up in 2002[24]. Similar dynamics could have affected the ice sheet during ancient warm intervals[25], and given enough future warming, could eventually affect many ice shelves and ice tongues, including the major buttressing shelves in the Ross and Weddell seas.

Another physical mechanism previously underappreciated at the ice-sheet scale involves the mechanical collapse of ice cliffs in places where marine-terminating ice margins approach 1 km in thickness, with >90 m of vertical exposure above sea level[26]. Today, most Antarctic outlet glaciers with deep beds approaching a water depth of 1 km are protected by buttressing ice shelves, with gently sloping surfaces at the grounding line (Fig. 2d). However, given enough atmospheric warming above or ocean warming below (Fig. 2e), ice-shelf retreat can outpace its dynamically accelerated seaward flow as buttressing is lost and

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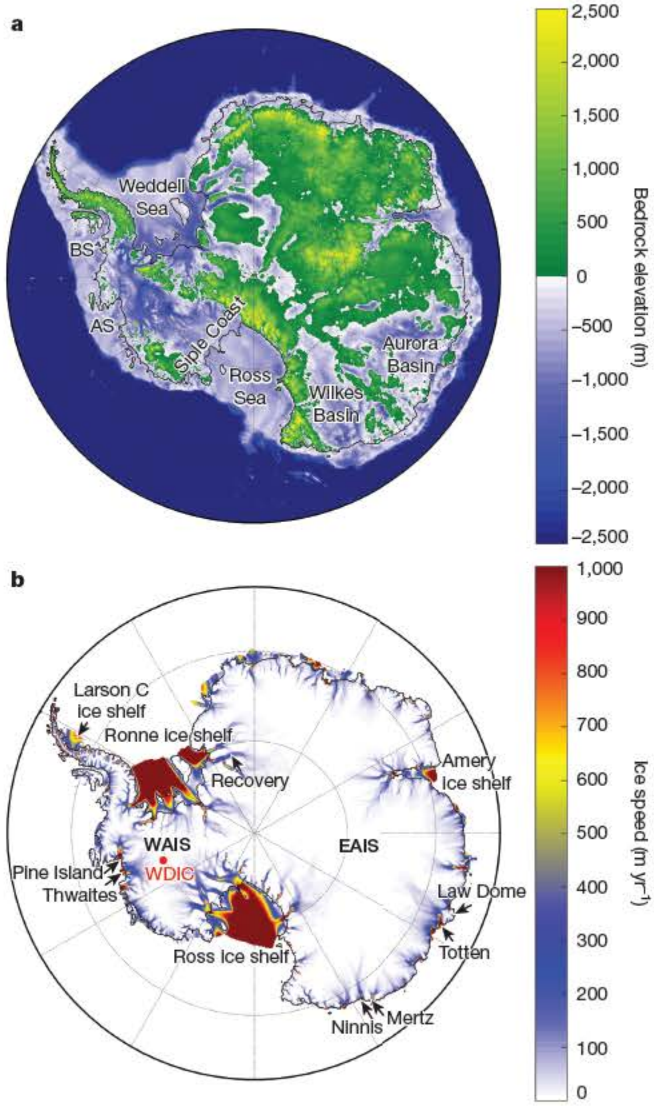

Figure 1 | Antarctic sub-glacial topography and ice sheet features. **a**, Bedrock elevations[13] interpolated onto the 10-km polar stereographic ice-sheet model grid and used in Pliocene, LIG, and future ice-sheet simulations. **b**, Model surface ice speeds and grounding lines (black lines) show the location of major ice streams, outlet glaciers, and buttressing ice shelves (seaward of grounding lines) relative to the underlying topography in **a**. Features and place names mentioned in the text are also shown. AS, Amundsen Sea; BS, Bellingshausen Sea; WDIC, WAIS Divide Ice Core. The locations of the Pine Island, Thwaites, Ninnis, Mertz, Totten, and Recovery glaciers are shown. Model ice speeds (**b**) are shown after equilibration with a modern atmospheric and ocean climatology (see Methods).

retreating grounding lines thicken[15]. In places where marine-terminating grounding lines are thicker than 800 m or so, this would produce >90 m subaerial cliff faces that would collapse (Fig. 2f) simply because longitudinal stresses at the cliff face would exceed the yield strength (about 1 MPa) of the ice[26].

More heavily crevassed and damaged ice would reduce the maximum supported cliff heights. If a thick, marine-terminating grounding line began to undergo such mechanical failure, its retreat would continue unabated until temperatures cooled enough to reform a buttressing ice shelf, or the ice margin retreated onto bed elevations too shallow to support the tall, unstable cliffs[25]. If protective ice shelves were suddenly lost in the vast areas around the Antarctic margin where reverse-sloping bedrock is more than 1,000 m deep (Fig. 1a), exposed grounding-line ice cliffs would quickly succumb to structural failure, as is happening in the few places where such conditions exist today (the Helheim and Jakobsavn glaciers on Greenland and the Crane Glacier on the Antarctic Peninsula), hinting that a Marine Ice Cliff Instability (MICI) in addition to MISI could be an important contributor to past and future ice-sheet retreat.

Our three-dimensional ice sheet–ice shelf model[25,27] (Methods) predicts the evolution of continental ice thickness and temperature as a function of ice flow (deformation and sliding) and changes in mass balance via precipitation, runoff, basal melt, oceanic melt under ice shelves and on vertical ice faces, calving, and tidewater ice-cliff failure. The model captures MISI (Fig. 2a–c) by accounting for migrating grounding lines and the buttressing effects of ice shelves with pinning points and side-shear. To capture the dynamics of MICI (Fig. 2d–f), new physical treatments of surface-melt and rainwater-enhanced calving (hydrofracturing) and grounding-line ice-cliff dynamics have been added[25]. Including these processes was found to increase the model's contribution to Pliocene GMSL from +7 m (ref. 18) to +17 m (ref. 25). The model formulation used here is similar to that described in ref. 25, but with improvements in the treatment of calving, thermodynamics, and climate–ice–ocean coupling (Methods).

The Antarctic Ice Sheet in the Pliocene

The warm mid-Pliocene and LIG provide complementary targets for model performance, via the ability to produce ~5–20 m and ~3.5–7.5 m GMSL from Antarctica, respectively. These two time periods highlight model sensitivities to different processes, because Pliocene summer air temperatures were capable of producing substantial surface meltwater, especially during warm austral summer orbits[28]. Conversely, LIG temperatures were cooler[29], with limited potential for surface meltwater production. Instead, ocean temperatures[30] could have been the determining factor in LIG ice retreat[31].

To simulate Pliocene and LIG ice sheets, we couple the ice model to a high-resolution, atmospheric regional climate model (RCM) adapted to Antarctica and nested within a global climate model (GCM; see Methods). The RCM captures the orographic details of ice shelves and adjacent ice-sheet margins, which is critical here because the new calving and grounding line processes are mechanistically linked to the atmosphere.

High-resolution ocean modelling beneath time-evolving ice shelves on palaeoclimate timescales exceeds existing capabilities. Instead, we use a modern ocean climatology[32] interpolated to our ice-sheet grid, with uniformly imposed sub-surface ocean warming providing melt rates on sub-ice-shelf and calving-front surfaces exposed to sea water. The RCM climatologies and imposed ocean warming are applied to quasi-equilibrated initial ice-sheet states, with atmospheric temperatures and the precipitation lapse-rate corrected as the ice sheet evolves.

As in ref. 25, the Pliocene simulation uses a RCM climatology with 400 p.p.m.v. CO_2, a warm austral summer orbit[28], and 2 °C imposed ocean warming to represent maximum mid-Pliocene warmth (Extended Data Fig. 1). The model produces an 11.3-m contribution to GMSL rise, reflecting a reduction in its sensitivity of about 6 m relative to the formulation in ref. 25, but within the range of plausible sea-level estimates[1,7]. Pliocene retreat is triggered by meltwater-induced hydrofracturing of ice shelves, which relieves backstress and initiates both MISI and MICI retreat into the deepest sectors of WAIS and EAIS marine basins.

The Antarctic Ice Sheet during the LIG

Summer air temperatures in the RCM are slightly warmer at 116 kyr ago than 128 kyr ago, but remain below freezing in both cases, with little to no surface melt (Extended Data Fig. 2). As a result, substantial oceanic warming >4 °C is required to initiate WAIS retreat at 128 kyr ago, which occurs once an ocean-melt threshold is reached in the stability of the Thwaites grounding line (Extended Data Fig. 3a and d). Allowing two-way coupling between the RCM and the ice-sheet model

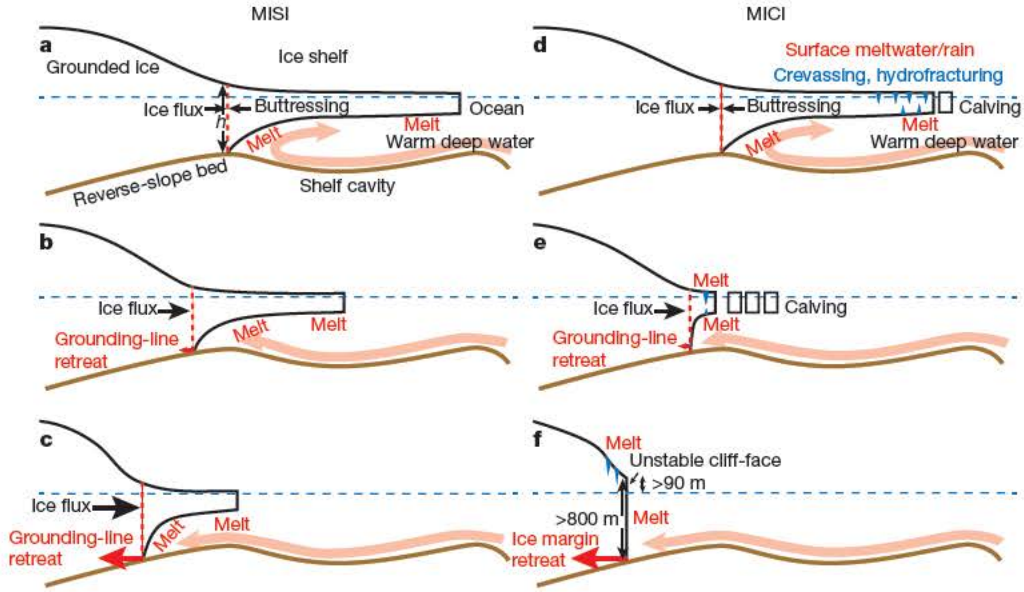

Figure 2 | Schematic representation of MISI and MICI and processes included in the ice model. Top-to-bottom sequences (**a–c** and **d–f**) show progressive ice retreat into a subglacial basin, triggered by oceanic and atmospheric warming. The pink arrow represents the advection of warm circumpolar deep water (CDW) into the shelf cavity. **a**, Stable, marine-terminating ice-sheet margin, with a buttressing ice shelf. Seaward ice flux is strongly dependent on grounding-line thickness *h*. Sub-ice melt rates increase with open-ocean warming and warm-water incursions into the ice-shelf cavity. **b**, Thinning shelves and reduced buttressing increase seaward ice flux, backing the grounding line onto reverse-sloping bedrock. **c**, Increasing *h* with landward grounding-line retreat leads to an ongoing increase in ice flow across the grounding line in a positive runaway feedback until the bed slope changes. **d**, In addition to MISI (**a–c**), the model physics used here account for surface-meltwater-enhanced calving via hydrofracturing of floating ice (**e**), providing an additional mechanism for ice-shelf loss and initial grounding-line retreat into deep basins. **f**, Where oceanic melt and enhanced calving eliminate shelves completely, subaerial cliff faces at the ice margin become structurally unstable where *h* exceeds 800 m, triggering rapid, unabated MICI retreat into deep basins.

(Methods) captures dynamical atmospheric feedbacks as the ice margin retreats. This enhances retreat (Extended Data Fig. 3b, e), but still requires >4 °C of ocean warming to produce a >3.5 m increase in GMSL. We find that by accounting for the additional influence of circum-Antarctic ocean warming on the RCM atmosphere (Methods), the GMSL contribution increases to >6.5 m with just 3 °C sub-surface ocean warming (Extended Data Fig. 3c and f), despite the cooler orbit of the Earth 128 kyr ago. The ocean-driven continental warming at 128 kyr ago agrees with ice core records[29] and supports a Southern Ocean control on the timing of ice-sheet retreat[30,31], possibly through Northern Hemisphere influences on the ocean meridional overturning circulation[33].

Alternative simulations (Fig. 3) use time-evolving atmospheric and oceanic climatologies (Methods) based on marine and ice-core proxy reconstructions[29]. These time-continuous simulations produce GMSL contributions of 6–7.5 m early in the interglacial, followed by a prolonged plateau and rapid recovery of the ice sheet beginning around 115 kyr ago. This result matches the magnitude, temporal pattern, and rate of LIG sea-level change in ref. 3. (Fig. 3a), and the simulated recovery of the WAIS satisfies the presence of ice >70 kyr ago at the bottom of the WAIS Divide Ice Core[34].

Combined with estimates of Greenland ice loss[11,12,35] and ocean thermal effects[10], the simulated, Antarctic contributions to Pliocene and LIG sea level are in much better agreement with geological estimates[2–4] than previous versions of our model[18,27], which lacked these new treatments of meltwater-enhanced calving and ice-margin dynamics, suggesting that the new model is better suited to simulations of future ice response.

Future simulations

Using the same model physics and parameter values as used in the Pliocene and LIG simulations, we apply the ice-sheet model to long-term future simulations (Methods). Here, atmospheric forcing is provided by high-resolution RCM simulations (Extended Data Fig. 4) following three extended Representative Carbon Pathway (RCP) scenarios (RCP2.6, RCP4.5 and RCP8.5)[36]. Future circum-Antarctic ocean temperatures used in our time-evolving sub-ice melt-rate calculations come from matching, high-resolution (1°) National Center for Atmospheric Research (NCAR) CCSM4 simulations (ref. 37, Extended Data Fig. 5). The simulations begin in 1950 to provide some hindcast spinup, and are run for 550 years to 2500.

The RCP scenarios (Fig. 4) produce a wide range of future Antarctic contributions to sea level, with RCP2.6 producing almost no net change by 2100, and only 20 cm by 2500. Conversely, RCP4.5 causes almost complete WAIS collapse within the next five hundred years, primarily owing to the retreat of Thwaites Glacier into the deep WAIS interior. The Siple Coast grounding zone remains stable until late in the simulation, thanks to the persistence of the buttressing Ross Ice Shelf (see Supplementary Video 2). In RCP4.5, GMSL rise is 32 cm by 2100, but subsequent retreat of the WAIS interior, followed by the fringes of the Wilkes Basin and the Totten Glacier/Law Dome sector of the Aurora Basin produces 5 m of GMSL rise by 2500.

In RCP8.5, increased precipitation causes an initial, minor gain in total ice mass (Fig. 4d), but rapidly warming summer air temperatures trigger extensive surface meltwater production[38] and hydrofracturing of ice shelves by the middle of this century (Extended Data Fig. 4). The Larsen C is one of the first shelves to be lost, about 2055. Around the same time, major thinning and retreat of outlet glaciers commences in the Amundsen Sea Embayment, beginning with Pine Island Glacier (Fig. 4h), and along the Bellingshausen margin. Massive meltwater production on shelf surfaces, and eventually on the flanks of the ice sheet, would quickly overcome the buffering capacity of firn[39]. In the model, the meltwater accelerates WAIS retreat via its thermomechanical influence on ice rheology (Methods) and the influence of hydrofacturing on crevassing and structural failure of the retreating margin. Antarctica contributes 77 cm of GMSL rise by 2100, and continued loss of the Ross and Weddell Sea ice shelves drives WAIS retreat from three sides simultaneously (the Amundsen, Ross, and Weddell seas), all with

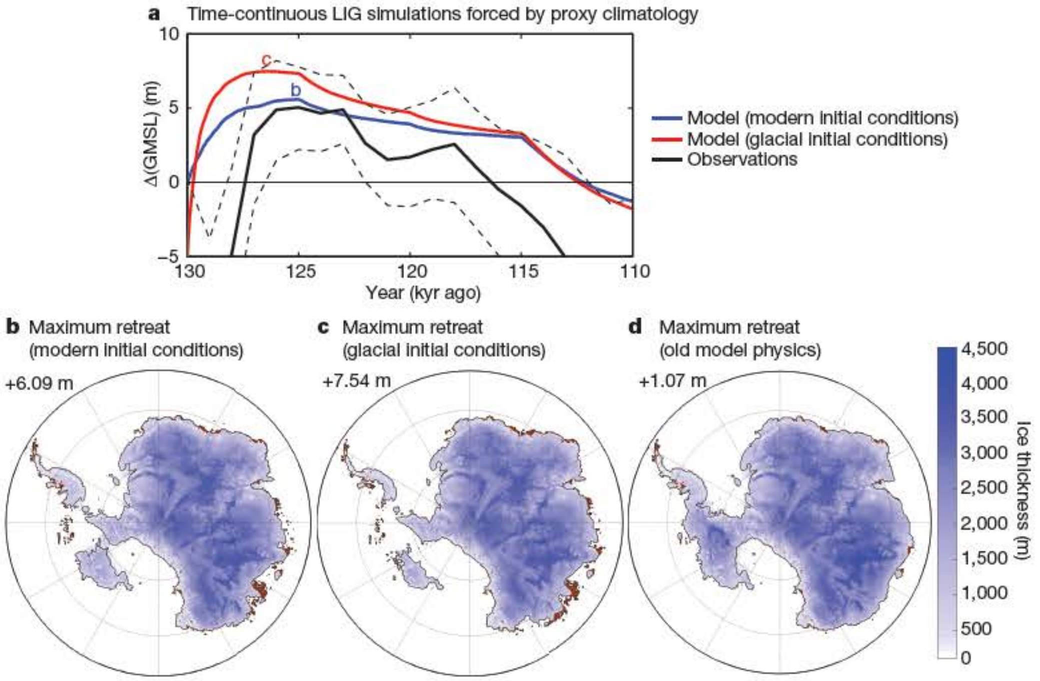

Figure 3 | Ice-sheet simulations and Antarctic contributions to GMSL through the LIG driven by a time-evolving, proxy-based atmosphere–ocean climatology. a, Change in GMSL in LIG simulations starting at 130 kyr ago and initialized with a modern ice sheet (blue) or a bigger LGM ice sheet representing glacial conditions at the onset of the LIG (red). A probabilistic reconstruction of Antarctica's contribution to GMSL is shown in black[3] with uncertainties (16th and 84th percentiles) as dashed lines. **b**, **c**, Ice-sheet thickness at the time of maximum retreat using modern initial conditions (**b**) and using glacial initial conditions (**c**). Ice-free land surfaces are brown. The bigger sea-level response when initialized with the 'glacial' ice sheet is caused by deeper bed elevations and the ~3,000-yr lagged bedrock response to ice retreat[50], which enhances bathymetrically sensitive MISI dynamics. **d**, The same simulation as **b** without the new model physics accounting for meltwater-enhanced calving or ice-cliff failure[27]. GMSL contributions are shown at top left.

reverse-sloping beds into the deep ice-sheet interior. As a result, WAIS collapses within 250 years. At the same time, steady retreat into the Wilkes and Aurora basins, where the ice above floatation is >2,000 m thick, adds substantially to the rate of sea-level rise, exceeding 4 cm yr^{-1} (Fig. 4c) in the next century, which is comparable to maximum rates of sea-level rise during the last deglaciation[40]. At 2500, GMSL rise for the RCP8.5 scenario is 12.3 m. As in our LIG simulations, atmosphere–ice sheet coupling accounting for the warming feedback associated with the retreating ice sheet adds an additional 1.3 m of GMSL to the RCP8.5 scenario (Fig. 4b).

The CCSM4 simulations providing the model's sub-ice-shelf melt rates (Extended Data Fig. 5) underestimate the penetration of warm Circum-Antarctic Deep Water into the Amundsen and Bellingshausen seas observed in recent decades[41]. As a result, the model fails to capture recent, 21st-century thinning and grounding-line retreat along the southern Antarctic Peninsula[42] and the Amundsen Sea Embayment[43]. Correcting for the ocean-model cool bias along this sector of coastline improves the position of Pine Island and Thwaites grounding lines relative to observations[42,43] (Fig. 4h) and increases GMSL rise by 9 cm at 2100 (mainly due to the accelerated retreat of Pine Island Glacier), but the correction has little effect on longer timescales (Extended Data Table 1). Ocean warming is important to the behaviour of individual outlet glaciers early in the simulations, but we find that most of the long-term sea-level rise in RCP4.5 and RCP8.5 scenarios is caused by atmospheric warming and the onset of extensive surface meltwater production, rather than ocean warming as implied by other recent studies[44–46]. Without atmospheric warming, the magnitude of RCP8.5 ocean warming in CCSM4 is insufficient to cause the major retreat of the WAIS or East Antarctic basins; and even with >3 °C additional warming in the Amundsen and Bellingshausen seas it takes several thousand years for WAIS to retreat via ocean-driven MISI dynamics alone (Extended Data Fig. 6). We note that despite the 10-km grid resolution, the model simulates major ice streams well (Fig. 1), including their internal variability[18]. However, during drastic subglacial-basin retreat the internal variability is quickly overtaken as grounding lines recede into deep interior catchments (see Supplementary Video 10).

Large Ensemble analysis

To better utilize Pliocene and LIG geological constraints on model performance, we perform a Large Ensemble analysis (Methods) to explore the uncertainty associated with the primary parameter values controlling (1) relationships between ocean temperature and sub-ice-shelf melt rates, (2) hydrofracturing (crevasse penetration in relation to surface liquid water supply), and (3) maximum rates of marine-terminating ice-cliff failure. The combination of Pliocene and LIG sea level targets is ideal, because Pliocene retreat is dominated by processes associated with (2) and (3), while the LIG is dominated by process (1).

Both Pliocene and LIG ensembles are run with combinations of widely ranging parameter values associated with the three processes, and the combinations are scored by their ability to simulate target ranges of Pliocene and LIG Antarctic sea-level contributions (Methods). The filtered subsets of parameter values capable of reproducing both targets are then used in ensembles of future RCP scenarios (Extended Data Table 2), providing both an envelope of possible outcomes and an estimate of the model's parametric uncertainty (Fig. 5). Importantly, the ensemble analysis supports our choice of 'default' model parameters used in the nominal Pliocene, LIG, and future simulations (Fig. 4, Extended Data Table 2). The lack of substantial ice-sheet retreat in the optimistic RCP2.6 scenario remains unchanged, but the Large Ensemble analysis substantially increases our RCP4.5 and RCP8.5 2100 sea-level projections to 49 ± 20 cm and 105 ± 30 cm, if higher (>10 m instead of >5 m) Pliocene sea-level targets are used. Adding the ocean temperature correction in the Amundsen and Bellingshausen seas (Fig. 4d and h) further increases the 2100 projections in RCP2.6, RCP4.5 and RCP8.5 to 16 ± 16 cm, 58 ± 28 cm and 114 ± 36 cm, respectively (see Methods and Extended Data Tables 1 and 2).

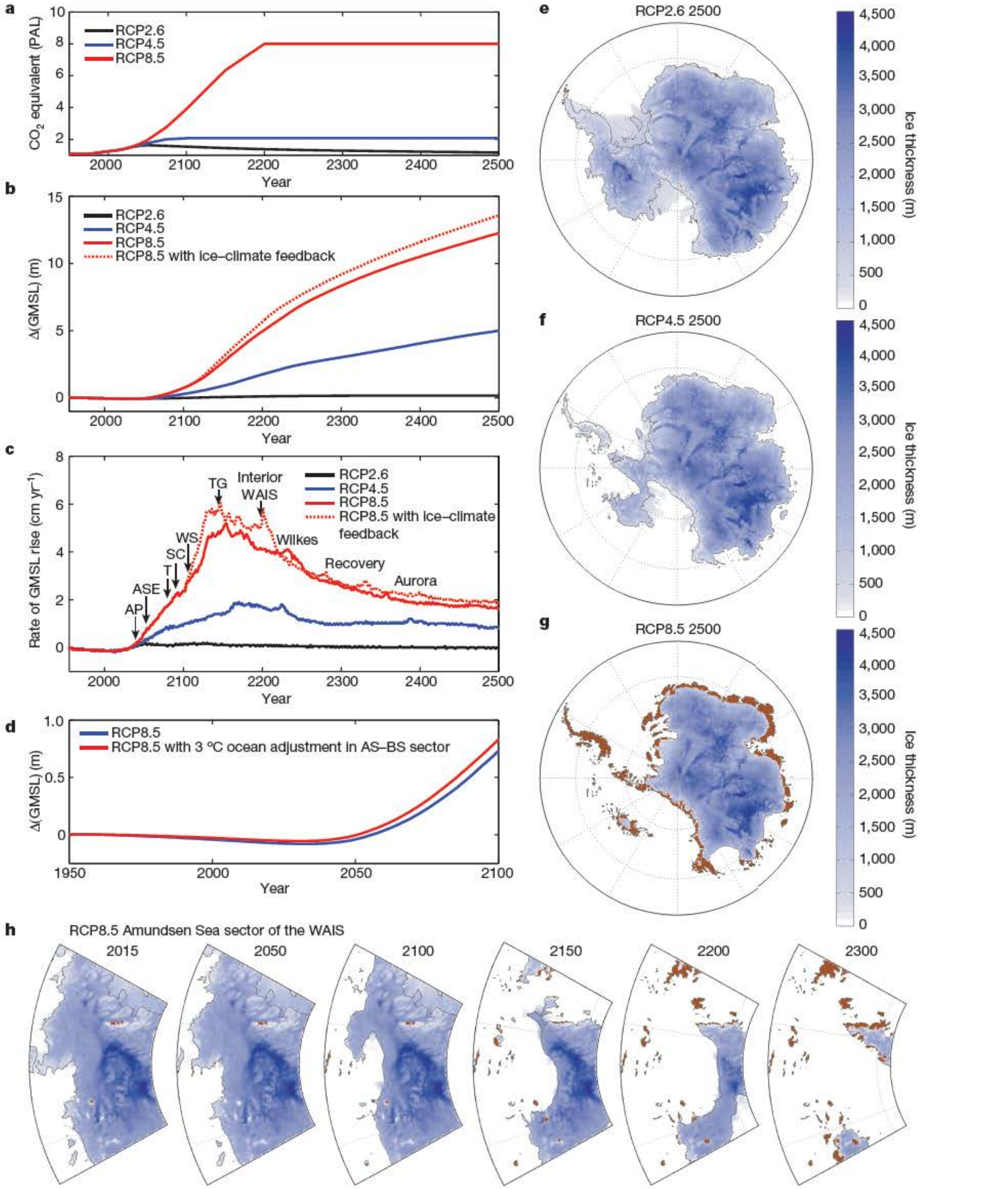

Figure 4 | Future ice-sheet simulations and Antarctic contributions to GMSL from 1950 to 2500 driven by a high-resolution atmospheric model and 1° NCAR CCSM4 ocean temperatures. **a**, Equivalent CO_2 forcing applied to the simulations, following the RCP emission scenarios in ref. 36, except limited to $8 \times$ PAL (preindustrial atmospheric level, where 1 PAL = 280 p.p.m.v.). **b**, Antarctic contribution to GMSL. **c**, Rate of sea-level rise and approximate timing of major retreat and thinning in the Antarctic Peninsula (AP), Amundsen Sea Embayment (ASE) outlet glaciers, AS–BS, Amundsen Sea–Bellingshausen Sea; the Totten (T), Siple Coast (SC) and Weddell Sea (WS) grounding zones, the deep Thwaites Glacier basin (TG), interior WAIS, the Recovery Glacier, and the deep EAIS basins (Wilkes and Aurora). **d**, Antarctic contribution to GMSL over the next 100 years for RCP8.5 with and without a +3 °C adjustment in ocean model temperatures in the Amundsen and Bellingshausen seas as shown in Extended Data Fig. 5d. **e–g**, Ice-sheet snapshots at 2500 in the RCP2.6 (**e**), RCP4.5 (**f**) and RCP8.5 (**g**) scenarios. Ice-free land surfaces are shown in brown. **h**, Close-ups of the Amundsen Sea sector of WAIS in RCP8.5 with bias-corrected ocean model temperatures.

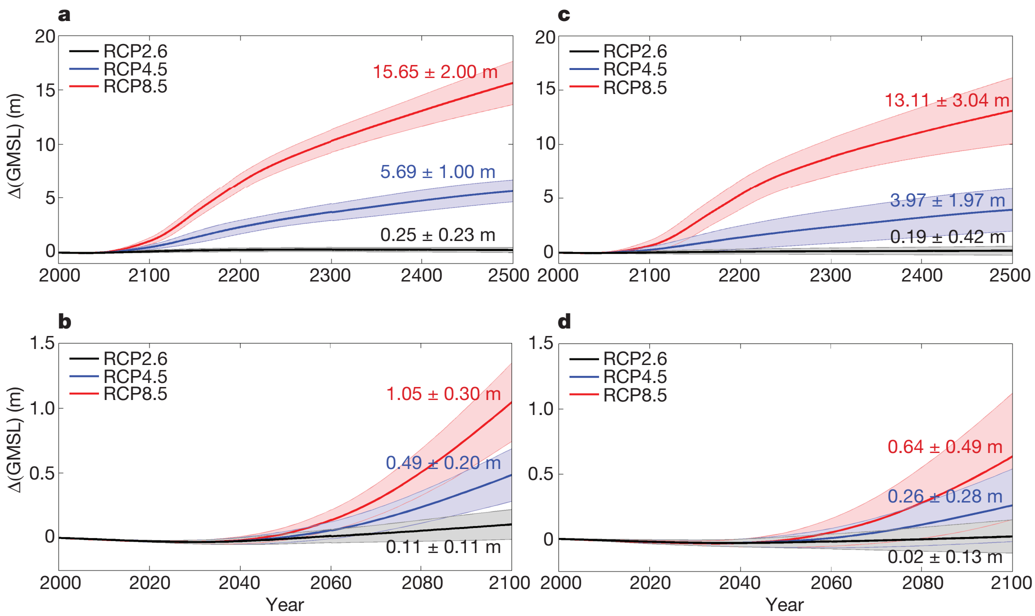

Figure 5 | Large Ensemble model analyses of future Antarctic contributions to GMSL. a, RCP ensembles to 2500. **b**, RCP ensembles to 2100. Changes in GMSL are shown relative to 2000, although the simulations begin in 1950. Ensemble members use combinations of model parameters (Methods) filtered according to their ability to satisfy two geologic criteria: a Pliocene target of 10–20 m GMSL and a LIG target of 3.6–7.4 m. **c** and **d** are the same as **a** and **b**, but use a lower Pliocene GMSL target of 5–15 m. Solid lines are ensemble means, and the shaded areas show the standard deviation (1σ) of the ensemble members. The 1σ ranges represent the model's parametric uncertainty, while the alternate Pliocene targets (**a** and **b** versus **c** and **d**) illustrate the uncertainty related to poorly constrained Pliocene sea-level targets. Mean values and 1σ uncertainties at 2500 and 2100 are shown.

Long-term commitment to elevated sea level

Ocean warming alone may be limited in its potential to trigger massive, widespread ice loss, but the multi-millennial thermal response time of the ocean[47] will have a profound influence on the ice sheet's recovery. In simulations run 5,000 years into the future, we conservatively assume no ocean warming beyond 2300 and simply maintain those ocean temperatures while the atmosphere cools assuming different scenarios of CO_2 drawdown beginning in 2500 (Methods). For RCP8.5 and natural CO_2 drawdown, GMSL continues to rise until 3500 with a peak of about 20 m, after which the warm ocean inhibits the re-advance of grounding lines into deep marine basins for thousands of years (Extended Data Fig. 7). Even in the moderate RCP4.5 scenario with rapidly declining CO_2 after 2500, WAIS is unable to recover until the global ocean cools, implying a multi-millennial commitment to several metres of sea-level rise despite human-engineered CO_2 drawdown.

Given uncertainties in model initial conditions, simplified hybrid ice dynamics, parameterized sub-ice melt, calving, structural ice-margin failure, and the ancient sea-level estimates used in our Large Ensemble analysis, the rates of ice loss simulated here should not be viewed as actual predictions, but rather as possible envelopes of behaviour (Fig. 5) that include processes not previously considered at the continental scale. These are among the first continental-scale simulations with model physics constrained by ancient sea-level estimates, simultaneously accounting for high-resolution atmosphere–ice sheet coupling and ocean model temperatures.

However, several important processes are lacking and should be included in future work. In particular, the model lacks two-way coupling between the ice sheet and the ocean. This is especially relevant for RCP8.5, in which >1 Sv of freshwater and icebergs would be supplied to the Southern Ocean during peak retreat (Extended Data Fig. 8). Rapid calving and ice-margin collapse also implies ice mélange in restricted embayments that could provide buttressing and a negative feedback on retreat. The loss of ice mass would also have a strong effect on relative sea level at the margin owing to gravitational and solid-earth deformation effects[48], which could affect MISI and MICI dynamics because of their strong dependency on bathymetry. Future simulations should include coupling with Earth models that account for these processes. Improved ancient sea-level estimates are also needed to further constrain model physics and to reduce uncertainties in future RCP scenarios (Fig. 5).

Despite these limitations, our new model physics are shown to be capable of simulating two very different ancient sea-level events: the LIG, driven primarily by ocean warming and MISI dynamics, and the warmer Pliocene, in which surface meltwater and MICI dynamics are also important. When applied to future scenarios with high greenhouse gas emissions, our palaeo-filtered model ensembles show the potential for Antarctica to contribute >1 m of GMSL rise by the end of this century, and >15 m metres of GMSL rise in the next 500 years. In RCP8.5, the projected onset of major ice-sheet retreat occurs sooner (about 2050), and is substantially faster (>4 cm yr^{-1} after 2100) and higher (Figs 4 and 5) than implied by other recent studies[44,45,49]. These differences are mainly due to our addition of model physics linking surface meltwater and ice dynamics via hydrofracturing of buttressing ice shelves and structural failure of marine-terminating ice cliffs. In addition, we use (1) freely evolving grounding-line dynamics that preclude the need for empirically calibrated retreat rates[49], (2) highly resolved atmosphere and ocean model components rather than intermediate-complexity climate models[45] or simplified climate forcing[44], and (3) calibration based on major retreat during warm palaeoclimates rather than recent minor retreat driven by localized ocean forcing.

As in these prior studies, we also find that ocean-driven melt is an important driver of grounding-line retreat where warm water is in contact with ice shelves, but in scenarios with high greenhouse gas emissions we find that atmospheric warming soon overtakes the ocean as the dominant driver of Antarctic ice loss. Surface meltwater may lead to the ultimate demise of the major buttressing ice shelves (Supplementary Videos 8 and 9) and extensive grounding-line retreat, but it is the long thermal memory of the ocean that will inhibit the recovery of marine-based ice for thousands of years after greenhouse gas emissions are curtailed.

Online Content Methods, along with any additional Extended Data display items and Source Data, are available in the online version of the paper; references unique to these sections appear only in the online paper.

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Author Information Reprints and permissions information is available at www.nature.com/reprints. The authors declare no competing financial interests. Readers are welcome to comment on the online version of the paper. Correspondence and requests for materials should be addressed to R.M.D. (deconto@geo.umass.edu).

METHODS

Ice sheet–ice shelf model. We use an established ice-sheet model, with hybrid ice dynamics following the formulation described in ref. 27, and an internal condition on ice velocity at the grounding line[15] that captures MISI (Fig. 2a–c) by accounting for migrating grounding lines and the buttressing effects of ice shelves with pinning points and side shear. Bedrock deformation under changing ice loads is modelled as an elastic lithospheric plate above local isostatic relaxation. A grid resolution of 10 km is used for all simulations, the finest resolution computationally feasible for long-term continental simulations. The model includes newly added treatments of hydrofracturing and ice cliff failure (Fig. 2d–f) described in ref. 25 and extended here. Basal sliding coefficients are determined by an inverse method[51], iteratively matching ice-surface elevations to observations until a quasi-equilibrium is reached. In this case, inverted sliding coefficients are derived from a modern (preindustrial) surface climatology, using the same RCM used in our Pliocene, LIG, and future simulations.

In addition to the Pliocene and LIG targets highlighted here, the ice sheet–ice shelf model has been shown capable of simulating: (1) the modern ice sheet, including grounding-line positions, ice thicknesses, velocities, ice streams, and ice shelves (Fig. 1b), (2) the Last Glacial Maximum (LGM) extent[27], (3) the timing of post-LGM retreat[18], and (4) the ability of the ice sheet to regrow to its modern extent following retreat[25].

Calving and hydrofracturing. Calving depends on the combined penetration depths of surface and basal crevasses, relative to total ice thickness[23,26,52,53]. Crevasse depths are parameterized according to the divergence of the ice velocity field[52], with an additional contribution depending on the logarithm of ice speed that crudely represents the accumulated strain history (ice damage) along a flow path[25]. Rapid calving is imposed as ice thickness falls below 200 m for unconfined embayments. The 200-m criterion is decreased in confined embayments according to $200 \times \max[0, \min[1, (\alpha - 40)/20]]$, where α is the 'arc to open ocean' (in degrees), crudely representing the effects of ice mélange in narrow seaways. The unconfined onset thickness of 200 m was increased from its value of 150 m in ref. 25 in order to improve modern Ross and Weddell Sea calving-front locations. A similar dependence on α is imposed for oceanic sub-ice-shelf melt rates, as described below.

Surface crevasses are additionally deepened (hydrofractured) as they fill with liquid water, which is assumed to depend on the grid-scale runoff of surface melt and rainfall available after refreezing[23,53]. The crevasse-depth dependence on surface runoff plus rainfall rate R (in metres per year) has been modified slightly for low R values. The R used in equation (B.6) of ref. 25 is changed to:

$$\begin{array}{ll} 0 & \text{for } R < 1.5 \text{ m yr}^{-1} \\ 4 \times 1.5 \times (R - 1.5) & \text{for } 1.5 \text{ m yr}^{-1} < R < 3 \text{ m yr}^{-1} \\ R^2 & \text{for } R > 3 \text{ m yr}^{-1} \text{ (as before)} \end{array}$$

This supposes that minimal hydrofracturing occurs for relatively small R values. The linear segment between 1.5 m yr^{-1} and 3 m yr^{-1} intersects the R^2 parabola as a tangent at $R = 3$. This modification prevents small amounts of recession in some East Antarctic basins for modern conditions, where small amounts of summer melt and rainfall occur.

Structural failure of ice cliffs. To account for structural ice-cliff failure[26,54] (MICI in Fig. 2), a wastage rate of ice W is applied locally to the grid cell adjacent to tide-water grounding lines with no floating ice, if the required stresses at the exposed cliff face exceed the yield strength of ice. This condition depends on the subaerial cliff height at the interpolated grounding line relative to the maximum ice thickness that can be supported, modified locally to account for any meltwater-enhanced crevasse penetration (hydrofracturing), and any reductions in crevassing caused by backstress. For dry crevassing at an ice margin with no hydrofracturing and no buttressing (backstress), the maximum exposed cliff height is 100 m, assuming an ice yield strength of 1 MPa[25,26]. The formulation of W results in a steep ramp in wastage rates of 0–3 km yr^{-1}, where exposed ice cliffs ramp from 80 m to 100 m. The maximum wastage rate of 3 km yr^{-1} used as our default is conservatively chosen, based on recent observations of the Jakobshavn Isbrae Glacier (up to ~12 km yr^{-1}) and the Crane Glacier (~5 km yr^{-1}) following the loss of their ice-buttressing shelves[55–57].

Other modifications to ice-sheet model physics. The model is modified from ref. 25 to include a more physically based parameterization of the vertical flow of surface mobile liquid water (runoff and rainfall) through moulins and other fracture systems towards the base[22,58], which affects the vertical temperature profiles within the ice sheet. Vertical sub-grid-scale columns of liquid water are assumed to exist, through which the water freely drains while exchanging heat by conduction with the surrounding ambient ice that cools and can freeze some or all of the liquid water within the ice interior.

We use uniform parameter values everywhere: we set the fractional area of sub-grid columns to overall area to be 0.1, and the horizontal scale of drainage elements to be 10 m (R in ref. 22, used in the calculations of conductive heat exchange with ambient ice). The fractional area includes both large moulins and any downward movement of liquid water in crevasses or cracks of all scales, which would be prevalent in the future melting scenarios investigated here. Offline sensitivity tests show low sensitivity of our model behaviour to these values, but further investigation is warranted.

For reasonable numerical behaviour, the horizontal heat exchange needs to be part of the time-implicit vertical diffusive heat solution for ambient ice temperature in the main model. To avoid an iterative procedure in cases where all liquid water is frozen before reaching the bed, a time-explicit calculation of the water penetration is made first, and one of the following measures is applied in the time-implicit ice-temperature step: (1) the conductive heat exchange coefficient at all levels is reduced by a constant factor for the column, so that the liquid penetrates to the lowest layer but no further; and (2) the conductive coefficient is set to zero below the depth of furthest penetration. Both methods give very similar results in idealized single-column tests; method (1) was used for all runs here. In cases with greater surface liquid flux, there is no reduction of coefficients and some water reaches the base.

A minor bug fix is corrected in the calculation of vertical velocities within the ice (w' in ref. 27), which previously did not account for the removal of ice at the base due to oceanic melting. This only affects advection of temperature in ice shelves, and has negligible effects on results.

Ice-sheet initial conditions. Ice-sheet initial conditions and basal sliding coefficients are provided by a 100-kyr inverse simulation following the methodology in ref. 51, using mass-balance forcing provided by a bias-corrected RCM climatology and modern observed ocean temperatures (described below). In the inverse procedure, basal sliding coefficients under modern grounded ice are adjusted iteratively to reduce the misfit with observed ice thickness, with grounding-line positions fixed to observed locations. The LIG simulation using 'glacial' initial conditions (Fig. 3) uses the same basal sliding coefficients (along with a relatively slippery value for modern ocean beds), but initialized from a previous simulation of the LGM with a prescribed, cold glacial climate representing conditions at ~20 kyr ago. The total ice volume in the modern and glacial ice sheets is 26.55×10^6 km^3 and 32.30×10^6 km^3, respectively, equivalent to bedrock-compensated GMSL values of 56.80 m and 62.28 m.

Atmospheric coupling. Atmospheric climatologies providing surface mass-balance inputs to the ice model are provided by decadal averages of meteorological fields from the RegCM3 RCM[59], adapted to Antarctica with a polar stereographic grid and small modifications of model physics for polar regions. The RCM uses a 40-km grid, over a generous domain spanning Antarctica and surrounding oceans, nested within the GENESIS v3 Global Climate Model[60,61]. The GCM and RCM share the same radiation code[62] and orbitally dependent calculations of shortwave insolation, important for the Pliocene and LIG palaeoclimate simulations.

Anomaly methods are used to correct a small <2 °C Antarctic cold bias in the RCM:

$$T = T_{\text{exp}} + T_{\text{obs}} - T_{\text{ctl}}$$
$$P = P_{\text{exp}} \times P_{\text{obs}} / P_{\text{ctl}}$$

where T is monthly surface air temperature and P is monthly precipitation. Subscripts 'exp', 'obs' and 'ctl' refer to model experiment, observed modern climatology, and model modern control, respectively. A modern (1950) RCM simulation is used for the model modern control, and the ALBMAP data set[63] is used for observed modern climatology.

In the climatic correction for the difference between the ice-model surface elevation and the interpolated elevation in the climate model or observational data set[27], precipitation is now corrected as well as temperature. As before, air temperature T (in degrees Celsius) is shifted by $\Delta T = \gamma \Delta z$, where $\gamma = -0.008$ °C m^{-1} is the lapse rate (that is, the decrease in atmospheric temperature with respect to altitude) and Δz is the elevation difference. Now, precipitation P is multiplied by a Clausius–Clapeyron-like factor:

$$P \times 2^{\Delta T/10}$$

Rates of surface snowfall and rainfall are now consistently multiplied by a factor $\rho_w/\rho_i \approx 1.1$, where ρ_w and ρ_i are the densities of liquid water and of ice respectively. This consistently converts between the units of most climate models and climatological databases (metres of liquid water equivalent per year) and the ice-model surface budget terms (metres of ice equivalent per year).

Oceanic sub-ice shelf and calving-face melt rates. Direct coupling of high-resolution ocean models and ice sheets remains challenging. For present-day simulations we use a parameterization of sub-ice shelf melt rates, similar to that used by other model groups[64]. The parameterization[27] links oceanic melt rates to the nearest observed (or modelled) ocean temperatures:

$$\mathrm{OM} = \frac{K_T \rho_w C_w}{\rho_i L_f} |T_o - T_f| (T_o - T_f)$$

where T_o is ocean temperature interpolated from the nearest point in an observational (or ocean model) gridded data set, T_f is the local freezing-point temperature at the depth of the ice base, and C_w is the specific heat of ocean water. The transfer factor $K_T = 15.77\ \mathrm{m\,yr^{-1}\,°C^{-1}}$ results in a combined coefficient $(K_T \rho_w C_w / \rho_i L_f)$ of $0.224\ \mathrm{m\,yr^{-1}\,°C^{-2}}$. The depth dependence on T_f produces higher melt rates at the grounding line, as observed, and the dependence on $T_0 - T_f$ is quadratic[65]. Although spatially coarse observational data sets and standard GCM ocean models fail to capture detailed ocean current systems below ice-shelf cavities, this approach (Extended Data Fig. 6e and f) is preferable to the *ad hoc* prescription of single temperatures and transfer coefficients along individual sectors of the Antarctic margin as in ref. 27.

The effects of confined geography on ocean currents are represented by reducing basal melting depending on the total arc to open ocean α, representing the concavity of the coastline[25]. The melt rate computed from ocean temperatures as above is multiplied by the factor:

$$\max[0,\ \min[1, (\alpha - 20)/20]]$$

This effect, combined with the reduction of thin-ice calving with a similar dependence on α described above, allows ice to expand into interior basins during cool-climate recovery after major retreats of marine-based ice, as presumably occurred many times in West Antarctica over the last several million years[66].

Melting of vertical ice surfaces in direct contact with ocean water is derived from the oceanic melt rate (OM) of surrounding grid cells, but is increased by a scaling factor of 10, producing more realistic calving front positions and in better agreement with hydrographic melt rate observations and detailed modelling[67]. Present-day sub-ice shelf and calving-face melt rates described here use the 1° resolution World Ocean Atlas[32,68] temperatures at 400-m depth, interpolated to the time-evolving ice model grid and propagated under ice-shelf surfaces using contiguous neighbour iteration to provide T_o. The depth of 400 m represents typical observed levels of Circum-Antarctic Deep Water, a main source of warm-water incursions into the Amundsen Sea Embayment today[69].

Pliocene simulation. Our default Pliocene simulation uses the same nested GCM–RCM climatology used in a prior study[25], with 400 p.p.m.v. CO_2 and a generic warm austral summer orbit[28] (Extended Data Fig. 1). Ocean temperatures are increased uniformly by 2 °C everywhere in the Southern Ocean. The resulting Antarctic contribution of 11.3 m GMSL implies >15 m GMSL rise if an additional ~5 m contribution from Greenland[70] and the steric effects of a warm Pliocene ocean are also considered. This result is ~6 m less than in ref. 25, reflecting a reduction in the sensitivity of the model with the changes described above.

LIG simulations. The LIG spans a ~20-kyr interval with greenhouse-gas atmospheric mixing ratios comparable to the pre-industrial Holocene[9]. Opportunities for Antarctic ice-sheet retreat within this interval include a peak in the duration of Antarctic summers coeval with a boreal summer insolation maximum at 128 kyr ago, and an Antarctic summer insolation maxima one half-precession cycle later at 116 kyr ago (Extended Data Fig. 2). We target these two orbital time slices because they contrast radiatively long and weak (128 kyr ago) versus short and intense Antarctic summers (116 kyr ago), both of which have been postulated to be important drivers of ice volume on glacial–interglacial timescales[71].

LIG simulations that include climate–ice sheet feedback asynchronously couple the GCM–RCM and the ice-sheet model. In this case, the nested RCM land (ice) surface boundary conditions are updated at the end of the initial retreat at ice model-year 5000 and the ice-sheet model is rerun using the updated climatology. This improves the representation of ice-climate feedbacks via albedo, ocean surface conditions (sea surface temperatures and sea ice), and dynamical effects of the changing topography on the atmosphere. We find that explicitly including climate–ice feedbacks improves model performance, relative to simple lapse-rate adjustments.

LIG simulations (Extended Data Table 1; Extended Data Fig. 3d, e) apply anomaly-corrected RCM mass-balance forcing at each LIG time slice, using the appropriate greenhouse gas[9,72] and orbital values[73] in the nested GCM–RCM. Ocean temperatures are provided by the World Ocean Atlas data set[32], with incremental warming of 1–5 °C applied uniformly over the Southern Ocean grid domain.

To allow the RCM atmosphere to respond to a warmer Southern Ocean in addition to applying elevated ocean temperatures to the ice model, we increase the southward ocean-heat convergence in the nested GCM–RCM using the methodology described in ref. 28, effectively warming the Southern Ocean sea surface temperatures by ~2 °C and reducing sea-ice extent. Accounting for the effect of a warmer Southern Ocean on the overlying atmosphere produces more LIG ice-sheet retreat for a given ocean warming, improving our model–data fit. With this technique, only 3 °C of assumed sub-surface ocean warming is required to produce >6 m GMSL rise from Antarctica at either LIG orbital time slice, reinforcing the notion of a dominant oceanic control on LIG ice-sheet retreat.

The two time-continuous LIG simulations using prescribed climatologies (Fig. 3) use bias-corrected, present-day RCM climatologies with a uniform, time-evolving perturbation derived from the average of Antarctic ice-core climatologies compiled in ref. 29. Southern Ocean temperatures are treated similarly, with World Ocean Atlas temperatures[32] increased according to the average of circum-Antarctic LIG anomalies[29]. Only records from marine drill-cores poleward of 45° S are used in the averages, but we note that there is considerable uncertainty in the proxy sea surface temperature estimates (>2 °C)[29]. This approach also assumes that the proxy sea surface temperatures reflect changes at sub-surface depths (~400 m), which is uncertain. The resulting anomalies are applied to the ice sheet model at 130 kyr ago, 125 kyr ago, 120 kyr ago, and 115 kyr ago and the ice-sheet model is run continuously from 130 kyr ago to 115 kyr ago. The pairs of air and ocean temperature perturbations applied at each 5-kyr LIG timestep are 1.97° and 1.70°, 1.41° and 1.51°, 0.83° and 1.09°, −1.57° and 0.31°, respectively.

The time-continuous LIG simulations are initialized from either a present-day initial ice state (Fig. 1b), or from a prior Last Glacial Maximum simulation with $5.76 \times 10^6\ \mathrm{km^3}$ more ice than today. The latter initial condition may better represent the ice sheet at the onset of the LIG and leads to a greater potential sea-level rise owing to the deeper bed conditions early in the deglaciation, which enhances the bathymetrically sensitive MISI dynamics.

The proxy-forced LIG simulation clearly supports a maximum Antarctic contribution to GMSL early in the interglacial period (Fig. 3). However, we note that owing to the demonstrated influence of Southern Ocean temperature on the timing of retreat and the uncertain magnitude and chronology of our imposed forcing[29], these results cannot definitively rule out maximum Antarctic retreat at the end of the LIG, as has also been proposed[4,74]

Future simulations. Because of the new ice-model physics that directly involve the atmosphere via meltwater enhancement of crevassing and calving, highly resolved atmospheric climatologies are needed at spatial resolutions beyond those of most GCMs. However, multi-century RCM simulations are computationally infeasible. To accommodate the need for long but high-resolution climatologies, the nested GCM–RCM is run to equilibrium with 1 × PAL, 2 × PAL, 4 × PAL and 8 × PAL CO_2. In the ice-sheet simulations, CO_2 follows the extended RCP greenhouse gas emissions[36] to the year 2500, and the climate at any time is the average of the two appropriate surrounding RCM solutions, weighted according to the logarithm of the concentration of CO_2. The RCM climatologies follow total equivalent CO_2, which accounts for all radiatively active trace gases in the RCP timeseries. In RCP8.5, equivalent CO_2 forcing exceeds 8 × PAL after 2175, but it is conservatively limited here to a maximum of 8 × PAL (Fig. 4a). A 10-yr lag is imposed in the RCM climatologies to reflect the average offset between sea surface temperatures and surface air temperatures in the equilibrated RCM (with equilibrated sea surface temperatures from the parent GCM) and the transient response of the real ocean's mixed layer.

Ocean temperatures in the RCP scenarios are provided by high-resolution (0.5° atmosphere and 1° ocean) NCAR CCSM4[37] ocean model output, following the RCP2.6, RCP4.5, and RCP8.5 greenhouse gas emissions scenarios run to 2300. Ocean temperatures beyond the limit of the CCSM4 simulations at 2300 are conservatively maintained at their 2300 values. As with the World Ocean Atlas, water temperatures at 400-m depth (between ocean model *z*-levels 30 and 31) are used in the parameterization of oceanic sub-ice melt (oceanic melt rate) described above. The CCSM4 underestimates the wind-driven warming of Antarctic Shelf Bottom Water[41] in the Amundsen and Bellingshausen seas associated with recent increases in melt rates and grounding-line retreats[20,42,43]. To account for this, additional warming is added to the Amundsen and Bellingshausen sectors of the continental margin. We find the addition of 3 °C to the CCSM4 ocean temperatures increases melt rates to 25–30 $\mathrm{m\,yr^{-1}}$ (Extended Data Fig. 5f). While still less than observed, this substantially improves grounding-line positions in the Amundsen Sea (Pine Island Glacier in particular) from 1950 to 2015. When applied to RCP4.5 and RCP8.5, the ocean-bias correction accelerates twenty-first-century WAIS retreat (Fig. 4d, g, h) but is found to have little effect beyond 2100 (Extended Data Table 1).

Extended RCP greenhouse gas scenarios[36] are available up to 2500, beyond which we assume two different scenarios: (1) natural decay of CO_2[75,76] and no further anthropogenic emissions, or (2) engineered, fast drawdown towards pre-industrial levels with an e-folding time of 100 years. These choices are not intended to be definitive, but serve to illustrate the ice-sheet response to a wide range of possible long-term future forcings.

Future high-resolution ocean-model output is not available on multi-millennial timescales. In our long (5,000-year) future simulations (Extended Data Fig. 7), CCSM4 ocean temperatures at 400 m depth are assumed to remain at their 2300 values for thousands of years beyond 2300 (until 7000). This assumption is based on the thermal inertia of the deep ocean (thousands of years)[47], its longwave radiative feedback on atmospheric temperatures[77], and its relative isolation from surface variations. The response of the intermediate and deep ocean to atmospheric and surface-ocean warming before 2300 is heavily lagged in time, and consequently deep-ocean temperatures would continue to rise long after CO_2 levels and surface temperatures began to decline after 2500[77]. However, at some point several thousand years later, intermediate- and deep-ocean waters would start to cool if CO_2 levels decay as in Extended Data Fig. 7. The trajectory of these temperatures would vary spatially and depend on details of the ocean circulation. To our knowledge, the state of the ocean as it recovers from a greenhouse gas perturbation over these timescales is largely unknown, as relevant coupled atmosphere–ocean global climate model simulations at the resolution and duration appropriate to our ice model have not been run. Consequently, our assumption of constant 400-m ocean temperatures after 2300, although likely to be conservative beyond 2500, may be questionable for the latter parts of the simulations assuming fast, engineered CO_2 drawdown. However, assuming the slow, natural pace of CO_2 recovery[76], atmospheric concentrations would remain above twice the current level of carbon dioxide ($2 \times CO_2$) for thousands of years in the RCP8.5 scenario (Extended Data Fig. 7). Assuming a global temperature sensitivity of $\sim$3 °C per doubling of CO_2, our ocean temperatures applied to the long RCP8.5 scenario are probably conservative over the duration of the simulation.

Geologically constrained Large Ensemble analysis of future ice-sheet retreat. To quantify model uncertainty due to poorly known parameter values, ensembles of future RCP scenarios are performed with varying model parameters affecting sub-ice oceanic melt rates, meltwater-enhanced calving (hydrofracturing) and marine-terminating ice cliff failure. Ensemble members use the high-resolution atmospheric and ocean forcing described in the main text and above. Alternative ensembles are run both with and without the bias correction of CCSM4 ocean temperatures in the Amundsen and Bellingshausen Seas. The three parameters and four values used for each are as follows.

OCFAC is the coefficient in the parameterization of sub-ice-shelf oceanic melt, which is proportional to the square of the difference between nearby ocean water temperature at 400-m depth, and the pressure-melting point of ice. It corresponds to K in equation (17) of ref. 27. The relationship between proximal ocean conditions and melting at the base of floating ice shelves remains a challenging topic of ongoing research[78], and a simple parameterization[64] is used here. Ensemble values of OCFAC are 0.1, 1, 3 and 10 times the default value of $0.224\,\mathrm{m\,yr^{-2}\,°C^{-2}}$.

CREVLIQ is the coefficient in the parameterization of hydrofracturing due to surface liquid. It replaces the constant 100 in equation (B.6) of ref. 25, and is the additional crevasse depth due to surface melt plus rainfall rate, with a quadratic dependence. This crudely represents the complex relationship between surface water and crevasse propagation, and basic model sensitivity is shown in supplementary figure 7b of ref. 25. Values of CREVLIQ are 0 m, 50 m, 100 m and 150 m per $(\mathrm{m\,yr^{-1}})^{-2}$.

VCLIF is the maximum rate of horizontal wastage due to ice-cliff structural failure. It replaces the default value of 3,000 ($3\,\mathrm{km\,yr^{-1}}$) in equation (A.4) of ref. 25. Its magnitude is based on observed retreat rates of modern large ice cliffs, and basic model sensitivity is shown in supplementary figure 7a of ref. 25. Values of VCLIF are $0\,\mathrm{km\,yr^{-1}}$, $1\,\mathrm{km\,yr^{-1}}$, $3\,\mathrm{km\,yr^{-1}}$ and $5\,\mathrm{km\,yr^{-1}}$.

Medium-range, default values of OCFAC, CREVLIQ, and VCLIF used in our nominal Pliocene (Extended Data Fig. 1), LIG (Fig. 3), and Future (Fig. 4) simulations are OCFAC = 1 (corresponding to $0.224\,\mathrm{m\,yr^{-2}\,°C^{-2}}$), CREVLIQ = 100 m per $(\mathrm{m\,yr^{-1}})^{-2}$, and VCLIF = $3\,\mathrm{km\,yr^{-1}}$, respectively.

Simulations for the Pliocene and LIG scenarios are run with all possible combinations of these parameter values, that is, 64 ($=4^3$) runs (Extended Data Table 2). Each run is subject to a pass/fail test that its equivalent GMSL rise falls within the observed ranges for the LIG (3.6–7.4 m) and the Pliocene (10–20 m). The filtered subset of parameter combinations that pass (15 out of 64) are then used in an ensemble of future RCP scenarios. An additional ensemble calculation is performed using the same LIG criteria, but a lower accepted range for Pliocene sea-level rise (5–15 m), to reflect the large uncertainty in Pliocene sea-level reconstructions[1] (29 out of 64 passed this test). The mean and 1σ range of each ensemble are shown for the three RCP scenarios in Fig. 5, providing both an envelope of possible outcomes and an estimate of the model's parametric uncertainty. Two alternative sets of future RCP ensembles are run with the ocean-temperature bias correction in the Amundsen and Bellingshausen seas shown in Extended Data Fig. 5. This increases Antarctica's GMSL contribution by $\sim$9 cm over the next century in both RCP8.5 and RCP8.5, but has almost no effect on longer timescales (Extended Data Tables 1, 2). In the RCP2.6 ensemble calibrated against the higher >10 m Pliocene sea-level targets, the ocean-bias correction increases both the ensemble-mean and 1σ standard deviation to 16 ± 16 cm in 2100 and 62 ± 76 cm in 2500 (Extended Data Table 1). The increased variance is caused by three simulations in the RCP2.6 ensemble set, in which the stability of the Thwaites Glacier grounding line is exceeded and the WAIS retreats into the deep interior. Although the ensemble members with bias-corrected ocean temperatures are generally more consistent with observations of recent retreat in the Amundsen–Bellingshausen sector, the validity of the bias correction in the long-term future is unknown.

Code availability. Ice sheet and climate model codes, results from Pliocene, LIG, and future simulations, and tabulated ensemble results are freely available from the corresponding author.

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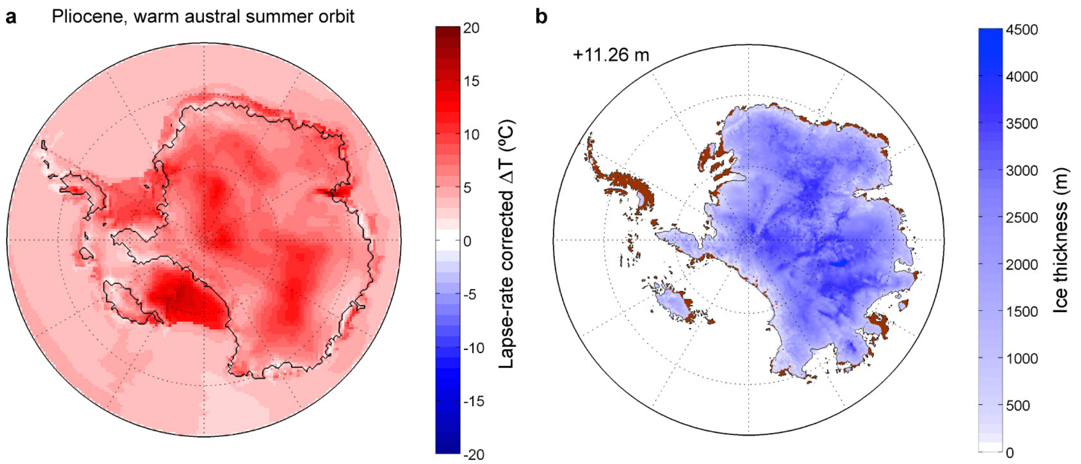
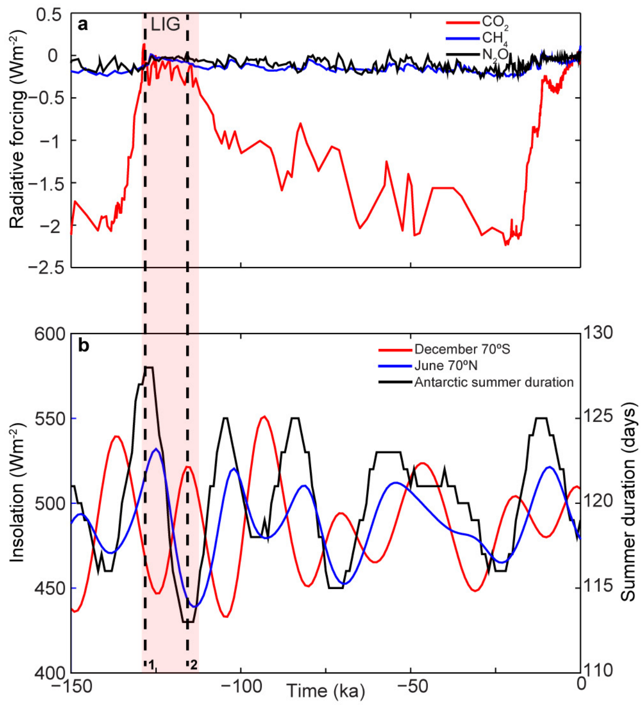
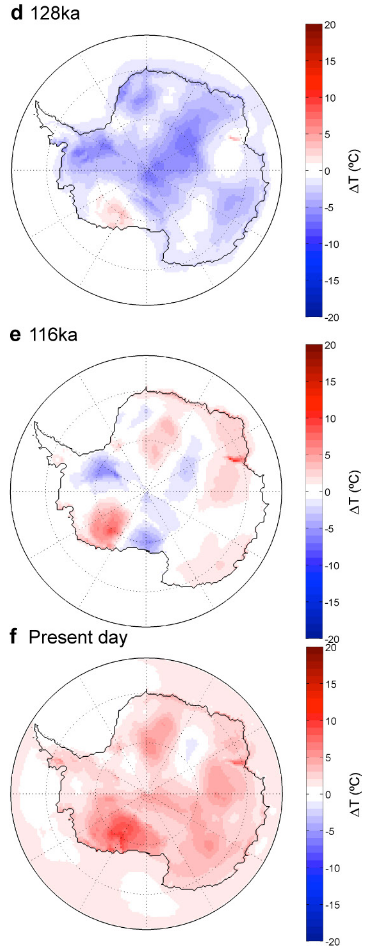


Extended Data Figure 1 | Warm mid-Pliocene climate and ice-sheet simulation. **a**, January (warmest monthly mean) difference in 2-m (surface) air temperature simulated by the RCM relative to a preindustrial control simulation with 280 p.p.m.v. CO_2 and present-day orbit. The temperature difference is lapse-rate-corrected to account for the change in ice-sheet geometry and surface elevations. The Pliocene simulation uses 400 p.p.m.v. CO_2, a warm austral summer orbit, and assumes a retreated WAIS to represent maximum Pliocene warm conditions. **b**, The Pliocene ice-sheet is shown after 5,000 model years, driven by the RCM climate in **a**, and assuming 2 °C ocean warming relative to a modern ocean climatology[32]. In the model formulation used here, maximum Pliocene ice-sheet retreat with default model parameters is equivalent to 11.26 m GMSL, about 6 m less than in ref. 25.

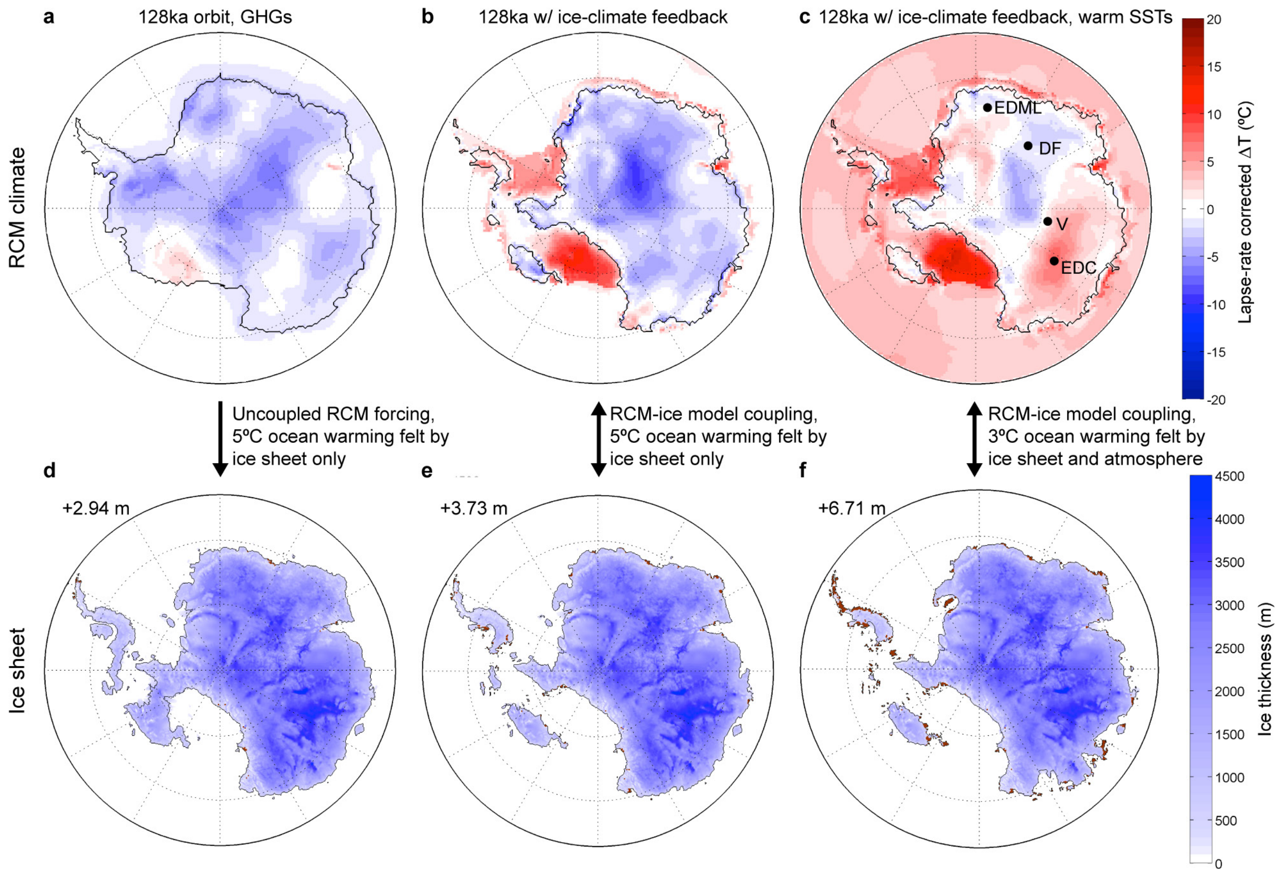


c

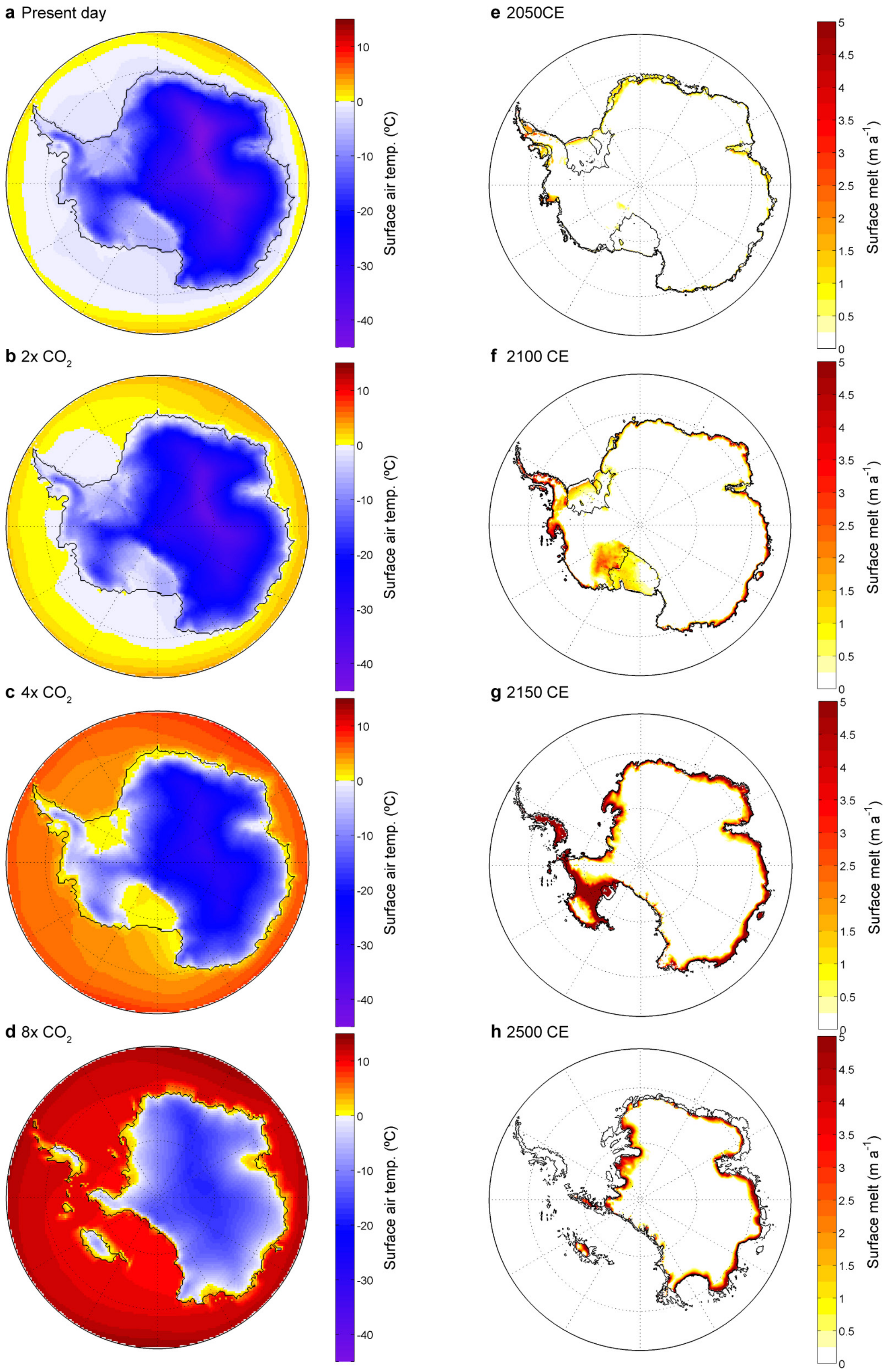
LIG exp.	Ecc.	Obl.º	Prec.(Ω)	CO_2(ppmv)	CH_4(ppbv)	N_2O(ppbv)
128ka	0.039017	24.012	259.65	276	515	244
116ka	0.041409	22.488	94.17	263	578	274



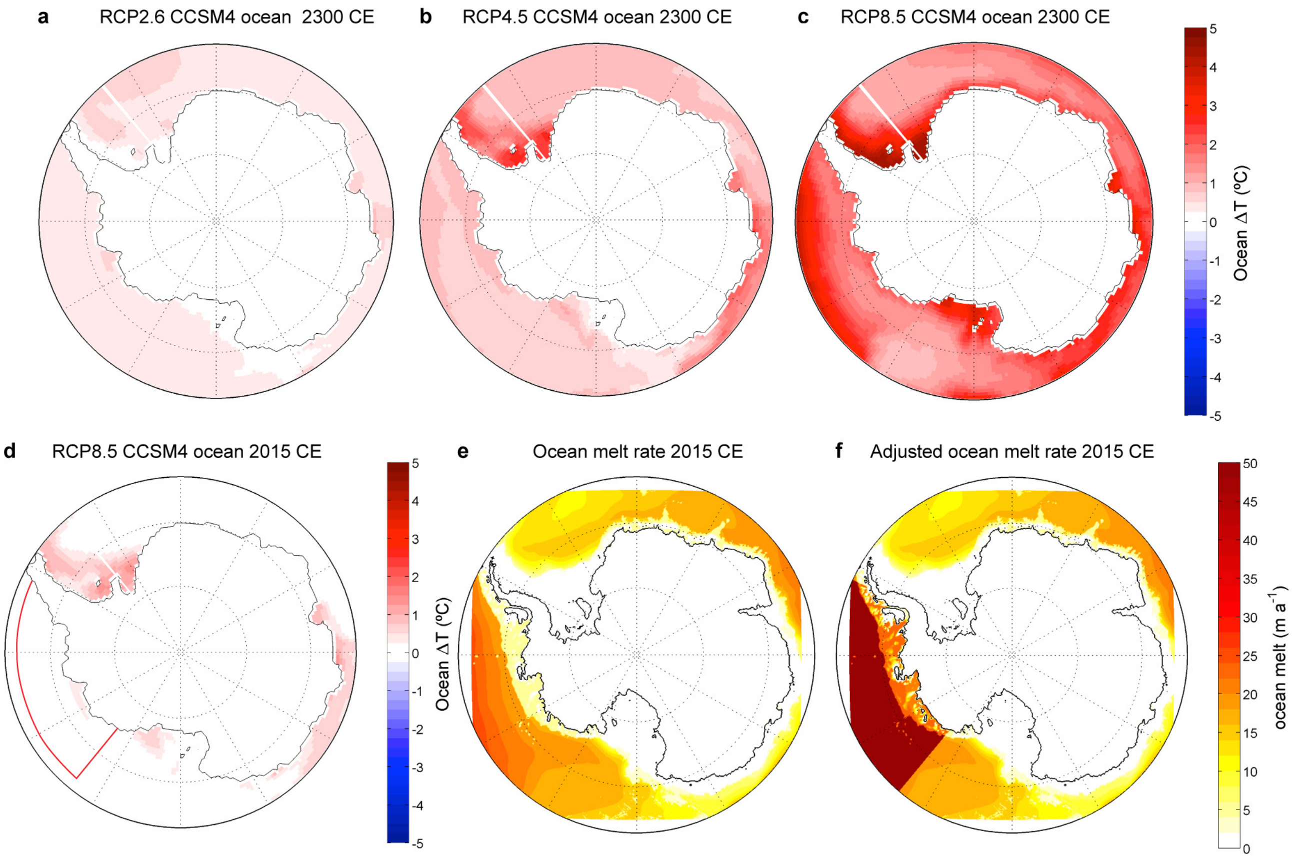
Extended Data Figure 2 | LIG greenhouse gases, orbital parameters, and RCM climates. a, Greenhouse gas concentrations[9,72] converted to radiative forcing shows the LIG interval (light red bar) and the best opportunity for ice-sheet retreat. **b**, Summer insulation at 70° latitude in both hemispheres[73] (red, south; blue, north) and summer duration at 70° S (black)[79] shown over the last 150 kyr, and the two orbital time slices (vertical dashed black lines at 128 kyr ago and 116 kyr ago). **c**, Table showing the greenhouse gas atmospheric mixing ratios (CO_2 in parts per million by volume; CH_4 and N_2O in parts per billion by volume) and orbital parameters (eccentricity, obliquity, precession) used in the GCM–RCM at the LIG time slices (dashed lines 1 and 2 in **a** and **b**), respectively. **d**–**f**, January (warmest monthly mean) differences in 2-m surface air temperature relative to a preindustrial control simulation at 128 kyr ago (**d**), 116 kyr ago (**e**), and the present-day (2015) (**f**). Simulated austral summer temperatures at 116 kyr ago (**e**) with relatively high-intensity summer insolation is warmer than the long-duration summer orbit at 128 kyr ago (**d**), but unlike the Pliocene (Extended Data Fig. 1a), neither LIG climatology is as warm as the present day, producing little to no rain or surface melt on ice-shelf surfaces.



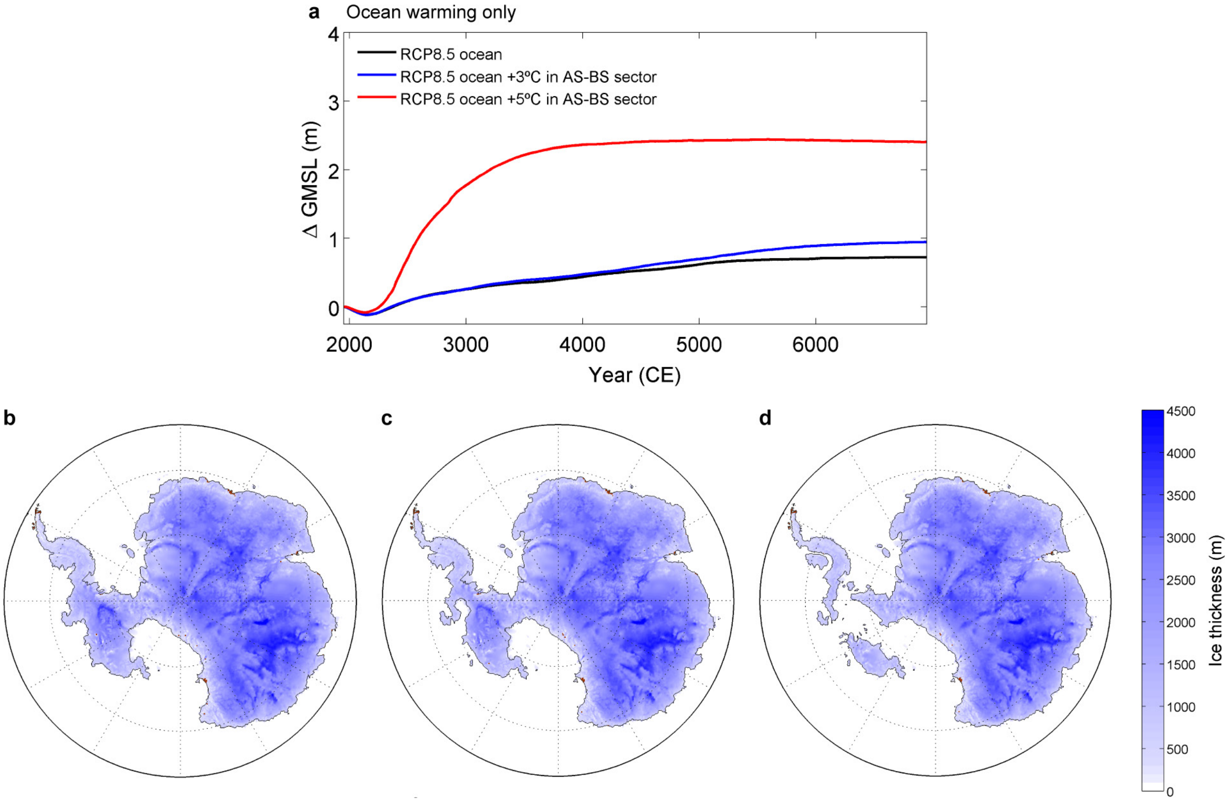
Extended Data Figure 3 | Effect of Southern Ocean warming on Antarctic surface air temperatures and the ice sheet at 128 kyr ago. **a**–**c**, January (warmest monthly mean) differences in 2-m surface air temperature at 128 kyr ago, relative to a preindustrial control simulation (top row). GHG, greenhouse gas; SST, sea surface temperature. **d**, **e**, Ice-sheet thickness (m) after 5,000 model years, driven by the corresponding climate in **a**–**c**. **a** and **d**, Without climate–ice sheet coupling (present-day ice extent and surface ocean temperatures in the RCM), and prescribed 5 °C sub-surface ocean warming felt only by the ice sheet. **b** and **e**, With asynchronous coupling between the RCM atmosphere and ice sheet, and prescribed 5 °C sub-surface ocean warming felt only by the ice sheet. **c** and **f**, With asynchronous coupling between the RCM atmosphere and ice sheet, prescribed 3 °C sub-surface ocean warming felt by the ice sheet, and ∼2 °C surface ocean warming felt by the RCM atmosphere. **c** shows the locations of East Antarctic ice cores (EDC, EPICA Dome C; V, Vostock; DF, Dome F; EDML, EPICA Dronning Maud Land) indicating warming early in the interglacial[29] and previously attributed to WAIS retreat[80]; this warming is similar to that simulated in **c** from a combination of ice-sheet retreat and warmer Southern Ocean temperatures, supporting the notion that the timing of LIG retreat was largely driven by far-field ocean influences, rather than local astronomical forcing.



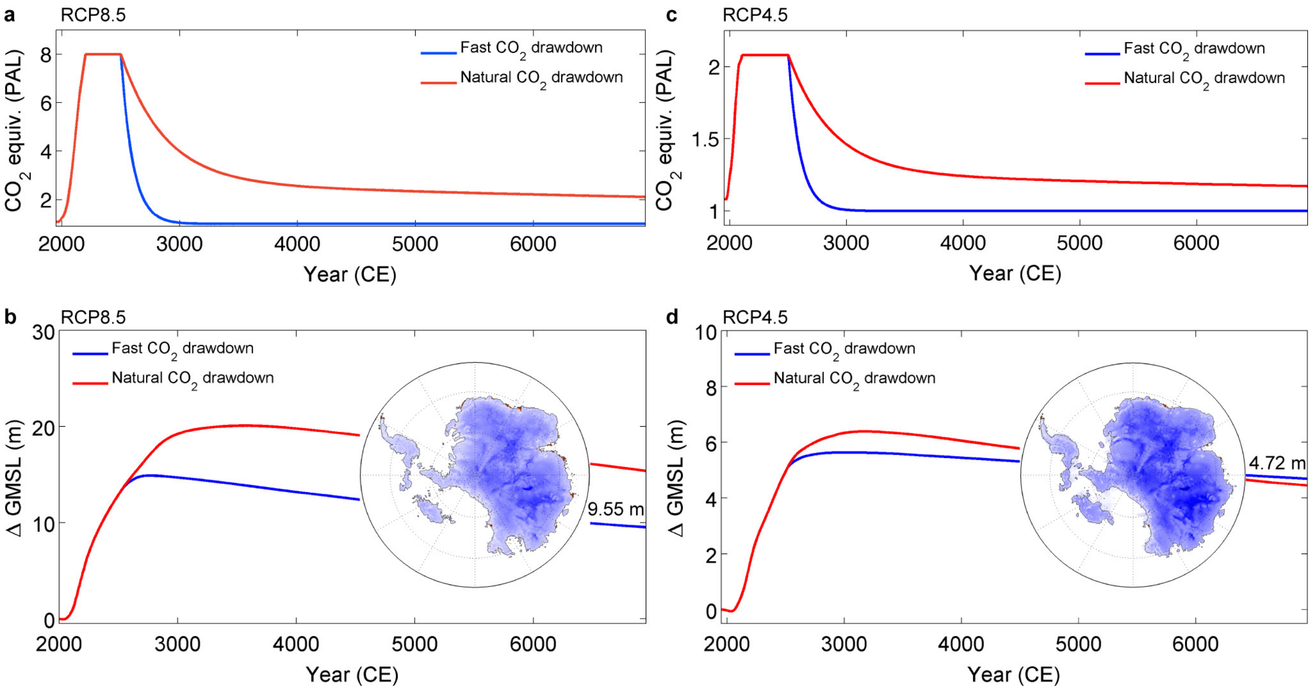
Extended Data Figure 4 | RCM climates used in future, time-continuous RCP scenarios and evolving ice-surface melt rates linked to hydrofracturing model physics. a–d, January surface (2-m) air temperatures simulated by the RCM at the present-day (2015) (**a**), twice the present level of carbon dioxide, $2 \times CO_2$ (**b**), $4 \times CO_2$ (**c**), and $8 \times CO_2$ (**d**) with the retreating ice sheet. The colour scale is the same in all panels. Yellow to red colours indicate temperatures above freezing with the potential for summer rain, and surface meltwater production. **e–h**, Evolving ice-surface meltwater production (in metres per year) in the time-evolving RCP8.5 ice-sheet simulations, driven by a time-continuous RCM climatology (Methods) following the RCP8.5 greenhouse gas time series (Fig. 4a). Black lines show the positions of grounding lines and ice-shelf calving fronts at discrete time intervals—**e**, 2050; **f**, 2100; **g**, 2150; and **h**, 2500—with superposed meltwater production rates.



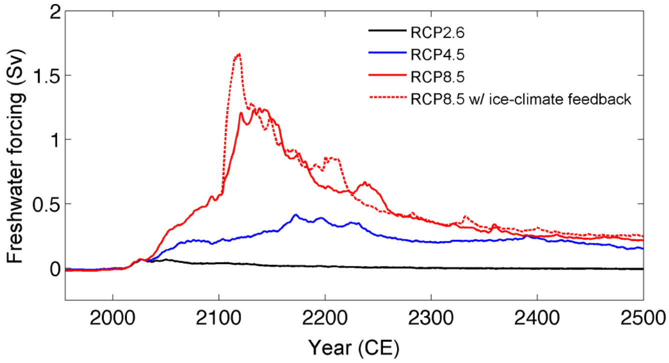
Extended Data Figure 5 | NCAR CCSM4 ocean temperatures and oceanic sub-ice-shelf melt rates. a, RCP2.6 ocean warming at 400-m depth, shown as the difference of decadal averages from 1950–1960 to 2290–2300. **b**, Same as **a** but for RCP4.5. **c**, Same as **a** but for RCP8.5. **d**, CCSM4 RCP8.5 ocean warming from 1950–1960 to 2010–2020 showing little to no warming in the Amundsen and Bellingshausen seas. The red line shows the area of imposed, additional ocean warming. **e**, **f**, Oceanic melt rates at 2015 calculated by the ice-sheet model from interpolated CCSM4 temperatures (**e**), and with +3 °C adjustment in the Amundsen and Bellingshausen seas (**f**), corresponding to the area within the red line in **d**.



Extended Data Figure 6 | Effect of future ocean warming only. **a**, Antarctic contribution to future GMSL rise in long, 5,000-yr ice-sheet simulations driven by sub-surface ocean warming simulated by CCSM4, following RCP8.5 (black line), with a +3 °C adjustment in the Amundsen and Bellingshausen seas (blue line; see Extended Data Fig. 5) and a warmer +5 °C adjustment (red line). Atmospheric temperatures and precipitation are maintained at their present values. **b**–**d**, Ice-sheet thickness at model-year 5,000, driven by sub-surface ocean forcing from CCSM4 (**b**) and from CCSM4 with a +3 °C (**c**) or +5 °C (**d**) adjustment in the Amundsen and Bellingshausen seas. Note the near-complete loss of ice shelves, but modest grounding-line retreat in **b**, the retreat of Pine Island Glacier in **c**, and the near-complete collapse of WAIS once a stability threshold in the Thwaites Glacier grounding line is reached in **d**.



Extended Data Figure 7 | The long-term future of the ice sheet and GMSL over the next 5,000 years following RCP8.5 and RCP4.5. **a**, Equivalent CO_2 forcing following RCP8.5 until the year 2500, and then assuming zero emissions after 2500 and allowing a natural relaxation of greenhouse gas levels (red) or assuming a fast, engineered drawdown (blue) with an e-folding timescale of 100 years. **b**. Antarctic contribution to GMSL over the next 5,000 years, following the greenhouse gas scenarios in **a**. **c**, The same as **a**, except showing long-term RCP4.5 greenhouse gas forcing. **d**, The same as **b**, except following the RCP4.5 scenarios in **c**. The insets in **b** and **d** show the ice sheet (and remaining sea-level rise) after 5,000 model years in RCP8.5 and RCP4.5, respectively, assuming fast CO_2 drawdown (blue lines), highlighting the multi-millennial commitment to a loss of marine-based Antarctic ice, even in the moderate RCP4.5 scenario. Note the different *y*-axes in RCP8.5 versus RCP4.5.



Extended Data Figure 8 | Freshwater input to the Southern Ocean. Total freshwater and iceberg flux from 1950 to 2500, following the future RCP scenarios shown in Fig. 4b. Freshwater input calculations include contributions from ice loss above and below sea level and exceed 1 Sv in RCP8.5.

Extended Data Table 1 | Summary of Antarctic contributions to GMSL during the Pliocene, LIG, future centuries, and future millennia

RCM climate forcing, default model parameter values	Pliocene GMSL (m)	
	11.26	
	LIG 128ka GMSL (m)	LIG 116ka GMSL (m)
Modern ocean	-1.63	-0.69
+2 ºC ocean	0.41	0.65
+3 ºC ocean	0.85	1.12
+4 ºC ocean	1.43	1.73
+5 ºC ocean	2.94	3.29
+5 ºC ocean, ice-climate feedback	3.73	3.84
+3 ºC ocean, ice-climate-SST feedback	6.71	6.01
+5 ºC ocean, ice-climate-SST feedback	7.16	7.52
Proxy-based climate and ocean forcing, default model parameters	LIG max. GMSL (m)	
Modern ice-sheet initial conditions	6.09	
Glacial ice-sheet initial conditions	7.54	
Old model physics	1.07	
RCM climate forcing, CCSM4 ocean, default model parameters	2100 CE GMSL (m)	2500 CE GMSL (m)
RCP2.6	0.03	0.20
RCP4.5	0.32	5.03
RCP8.5, no ice-climate feedback	0.77	12.30
RCP8.5	0.77	13.62
RCP8.5 +3ºC AS-BS adjustment	0.86	13.60
RCM climate forcing, CCSM4 ocean, ensemble-filtered model parameters: LIG 3.6-7.4 m, Pliocene 10-20 m	2100 CE GMSL (m)	2500 CE GMSL (m)
RCP2.6	0.11±0.11	0.25±0.23
RCP4.5	0.49±0.20	5.69±1.00
RCP8.5	1.05±0.30	15.65±2.00
RCP2.6 +3ºC AS-BS adjustment	0.16±0.16	0.62±0.76
RCP4.5 +3ºC AS-BS adjustment	0.58±0.28	5.76±1.00
RCP8.5 +3ºC AS-BS adjustment	1.14±0.36	15.65±2.00
RCM climate forcing, CCSM4 ocean, ensemble-filtered model parameters: LIG 3.6-7.4 m, Pliocene 5-20 m	2100 CE GMSL (m)	2500 CE GMSL (m)
RCP2.6	0.02±0.13	0.19±0.42
RCP4.5	0.26±0.28	3.97±1.97
RCP8.5	0.64±0.49	13.11±3.04
RCP2.6 +3ºC AS-BS adjustment	0.14±0.19	0.70±0.78
RCP4.5 +3ºC AS-BS adjustment	0.41±0.30	4.20±1.80
RCP8.5 +3ºC AS-BS adjustment	0.79±0.46	13.09±3.05
Long-term simulations using default model parameters	7000 CE GMSL (m)	
RCP4.5 no CO_2 drawdown	8.47	
RCP4.5 natural CO_2 drawdown	4.48	
RCP4.5 fast CO_2 drawdown	4.72	
RCP8.5 no CO_2 drawdown	35.99	
RCP8.5 natural CO_2 drawdown	15.41	
RCP8.5 fast CO_2 drawdown	9.55	

Antarctic contributions to GMSL for the Pliocene and LIG simulations (rows 1–9) with +2 °C ocean warming in the Pliocene and incrementally imposed ocean warming in the LIG simulations. Values shown represent ice retreat at the end of quasi-equilibrated 5000-yr simulations. Time-continuous LIG simulations forced by proxy-based atmosphere and ocean climatologies (rows 10–12) list maximum GMSL contributions occurring early in the LIG (Fig. 3a). The remaining rows list Antarctic contributions to GMSL at specific times (years as shown) in time-dependent future simulations. Ensemble means and standard deviations (1σ) of the RCP ensemble members listed in Extended Data Table 2 are also shown. Future GMSL contributions are shown relative to 2000.

Extended Data Table 2 | Ensemble simulations of Pliocene, LIG, and future Antarctic contributions to GMSL

Parameter values	Pliocene GMSL (m)	LIG GMSL (m)	LE#
0.1,0,0	3.54	-0.45	
0.1,0,1	3.52	-0.44	
0.1,0,3	3.65	-0.43	
0.1,0,5	3.66	-0.42	
0.1,50,0	4.39	-0.30	
0.1,50,1	8.29	-2.63	
0.1,50,3	10.72	3.53	1
0.1,50,5	10.89	3.76	2
0.1,100,0	4.31	-0.27	
0.1,100,1	8.42	3.41	
0.1,100,3	11.15	4.44	3
0.1,100,5	11.31	4.72	4
0.1,150,0	4.14	-0.23	
0.1,150,1	8.66	3.68	5
0.1,150,3	11.24	4.75	6
0.1,150,5	11.57	4.92	7
1,0,0	3.74	1.15	
1,0,1	3.81	1.17	
1,0,3	4.36	1.22	
1,0,5	4.50	1.18	
1,50,0	4.57	1.20	
1,50,1	8.53	4.68	8
1,50,3	10.93	5.73	9
1,50,5	11.00	5.92	10
1,100,0	4.56	1.20	
1,100,1	8.83	5.02	11
1,100,3	**11.26**	**6.09**	**12**
1,100,5	11.47	6.22	13
1,150,0	4.51	1.13	
1,150,1	8.88	5.12	14
1,150,3	11.39	6.21	15
1,150,5	11.81	6.41	16
3,0,0	4.21	3.18	
3,0,1	4.63	3.28	
3,0,3	4.87	3.31	
3,0,5	4.95	3.27	
3,50,0	4.76	3.28	
3,50,1	9.02	5.37	17
3,50,3	11.29	6.23	18
3,50,5	11.45	6.34	19
3,100,0	4.82	3.30	
3,100,1	9.28	6.31	20
3,100,3	11.38	7.70	
3,100,5	11.60	6.55	21
3,150,0	4.84	3.32	
3,150,1	9.40	6.36	22
3,150,3	11.49	7.89	
3,150,5	11.90	7.99	
10,0,0	5.36	5.32	23
10,0,1	5.73	5.65	24
10,0,3	5.84	5.80	25
10,0,5	5.89	5.81	26
10,50,0	6.01	5.28	27
10,50,1	9.69	7.67	
10,50,3	11.59	8.55	
10,50,5	11.83	8.66	
10,100,0	6.01	5.32	28
10,100,1	9.86	7.80	
10,100,3	11.88	8.79	
10,100,5	12.05	8.89	
10,150,0	5.98	5.34	29
10,150,1	9.97	7.82	
10,150,3	11.97	8.93	
10,150,5	12.41	9.04	

	Future GMSL ensembles (m) — LIG 3.6-7.4 m, Pliocene 5-15 m — No AS-BS ocean bias correction						Future GMSL ensembles (m) — LIG 3.6-7.4 m, Pliocene 5-15 m — With AS-BS ocean bias correction					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
LE#	2100	2500	2100	2500	2100	2500	2100	2500	2100	2500	2100	2500
1	-0.06	-0.13	0.20	4.07	0.66	13.51	-0.06	-0.10	0.20	4.06	0.65	13.52
2	0.08	0.07	0.51	5.69	1.15	17.27	0.07	0.10	0.51	5.71	1.14	17.32
3	-0.01	0.01	0.28	4.56	0.74	13.57	0.01	0.04	0.28	4.55	0.74	13.58
4	0.18	0.21	0.64	6.30	1.29	17.45	0.18	0.24	0.62	6.31	1.28	17.43
5	-0.16	-0.53	-0.03	1.97	0.21	10.64	-0.16	-0.50	-0.03	2.00	0.21	10.66
6	0.02	0.06	0.31	4.74	0.77	13.59	0.02	0.08	0.31	4.80	0.77	13.59
7	0.21	0.27	0.67	6.53	1.34	17.48	0.22	0.30	0.68	6.62	1.34	17.47
8	-0.17	-0.46	-0.04	2.03	0.19	10.66	-0.14	-0.33	0.00	2.32	0.23	10.65
9	-0.03	0.06	0.25	4.52	0.69	13.58	0.01	0.23	0.31	4.66	0.77	13.56
10	0.11	0.25	0.55	6.10	1.20	17.38	0.16	0.42	0.63	6.22	1.30	17.38
11	-0.14	-0.38	-0.01	2.32	0.22	10.69	-0.11	-0.22	0.03	2.51	0.26	10.67
12	**0.03**	**0.20**	**0.32**	**5.03**	**0.77**	**13.62**	**0.07**	**0.37**	**0.39**	**5.16**	**0.86**	**13.60**
13	0.22	0.41	0.67	6.80	1.33	17.47	0.27	0.58	0.78	6.83	1.45	17.48
14	-0.13	-0.32	0.00	2.41	0.24	10.70	-0.10	-0.17	0.04	2.59	0.27	10.69
15	0.06	0.25	0.35	5.24	0.81	13.62	0.10	0.41	0.43	5.37	0.88	13.62
16	0.25	0.46	0.72	6.94	1.38	17.50	0.31	0.62	0.84	7.04	1.48	17.51
17	-0.10	-0.19	0.04	2.59	0.27	10.75	-0.04	0.52	0.14	2.89	0.39	10.74
18	0.04	0.36	0.34	5.09	0.80	13.66	0.12	1.54	0.55	5.31	0.99	13.63
19	0.18	0.54	0.67	6.61	1.34	17.50	0.37	2.16	1.02	6.67	1.66	17.47
20	-0.07	-0.04	0.07	2.79	0.30	10.78	0.00	0.64	0.18	3.09	0.43	10.74
21	0.33	0.76	0.83	7.12	1.48	17.59	0.53	2.35	1.17	7.12	1.75	17.55
22	-0.05	0.00	0.08	2.87	0.31	10.77	0.01	0.70	0.19	3.17	0.44	10.77
23	-0.05	0.17	-0.01	1.21	0.09	9.76	0.22	1.19	0.25	2.03	0.35	9.72
24	-0.04	0.44	0.00	1.44	0.10	9.78	0.29	1.40	0.34	2.26	0.42	9.75
25	-0.02	1.01	0.02	2.00	0.11	9.95	0.41	1.88	0.45	2.74	0.54	9.91
26	0.03	1.44	0.04	2.37	0.12	10.20	0.57	2.05	0.61	2.87	0.71	10.15
27	-0.04	0.21	0.03	1.86	0.18	10.22	0.22	1.22	0.31	2.31	0.51	10.18
28	-0.03	0.22	0.03	1.96	0.20	10.22	0.23	1.24	0.33	2.38	0.53	10.18
29	-0.03	0.21	0.04	2.00	0.20	10.22	0.23	1.22	0.33	2.34	0.53	10.18
mean	0.02	0.19	0.26	3.97	0.64	13.11	0.14	0.70	0.41	4.20	0.79	13.09
1-σ	0.13	0.42	0.28	1.97	0.49	3.04	0.19	0.78	0.30	1.80	0.46	3.05

	LIG 3.6-7.4 m, Pliocene 10-20 m — No AS-BS ocean bias correction						LIG 3.6-7.4 m, Pliocene 10-20 m — With AS-BS ocean bias correction					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
LE#	2100	2500	2100	2500	2100	2500	2100	2500	2100	2500	2100	2500
1	-0.06	-0.13	0.20	4.07	0.66	13.51	-0.06	-0.10	0.20	4.06	0.65	13.52
2	0.08	0.07	0.51	5.69	1.15	17.27	0.07	0.10	0.51	5.71	1.14	17.32
3	-0.01	0.01	0.28	4.56	0.74	13.57	0.01	0.04	0.28	4.55	0.74	13.58
4	0.18	0.21	0.64	6.30	1.29	17.45	0.18	0.24	0.62	6.31	1.28	17.43
6	0.02	0.06	0.31	4.74	0.77	13.59	0.02	0.08	0.31	4.80	0.77	13.59
7	0.21	0.27	0.67	6.53	1.34	17.48	0.22	0.30	0.68	6.62	1.34	17.47
9	-0.03	0.06	0.25	4.52	0.69	13.58	0.01	0.23	0.31	4.66	0.77	13.56
10	0.11	0.25	0.55	6.10	1.20	17.38	0.16	0.42	0.63	6.22	1.30	17.38
12	**0.03**	**0.20**	**0.32**	**5.03**	**0.77**	**13.62**	**0.07**	**0.37**	**0.39**	**5.16**	**0.86**	**13.60**
13	0.22	0.41	0.67	6.80	1.33	17.47	0.27	0.58	0.78	6.83	1.45	17.48
15	0.06	0.25	0.35	5.24	0.81	13.62	0.10	0.41	0.43	5.37	0.88	13.62
16	0.25	0.46	0.72	6.94	1.38	17.50	0.31	0.62	0.84	7.04	1.48	17.51
18	0.04	0.36	0.34	5.09	0.80	13.66	0.12	1.54	0.55	5.31	0.99	13.63
19	0.18	0.54	0.67	6.61	1.34	17.50	0.37	2.16	1.02	6.67	1.66	17.47
21	0.33	0.76	0.83	7.12	1.48	17.59	0.53	2.35	1.17	7.12	1.75	17.55
mean	0.11	0.25	0.49	5.69	1.05	15.65	0.16	0.62	0.58	5.76	1.14	15.65
1-σ	0.11	0.23	0.20	1.00	0.30	2.00	0.16	0.76	0.28	1.00	0.36	2.00

Varying combinations of three model parameters (first column) correspond to OCFAC, CREVLIQ and VCLIF, respectively (see Methods). The resulting GMSL contributions of each ensemble member driven by Pliocene and LIG climatologies are shown in the second and third columns. Combinations of model parameters satisfying Pliocene and LIG sea-level targets are assigned a Large Ensemble number (LE#) in the fourth column. Default model parameter values (LE# 12) and resulting Pliocene and LIG GMSL rise are in bold type. Four future ensembles using alternative sets of the palaeo-filtered Large Ensemble members and following RCP2.5, RCP4.5 and RCP8.5 emissions scenarios are shown at right. The top two ensembles use 29 combinations of parameter values that satisfy LIG sea-level targets and a range of Pliocene sea-level targets between 5 m and 15 m. The bottom two ensembles use a more restricted set of 15 parameter combinations that satisfy a higher Pliocene target range >10 m. Future RCP ensembles at left correspond to the GMSL time series in Fig. 5. The two ensemble sets at far right include the ocean-temperature bias correction described in the text, Fig. 4 and Extended Data Fig. 5. Antarctic GMSL contributions for each ensemble member are shown at 2100 and 2500. Ensemble means and 1σ standard deviations are also shown. GMSL contributions in future ensembles are relative to 2000.

14 2 Attachment Boetsch DF etal 2008 MD CC impact assessment.pdf

Global Warming and the Free State

Comprehensive Assessment of Climate Change Impacts in Maryland




REPORT OF THE SCIENTIFIC AND TECHNICAL WORKING GROUP
MARYLAND COMMISSION ON CLIMATE CHANGE

Scientific and Technical Working Group

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University of Maryland CENTER FOR ENVIRONMENTAL SCIENCE

Integration & Application Network

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Cover photos: NASA, Peggy Davis, Jane Thomas, and Andrew Bossi.

Global Warming and the Free State

Comprehensive Assessment of Climate Change Impacts in Maryland

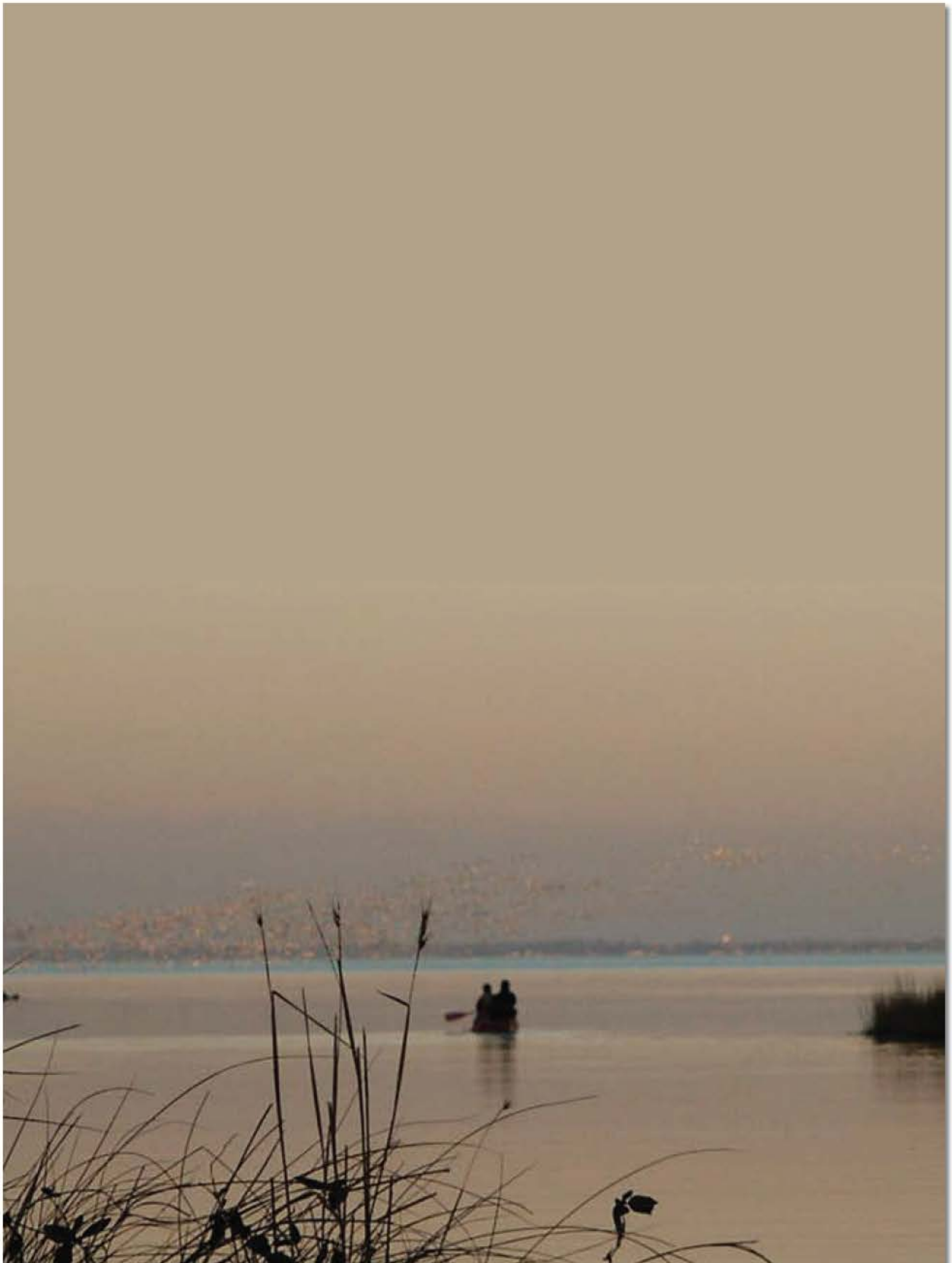
REPORT TO THE MARYLAND COMMISSION ON CLIMATE CHANGE
JULY 2008

THE SCIENTIFIC AND TECHNICAL WORKING GROUP

EDITED BY DONALD F. BOESCH
DESIGNED AND PRODUCED BY JANE M. HAWKEY


Michael Juskelis, Maryland Sierra Club

MDE
UNIVERSITY SYSTEM OF MARYLAND
MARYLAND DEPARTMENT OF NATURAL RESOURCES



Victoria Coles

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EXECUTIVE SUMMARY

Heritage Festival celebration, Cumberland, Maryland.

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THE ASSESSMENT

This is an assessment of the likely consequences of the changing global climate for Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. It was undertaken by the Scientific and Technical Working Group of the Maryland Commission on Climate Change as part of the Commission's charge to develop a Plan of Action to address the drivers and causes of climate change and prepare for its likely consequences in Maryland.

The Assessment was based on extensive literature review and model projections. In addition to the scientific literature, other international, national, and regional assessments of the impacts of climate change were consulted. The results from supercomputer models of the responses of climate to increased greenhouse gas concentrations were used to project future conditions for Maryland. These were the same models and scenario assumptions that were used in the acclaimed assessment completed in 2007 by the Intergovernmental Panel on Climate Change (IPCC). Model projections were based on averages for multiple climate models, and selected based on how well they replicated both global conditions and those observed in Maryland during the 20th century. Mean projections for 17 selected models produced more reliable results than individual models. Changes in temperature and precipitation were projected through the 21st century.

In order to estimate the degree of climate change in Maryland that could be avoided by actions to reduce emissions of greenhouse gases, two emissions scenarios were employed. The higher emissions scenario assumes continued growth in global emissions throughout the century, while the lower emissions scenario assumes slower growth, a peak at mid-century, and thereafter, a decline to about 40% of present levels by the end of the century.

RECENT & LIKELY CLIMATE CHANGES IN MARYLAND

Maryland's climate warmed after the peak of the last Ice Age 20,000 years ago, but has been relatively stable for the past 6,000 years. Around these long-term average conditions, there have, of course, been variations in temperature and precipitation due to ocean current cycles and solar and volcanic activity. However, atmospheric concentrations of greenhouse gases—gases, such as carbon dioxide, methane, and nitrous oxide, that trap the sun's energy from radiating back into space—have dramatically increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over at least the last 650,000 year.

Largely as a result of this increase in greenhouse gases, average global temperature and sea level began to increase rapidly during the 20th century. In its 2007 report, the IPCC concluded that the evidence for the warming of the Earth is "unequivocal." The IPCC also concluded that most of the observed temperature increase since the middle of the 20th century is very likely due to the observed increase in greenhouse gases.

In evaluating the changes in Maryland's climate that we are likely to experience over the 21st century, it should be remembered that climatic regimes will continue to vary across the state. Western Maryland has cooler winters and summers and less precipitation during the winter than the rest of the state. Changes that occur will overlay these regional differences, perhaps with some greater warming during the summer to the west than on the Eastern Shore. Temperature is projected to increase substantially, especially under higher emissions. The increase in average summer temperatures in terms of degrees of warming is greater than that in winter. Annual average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable. The amount of warming later in the century is dependent on the degree of mitigation of greenhouse gas emissions, with summer temperatures projected to increase by as much 9°F and heat waves extending throughout most summers if greenhouse gas emissions continue to grow unchecked.

Sailing club event on the Chesapeake Bay.

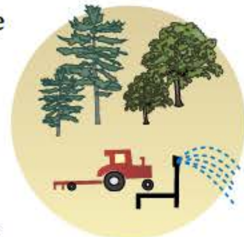
Precipitation is projected to increase during the winter, but become more episodic, with more falling in extreme events. Projections of precipitation are much less certain than for temperature, but the mean projections indicated modest increases of about 10% or so are likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are more likely to occur during the summer.

WATER RESOURCES & AQUATIC ENVIRONMENTS

Increased precipitation in the winter and spring would mean that the water supplies in the greater Baltimore area will probably not be diminished, but the adequacy of summer water supplies in the greater Washington region, which rely on Potomac River flows, is less certain. Any increases in precipitation are unlikely to replace groundwater substantially enough to compensate excessive withdrawals of some aquifers. At the same time, summer droughts may increase groundwater demand for agricultural irrigation.

More intense rainfall resulting from the combined effects of global climate change and localized factors, for example, the influence of the urban canopy on rainfall, is likely to increase peak flooding in urban environments. Continued increase in impervious surfaces attendant with development would exacerbate this problem. Aquatic ecosystems will likely be degraded by more flashy runoff and increased temperatures. Intensified rainfall events and warmer surfaces (roads, roofs, etc.) would result in rapid increases in stream temperatures, limiting habitat suitability for native fishes and other organisms. Higher peak flows and degraded streams would also transmit more nutrients and sediments to the Chesapeake Bay and its tidal tributaries, contributing to water quality impairment in the estuaries.

FARMS & FORESTS



Crop production may increase initially, but then decline later in the century if emissions are not reduced. The longer growing season and higher carbon dioxide levels in the atmosphere are likely to increase crop production modestly during the first half of the century. Later in the century, crop production is likely to be reduced due to heat stress and summer drought under the higher emissions scenario. Milk and poultry production would be also reduced by heat stress. These changes will require adaptation by Maryland's agricultural industry, including changes in crop or animal varieties, increased irrigation, and air conditioning for some livestock.

The maple-beech-birch forest of Western Maryland is likely to fade away and pine trees to become more dominant in Maryland's forests. Forest productivity in terms of timber produced is likely to decline late in the century under the higher emissions scenario as a result of heat stress, drought, and climate-related disturbances such as fires and storms. The biodiversity of plants and animals associated with Maryland's forests is likely to decline. Habitat alterations resulting from climate change may force out 34 or more bird species, including the emblamatic Baltimore oriole, although southern species may replace them.

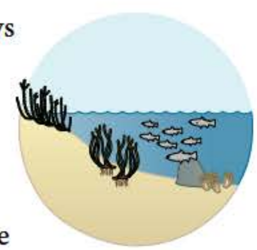
COASTAL VULNERABILITY

Sea level in Maryland rose by 1 foot in the 20th century, partially because the land is sinking as a result of slow adjustments of the Earth after the last Ice Age. Maryland coastal regions have been subsiding at about a rate of 6 inches per century and should continue at this rate during this century. Additionally, the average level of the sea in this region rose by about the same amount (6 inches) during the past century, resulting in the observed 1 foot of rise of the mean tidal level relative to the land. As a result, Maryland has experienced considerable shoreline erosion and deterioration of coastal wetlands which are a critical component of its bays and estuaries.

Sea-level rise is very likely to accelerate, inundating hundreds of square miles of wetlands and land. Projections that include accelerating the melting of ice would increase the relative sea-level along Maryland's shorelines by more than 1 foot by mid-century and 3 feet by late century if greenhouse gas emissions continue to grow. If sea level rises by 3 feet, most tidal wetlands would be lost—about 200 square miles of land would be inundated. New tidal wetlands developed on newly flooded land would not offset the loss of existing wetlands and significant negative effects on living resources dependent on these wetlands would result. Moreover, if sea level were to rise by 3 or more feet, this would mean that rapid and probably uncontrollable melting of land-based ice was underway and that sea level would rise at an even greater rate during subsequent centuries.

Rains and winds from hurricanes are likely to increase, but changes in their frequency cannot now be predicted. The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with warming sea surface temperatures. This trend is likely to continue as ocean waters warm. Whether Maryland will be confronted with more frequent or powerful storms depends on storm tracks that cannot yet be predicted. However, there is a greater likelihood that storms striking Maryland would be more powerful than those experienced during the 20th century and would be accompanied by higher storm surges—made worse because of higher mean sea level—and greater rainfall amounts.

CHESAPEAKE BAY & COASTAL ECOSYSTEMS



Chesapeake and Coastal Bays restoration goals will likely be more difficult to achieve as the climate in Maryland and the Chesapeake watershed changes. Increased winter-spring runoff would wash more nutrients into the bays, and higher temperatures and stronger density stratification in the estuaries would tend to exacerbate water quality impairment, the alleviation of which is the prime restoration objective. Consequently, nutrient loads would have to be reduced beyond current targets to achieve water quality requirements. Very significant changes are also likely to occur that affect sediment delivery and sedimentation in the estuaries, but are difficult to quantitatively predict. These include potential increases in sediment loads from rivers as a result of increased runoff and more erosive extreme discharge events, including those caused by hurricanes, and from shoreline and wetland erosion as a result of accelerated sea-level rise.

Living resources will very likely change in species composition and abundance with warming. A mixture of northern, cool water species and southern, warm water species currently resides in the Chesapeake Bay. Northern species such as soft shell clams and eelgrass are likely to be eliminated later in the century, almost certainly if greenhouse gas emissions are not mitigated. Southern species are very likely to increase in abundance because the milder winters would allow or enhance overwintering populations.

As ocean water becomes more acidic, shellfish production could be affected. Increased atmospheric carbon dioxide concentrations in the atmosphere have already lowered pH in the world's oceans, a trend that is very likely to continue. Recent research indicates that the rate at which oysters and other coastal shellfish build their calcium carbonate shells will likely be affected, but whether this would occur in Maryland waters has not been evaluated.

HUMAN HEALTH

Health risks due to heat stress are very likely to increase, if emissions are not reduced. Under the higher emissions scenario, heat waves are projected to greatly increase risks of illness and death before the end of the century, with an average of 24 days per summer exceeding 100°F. The poor, the elderly, and urban populations are most susceptible. Some, but not all, of these increased risks can be reduced by air conditioning and other adaptation measures.

Respiratory illnesses are likely to increase, unless air pollution is greatly reduced. More ground-level ozone, responsible for multiple respiratory illnesses, is formed under prolonged, high temperatures. Releases of air pollutants (nitrogen oxides and volatile organic compounds) that cause ozone to be formed have been declining, but would have to be reduced much more in a warmer climate to avoid a reversal in progress toward achieving air quality standards.

Increased risks of pathogenic diseases may be less likely. The mortality due to vector-borne and non-vector borne diseases in the United States is low because of public health precautions and treatment, which would likely adapt to changes in disease risks. Climate change might affect the exposure of Marylanders to pathogens such as the West Nile virus, but precautions and treatment could manage this greater risk.

MITIGATION & ADAPTATION

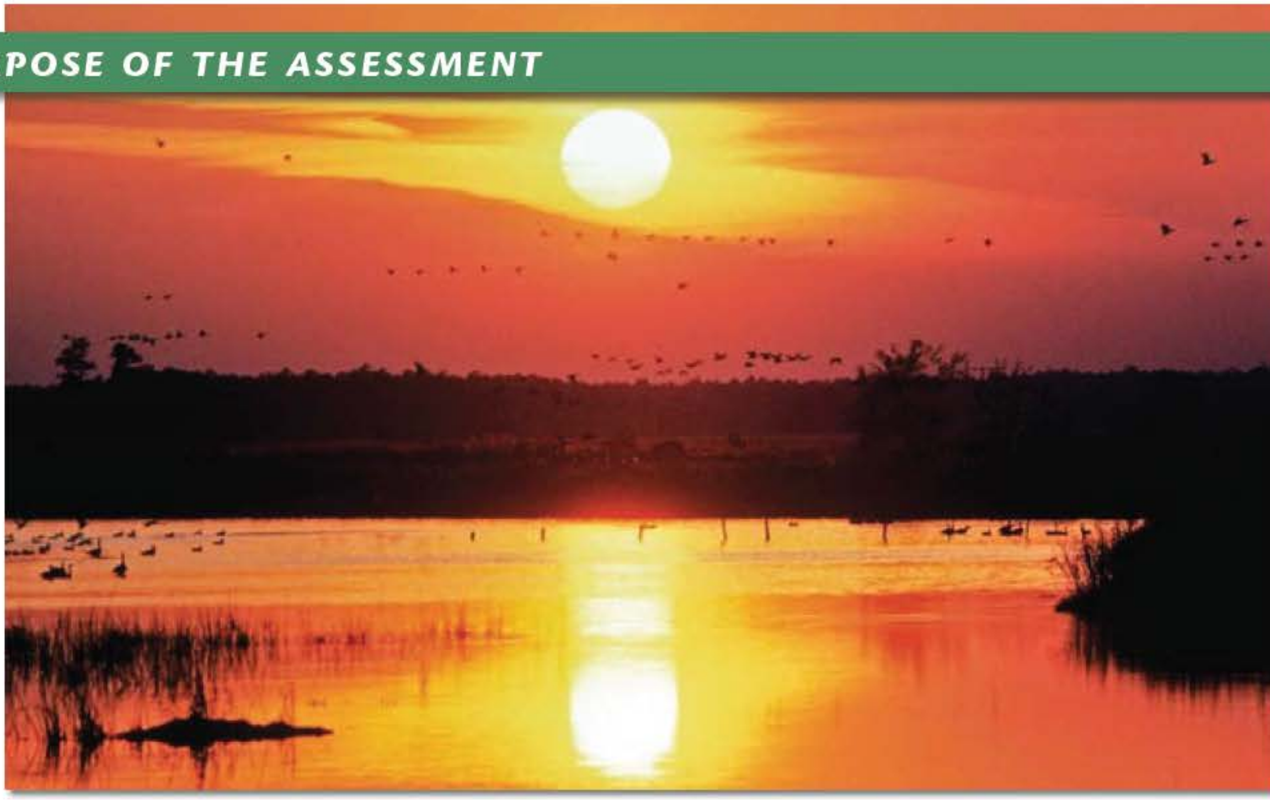
The reduction of greenhouse gas emissions has substantial benefits for Maryland. The mitigation of global emissions by mid-century would very likely result in significantly lower sea-level rise, reduced public health risks, fewer extreme weather events, and less decline in agricultural and forest productivity and loss of biodiversity and species important to the Chesapeake Bay. More serious impacts beyond this century, such as sea-level rise of 10 feet or more, would be avoided.

Based on the projections made in this report, adaptation strategies for human health, water resources, and restoration of Maryland's bays should be evaluated and, where necessary, implemented. Adaptation measures to reduce coastal vulnerability should plan for a 1 foot rise in sea level by mid-century and a rise of at least 2 feet by late in the century. Depending on the course of greenhouse gas emissions, observations, and modeling, planning for increases in sea level of up to 4 feet by the end of the century may be required. The Commission on Climate Change should evaluate additional adaptation strategies related to human health, water resources, forest management, and restoration of the Chesapeake Bay and Maryland's Coastal Bays. The projections of impacts provided in this assessment provide a frame of reference for these evaluations.

Maryland should marshal and enhance its capacity for monitoring and assessment of climate impacts, as a more extensive, sustained, and coordinated system for monitoring the changing climate and its impacts is required. Because of its national laboratories, strong university programs, knowledge-based economy, and proximity to the nation's capital, Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to innovative mitigation and adaptation.

Section 1

PURPOSE OF THE ASSESSMENT



Sunset over Maryland marshlands.

Recognizing the scientific consensus about climate change, the contribution of human activities, and the vulnerability of Maryland's people, property, natural resources and public investments, Governor Martin O'Malley issued an Executive Order on April 20, 2007, that established Maryland's Commission on Climate Change in order to address the need to reduce greenhouse gas emissions and prepare the State for likely consequences of climate change. The Commission was given the task of developing a Plan of Action to address the drivers and causes of climate change, prepare for the likely consequences and impacts of climate change to Maryland, and establish firm benchmarks and timetable for implementing the Plan.

The Plan of Action includes three components:

1. a Comprehensive Climate Change Impact Assessment,
2. a Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy, and
3. a Comprehensive Strategy for Reducing Maryland's Climate Change Vulnerability.

This report constitutes the climate change impact assessment and thus a key part of the Commission's Action Plan. It was prepared by a Scientific and


Governor Martin O'Malley signs the Executive Order creating the Maryland Commission on Climate Change, joined by Cabinet members and General Assembly leaders.

Technical Working Group comprised of Maryland-based scientists, engineers and other experts, who worked over ten months to produce this report. Specifically, the Working Group was charged to investigate climate change dynamics, including current and future climate models and forecasts and evaluate the likely consequences of climate change to Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. In addition, the Working Group was called on to advise the Commission and its other working groups as their work proceeded. In particular, the Scientific and Technical Working Group provided information and analysis for the development of the goals for reducing greenhouse gas emissions and for adaptation strategies for reducing coastal vulnerability.

This Comprehensive Assessment of Climate Change Impacts in Maryland is intended to serve a number of purposes. First, it is one of the three legs of the stool for the Commission's Plan of Action, providing regional context for the importance of reducing Maryland's greenhouse gas emissions and projections of future climate change for which we should be prepared to adapt. For this reason, projections for climate change and its impacts present two scenarios, one assuming continued growth in greenhouse gas emissions and the other assuming global action to reduce these emissions. The second scenario helps to identify the changes that may be inevitable and for which Maryland must be prepared to adapt. In this manner, it seeks to provide a basis for the development of prudent and effective public policy by the Governor and General Assembly.

Secondly, this Assessment is presented so as to be accessible and comprehensible to the citizens of Maryland as they develop their understanding of this unprecedented challenge to humankind and make personal choices and decisions regarding policy options at local, state, and national levels.

Finally, this Assessment is just the first installment of what must be continuous reassessment of Maryland's changing climate, the impacts of this change, and what science and engineering can do to understand, predict, and manage these impacts.

Victoria Coles

Forested mountains and grass meadows of western Maryland.

Section 2

WHY IS THE WORLD'S CLIMATE CHANGING?

KEY POINTS

- **Maryland's climate has been variable but stable for several thousand years.**
  Maryland's climate warmed after the peak of the last Ice Age and has been relatively stable for the past 6,000 years. Around these long-term average conditions there have, of course, been variations in temperature and precipitation due to ocean current cycles, solar activity, and volcanic activity.
- **Atmospheric concentrations of greenhouse gases have dramatically increased.**
  Certain gases that trap the sun's energy from radiating back into space have increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over at least the last 650,000 years. Average global temperature and sea level began to increase rapidly during the 20th century.
- **Global warming is unequivocal.**
  The Intergovernmental Panel on Climate Change found the evidence for the warming of the Earth to be "unequivocal." The IPCC concluded that most of the observed temperature increase since the middle of the 20th century is very likely due to the observed increase in greenhouse gases.

CLIMATE VARIABILITY & CHANGE

Maryland's climate has changed over millennia as the major planetary forces affecting the Earth's climate caused glaciers to spread and recede. However, after the peak of the last Ice Age about 20,000 years ago, the climate warmed, most of the glaciers melted, and sea level rose, reaching approximately the present conditions about 6,000 or more years ago. The slow, continued rise in local water levels was mainly the result of the slow sinking of the Earth's crust beneath us—this itself is a delayed effect of melting glaciers. The first Native Americans came to Maryland as its climate was becoming more moderate and habitable. For most of the time they have been here and all of the time of occupancy by Europeans, Africans and other subsequent migrants, our climate has been relatively stable. Our society, economy, and quality of life has developed under and adapted to this climatic regime.

Of course, our weather (see Section 4 for a discussion of the differences between weather and climate) still varies from year to year—some years are warmer or wetter than others—and even over cycles that extend over several years to a decade or more. This variability is caused by shifts in large-scale processes in the ocean and atmosphere such as the El Niño cycles in the Pacific Ocean, variations in solar activity, and even volcanic eruptions halfway around the world. But, over the past few thousand years, this has caused climate to fluctuate around a rather consistent average.

During the 20th century, however, scientists have concluded that the Earth's climate was warming and is very likely to warm much more dramatically as a result of human activities that have increased the amount of certain gases in the atmosphere. These gases, most notably carbon dioxide, but also methane and nitrous oxide, trap some of the sun's energy radiating back out into space, much as the glass panes of a garden greenhouse. The presence of these gases warms the atmosphere sufficiently for life to flourish—without these greenhouse gases the average surface temperature of Earth would be 0°F rather than 57°F.[1] But, as these heat-trapping gases continue to increase the temperature of Earth's atmosphere and oceans will also continue to increase—this is what is meant by global warming.

MAJOR CHANGES DOCUMENTED

There is no doubt that greenhouse gases in the atmosphere have been increasing. Since pre-industrial times (1750) carbon dioxide concentration has increased by 38 percent, methane by nearly

170 percent, and nitrous oxide by 17 percent.[2] The increase in carbon dioxide has been caused primarily by burning of fossil fuels (coal, oil, and natural gas) and the clearing of forests which held reservoirs of carbon in wood and soils and removed carbon dioxide from the atmosphere through photosynthesis. The increase in the other two major greenhouse gases is mostly due to agricultural activities: methane through growing rice and raising cattle, and nitrous oxide from the application of industrial fertilizers to crops, as well as a result of the high-temperature combustion of fossil fuels.

Carbon dioxide concentration in the atmosphere has increased from a pre-industrial value of about 280 parts per million (ppm) to 384 ppm by 2007 (Figure 2.1), exceeding by far the natural range over at least the last 650,000 years as determined from analyses of air bubbles trapped in glacial ice. The global mean surface temperature, based on both air and ocean temperatures, has increased by more than 1°F (0.6°C) since 1930 (Figure 2.2), with most of this due to a steady and rapid increase since 1980. Twelve of the last thirteen years rank among the warmest years since 1850, when thermometer measurements became widely recorded. In the Northern Hemisphere, where there are numerous data on temperature proxies such as tree ring thickness and ratios of stable isotopes, neither the recent high global mean temperature nor the rapid rate of temperature increase have been experienced during the last 2000 years.[2]

Global warming affects not only air and ocean temperatures but also precipitation and sea level—ocean waters expand as they warm and as melting glaciers and polar ice sheets further contribute to the ocean's volume. Warmer conditions cause

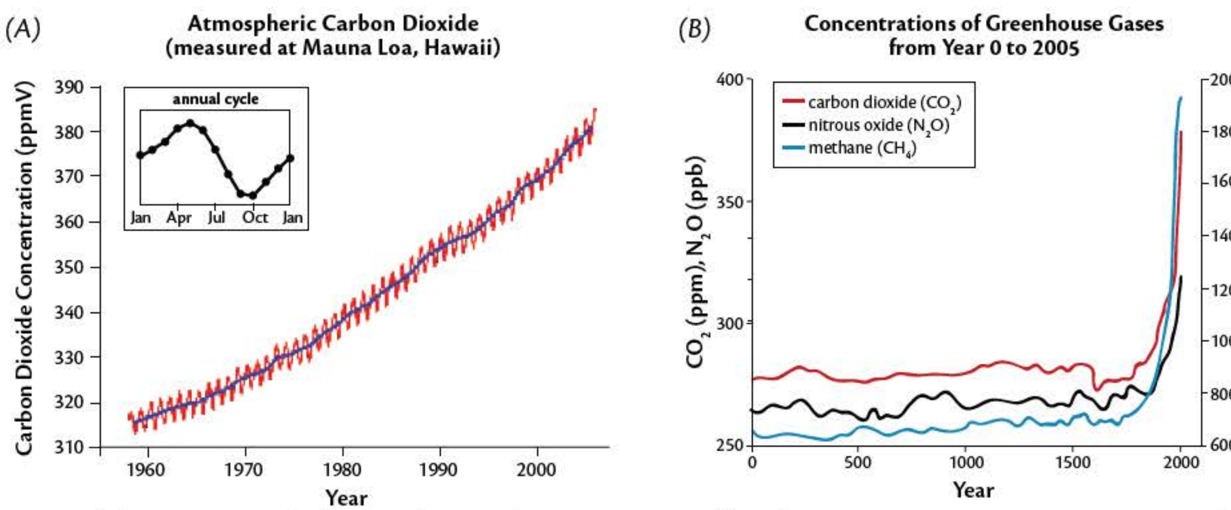


Figure 2.1. (A) Concentrations of carbon dioxide measured at Mauna Loa, Hawaii have shown a continuous increase since measurements began in 1958. Annual fluctuations represent seasonal biological cycles of photosynthesis and respiration. (B) Concentrations of the greenhouse gases carbon dioxide, methane, and nitrous oxide dramatically increased during the 20th century, exceeding by far concentrations that occurred over the last 2,000 years.[2]

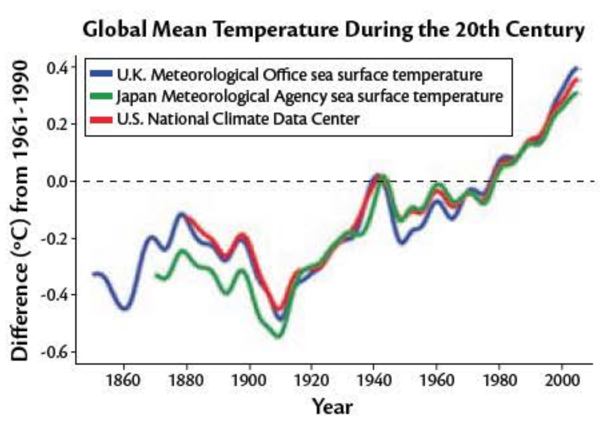


Figure 2.2. Global mean temperature has increased approximately 1.4°F (0.8°C) during the 20th century as reflected in three separate meteorological databases.[2]

NASA Jet Propulsion Lab, CIT

AIRS, a new spaceborne instrument, is designed specifically to measure the amounts of water vapor and greenhouse gases.

more moisture to go into the atmosphere through evaporation and plant transpiration, and this water vapor must come down in the form of precipitation. However, the effect is not uniform, with increased precipitation documented over the middle and high latitudes of the Northern Hemisphere and over tropical land areas, while precipitation declined in the already dry, lower latitude lands.

WARMING IS UNEQUIVOCAL

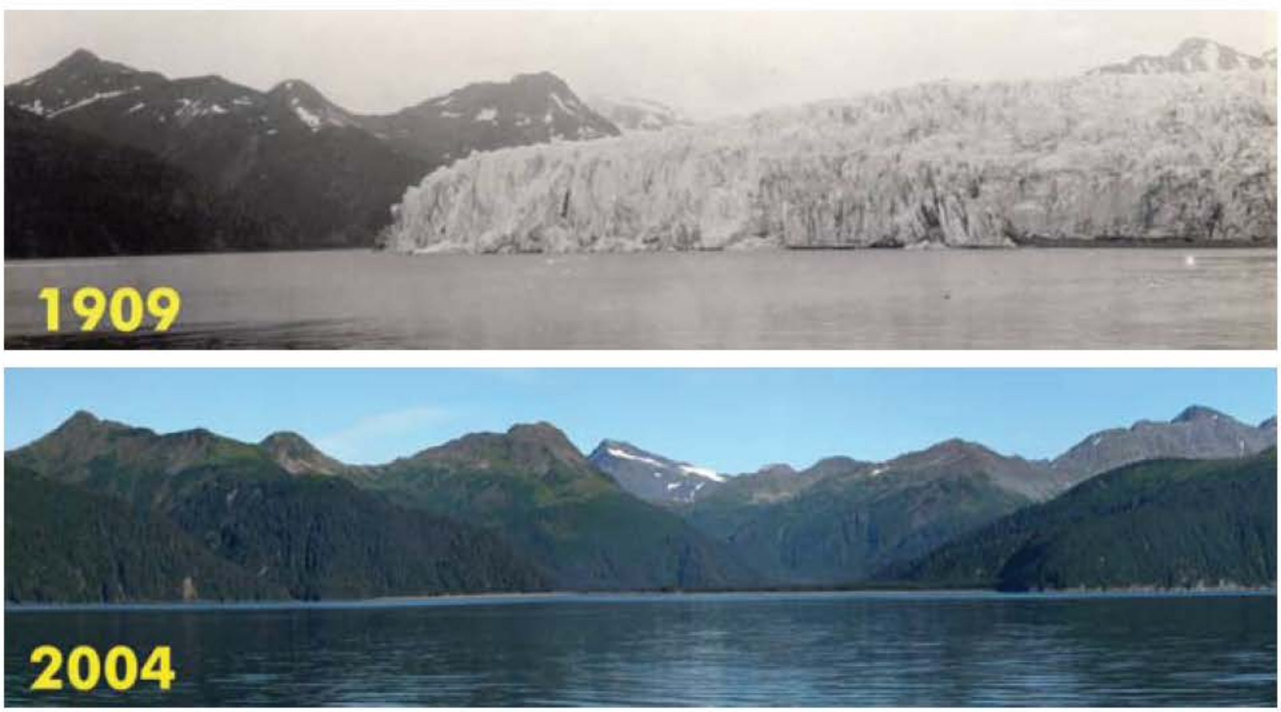
The conclusion that the warming of the climate system is unequivocal and the preceding observations come from the most recent assessment of the Intergovernmental Panel on Climate Change, an international scientific body established by the World Meteorological Organization and by the United Nations Environment Programme. The IPCC was awarded, along with Vice-President Al Gore, the Nobel Peace Prize for its Fourth Assessment Report[3], released in 2007. The findings of the Panel are careful and deliberate and enjoy the wide acceptance of the climate science community—in fact, scientific criticism that the IPCC was too cautious and reticent[4] is more common than criticism for overstating the case.

Global warming is unequivocal and could cause irreversible damage to the planet

The IPCC concluded that most of the observed increase in globally averaged temperatures since the middle of the 20th century is very likely due to the observed increase in greenhouse gas concentrations resulting from human activities. The Panel also found decreases in snow cover and sea ice extent and the retreat of mountain glaciers during this period. Global average sea level rose with increasing ocean water temperatures. Heavy rains increased in frequency in some regions of the world.

Extensive physical and ecological changes resulting from the changing climate are also described in the IPCC assessment, including thawing of permafrost, lengthening of the growing season in middle and high latitudes, shifts in the ranges of animals and plants toward the poles and up mountain elevation gradients, declines in some plant and animal species, and earlier seasonal flowering of trees, emergence of insects, and egg-laying in birds.[5]

The same detailed appraisal of the relationship of the changes in Maryland's climate and the increase in greenhouse gas concentrations has not been undertaken, and indeed is not practical because of the global scale of the climate system. However, the trends of increased temperature, precipitation, and sea level rise and many of the biological changes that have been observed are very consistent with the assessment of the IPCC for North America.[2,5]



U.S. Geological Survey

Comparison photos of McCarty Glacier in Kenai Fjords National Park, Alaska. McCarty glacier retreated ~12 miles between the period these two photos were taken and is not visible in the 2004 photo.

NPS

The lakes, ponds, and streams of Maryland are a favorite habitat for the twelve-spotted dragonfly.

Section 3

APPROACH TO ASSESSING RECENT & FUTURE CLIMATE CHANGE

KEY POINTS

- **The Assessment was based on extensive literature and model projections.**
  In addition to the scientific literature, other international, national and regional assessments of the impacts of climate change were consulted. The results from supercomputer models of the responses of climate to increased greenhouse gas concentrations were used to project future conditions in Maryland.

- **Model projections were based on averages for multiple climate models.**
  Models were selected based on how well they replicated both global conditions and those observed in Maryland during the 20th century. Mean projections for 17 models produced more reliable results than individual models. Changes in temperature and precipitation were projected through the 21st century.

- **Higher and lower emissions scenarios were employed.**
  In order to estimate the degree of climate change in Maryland that could be avoided by actions to reduce emissions or greenhouse gases, two emissions scenarios were employed. The higher emissions scenario assumes continued growth in emissions throughout the century, while the lower emissions scenario assumes a slower growth peak at mid-century and declines thereafter to about 40% of present emissions levels by the end of the century.

THE PROCESS

The Scientific and Technical Working Group (STWG) developed this assessment using published scientific information on Maryland's climate and environments, the recent IPCC reports, even more recent scientific literature, and several new assessments of specific issues or region impacts. Particularly important among these assessments were various Synthesis and Assessment Products being produced by the U.S. Climate Change Science Program (some drafts still in preparation or review)[6] and regional assessments, especially the Northeast Climate Impacts Assessment (NECIA). The NECIA, led by the Union of Concerned Scientists, produced two very readable reports[7] on climate change, its impacts and solutions in the northeastern United States, defined as the nine-state region including Pennsylvania and New Jersey northward. Because of its proximity, the findings of the NECIA are highly relevant and have been reflected in the Maryland assessment.

The STWG did not have the time or resources to collect or analyze extensive data or to develop new models of Maryland's climate, relying instead on the primary or summary literature as described above. It did, however, use the results of the extensive general circulation models that were run on a global scale for the IPCC assessment. Such models are run on supercomputers using common assumptions about future emissions of greenhouse gases and have become increasingly skillful in reproducing the climatic conditions experienced during the 20th century looking backward in hindcast mode. This gives some level of confidence in their ability to project conditions with future increases in greenhouse gases for at least the near future. The models were used by the IPCC in demonstrating that the warming observed over the past 100 years is unlikely to be due to natural causes, such as the sun and volcanoes, alone. Model results that take into account greenhouse gas emissions and the cooling effects of sulfate aerosols, also emitted by burning fossil fuels, are able to reproduce the observed 20th century warming, while those that only account for the natural climate forces do not (Figure 3.1).

While our understanding of the forces that affect the Earth's climate will improve, the scientific community believes that the current generation of models produces reasonable projections of future climatic conditions. They cannot, of course, predict the weather on a specific place or day, but can represent best estimates of future climatic conditions within a broad region averaged over a decade.

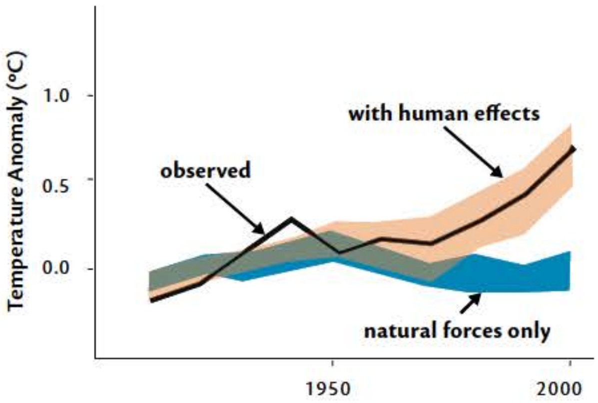


Figure 3.1. Climate models run with just natural forces due to solar activity and volcanoes (blue band) suggest slight declines in global mean temperature during the latter 20th century, while the same models including greenhouse gases and aerosol sulfates from human activities (pink band) show warming very consistent with what was actually observed (solid black line).[2]

OBSERVATIONS

The focus of this assessment is the impacts of future climate change, rather than how much of past climate variability is due to human effects, so the emphasis is on model projections. However, data from stations from the United States Historical Climate Network, corrected for the warming effects of urbanization and the local effects of topography, were used to determine how well models reproduce recent climate in Maryland. These individual weather station records also yield information on the trends in temperature and precipitation that have been experienced.

Beyond temperature and precipitation, sufficiently long records of other climate-sensitive variables are scarce, thus attribution of past changes to climate is difficult. One example of the value of such secondary indicators is the recorded trend toward earlier start of honey production in the Piedmont region.[8] Honey production requires both temperatures high enough to maintain larval bees and an ample source of nectar from flowering trees, thus integrating two measures of climate change. Other examples of observed changes in forestry and agriculture, Chesapeake Bay processes, sea level, and hydrology are highlighted later in the report.

PROJECTIONS

In forecasting the storm tracks of active or developing hurricanes, for example, an ensemble of models is used rather than just relying on one. This allows for a 'best estimate' prediction within a range of plausible tracks. A similar approach was used in the IPCC Fourth Assessment by employing a group of satisfactorily performing general circulation models all run with the same assumptions for greenhouse gas emissions. The archived files of output from these supercomputer model runs were accessed for this assessment.[9] The average of the model outputs yields a better representation of present climate than any single model[10] or the small number of models used in the Northeast Assessment.[7] This ensemble mean gives the best projections because some model inaccuracies are unrelated to the shortcomings of other models, so they cancel out on average.

This assessment used a similar strategy, beginning with the 24 models used for the IPCC Fourth Assessment model intercomparison. The 17 best performing models were selected based on how well the models reproduce the climate in Maryland over the past century.[11] Net error scores were computed for temperature and precipitation based on means, trends over the century, seasonal and ten-year filtered correlations, the standard deviation, and the skill with which the models represent global climate. The subset of better performing models was then averaged over the state of Maryland to estimate changes in future climate in this region.

Projections of the 17 best performing models were averaged

Because the global models require so many hours of supercomputer time to run, they cannot represent regions as small as Maryland with more than a few grid points (Figure 3.2). Thus, the projected changes over the state need to be considered in the context of the large differences in local state climate. For example, one would expect the climate in high elevation regions of western Maryland to remain cooler than the climate on the coastal plain despite similar temperature increases in both regions (see Table 4.1 in the next chapter). The average seasonal cycle for 1979-1999 is removed from each model output prior to determining future changes. This reduces the effect of individual model biases on the projection of future changes and projects future climate relative to the average conditions around 1990.

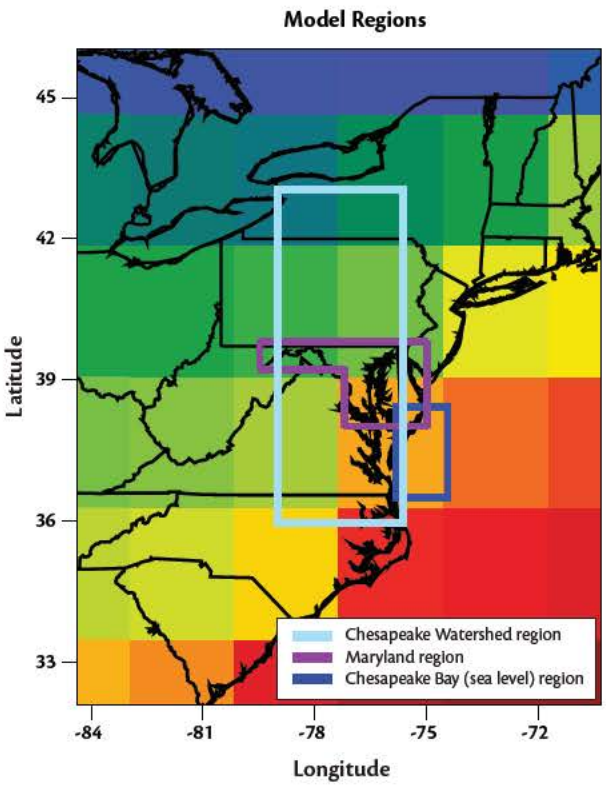


Figure 3.2. Surface air temperature for one of the climate models, showing the number of grid cells covering Maryland, and also the averaging regions employed for this assessment.

EMISSION SCENARIOS

A critical objective of this assessment was to compare future climate impacts under the situation in which greenhouse gas emissions continue to grow throughout the 21st century with the situation that might be realized if global action was taken to reduce greenhouse gas emissions. A similar approach was used in the Northeast Assessment. Two plausible global emissions scenarios were selected from among those used by the IPCC assessments. The higher emissions (A2) scenario assumes a heterogeneous world, with locally self-reliant response to climate change, regional technological and economic development, and faster growing population. The even higher emission, A1Fi, scenario used in the Northeast Assessment was not used because of the limited archived output available for this scenario. The lower emissions (B1) scenario assumes slower population growth, clean technologies are developed and implemented globally, and there is a general emphasis on global solutions to economic and environmental issues.

These scenarios can be viewed representing the 'business as usual' response to climate change versus sustained emissions reduction strategy, although the lower emissions scenario was not developed with that specific assumption in mind. However, the scenarios should not be seen as either a floor or ceiling of possible outcomes. Recent growth in carbon dioxide emissions exceed the higher emissions scenario.[12] On the other hand, the emission reduction goals being actively discussed internationally, i.e. reductions of 60-80% by 2050, would, if implemented, reduce emissions more and result in less warming than the lower emissions scenario. Although the IPCC intends to use several specific emissions mitigation scenarios in its next assessment, projections do not yet exist for such scenarios.

While carbon dioxide emissions for the two scenarios begin to diverge significantly around 2025 and decline in the low emissions scenario after 2050 (Figure 3.3), the cumulative emissions begin to diverge only after 2040. Because carbon dioxide is retained in the atmosphere for a long time, the full effects of this divergence are not fully manifest until late in the century. Thus, in the model projections,

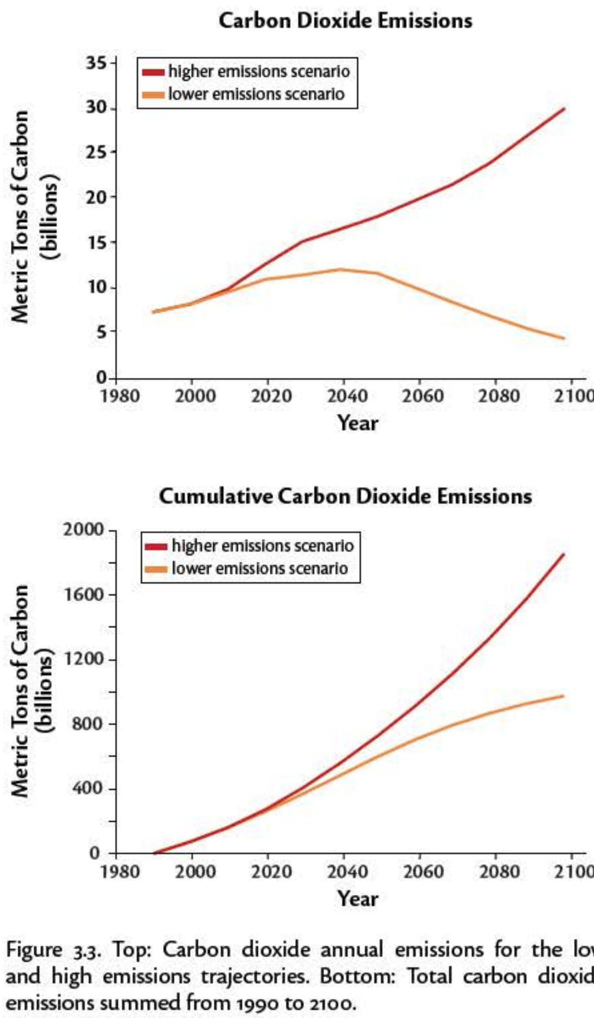


Figure 3.3. Top: Carbon dioxide annual emissions for the low and high emissions trajectories. Bottom: Total carbon dioxide emissions summed from 1990 to 2100.

Wikipedia Commons

Smog hangs over a Baltimore highway clogged with traffic.

there is often little difference between the higher and lower emissions scenarios until after 2050 and the differences increase thereafter.

CONFIDENCE

The spread in model predictions is one indication of how well the underlying physics and feedbacks of climate processes are represented. The hydrological cycle, for example, is less well represented than temperature in all of the climate models because coarse spatial resolution of models precludes a good representation of the physics involved in evaporating, transporting, and precipitating water. As a result, we have high confidence in temperature projections for which the physical processes represented in the model are better understood, moderate confidence in trends in temperature extremes, moderate confidence in directional changes in precipitation and other hydrological variables, and relatively low confidence in model projections of precipitation extremes at this scale.

The spread of model projections for a given parameter is used to assess the likelihood of the projected outcome. Throughout this report, the characterization of likelihood of both trends in observations and certainty of projections has followed with the IPCC assessments, except without the discrete probabilities assigned by the IPCC (Figure 3.4). Similar to the assessment of weather and climate extremes by the U.S. Climate Change Science Program[13], this approach allows the communication of the level of certainty that is consistent throughout the report.

Terms Used to Express Judgement of Likelihood

Figure 3.4. Terms used in this assessment to communicate judgment of likelihood.

ABRUPT CLIMATE CHANGE

Finally, a word of caution is offered about the use of climate model projections in planning for future climate conditions. There is greater confidence regarding some variables (such as global and regional temperature) than others (such as regional precipitation). Some variables (such as soil moisture or stream flow) result from the complex interplay of temperature, water, carbon dioxide concentrations, and living organisms, making them difficult to model with great reliability. Still others will be influenced by processes that may dramatically change and thus are inherently challenging for scientists to predict (such as the contribution of future polar ice sheet melting to sea-level rise).

Because of the way they are constructed, climate models can be used to assess gradual trends averaged over decades. They are, at this point in their development, less reliable as a signal of more abrupt climate changes. Various records of past climate changes, including deep sea sediments, ice cores, tree rings, and other natural recorders, indicate that they have often taken place within a fairly short period of time, within a century or even a decade. Scientists are actively conducting research on the causes and consequences of such abrupt climate changes, but few attempts have been made to model them under future global warming conditions. For the purpose of this assessment, it is simply important to keep in mind that the changes that will take place during this century may be more 'jerky' than continuous, with trends reversing for some years and advancing more dramatically over the period of just a decade. This places a challenge both for our observations of trends and for our ability to adapt quickly.

Section 4

RECENT & LIKELY CLIMATE CHANGES IN MARYLAND

KEY POINTS

- **Climatic regimes will continue to vary across Maryland.**
  Western Maryland has cooler winters and summers and less precipitation during the winter than the rest of the state. Changes will occur on top of these regional differences, perhaps with some greater warming during the summer to the west than on the Eastern Shore.

- **Temperature is projected to increase substantially, especially under higher emissions.**
  Average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable. The amount of warming later in the century is dependent on the mitigation of greenhouse gas emissions, with summer temperatures projected to increase by as much 9°F, and heat waves extending throughout most summers.

- **Precipitation is projected to increase during the winter, but become more episodic.**
  Projections of precipitation are much less certain than for temperature, but modest increases are more likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are projected to be more likely during the summer.

THE CONTEXT

The state of Maryland, although comprising only 12,303 square miles, spans diverse geographic and climatic zones, from the flat Coastal Plain, westward to the Piedmont foothills, and the Appalachian Plateau. Well-defined seasons divide the cool, northwesterly wind-dominated, dormant season for plant growth from the warm summers with southwesterly winds and high humidity in the coastal regions. Spring and fall are highly variable with weather changing almost daily as warm and cool fronts push through mainly from the west. Although Maryland lies south of the main winter cyclone track, the influence of these storms can affect winter climate. Storms originating in the south or coastal regions (Nor'easters) also play a role in destructive winter weather, as they are accompanied by large amounts of rainfall and high tides. Hurricanes and tropical storms, although infrequent with only eight storms affecting Maryland since 1954, also can have a destructive influence on Maryland Coastal Plain regions in particular, primarily through flooding and storm surge.

Figure 4.1 illustrates the seasonal range of temperature across Maryland. While the higher elevations to the west remain cooler in both winter and summer, the rate of temperature increase from 1977 to 1999, is similar across the state, with an increase in the mean annual temperature of 2°F. No weather stations show a temperature decrease. This is significantly more warming than the global average.[2] The rainfall differences across the state are much smaller, with Maryland having little seasonality in rainfall; consequentially, most agriculture relies on precipitation rather than irrigation (see Section 6). Precipitation is highly variable from year to year, and no clear trend emerges from the stations in Maryland, although significant increases in precipitation have been documented to the north.

Adrian Jones

Winter wheat is sometimes planted in a mix with cool-season clovers or field peas to suppress weeds and prevent soil erosion.

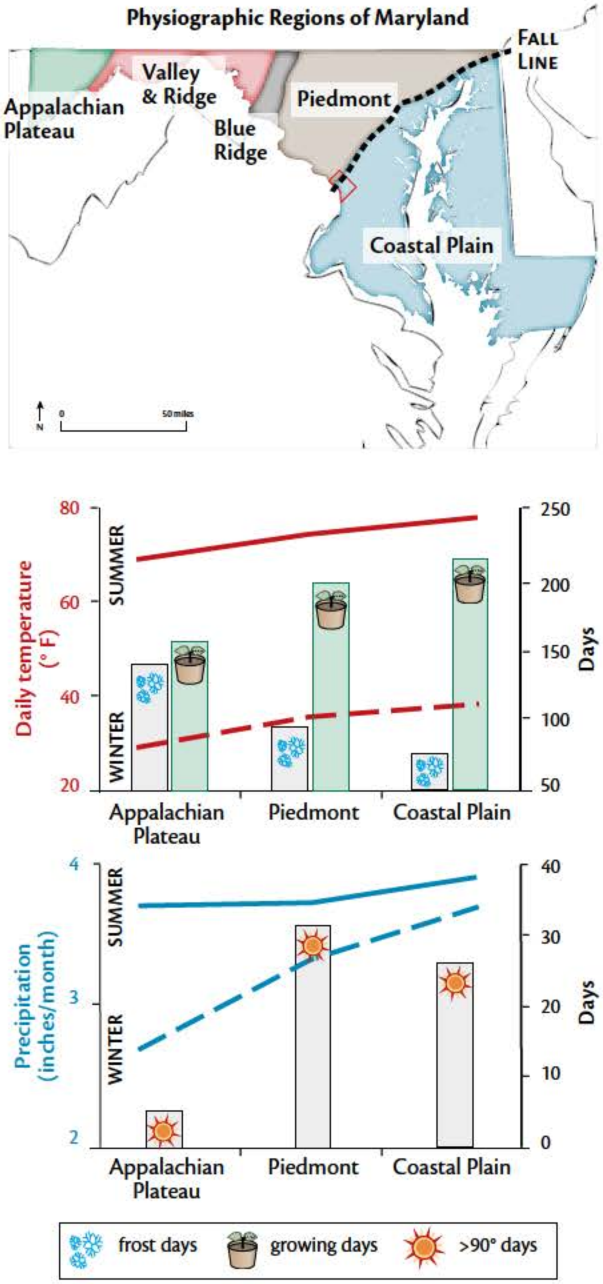


Figure 4.1. Top: The five physiogeographic regions of Maryland. Middle: Temperatures range seasonally across Maryland, with the elevated, inland regions to the west remaining cooler in both winter and summer and experiencing a shorter growing season. Bottom: The precipitation differences across the state are modest, except in winter, when it is lower on the Appalachian Plateau. The average number of days with temperatures greater than 90°F is much lower in the Appalachian Plateau.[13]

TEMPERATURE

Human-induced climate change is most directly linked to global temperature rise. However, atmospheric circulation, interactions of climate with land surfaces and oceans, and other factors drive patterns of heating and cooling that affect the projected temperature increases. On a global scale, temperature increases are generally expected to be greater in the Northern Hemisphere, particularly toward the Arctic regions.[2] Maryland, therefore, will not warm by as many degrees as the New England states.[7] Nonetheless, Maryland will experience significant warming in the coming decades and century (Figure 4.2).

The climate model mean projects an additional 2°F of warming by 2025, regardless of which emissions scenario is followed. By 2050, the policy decisions applying to which emissions path is followed begin to have an effect, and a difference in winter versus summer warming also emerges. The lower emissions scenario warms slightly less by 2050, with summertime temperature increases of nearly 3°F. Temperature under the higher emissions scenario begins to increase sharply after mid-century, with summertime seeing somewhat greater warming than winter.

By the end of the century, the difference between the higher and lower emissions scenario is marked. The low emissions path has held temperature increase to 4.8°F in summer, and 4°F in winter, while the higher emissions scenario leads to warming of nearly 9°F in summer and 7°F in winter in Maryland. One would expect these increases to be above the current mean temperatures for the three regions of the state as shown in Figure 4.1. Summertime average (over both night and day) temperatures in the Coastal Plain would increase from 77°F to 86°F by the end of the century under the higher emissions scenario. However, an ongoing national assessment has produced statistically

Under higher emissions, summers are projected to be nearly 9°F hotter by end of century

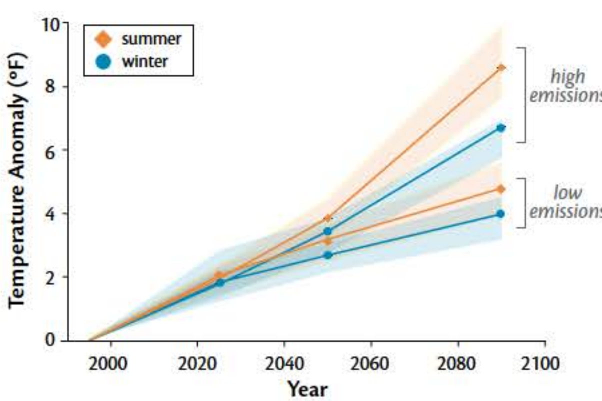


Figure 4.2. Temperature increase (°F) for Maryland from 1990 to the year 2100. The shaded regions depict the 25th-75th percentile spread between all the models.

downscaled maps based on the averages of a similar array of outputs that suggest summertime warming would be greater in Western Maryland and less on the lower Eastern Shore because of the moderating influence of the ocean (Figure 4.3)

These projections have relatively little spread between model projections for a given scenario, thus it is very likely that there will be more warming in summer than winter, and that the higher emissions scenario will result in substantially greater warming than the lower emissions scenario. Confidence in how well models represent the underlying physics of human caused warming is also high. While the likelihood of warming is high, the exact magnitude of the amount of increase is less so. However, none of the models project less than 4°F of warming in summer by 2100.

This is not to say that as the century progresses each year will be warmer than the preceding year. There will likely be months and even years that are on average cooler than the current seasonal norms. This is due to variations in the weather, not changes in climate. This assessment focuses on the average temperature over longer periods, and this continues to increase in all emission scenarios. Thus, any given warm or cold weather episode cannot be unambiguously attributed to climate; rather it is the accumulation of weather over time that gives rise to changes in climate.

HEAT WAVES

These projections for summer and winter are based on temperatures averaged over a three-month season. However, it is not the average temperature that affects our comfort or health, but rather the daily extremes. A 4°F average warming could be derived from an endless succession of slightly warm days or from average summer days interspersed with intense heat waves (operationally defined here as three or more consecutive days with temperatures exceeding 90°F). Figure 4.4 depicts increases in the number of days with maximum daily temperatures above 90°F and 100°F. In the late 20th century, there was an average of 30 days per year with maximum temperatures in excess of 90°F. Of course, this number would be higher in urban areas, and lower at higher elevation or near the ocean (see Figure 4.1). On the average, temperatures reached 100°F on only about two days per year. Recent trends suggest a moderation in the number of high maximum temperature days in the Mid-Atlantic region[14], however the monthly average maximum temperature at Maryland weather stations has been increasing faster than the average temperature, suggesting that maximum daily temperature will ultimately follow suit.

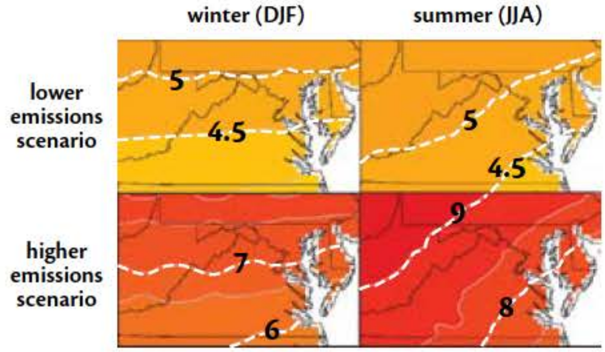
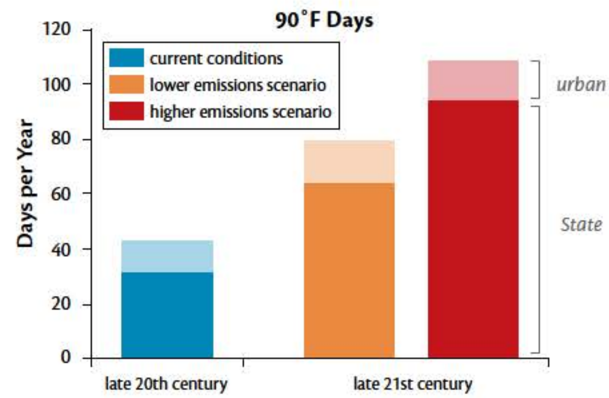


Figure 4.3. National maps of downscaled model projections of mean temperature increases for the period 2080-2099 show results very similar to this assessment. Note the east to west trend in the warming during the summer. Courtesy of Katherine Hayhoe, Texas Tech University.



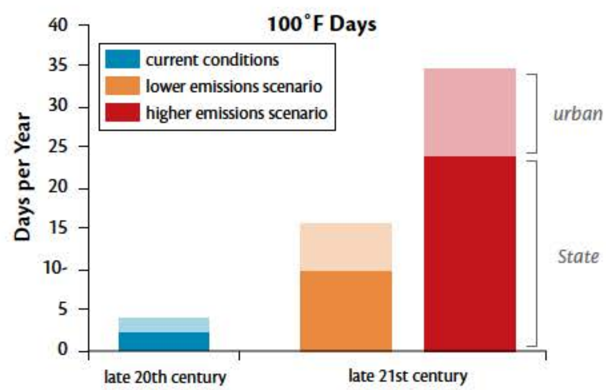


Figure 4.4. Number of days with high temperatures reaching or exceeding 90°F and 100°F in the late 20th century and projected for the late 21st century under higher and lower emission scenarios. Extension of the bars show the number days exceeding these levels in urban settings.

The number of days with temperatures exceeding 90°F is projected to double by the end of the century even under the low emissions scenario and triple under the higher emissions scenario in which virtually all summer days would exceed 90°F during an average summer (Figure 4.4). Under the higher emissions scenario, the number of days with temperatures in excess of 100°F is projected to increase by a factor of five, with most summer days exceeding this threshold. While at present, heat waves tend to have a limited duration with only a 13% chance per year of a heat wave lasting longer than 20 days, extended heat waves are likely to be much more frequent and longer lasting, especially under the higher emissions scenario (Figure 4.5). In the low emissions scenario, it remains most likely that any heat wave experienced will be of less than 20 days duration; however, the chance of a longer heat wave increases greatly. Under the higher emissions scenario, any given year is more likely to have a heat wave persisting for 140 days or more than it is to not have a heat wave exceeding 20 days. The predictions for increasing heat waves and temperature extremes are likely, with moderate confidence.

CHESAPEAKE BAY TEMPERATURES

Climate models currently do not resolve at the scale of estuaries, even for an estuary as large as the Chesapeake Bay (see Figure 3.2). However, observations of Chesapeake water temperatures extend back into the 1940s (Figure 4.6). These observations show a trend of increasing water temperature of 0.4°F per decade, with much of that increase over the past 30 years, consistent with increasing air temperatures. This amounts to a warming of 2.8°F over much of the Bay since 1940.

A statistical model was used to quantify the relationship between air temperature, over the preceding month, and Chesapeake Bay surface water temperature based on these observations.

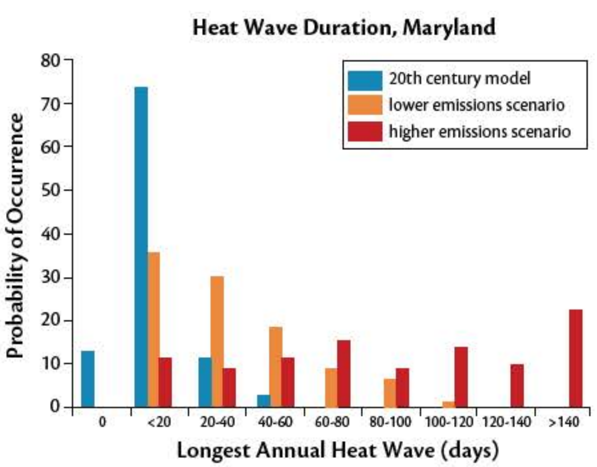


Figure 4-5. The chance that any given year will experience a heat wave of the indicated duration for present day and for the end of the century under low emissions and high emissions scenarios.

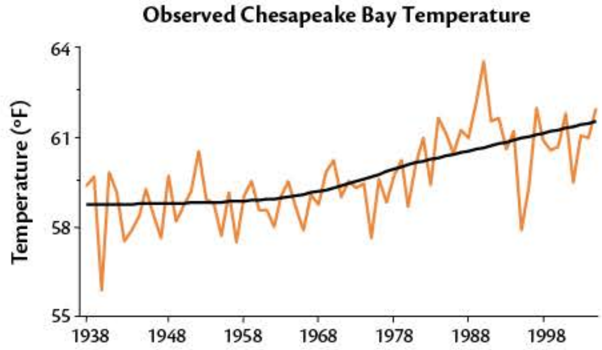


Figure 4.6: Bay temperature at Chesapeake Biological Laboratory at Solomons, MD, annual temperature, and a smoothed line illustrating the trend through 2006.

This relationship was then applied to project Bay temperatures as a function of climate-model projections of air temperature. Because the Chesapeake Bay is shallow in most places, surface water temperature is not only closely related to the air temperature, but also reflects temperatures in the shallows where many benthic organisms such as seagrasses, oysters, or blue crabs live. The temperature increases projected by the model average for Chesapeake Bay closely follow the air temperature increase shown in Figure 4.2, suggesting increases of 4°F by 2050 in the higher emissions scenario and 2.5°F for the low emissions path. This additional warming is of a similar magnitude to that observed in the Bay since 1940 (Figure 4.6). By 2100, the model projections suggest warming of 9°F and 5°F for the higher and lower emissions scenarios, respectively.

Temperatures in the Chesapeake Bay have already warmed by more than 2°F

Another way to express how these temperature changes might affect the ecology of the future Bay, including what plants and animals might live there, is to compare these future conditions with those currently experienced elsewhere along the Atlantic coast where current conditions resemble those projected for the Bay (Figure 4.7). Summertime water temperatures are likely to be similar to those of the North Carolina sounds by 2050. Under the higher emissions scenario, summertime water temperatures in the Bay might approximate conditions in South Florida. The effects of temperature increase and other climate changes on the Chesapeake Bay ecosystem are discussed further in Section 8.

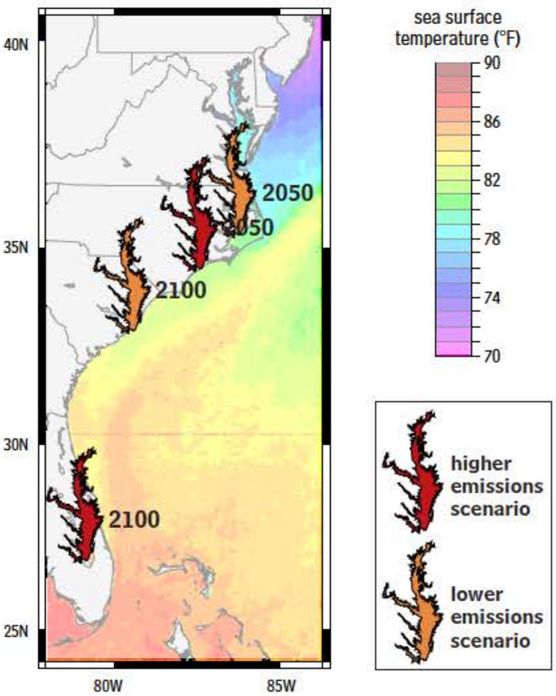


Figure 4.7. Summertime surface water temperatures in the Chesapeake Bay are projected to approximate those of estuaries well down the Atlantic Coast by 2050 and 2100.

PRECIPITATION

There has not been a statistically significant trend in precipitation in Maryland in recent years and this is consistent with the relatively modest changes projected by the climate model ensemble mean (Figure 4.8). Projections of winter rainfall show the greatest change, with increases of 5% by 2025

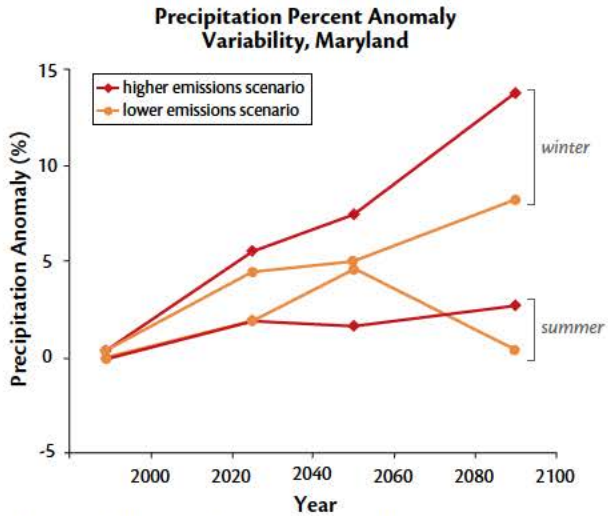
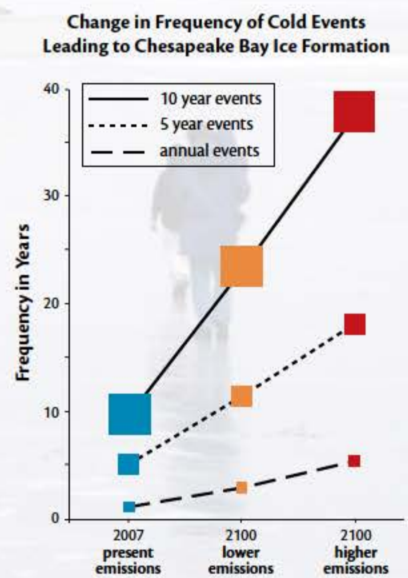


Figure 4.8. Winter and summer percent change in precipitation.

BOX 4.1 CHESAPEAKE FREEZE IS LESS FREQUENT

An ice-covered Chesapeake Bay is an iconic symbol of winter for many Maryland residents. Thin ice presently forms in sheltered embayments in most years. However, at roughly ten-year intervals, the Bay freezes over from shore to shore at the Chesapeake Bay Bridge. While these infrequent ice cover events may have little effect on the ecology of the Chesapeake Bay, they represent an obstacle to shipping, and ice cover reports are routinely issued for Chesapeake Bay by the U.S. Coast Guard. The climate model average predicts that these once every ten year ice cover events are likely to occur much less frequently in the future: every 25 years for the year 2100 low emissions scenario and as infrequently as once every 40 years under the higher emissions scenario (Box Figure 4.1). Ice cover that occurs every year at present may become less common in the future, with ice in the nearshore environment occurring only every 2-5 years by the end of the century under both the lower and higher emissions scenarios. This may have beneficial implications for nearshore oyster communities (see Section 8).



Box Figure 4.1 Time between ice cover events at the end of the century that occur every 1, 5, and 10 years at present.

Victoria Coles

projected for both scenarios, a 6.6 to 6.8% increase by 2050, and increases of 10.4 to 12.6% by 2090 under the lower and higher emissions scenarios respectively. However, there is a very wide band of uncertainty around these mean tendencies and increases of that scale do not approach the level of present year-to-year variability in winter precipitation. No season is projected to experience a substantial decrease in mean precipitation; however, some models project small declines in summer or fall precipitation and larger increases of up to 40% in winter precipitation by the end of the century. At the same time, large decreases are projected in winter snow volume (25% less in 2025 to 50% less in 2100 regardless of emission scenario). While Maryland does not receive large amounts of snowfall compared with states to the north[7], these reductions are large enough to reduce the spring river discharge associated with melting snow. Also, snow accumulation is very likely to be less common in western Maryland, thus affecting winter recreational activities.

When precipitation (P) is compared with the loss of water due to evaporation and plant transpiration (ET) that accompany increased temperatures, the water remaining (P-ET) shows little difference between the higher and lower emissions scenarios. However, the mean P-ET difference, reflecting the water available for runoff or groundwater recharge, is projected to decrease by 2 to 7 mm per month during the summer and increase by 6 to 7 mm (or only about one quarter of an inch) per month during the winter by end of the century; spring and fall projections show more modest changes.

Precipitation is likely to increase, but become more variable

Perhaps more relevant than the average rainfall, is how that rainfall is delivered. There is little change projected for the precipitation in the one-quarter of months that are driest. However, the range of precipitation from 25 to 75 percent of the time suggests a trend to increasing precipitation in the wet winter and summer months. The widening

NOAA

Summer rain drenches the landscape.

of this range in the projections illustrates that the month-to-month precipitation variability is projected to increase.

One measure of this variability is the amount of rainfall delivered in each rainy day. Climate models typically underestimate this at present, having too many days with weak precipitation.[15] However, even with this shortcoming, the mean of model ensemble projects increases in the amount of rain in any given day. The models also predict a increase in the maximum amount of rainfall occurring in any 5-day period, with the likelihood of getting more than 5 inches of rainfall in a storm event increasing from 5% at present, to 8% for the lower emissions scenario, and to 15% for the higher emissions scenario. These projections, coming as they do from models that are not able to spatially resolve many aspects of the hydrological cycle, are only moderately likely; however, they are broadly consistent with observed trends.[16] More accurate model predictions of precipitation will require development of regional climate models with finer spatial resolution.

The Northeast Climate Impacts Assessment (NECIA) report also projected increases in precipitation over the region to the immediate north of Maryland of up to 10% by the end of the century, with larger increases in winter and little change in summer. Indices of precipitation intensity, number of days with precipitation greater than two inches, and maximum five-day precipitation all showed comparable trends with the higher emission scenario used in that assessment yielding greater effects. The NECIA also found that increased evapotranspiration and frequency of short-term droughts were likely, particularly under higher emissions. This is consistent with this Maryland assessment. The NECIA projected less snow accumulation and earlier snowmelt, higher winter stream flows, and longer summer low-flow periods than at present, and these trends are also reproduced here.

SOIL MOISTURE

The effect of changes in temperature and precipitation and their implications for evaporation from water or soil and from plants are integrated in the projections of the changes in soil moisture. In spite of moderate increases in precipitation, increases in temperature in the models lead to decreases in soil moisture throughout the year. This is consistent with recent studies showing a change in the trend in North American soil moisture toward drying over the past 30 years.[17]

Changes represent 10% more drying in summer and fall by 2100 for both emissions scenarios in comparison to present normal summer conditions. Curiously, there is little difference between the lower and higher emissions scenarios, despite the much warmer temperatures projected under the higher emission scenario. This may be due to the very high relative humidity likely to occur, which will limit the rate of evapotranspiration. In years with lower than average rainfall, soil moisture reductions in spring and fall may be important to the local ecosystem and agricultural production. While soil moisture is dependent on the hydrological cycle and thus we have moderate confidence in the underlying physics, there is high agreement among models that summertime soil moisture will decrease, which makes this prediction likely.

GROWING SEASON

The length of the growing season is also important to terrestrial ecosystems in Maryland. The climate models project decreases in the number of frost days, where temperatures dip below freezing, and increases in the length of the frost-free growing season (Figure 4.9). Increases in growing season have been observed over the past fifty years.[18] While an increase in growing season may be a boon for gardeners, the increased active growth time coupled

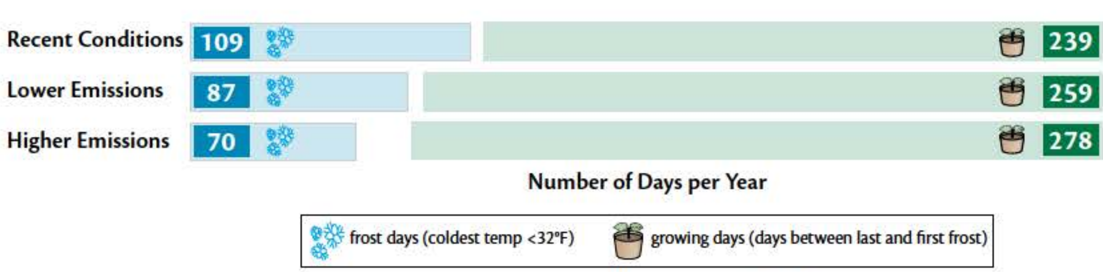


Figure 4.9. The number of frost days and growing season length projected before the end of the 21st century under the lower and higher emissions scenarios compared to recent conditions (end of the 20th century). These represent averages for the state and will vary depending on regional differences (Figure 4.1).

with reductions in soil moisture will likely cause some regions of the state to experience increased water demand for crop and landscape irrigation.

Frost days and growing season length are related to model representation of temperature, and so there is moderate confidence in our understanding of the underlying mechanisms driving changes, although the range of the model predictions leads to only moderate likelihood. Nonetheless, all the models predict reductions in frost days and increases in growing season length.

DROUGHT AND FLOODS

Global climate models do not capture present day extremes in drought or flood very well. Projections for droughts are probably more reliable than for flood conditions, because droughts reflect the influence of weather patterns that develop over large parts of the United States during periods of weeks to months. Floods, on the other hand, are associated with short-term phenomena and more intense weather events of a smaller spatial and temporal scale than resolved in global climate models. Yet, because these extreme events have such devastating effects on humans, the economy, and the environment, it is critical to estimate how the occurrence of flood events may change in the future to ensure adequate time for developing response strategies.

The models project an increase in the duration of annual dry spells, from about 15 days on average at present, to 17 days for the higher emissions scenario, and a smaller increase under the lower emissions scenario. Most of this increase is projected to occur during the latter part of the century. Based on these projections, it is likely that summer-fall droughts of modest duration will increase, especially after the middle of the century and that under the higher emissions scenario, there will be longer periods without rain. This has greater significance for soil moisture and attendant agricultural drought than for water supply. However, it is not the average that affects agricultural drought, but rather the more extreme or unusual events. The models suggest that, at present, a month-long drought can be expected to occur every 40 years, but this might increase to occurring every 8 years in 2100 under the higher emissions scenario, and there would be no appreciable change for the lower emissions path.

Even for drought conditions, it is important to point out that model projections of the two emission scenarios are based on averaging the output of different models, each of which was run for a continuous period extending from 1980 through 2100. Because each model simulation is the result of a single model run rather than multiple runs from which probabilities can be assigned, the modeling results cannot accurately predict rare events with low probability of occurrence (e.g., such as a 100-year or longer recurrence interval). Thus the projections reported here provide guidance on the likelihood of moderate drought conditions, but cannot represent the probability of an extreme multi-year drought such as the drought of the mid-1960s. Water-supply drought is more heavily affected by periods of low precipitation extending over multiple months, and is most strongly correlated with dry periods persisting through winter and spring when soil moisture, water tables, and reservoir levels would normally experience recharge.

Long-term or water-supply droughts, where rainfall deficits of more than 14 inches persist over a period of two years or more occur slightly less than 4% of the time at present in both observations and the models (Figure 4.10). While this number increases slightly to 5% under the higher emissions scenario, the models do not predict a likely increase in incidence of long-term drought. In contrast, the models suggest that two-year precipitation excesses of more than 14 inches, which are almost never observed but occur 4% of the time in the models, will occur much more frequently in the future. The higher and lower emissions scenarios have 14 inch excesses in precipitation occurring 28% and 14% of the time respectively. Thus, the models predict that while some moderate increase in short-term droughts may occur, increases in extreme precipitation events are more likely in the long-

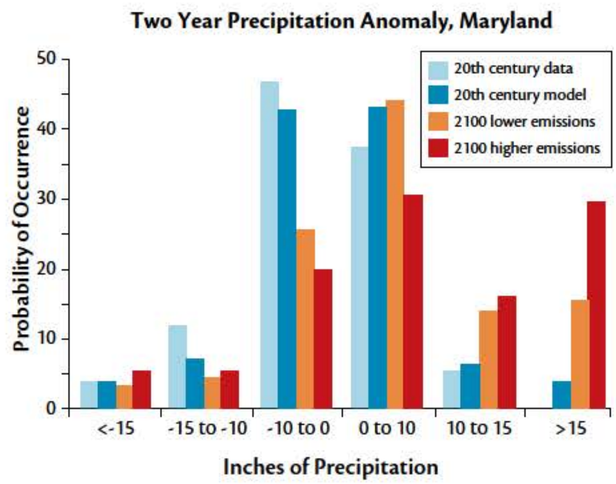


Figure 4.10. Long-term (two-year) drought and flood probability in the present day observations and models, and for the low and high emissions futures at the end of the century.

term. Further efforts to simulate extreme events at a regional scale are needed to reduce uncertainty.

Changes in precipitation extremes in the United States are already apparent in weather records. A report to be published later this year for the U.S. Climate Change Science Program (CCSP) concludes that extreme precipitation episodes (heavy downpours) have become more frequent and more intense in recent decades over most of North America and now account for a larger percentage of total precipitation.[13] Intense precipitation (the heaviest 1% of daily totals) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%. The CCSP report further concludes that the increase was consistent with increases in atmospheric water vapor, which have been associated with warming resulting from the increase in greenhouse gases, and that precipitation is likely to become less frequent and more intense. Under a medium emissions scenario, daily precipitation so heavy that it now occurs only once every 20 years is projected to occur approximately every eight years by the end of this century over much of eastern North America.

Heavy downpours have become more frequent and intense in the U.S.

For Maryland, the observed increase in frequency of extreme precipitation has to this point only been 3%, which is not a statistically significant increase. However, significant increases in intense precipitation of as much as 41% have been documented for West Virginia, Delaware, and Pennsylvania.[19] As was mentioned in Section 2, as the world warms increases in precipitation are expected to be greater at higher latitudes than lower latitudes. Maryland sits at the transition between the northeastern region where increases in precipitation are very likely in winter and spring, and the southeast region where projections of changes in precipitation cannot be confidently made.

At present, a watershed in Maryland might experience more than 8 inches of rain in a single day only once every 100 years. The climate models, however, consider 2.5 inches of rain in a single day to be a 100-year event. This is partly because the 2.5 inches of rain is spread evenly over more than 15,000 square miles in the model and because it does not provide high resolution at smaller scales (see Figure 3.2).

The percent of total rainfall coming in extreme events is projected to increase modestly but steadily during the century, with a slightly larger increase under the higher emissions scenario. However, this does not necessarily mean that less rain will fall the rest of the time. The model averages project only small changes in the number of days with more than 10 mm (about four tenths of an inch) of precipitation, with a slight increase under the lower emissions scenario and a slight decrease under the higher emissions scenario, by the end of the century. Five-day maximum precipitation is projected to increase more consistently from approximately 88 mm presently to 95-97 mm (i.e., from 3.4 to 3.8 inches), with little difference between higher and lower emissions scenarios. The maximum one-day precipitation over a year, a decade, and a century is projected to increase more, particularly under


The Delmarva Farmer

Finally ... some rain hits region

But flood warnings follow drought in Va.

Sean Clougherty

Maryland newspaper headlines failing corn crop due to lack of rain in 2007.


Frieda Squires

Heavy rain causes flooding and hazardous conditions for roadways.

the higher emissions scenario near the end of the century (Figure 4.11). The projected increases are greater for longer recurrence intervals, consistent with increasing climate volatility. But, again, it's important to remember that the global climate models have limited ability to project extreme rainfall events and tend to underestimate extreme precipitation events.

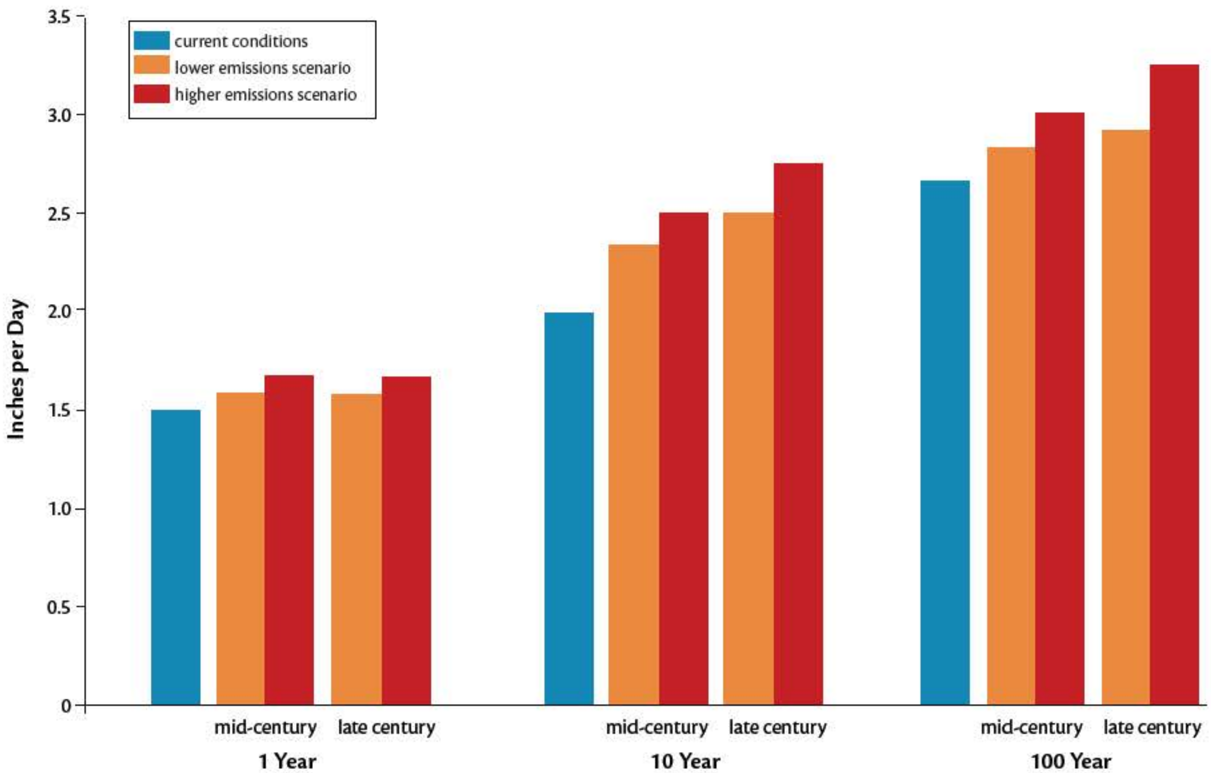


Figure 4.11. Projected one-day maximum precipitation for 1, 10 and 100 year return frequencies. Models tend to under-estimate extreme precipitation amounts, so the relative comparisons rather than the actual amounts are relevant.

Section 5

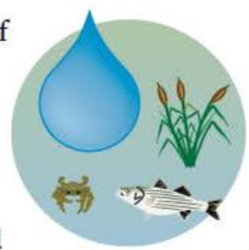
WATER RESOURCES & AQUATIC ECOSYSTEMS

KEY POINTS

- **Increased precipitation would supply reservoirs but not alleviate overdraft of aquifers.**
  Water supplies in the greater Baltimore area should not be diminished, but the adequacy of summer water supplies in the greater Washington region is less certain. Any increases in precipitation are unlikely to alleviate the present over-withdrawal of groundwater and summer droughts may increase groundwater demand for irrigation.

- **Urban flooding will likely worsen because of intensification of rainfall events.**
  More intense rainfall resulting from large-scale and localized (e.g., urban canopy) climate effects are likely to increase peak flooding in urban environments. Continued increase in impervious surfaces attendant with development would exacerbate this problem.

- **Aquatic ecosystems will likely be degraded by increased temperatures and flashy runoff.**
  Intensified rainfall events and warmer surfaces (roads, roofs, etc.) would result in rapid increases in stream temperatures, limiting habitat suitability for native fishes and other organisms. Degraded streams would transmit more nutrients and sediments to the Chesapeake Bay and its tidal tributaries.



The natural waters of Maryland provide essential habitat for aquatic life and support the fundamental needs of every economic sector of society. The water cycle and the physical and chemical character of natural waters are both strongly dependent on climate patterns and trends, including average and extreme weather conditions, such as floods and droughts, that although infrequent are very important. Although this assessment is intended primarily to address predictions associated with climate change, it is important to recognize that such changes will occur in the context of continuing population growth and economic development. Past experience strongly suggests that the combined impacts of climate change and development on water resources and aquatic ecosystems will be far greater than those of climate change alone. Therefore, reasonable predictions about Maryland's future must consider both factors.

This assessment addresses: (1) reliability of freshwater supply, including both surface water and groundwater; (2) changes in flood hazards; (3) effects of changes in runoff and water temperature on aquatic habitats and populations; (4) impacts on water quality with implications for management and regulation of sediments and nutrients; and (5) potential salt contamination of aquifers and freshwater intakes as the boundary between fresh and brackish water shifts with rising sea level. These impacts are examined with reference to climate projections based on the higher and lower emissions scenarios (see Section 3). The projections (Table 5.1) are broadly consistent with previous assessments conducted for the Mid-Atlantic region[20] and to a large extent with the Northeast Climate Impacts Assessment.[7]

Maryland Sierra Club

Burnt Mills Dam, Maryland.

Table 5.1. Summary of general projections of climate models related to water resources.

Property	21st Century Projection
Precipitation	Winter precipitation is likely to increase with smaller changes in other seasons.
Runoff	Wintertime runoff is likely to increase and summer runoff is likely to decrease, but with more frequent and larger summer floods.
Soil moisture	Soil moisture is likely to decrease during the summer and fall toward the end of the century.
Snow volume	Snow volume is very likely to decline substantially during the mid-late century.
Heavy precipitation events	Heavy precipitation events are likely to increase.
Drought	Consecutive dry days and summer-fall (but not multi-year) droughts are likely to increase under the higher emissions scenario.

FRESHWATER SUPPLY

Water stress—the imbalance between water demand and available supply—is anticipated to increase in many areas of the world over the coming decades. This is partly a result of increases in demand and partly a result of decreasing availability in some areas. Water availability must be examined not only in terms of average conditions, but also with respect to the amounts available during droughts that are expected to recur periodically. From a global perspective, the region including Maryland is considered as relatively low stress with regard to the projected ratio of water withdrawals to availability under the higher emissions (A2) scenario for 2050.[21] As the Advisory Committee on the Management and Protection of the State's Water Resources noted in 2004: "Nature provides Marylanders with abundant water, which, if well managed, could meet present and future needs." [22]

On the other hand, this same report identifies potential threats to water quantity and water quality resulting from population growth and land development. And, as recent difficulties in the southeastern U.S. demonstrate, the eastern seaboard is certainly not immune to drought.[23] Within the last six years in Maryland, we have witnessed two of the driest years on record as well as the wettest year on record, and there have been impacts on water supplies during the dry years that required public response. These short-term variations are larger than the range of variation in mean precipitation or moisture availability during this century predicted using global climate models. Sensitivity of water supply to wet and dry cycles is in large measure a function of the nature of the water-supply system, together with the array of management options that are available to be used during times of shortage.

Recent evidence suggests that summer drought may be correlated with patterns of sea-surface temperature—a consequence of multi-year cycles in the Atlantic (Atlantic Multidecadal Oscillation) or Pacific (El Niño-Southern Oscillation and the Pacific Decadal Oscillation) oceans—and that these correlations might be used in drought forecasting over time periods of one or two decades.[24] It has been suggested that superimposing these cycles on longer term trends projected by global climate models could improve forecasting of drought probabilities and provide a tool for water-supply management for the greater Washington area in adaptation for global warming.[25]

Within six years, Maryland experienced some of the driest and the wettest years on record

The Advisory Committee pointed out that total water use in Maryland has not increased even with the increase in population (Figure 5.1).[26] This reflects a complex set of changes in water used by different economic sectors, with declining industrial and commercial use and increasing domestic use, public supply, and irrigation. Demand is anticipated to rise over the next 30 years, coinciding with increased suburban land development, affecting

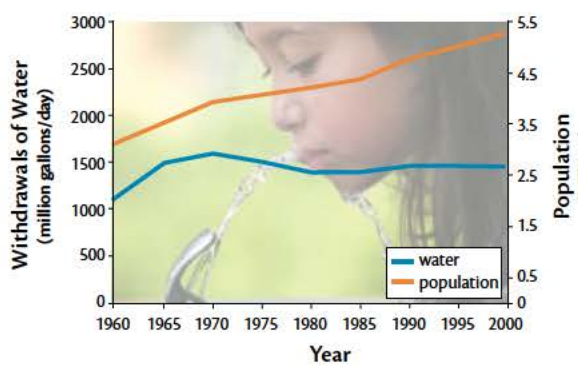


Figure 5.1. Trends in Maryland's water consumption and population.[26]

areas that might otherwise be available for recharge of groundwater, and with increased irrigation needs on agricultural land during summer droughts anticipated with the warmer climate. Summer water demand will increase as temperatures increase and water availability during the summer becomes less reliable. Options for demand reduction do exist but have not been fully explored by utilities and public agencies.

Marylanders rely both on surface water, derived from free-flowing streams and from storage in water-supply reservoirs, and on groundwater retrieved from wells in both shallow and deeper confined aquifers. The relative importance of these sources varies both as a function of urban versus rural location and physiographic province (Figure 5.2). Surface water is the primary source in and around major metropolitan areas with about 3.2 million of the state's population of 5.4 million (based on 2004 estimates; present population is at least 5.7 million) served by public water supply in the Baltimore and Washington, D.C. metropolitan areas.[26] Public and community water-supply systems elsewhere, using a mix of surface water and groundwater, served a cumulative population of 1.3 million. Groundwater is the primary source of supply in rural areas where public water is not available and in most of the Coastal Plain, with 900,000 people relying on private wells. Surface water withdrawals increased by 6% between 1985 and 2000, whereas groundwater withdrawals increased by 21%.

Groundwater withdrawals increased by 21% between 1985 and 2000

Although agriculture accounts for only 3 to 5% of state water use at the present time, agricultural needs of 285 million gallons per day (mgd) statewide are anticipated by 2030—more than currently used by the Baltimore metropolitan area. Much of this increased demand will be associated with irrigated agriculture on the Eastern Shore.[26] Furthermore, over half of the new households anticipated by 2030 will likely be located in the rapidly growing counties of Howard, Harford, Frederick, Carroll, Charles, Calvert, and St. Mary's. Many of these counties are already experiencing water stress because of rapid exploitation of local supplies, resulting in building moratoria in parts of Carroll County[27] and rapid declines in well levels in confined aquifers of southern Maryland.[28]

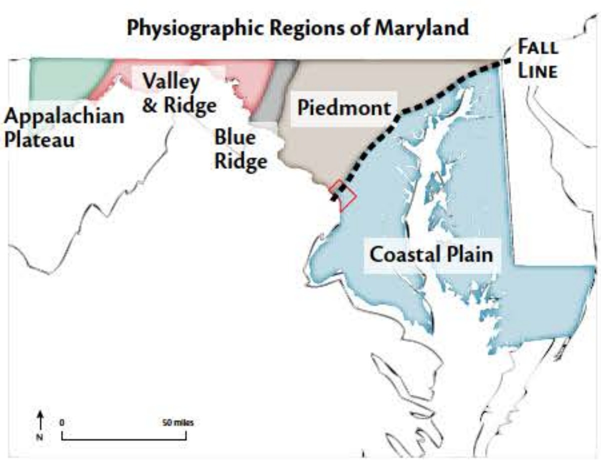


Figure 5.2. Maryland's five physiographic regions.

Surface water

The major metropolitan water-supply systems in Maryland rely on a mix of impoundments and direct withdrawal from major rivers. Baltimore City supplies water to Baltimore County as well as a portion of the public water-supply needs of Anne Arundel, Howard, Harford, and Carroll counties. The City has three major water-supply reservoirs with cumulative storage of 86.7 billion gallons, as well as a pipeline that can be used to augment the reservoir supply with water from the Susquehanna River during times of extreme drought.[29] Cumulative safe yield of the reservoirs is nearly 240 mgd and the intake on the Susquehanna River currently has a capacity of 250 mgd with ultimate capacity of 500 mgd. There are additional pumping stations on Deer Creek that can expand capacity further if necessary.

The climate change scenarios described in Section 3 suggest an increased frequency of short-term drought despite a net increase in average annual flow. Baltimore has managed to weather two severe droughts since 2000 without serious negative impacts, although it was necessary to pump water from the Susquehanna and this involved increased treatment costs. It is likely that Baltimore City's water-supply system should be sufficient to meet demands under the projected climate change. Greater winter-spring precipitation will increase the likelihood that reservoirs will be full heading into the drier summer periods, resulting in protection from water-supply shortages for areas served by the reservoirs.[30]

The Washington Metropolitan Area's water supply situation is somewhat more precarious. Average annual water use (including Maryland, D.C., and Virginia users) currently is about 488 mgd and projections call for an increase to 572 mgd by 2025.[31] About 75% of the water supply is derived from the Potomac River, the flow of which is largely unregulated. A total storage volume of about 17 billion gallons is available in reservoirs to augment the supply of the Potomac River during dry periods, and additional storage of about 18 billion gallons is available in other suburban reservoirs that do not connect directly to the Potomac supply. A Water Supply Coordination Agreement and a Low Flow Allocation Agreement among the various water suppliers are intended to coordinate the operation of all the water utilities in the region and to allocate shortfalls when water is insufficient to meet all demands.

The Interstate Commission on the Potomac River Basin (ICPRB) has estimated that the existing system is adequate to meet 2025 demand, and even 2045 demand, under a repeat of the worst historical drought conditions.[31] The ICPRB concluded that, even accounting for uncertainties associated with climate change, contingencies in place to restrict demand could be used to avert a water-supply crisis. However, Maryland's Advisory Committee on the Management and Protection of the State's Water Resources observed that planning has been complicated by the outcome of a 2003 Supreme Court case that gave Virginia the right to remove water from the Potomac River without following Maryland's permit regulations.[22] Furthermore, even if this issue can be resolved by mutual agreement, other measures, including development of additional supplies and water reuse, may be necessary to meet local needs.

Groundwater

Groundwater in the Piedmont and Appalachian Plateau regions occurs principally in fractured bedrock and the overlying layer of weathered material that can be as much as 100 feet thick (Figure 5.3).[32] The volume of storage available in these shallow aquifers is typically quite limited and there are strong connections between groundwater and local surface water, such that a reduction in groundwater storage is likely to be reflected in reduced base flow to local streams. Because of the complex flowpaths and connectivity of the fracture network, the spatial pattern of groundwater availability is unpredictable and is therefore unsuitable for large-scale water-supply development. Groundwater availability is sensitive to short-term climate fluctuations and to alteration of the land surface by development. These factors, plus the growing demand, led to the building moratoria near Westminster in Carroll County that were mentioned previously.[27]

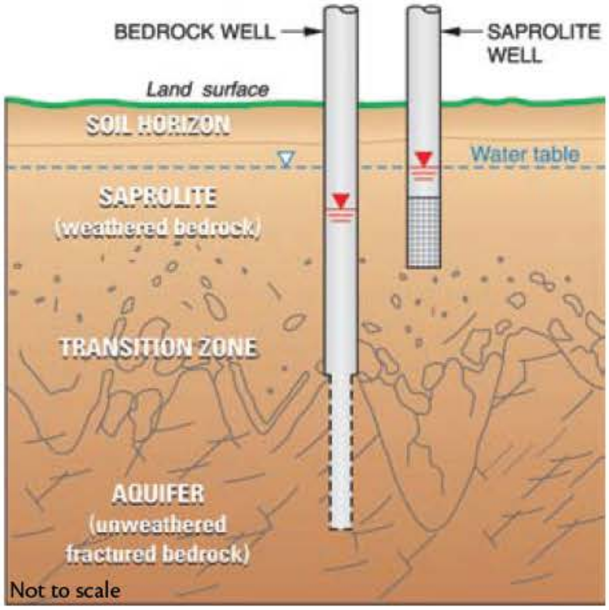


Figure 5.3. In the Piedmont, shallow wells draw from unconfined weathered bedrock and deep wells from bedrock aquifers.[32]

Although climate models generally project changes in water availability under average conditions, the likelihood of more frequent short-term drought poses a challenge to the reliability of water supply dependent on shallow groundwater during the late summer and fall in rural areas. Even with significant increases in winter and spring precipitation, it is not clear how much of the increase will contribute to recharge of groundwater in the Piedmont and Appalachian provinces if significant amounts are instead diverted to increased runoff.

The situation in the Coastal Plain of Maryland is quite different. Most groundwater is stored in deep, confined aquifers (Figure 5.4) that are not in direct contact with the surface or with overlying streams. Because the water that recharges these

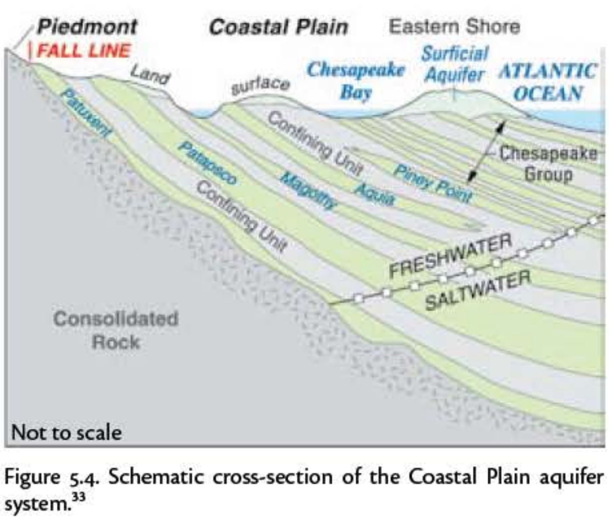


Figure 5.4. Schematic cross-section of the Coastal Plain aquifer system.[33]

aquifers may travel over long distances, these aquifers are not sensitive to short-term weather fluctuations. They are more likely to experience changes in storage and in well levels that are tied to long-term trends in the balance between recharge and water withdrawal. Thus, climate change projections in which precipitation increases more than evapotranspiration are less likely to pose a serious problem for aquifer storage, even if there are short-term droughts superimposed on the long-term trends.

A serious challenge does arise, however, as a result of pumping trends associated with rapid urban and suburban development in the Coastal Plain counties. Long-term trends showing declining well levels have accelerated sharply since the 1980s (Figure 5.5).[33] In many cases, the rate of decline exceeds 2 ft/yr and in the areas of most active pumping it can be substantially higher.[32] The Maryland Department of Environment uses an 80% rule to regulate groundwater extraction from confined aquifers—pumping is not supposed to lower well levels more than 80% of the distance between the pre-pumping water level and the top of the confined aquifer. At present, however, farmers are not required to report the amount of water pumped for irrigation and there are no significant ongoing monitoring studies to document head losses associated with irrigation. While the declines in well levels currently observed are mainly a result of urban and suburban uses, this lack of reporting and monitoring could pose a problem if demand for crop irrigation substantially increased.

Well levels have declined as much as 2' per year in Maryland's Coastal Plain

If the regional declines in confined aquifers continues or accelerates, regional land subsidence over the affected areas may exacerbate local relative sea-level rise as discussed in Section 7. Changes in freshwater storage and in relative sea level may also cause the freshwater/saltwater boundary illustrated in Figure 5.4 to move landward and to reach shallower depths. This may pose a particular problem for withdrawals from shallow aquifers on the Eastern Shore.

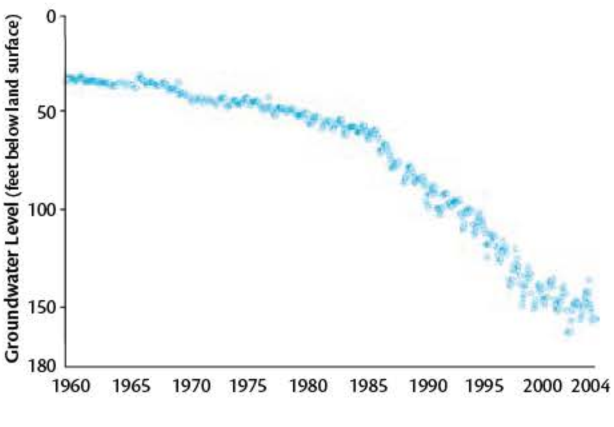


Figure 5.5. Water level decline in a well in the Aquia aquifer in Calvert County, Maryland.[33]

FLOOD HAZARDS

Because floods represent the extreme end of the frequency distribution of streamflows, prediction of flood probabilities is subject to uncertainty even under the best of circumstances. Estimation of the probability or return period of a flood of a given size typically is accomplished using historical records, and standard estimation techniques assume that flood occurrence is essentially a random process and that the underlying probabilities are not changing over time. Therefore, climate change presents a challenge to standard approaches in flood-frequency estimation because the future will no longer resemble the past.

Trends toward increased river runoff are already apparent beginning about 1970 in portions of the eastern United States, including the Mid-Atlantic region.[34] Annual runoff has further been projected to increase in the eastern United States by the middle of this century[35], consistent with increases in atmospheric water vapor and precipitation intensity.[36] The probability of occurrence of a great flood (defined as having a 100-yr return period) in a number of large river basins had increased substantially during the 20th century[37], prompting a group of leading hydrologists to write recently that climate change has undermined a basic assumption about the relevance of past observations for management of future water supplies, demands, and risks.[38] The authors suggest that new modeling approaches are needed to improve our ability to estimate flood hazards under alternative future scenarios. Although intense rainfall is the most important contributor to flood hazards, there are other aspects of land-surface conditions that determine how efficiently intense rainfall is converted into flood flow. These cannot be predicted on a statewide basis for all watersheds with information that is currently available; therefore, this report focuses on the probability of intense precipitation as the primary indicator of flood probability.

Susquehanna River Basin Flood Forecasting and Warning System

The Susquehanna River Basin is one of the most flood-prone watersheds in the nation. The main stem and its tributaries drain 27,510 square miles of New York, Pennsylvania, and Maryland.

As discussed earlier, probabilities of flood inducing rainfall are not well represented in global climate models that predict average conditions over large grid cells. A possible exception would be large-scale events such as powerful extratropical storms occurring in winter, particularly where rain on snow is a key element. These may generate large floods over very large drainage areas comparable to the model grid cells. Such events occur infrequently in Maryland, but can be important in the Susquehanna River Basin, which lies mostly in Pennsylvania and New York and supplies about one-half of the freshwater inflow to the Chesapeake Bay. The January 1996 flood in the Susquehanna River basin is an example of such an event. The magnitude of the flood was in part a result of the large volume of moisture already stored on the landscape in the form of snow, which was released very rapidly as it melted during the precipitation event. Although climate models project higher precipitation totals and greater intensity of rainfall during the winter season, the reduction in volume of snow stored on the landscape may well cause a reduction in the likelihood of this type of extreme flood even as moderate floods become more likely in winter and early spring.

Another major cause of flood hazards in the region is the occurrence of hurricanes and tropical cyclones. The flood of record for many locations in Maryland (including the Susquehanna River at Conowingo Dam) is still Hurricane Agnes, which struck the region in June 1972.[39] By the time it reached Maryland, Agnes was not a major cause of storm surge, wind damage or coastal flooding; its primary impact was as a rainfall-runoff event. Hurricane Floyd, in September 1999, dropped as much as 12.6 inches of rain on Maryland's Eastern Shore and generated floods in some Eastern Shore rivers with estimated return periods of 100-500 years.[40] As discussed in greater depth in Section 7, the current scientific consensus is that tropical cyclones are projected to increase in rainfall intensity even though their frequency may decline.

Precipitation intensities in small watersheds are underestimated in climate models

For small watersheds, the likelihood of flooding depends not only on total amount of precipitation but also on its intensity at smaller spatial and temporal scales. While climate models may be useful for projecting maximum one-day precipitation averaged over a large area (Figure 5.2), they cannot predict the actual rainfall over short periods or areas at a scale comparable to a storm cell. Point and small-area rainfall intensities associated with flood generation will be much higher. This is illustrated by comparing the predicted probabilities of intense precipitation from the model projections with precipitation frequencies based on regional observations for points within the Baltimore-Washington metropolitan area (Table 5.2).[41] Observed rainfall amounts associated with recurrence intervals of 1 to 100 years are already 170 to 300 percent greater than the one-day rainfall amounts projected from the climate models near the end of this century.

If flood magnitudes change in a manner commensurate with the trends in maximum rainfall predictions (Figure 4.11), then one might indeed

Table 5.2. Maximum rainfall amounts for four recurrence intervals based on observations in the Baltimore-Washington area, as summarized in NOAA Atlas 14 and projected for 2090 under higher and lower emissions scenarios.

Recurrence Interval (yr)	One-day Rainfall Amounts (inches)		
	Observed[41]	Higher Emissions	Lower Emissions
1	2.6	1.7	1.6
5	4.1	2.4	2.0
10	4.9	2.6	2.3
100	8.5	3.2	2.7

expect to see larger, more extreme floods in smaller watersheds as the century proceeds. The magnitude of such an increase is necessarily speculative; the point values of extreme rainfall under the present climate are already so much higher than those predicted by these GCM scenarios that only the general trends are relevant, and they are not based on simulation of the actual physical processes associated with extreme precipitation. Nevertheless, if one accepts the comparisons in maximum one-day rainfall as representative of likely changes in flood magnitude, then we might anticipate a 20% increase in the magnitude of the 100-year flood under the higher emissions scenario and a 10% increase under the lower emissions scenario. Comparable increases for the 10-year recurrence interval would be approximately 29% and 16%, respectively, with the increase in peak flood flows under higher emissions approximately double the increase under lower emissions.

These increases are consistent with the trends identified by the IPCC Fourth Assessment, the Northeast Climate Impacts Assessment, and the U.S. Climate Change Science Program concerning the increased likelihood of intense, flood-generating precipitation. However, it is important to remember that land development has had and will continue to have a major effect on increasing flood probabilities in smaller drainage areas. As the area of impervious surface and storm drain networks increase, runoff is accelerated.[42] Also, as was demonstrated with a 2004 event in Baltimore, the urban 'canopy' effect can play an important role in determining the conditions favoring intense thunderstorms.[43] Because of both these effects—surface properties affecting runoff response and atmospheric interactions affecting rainfall intensity—flood peak magnitudes in small urban watersheds may be several times larger than for comparable rural watersheds. This can be illustrated by plotting flood peak discharge as a function of drainage area for thunderstorms in Baltimore compared to some record floods in the Mid-Atlantic region (Figure 5.6). The straight lines are thresholds defining the upper range of extreme flood peaks that may attain values between 1000 and 2000 cfs/mi². The urban floods were, with one exception, events with recurrence intervals of the order of 5 to 10 years; yet these events, represented by blue dots on the plot, were comparable in magnitude to Mid-Atlantic floods that occur much less frequently.

Land development and urban microclimates intensify floods

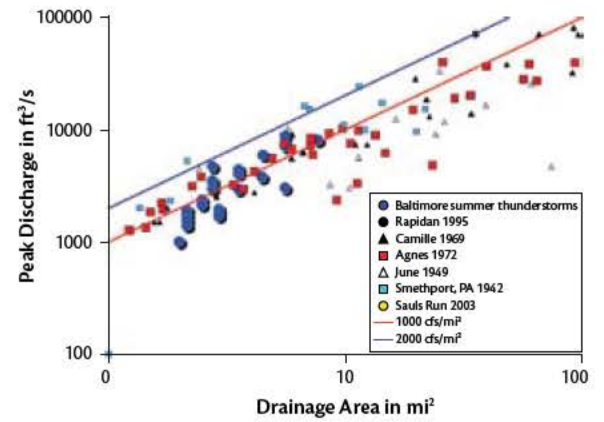


Figure 5.6. Relationship between peak discharges and watershed drainage area for urban floods in Baltimore and historic floods in the Mid-Atlantic region.

The increased frequency and magnitude of floods in urban watersheds has implications not only for flood protection and water allocation, but also for the design of treatment plants, dams, and even bridges. Prediction of future estimates will require the development of new modeling approaches that can incorporate the effects of changing climate superimposed on trends in urban development. Using such an approach, a recent study projected that the number of days with extreme rainfall in the New York metropolitan area is likely to increase from 1-2 days to 3-4 days by the end of the summer under the higher emissions (A2) scenario.[44] Building on efforts like this one, smaller scale atmospheric models linked with global climate models could more accurately project precipitation and those predictions could be used to drive hydrologic models to predict flood probabilities associated with combined climate change and urbanization scenarios.

WATER QUALITY & AQUATIC BIOTA

Freshwater ecosystems provide multiple goods and services (Table 5.3) valued highly by people and inextricably linked to water flows and the interaction of flow with the landscape. The ability of aquatic ecosystems to provide these benefits depends on how 'healthy' they are—that is, the degree to which physical and biological processes that maintain normal ecological functioning are working properly. Climate changes may modify these critical processes and thus diminish the health of the ecosystem.

Of particular concern are climate-induced changes that exacerbate human-caused stresses,

Table 5.3. Freshwater ecosystems (wetlands, rivers, streams, lakes, etc.) provide a number of goods and services that are critical to their health and provide benefits to society. The major services are outlined along with the ecological processes that support the function, how it is measured, and why it is important.[45]

Ecosystem Service	Consequences of Losing the Service	Supporting Ecological Process	Ecosystem/ Habitat
Water Purification a) nutrient processing	Excess nutrients (eutrophication) can build up in the water making it unsuitable for drinking or supporting life; Algal blooms resulting from excess nutrients can lead to anoxic conditions and death of biota	Retention, storage, and transformation of excess nitrogen and phosphorus; Decomposition of organic matter	Floodplain, river and streambeds, wetlands, lake littoral zones
b) processing of contaminants	Toxic contaminants kill biota; Excess sediments smother invertebrates, foul the gills of fish, etc; Water not potable	Biological removal by plants and microbes of materials such as excess sediments, heavy metals, contaminants, etc.	Floodplain and wetland soils and plants; Bottom sediments of rivers, lakes, and wetlands
Water Supply	Loss of clean water supply for residential, commercial, and urban use; Irrigation supply for agriculture	Transport of clean water throughout watersheds	Lakes, rivers, streams
Flood Control	Without the benefits of floodplains, healthy stream corridors, and watershed vegetation, increased flood frequency and flood magnitude	Slowing of water flow from land to freshwater body so flood frequency and magnitude reduced; Intact floodplains and stream-side vegetation buffer increases in discharge	Floodplains, wetlands, stream-side zones
Infiltration	Lost groundwater storage for private and public use; Vegetation and soil biota suffer; Increased flooding in streams	Intact floodplain, stream-side, wetland vegetation increase infiltration of rain water and increase aquifer recharge	Wetlands, streams, floodplains
Carbon Sequestration a) primary production	Water and atmospheric levels of CO_2 build up, contributing to global warming	Aquatic plants and algae remove CO_2 from the water and atmosphere, convert this into biomass thereby storing carbon	Freshwater ecosystems with sunlight, but particularly shallow water habitats such as wetlands or mid-order streams
b) secondary production	Water and atmospheric levels of CO_2 would build up contributing to global warming	Production of biomass by microbes and metazoans stores carbon until their death	All freshwater ecosystems but particularly the bottom sediments for microbes
Nitrogen Sequestration primary and secondary production	Secondary production supports fish and wildlife	Creation of plant or animal tissue over time	All freshwater ecosystems and habitats
Food Production a) primary production	Reduction in food and food products derived from aquatic plants such as algae, rice, watercress, etc.; Decreased production (secondary) by those consumers who rely on primary production as a food source	Production of new plant tissue	All freshwater ecosystems and habitats with sunlight but particularly shallow water habitats such as wetlands

Table 5.3. Continued.

Ecosystem Service	Consequences of Losing the Service	Supporting Ecological Process	Ecosystem/ Habitat
Food Production b) secondary production	Reduction in fisheries including finfish, crustaceans, shellfish, and other invertebrates	Production of new animal tissue or microbial biomass	All freshwater ecosystems and habitats, but particularly the water column and surficial sediments
Biodiversity	Loss of aesthetic features, impacts aquarium trade, potential destabilization of food web, loss of keystone species can impact water quality	Diverse freshwater habitats, watersheds in native vegetation, complex ecological communities support multiple trophic levels	All ecosystem and habitat types, but particularly wetlands for plants and rivers for fish
Temperature Regulation	If infiltration or shading are reduced (due to clearing of vegetation along stream), stream water heats up beyond what biota are capable of tolerating	Water temperature is 'buffered' if there is sufficient soil infiltration in the watershed; Shading vegetation keeps the water cool; Water has a high heat capacity which stores excess heat	Shallow water habitats, especially wetlands
Erosion/Sediment Control	Aquatic habitat burial impacts fisheries, decreases biodiversity, increases in contaminant transport, reduces downstream lake or reservoir storage volume	Intact stream-side vegetation and minimization of overland flow	Wetlands, streams, and rivers
Recreation/ Tourism/Cultural, Religious, or Inspirational Values	Lost opportunities for people to relax, spend time with family; Economic losses to various industries, particularly tourist oriented ones	Clean water, particularly water bodies with pleasant natural surroundings such as forests, natural wildlife refuges, or natural wonders	Lakes, rivers, and streams

Victoria Coles

A beautiful day is enjoyed on a family hike in western Maryland.

such as depletion of water flows and urbanization, both of which are already affecting streams and rivers over much of the State. As is the case with flood probabilities, the influence of urban development signal is likely to be at least as strong through the remainder of this century as the climate signal, and these two signals combined will tend to reinforce trends pointing in the same direction, i.e., more highly variable flows. Global warming will also directly change the temperature regimes, causing shifts in the species inhabiting the ecosystems.

Anticipating the future condition of a river in the face of climate change requires explicit consideration not only of the current climatic, hydrologic, and ecological conditions but also of how it is currently managed and how human behavior will affect the ecosystems. Thus, consideration of how climate change is likely to impact Maryland's freshwater ecosystems rests not only on the assumptions underlying climate models and scenarios, but also on future decisions regarding water use and watershed management. Options also exist for adapting these practices to reduce the impacts of climate change on freshwater ecosystems.[46]

Except for deep reservoirs, fresh waters are generally well mixed and respond to changes in atmospheric conditions fairly readily. Thus, they would become warmer as air temperatures increase.[47] As the water warms, individual growth and reproductive rates of biota are expected to increase so long as thermal tolerances are not exceeded.[48] Faster growth rates and time to maturation typically result in smaller adult size, and, because size is closely related to reproductive output in many aquatic organisms, population sizes may decline over time. The spawning time of native fish may also shift earlier if waters begin to warm earlier in the spring, and species that require prolonged periods of low temperatures may not survive.

For fish, amphibians, and water-dispersed plants, habitat fragmentation due to small dams (which are surprisingly common in Maryland's streams) or the isolation of wetlands and tributaries due to drought conditions may also result in elimination of their local populations. Because higher temperatures result in lower concentrations of dissolved oxygen in all but swift flowing waters, this may present an additional stress on organisms.[49]

Aquatic ecosystems in watersheds with significant urban development are expected to experience not only the greatest changes in temperature, but also greater temperature spikes during and immediately following rain storms that could result in the local loss of species. Such temperature spikes of 6 to 12°F occur in urban streams near Washington, D.C., and are strongly related to the amount of warm impervious surfaces (Figure 5.7).[50] A recent modeling study demonstrated how the combined effects of urbanization and climate change on suburban Washington streams would be greater than either alone. Under a moderate emissions (B2) scenario, warming produced an increase in stream temperatures of 6°F late in the century, while urbanization produced an increase of 7°F (Figure 5.8). However, when both urbanization and climate change were imposed, an increase of over 12°F resulted. The urbanization effects alone would stress 8 of the 39 fish species, but with additional effects of climate change, as many as 29 species would be stressed. Almost every recreationally important species (trout, bass, yellow perch, and bluegill) would experience decline in the growth and reproduction ranging from 40% to 90%.

Changes in flow regime toward greater frequency

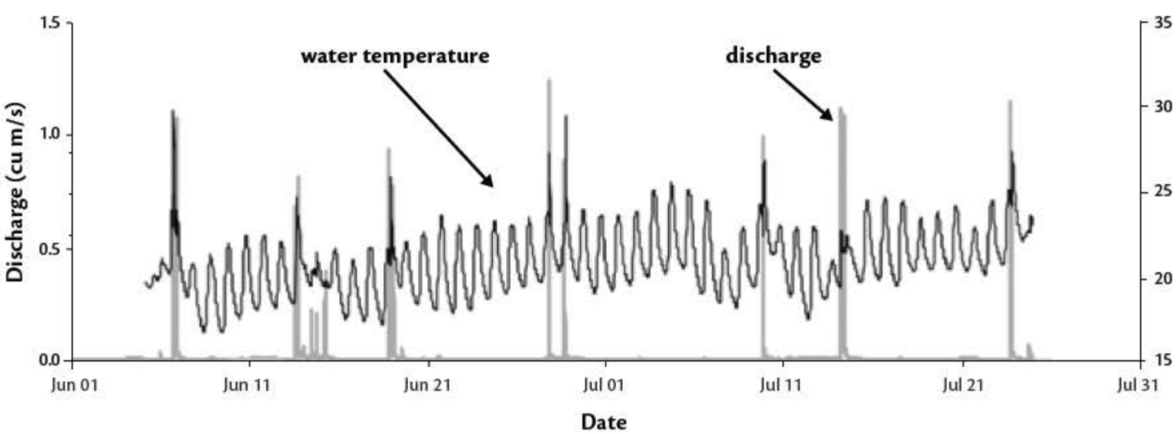


Figure 5.7. Temperature record for an urban stream north of Washington, D.C. Grey spikes represent episodes of warm runoff immediately following rain. Spikes such as these are largely dampened in watersheds with low levels of impervious cover.[50]

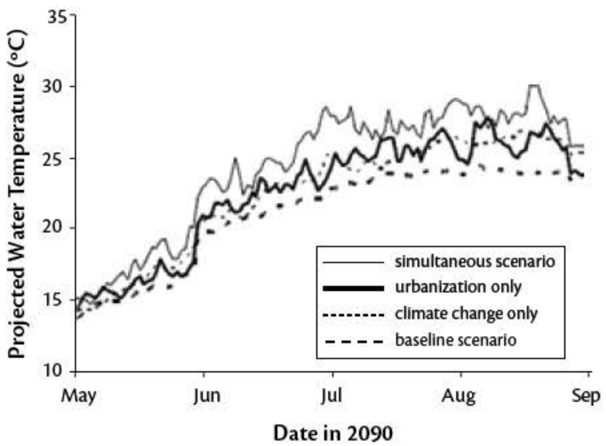


Figure 5.8. Model projections of water temperatures in a central Maryland stream under a moderate emissions (B2) scenario, the influence of urbanization and both simultaneously.[49]

of both wetter and drier conditions are projected under both the higher and lower emissions scenarios. While these changes are anticipated to be incremental, similar but much stronger effects are observed in urbanizing environments. Storm runoff occurs more rapidly and generates higher velocities and larger flood peaks, with serious consequences for the aquatic biota.[51] Higher peak flows associated with urbanization result in well-documented decreases in native biodiversity.[52] Higher flows increase suspended sediment and bedload transport, which interferes with animal feeding, while subsequent sediment deposition reduces the habitat availability for insects and spawning areas for fish.[53] Where flows increase sufficiently to prevent sediment deposition, eroded sediment will ultimately be deposited downstream or in the estuaries fed by the rivers and streams. The higher flows and increased inputs of sediment typically degrade stream habitat quality even when there is no net sediment deposition.

Higher runoff peaks degrade stream beds and transport more pollutants to the Bay

Increased flashiness and higher runoff peaks are likely to mobilize chemicals associated with sediment particles. Changes in the transport and processing of nutrients and organic matter are likely, but difficult to predict under changing climatic conditions. There is a considerable uncertainty about how rates of ecological processes affecting nutrients in wetlands and streams—an important factor in affecting the amount of nutrients reaching the already over-enriched Chesapeake Bay—will be influenced by climate change. Dissolved inorganic nitrogen (as nitrate) levels may decrease if rates of denitrification are increased by higher temperatures and associated lower dissolved oxygen levels. On the other hand, if discharge and sediment transport increase, then the downstream movement of nitrogen (as ammonium or organic nitrogen) and phosphorus (as phosphate) may increase. Concentrations of toxic contaminants in the form of petroleum hydrocarbons and combustion byproducts, metals, pesticides, and other organic compounds are typically much greater in urban settings and are related in part to the density of roads and efficiency of storm sewers in conveying materials from impervious surfaces directly into the drainage network.[54] Additional sources of trace contaminants may be derived from leaking sanitary sewers and include oxygen-demanding organic matter, pathogens, and a whole class of emerging contaminants including pharmaceutical compounds and trace constituents from personal care products.[55]

Drier conditions during summer months are likely to result in the loss of small wetlands and intermittent or ephemeral streams, potentially resulting in negative impacts on the water quality downstream. This impact will be particularly exacerbated in urbanized regions. With increased impervious area and less infiltration, there is less groundwater storage and lower baseflows in urban streams than in more natural streams. However, baseflow during dry periods could also be augmented by some combination of leaking infrastructure and lawn irrigation. A tendency toward reduced infiltration and baseflow would tend to exacerbate the lower summer stream flows projected by the climate models, while any baseflow augmentation would reduce the impacts of summer dry periods. Wetlands and streams experiencing reductions in water levels or baseflow often have stressed biota and stream-side vegetation, reduced dissolved oxygen levels, and loss of habitat for species that depend on currents.[56] Physiological stress and increased predation resulting from crowding, combined with habitat fragmentation (isolated stream pools and wetlands), may dramatically reduce survival and constrain dispersal.

Jane Hawkey

Herbicides are applied to a farm field.

Adrian Jones

Crop production is likely to be reduced under the higher emissions scenario.

Section 6

FARMS & FORESTS

KEY POINTS

- **Crop production may increase initially, but then decline if emissions are not reduced.**
  Longer growing season and higher CO_2 levels are likely to increase crop production modestly during the first half of the century. Later in the century, crop production is likely to be reduced due to heat stress and summer drought under the higher emissions scenario. Milk and poultry production would be also reduced by heat stress.

- **Northern hardwoods will likely disappear and pines become more abundant.**
  The maple-beech-birch forest of Western Maryland is likely to fade away and pine trees to become more dominant in Maryland forests. Forest productivity is likely to decline late in the century under the higher emissions scenario as a result of heat stress, drought, and climate-related disturbances.

- **Biodiversity of plants and animals associated with Maryland forests is likely to decline.**
  Habitat alterations resulting from climate change may force out 34 or more bird species, including the Baltimore oriole.

Maryland's landscapes, from the high mountains of the Appalachian Plateau to the barrier islands of the Eastern Shore, provide diversity and enjoyment to its people and visitors as well economic wealth from the productivity of its farms and forests. This section addresses the potential impacts of climate change on the land, including the living resources that are exploited economically and other natural resources that provide indirect services to us, not the least of which provide recreation and aesthetic satisfaction.

Prediction of the future of Maryland's natural resources is subject not only in the projections of climate model, but also because of the complexity of the responses of both living organisms and human decisions when faced with changing climate. The response of one species can affect others, for example warmer winters could allow some insect pests to survive in greater numbers, possibly increasing forest defoliation—and consequently, a loss of birds and other animal species—and runoff of materials from the watershed. Furthermore, the changes in vegetation may affect the regional climate itself, for example, through changes in the evapotranspiration, albedo (how an object reflects sunlight), and surface roughness of vegetation. Moreover, organisms influence the concentrations of greenhouse gases in the atmosphere by taking up or releasing carbon dioxide, methane, and nitrous oxide. Partially as a result of this complexity, knowledge of the impacts of climate change on terrestrial resources is less developed and predictions more difficult than for other sectors of the climate impact assessment for Maryland.

Climate change is not new for Maryland's terrestrial ecosystems. During the warming after the last Ice Age, very large changes in the biota occurred, but this was a slow warming that allowed migration and adaptation of plants and animals, unlike the rate of climate change projected over the 21st century. As discussed previously, the mean temperature of the Earth's atmosphere has been relatively stable until warming commenced about 50 years ago. After some basic considerations related to terrestrial ecosystems, in general, this section evaluates the likely impacts of projected climate change on Maryland's agriculture and forests.

SOME BASIC CONSIDERATIONS

Before getting to the specifics of the assessment of climate change impacts on Maryland's terrestrial ecosystems, it is useful to consider the complexity of likely responses to climate change, the other human activities that influence these responses, the means of observing changes, and the particular geographic conditions that may influence outcomes.

Responses are complex

Shifts in distribution of terrestrial vegetation of hundreds of miles in eastern North America occurred in association with the 3.6°F increase in global average temperature following the last Ice Age.[57] For example, one tree species, Jack Pine, moved about 800 miles north from the southern U.S. to Canada, passing through Maryland at an average of a quarter of a mile per year.[58] Numerous studies documenting more recent geographical shifts of the distribution of species toward the poles (in Maryland northwards) and toward higher elevation due to climate warming were summarized in the IPCC Fourth Assessment[5] and a recent CCSP synthesis report.[59] A small state such as Maryland can expect a greater proportion of its species to be lost to the north and gained from the south than in a larger state. These changes could be beneficial or deleterious. Not all species can adjust successfully. Biomes (broad geographic zones having distinct climates and species) that shift in a quickly warming world are likely to lose a portion of their species complement.[59] This loss could also disrupt important ecosystem functions if one or more ecologically important species is lost.

In agriculture and commercial forestry, human skill and knowledge can allow for some adaptation to climate change; for example, by changing crop and plantation tree species, and controlling new pest and diseases artificially. If all else fails, products that can no longer be produced in Maryland economically could be imported from elsewhere. And, other commodities will be produced that are not produced under today's climate. Some impacts on agriculture and forestry may be seen as beneficial and others would require adaptation but at an increased cost.

A significant and already apparent effect of warming on plants is to hasten the beginning of the growing season and prolong it in the fall. But while a shorter winter and earlier arrival of cherry blossoms may be welcomed, overwintering of plant pests that currently are killed by winter cold could also occur. Heat waves and drought can cause mortality directly through increased stress and reduced growth. Forests which grow more rapidly because of the carbon dioxide fertilization effect—plants require CO_2 for photosynthesis and an increase in atmospheric carbon dioxide can increase growth—may become increasingly fire-prone or subject to insect outbreaks. Animals, both livestock and wildlife, are affected directly by climate and indirectly through changes in the frequency and extent of pest outbreaks, spread of invasive species, animal and plant diseases, extreme weather events, and wildfire.

As ecosystems respond to climate changes, there will be not only changes in species found in

Ben Fertig

Wicomico County, Maryland, marshlands and forest share waterway with agriculture and development.

Forest cleared for agriculture in one watershed of Maryland's Coastal Bays.

Maryland and in biodiversity, in general, but also in the ecosystem services they provide. Ecosystem services are the benefits to humans that arise from the functioning of ecosystems, but without deliberate action by humans. These include purification of air and water by plants, decomposition of wastes by microbes, soil renewal, pollination of crops, groundwater recharge by wetlands, maintenance of potentially-useful genetic races, removal of greenhouse gases from the atmosphere by carbon sequestration, and provision for recreation in aesthetically pleasing landscapes.

Land use will affect responses

Climate change is taking place in the context of other rapid changes affecting terrestrial ecosystems, agriculture, and forestry. These include continued exurban development, conversion of natural vegetation to farms and pastures, and changes in air and water quality. Many of these factors affect more than one ecosystem or resource simultaneously and interact with each other, often compounding their individual effects.

An important factor in the response of living organisms to current and future warming that did not exist during the post-glacial warming is the extensive fragmentation of natural landscapes by cities, suburbs, farms, highways, and other features. Some species will be slowed in their northward migration by their requirement for specific habitats of suitable size—habitats that, for these species, are now broken into fragments within an impassable matrix of the human landscape. This will favor species capable of "jump dispersal," in which a few individuals can reach new, suitable habitats by occasional transport over long distances by wind and water or hitching a ride on vehicles or birds. Some species, such as weedy plants, are more likely to move by jump dispersal; others such as amphibians are very unlikely to do so. Species with very specific habitat requirements and limited dispersal capability, including many plants, may fail to move and could become, at least locally, extinct.

Observing changes is challenging

Our current capacity to observe meteorological and ecological changes is insufficient to provide early indicators and assess the effects of climate change on Maryland's agriculture, forestry, and terrestrial ecosystems. Meteorological sites on the ground are few in number and limited in the range of measurements they make. The role of these sites in weather forecasting has not been diminished by the development of satellite measurements and computer models; in fact, higher quality observations are required by the models.

Furthermore, ground meteorological stations are irreplaceable for documenting climate variability and change. Studies in other regions have documented changes in the distributions of various plants and animals that are likely the result of recent climate change.[60] Earth resource satellite observations offer a different approach. Satellite data can provide a record of changes in vegetation types and extent, carbon fixation, land cover, and human habitation—all essential components of a climate change monitoring and adaptive management system. While satellite measurements have been made over Maryland for over 30 years, the data have not been systematically acquired and archived. The existing record of crop yields by the National Agricultural Statistics Service (from 1961), the Forest Inventory and Analysis program (from 1953), the Maryland Biological Stream Survey (from 2000), the Breeding Bird Survey (from 1966), and Christmas Bird Count (from 1900) all contribute key information in a period of rapid climate change, but they are alone.

A slice of the regional landscape

Maryland is a cross-section of the Mid-Atlantic, from the eastern Atlantic Coastal Plain to the Appalachian Plateau. Altitude varies from sea level to 3,306 ft. There are substantial differences in climate across the state and within microclimates, such as the rain shadows of western mountains and local effects of ocean breezes. Although the global climate models used in this assessment are too coarse in spatial resolution to reveal all of the patterns of change that may be realized, it should not be forgotten that these changes are superimposed on the substantial cross-state and local differences that already exist.

At Hancock, Maryland, the State narrows to less than two miles from its northern boundary with Pennsylvania to its southern boundary with West Virginia and, even at its widest, Maryland is a relatively narrow slice of the eastern United States. The modest area of the State belies the fact that it crosses the full range of physiographic and climatic regimes of the Mid-Atlantic region and is therefore exceptionally diverse with respect to its area. Its small area also means that the species that may take the places of those unable to compete in a changed climate, including pest species, depend on the conditions in bordering states. Thus, Maryland cannot be separated from its context in a continuum of physiography, climate, geology, soils, and biota extending from Maine to Georgia.

AGRICULTURE

Maryland's agricultural commodities account for less than one percent of the value of all U.S. commodities, yet agriculture plays an important role in the economy, social fabric, and landscape diversity of the State. Despite the decline in agricultural lands as a result of urbanization, fully one-third of Maryland's land remains in agricultural land uses. The production of poultry (broilers, turkeys, and eggs) accounts for 36% of the $1.6 billion 2006 value of agricultural commodities, and the corn and soybeans largely grown to feed these birds represents another 17% (Figure 6.1).[61] Horticulture (greenhouse/nursery) accounts for 22% of the value of Maryland's agricultural output, reflecting the State's high population density and demand for landscaping and plants.

Greenhouses and nurseries are second only to broilers in agricultural value

Crop production

Crop species differ in their critical temperature range for growth and development. Growth and development of a particular crop requires temperatures at some minimum temperature, are fastest at some optimal temperature, and slows down and finally ceases at a temperature maximum. Vegetative development usually has a higher optimum temperature than reproductive development. At elevated temperatures, the life cycle of a grain crop will progress more rapidly but may reduce yield owing to the shorter time available to fill the grain. High temperatures can also result in failure in pollination and grain setting. Yield responses to temperature vary among species based

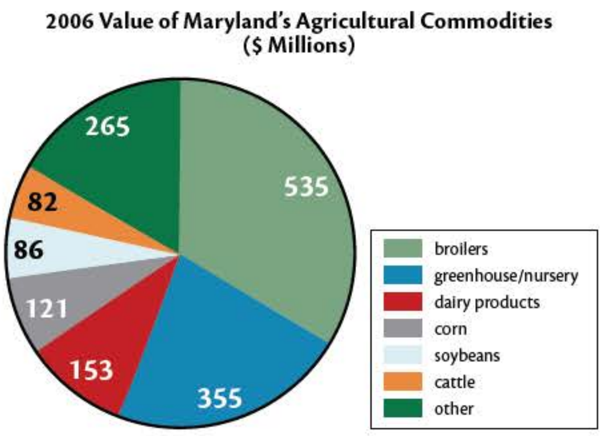


Figure 6.1. The value of Maryland's agricultural commodities in 2006.[61]

A Maryland farm surrounded by forest.

on the crop's temperature requirements. Plants that have an optimum range at cooler temperatures will exhibit significant decreases in yield as the temperature increases above this range. On its own, the projected increase in mean temperature of 2 to 3°F by 2040-2050 could decrease corn and wheat yields by 8-14% [62], but may have little effect on soybean yield.[63] Under the higher emission scenario, toward the end of the century, summer heat stress is likely to be a significant limiting factor in crop production unless there is a transition to new crops or varieties, which may be an expensive proposition for farmers.

Heat stress likely to limit crops under higher emissions scenario

Crop development and yield are also affected by the amount of water available in the soil, which is itself affected by elevated temperature. Furthermore, because evapotranspiration increases with temperature, maintaining soil moisture sufficient for germination, growth, and grain setting will be a significant factor in determining the response of crop production to climate change. Despite the mean projection of increased annual precipitation by the climate models, moderate declines in soil moisture are likely to be experienced in summer and fall during the second half of the century under both lower and higher emissions scenarios. Furthermore, rain is likely to be delivered in more intense events, separated by weeks to months with less rain. One has only to recall 2007, a year with relatively high winter and early spring precipitation and a disastrous, weeks-long summer drought as an example of what might occur more frequently. Under these conditions, farmers are likely to increase the use of irrigation—currently, just over 5% of Maryland's crop lands are irrigated—compounding the aquifer drawdown already taking place in some parts of the state (Section 5).

Plant growth is also dependent on the availability of the carbon dioxide required for photosynthesis. Plants respond differently to elevated carbon dioxide concentrations. Cold-season and broad-leaved weeds and cold-season grain crops, including wheat and barley, respond most dramatically to increased carbon dioxide. An increase of carbon dioxide concentrations to 550 ppm could increase the yield of these plants by 10-20%[5], mainly through increased grain production rather than grain size. Corn and many summer weed grasses respond less dramatically to carbon dioxide enrichment, with corn yields increasing less than 10% given the same increase in carbon dioxide.[64] However, high temperature stress during reproductive stages can negate the overall carbon dioxide effects on yield even though total plant biomass may increase and attaining even these modest productivity increases requires more fertilizer, unrestricted root growth, and effective control of weeds, insects and disease.[7]

Under the higher and lower emissions scenarios, atmospheric carbon dioxide concentrations would increase late in the century to 940 ppm and 550 ppm, respectively. By mid-century, a modest 5 to 9% increase in crop yield, except for corn, might be experienced as a result of fertilization.[65] However, under the higher emissions scenario, this effect would diminish as concentrations exceed 600-800 ppm. Deficiencies in soil moisture could further limit yield and require increased irrigation.

While carbon dioxide enrichment can stimulate the production of leafy vegetables such as lettuce, spinach, or radish, their greater leaf area increases their water requirement during the warmest and driest part of the growing season. Some moderation of this effect may be caused by a decrease in plant evapotranspiration as the stomata on the leaves constrict under higher carbon dioxide concentrations, leading to a reduction in water loss and increase in crop yield. This effect, however, is very likely to be small in comparison to the effects of temperature and carbon dioxide fertilization.

Wheat and barley grain and potato tubers contain 10 to 15% less protein when grown under carbon dioxide concentrations of 540 to 958 ppm, diminishing their nutritional value and performance in food processing, for example, producing sufficient gluten for making bread).[66] This effect can be counteracted by providing the plants more nitrogen, but in Maryland that would require more fertilizer, compounding the nutrient pollution problem in the Chesapeake Bay (see Section 8).

Ground level ozone is created on warm days by the reaction of sunlight with nitrogen oxides (NOx) and volatile organic carbon (VOC) compounds, present because of air pollution. Despite efforts to reduce this pollution, Maryland experiences some of the highest ozone in the country. As discussed in more depth in Section 8, warmer temperatures from global warming threatens to increase the concentrations of ground-level ozone and the frequency of high-ozone events. In addition to its effects on human health, ozone is toxic to many plants and particularly to crops such as soybean and wheat. Even mild chronic exposure (40-60 ppb) decreases yield in soybean.[67] However, these effects may be moderated by the reduction in the apertures of plant stomata under elevated carbon dioxide. While the net effects on crop production may be relatively small during the first half of this century, if the pollutant loads of NOx and VOC are not substantially reduced, the added stress of ozone together with heat stress and desiccation are likely to lead to declines in crop production during the second half of the century.

Crop production is affected by competition with weeds. Because the geographic range of many weed species is determined by temperature, climate warming is very likely to lead to a northern shift in the distribution of some economically significant weed species.[68] These include witchweed, cogongrass, and itchgrass that at present are found south of Maryland and the proliferation of invasive kudzu that is already here.[7] On the other hand, some current weed species may become less of a problem. On-going studies in Maryland are showing that weeds grow much faster under higher temperatures and carbon dioxide concentrations likely to be experienced in the next 30 to 50 years—these conditions simulated by experiments conducted in Baltimore.[69] The growth of many weed species is stimulated more by carbon dioxide enrichment than are the cash crops they invade, presenting an additional challenge for weed control.[69]

Weeds thrive under high temperature and CO_2

Beneficial and harmful insects, microbes, and other organisms present in agricultural ecosystems will also respond to climate change. Numerous studies have shown changes in spring arrival, over-wintering, and/or geographic range of several insect and animal species due to climate change.[5] Diseases caused by leaf and root pathogens may increase in Maryland if increases in humidity and frequency of heavy rainfall events occur, but will decrease if more frequent droughts occur.

Animal production

For optimum production, livestock require temperatures that do not significantly alter their behavioral or physiological functions needed to


Baltimore Sun

An increase in droughts may reduce reservoir water levels.

maintain a relatively constant body temperature. As their core body temperatures move outside normal boundaries, animals must begin to conserve or dissipate heat. This reduces the energy available for growth or the production of products such as milk, and ultimately affects reproduction. The onset of heat stress often results in declines in physical activity and eating or grazing. Hormonal changes, triggered by environmental stress, result in changes in cardiac output, blood flow to extremities, and digestion rates.[70] Adverse environmental stress can elicit a panting or shivering response, which increases the baseline energy requirements of the animal and contributes to decreases in productivity. The temperature thresholds of these responses depend on the species in question and the animal's genetics, temperment, and health.

Heat stress could affect milk production late in the century

The most important forms of animal production in Maryland are poultry (broilers), comprising 36% of all agricultural cash receipts, and dairy production, comprising over 11% (Figure 6.1). There are no quantitative assessments of the impacts of climate change on poultry production in this State, however housing large numbers of birds with a high metabolism in close quarters already makes them susceptible to heat stress during hot summers, when large numbers of birds can die. To reduce the chance of death requires costly insulation and ventilation of growing sheds. The temperature projections after mid-century, particularly under the higher emissions scenario, will pose a much more serious problem of heat stress on confined poultry production.

The Northeast Climate Impacts Assessment projected little increase in heat stress on dairy cattle and no significant heat-related reductions in milk production for the next several decades. However, under a higher emissions scenario generally similar to the one used here, by mid-century New Jersey and southern Pennsylvania were projected to experience moderate heat stress in July and declines of milk production of up to 12%. By late century, the declines are projected to be 10% under the lower emissions scenario and 15-20% under the higher emissions scenario. Similar or greater declines in dairy production are likely in Maryland.

To maintain levels of production under climate change, livestock producers will select breeds that are genetically adapted to the new, warmer climate. However, breeds that are more heat tolerant are generally less productive.

Climate change is also likely to affect the parasites, pathogens, and disease vectors that affect domesticated animals. Similar effects on pest migration and over-wintering as discussed for cropping systems are likely to be observed for some livestock parasites and pathogens. Also, accelerated development of pathogens and parasites due to the earlier spring and warmer winters is likely.

Warming and associated variation in weather patterns will likely result in more livestock being managed in climate-controlled facilities, even in a more energy-constrained world. Furthermore, agriculture, in general, and the animal production industry, in particular, will surely be under pressure to reduce its greenhouse gas emissions, particularly of methane and nitrous oxide.[71] This could incur additional costs to production, thereby affecting profitability and hence the nature of the agricultural industry in Maryland.

Summary of impacts on agriculture

In summary, agriculture in mid-latitude regions

Tom Hollyman

Increased temperatures can cause heat stress in chickens.

www.cornucopia.org

Heat stress can cause a decline in milk production.

such as Maryland may experience moderate warming benefits in the form of crop and pasture yields under moderate increases in temperature (2-5°F) and increases in atmospheric carbon dioxide and rainfall. However, increased risks of drought in summer and early fall and unknown changes in weed and pest damages will generate uncertainty among farmers and animal producers regarding adaptation to climate change. The warming in the lower emissions scenario during the latter part of this century is projected to have increasingly negative impacts as it approaches or passes the upper end of optimum ranges of different crop and animal species if the higher emissions scenario proves more accurate (Figure 4.3). Therefore, without mitigation of greenhouse gas emissions, the changing climate is likely to pose serious problems for Maryland agriculture resulting from heat stress and summer-fall drought that might increase groundwater demand for crop irrigation.

FORESTS

Although Maryland accounts for only 0.3% of the nation's softwood production and 1.6% of its hardwood production, the forest products industry is economically important in parts of the State, resulting in product output worth $262 million. Paper products account for 60% of that total. Forest products industries employed 9,326 in 2006 and generated $0.4 million in State tax receipts.

Climate change and forest productivity

Forest productivity in the United States has generally been increasing slightly since the middle of the 20th century[72], although there is no assessment specifically for Maryland forests. Forested area has increased dramatically from a minimum at the beginning of the 20th century as areas of the eastern U.S. that had been cleared for agriculture and other purposes have been reclaimed by forests. The potential causes of the increase in productivity include increases in temperature, atmospheric carbon dioxide and nitrogen deposition, but these are difficult to isolate. Temperature, water, and solar radiation are the primary climatic factors that affect forest productivity. Increased precipitation, higher temperature, and a longer growing season will increase productivity where those factors are currently limiting. Consequently, a modest increase in forest yields and regrowth is likely. During the latter part of the century under the higher emissions scenario, however, heat stress and the greater likelihood of summer-fall drought could obviate gains in forest productivity due to global warming earlier in the century. If forest species, such as loblolly pine, currently found farther south, migrate into Maryland or are planted and replace existing species, this could at least partially compensate for some of the lost productivity

Large departures from typical conditions and extreme events, such as late frosts, drought, and wind storms, can damage or kill trees. The occurrence and severity of such extreme events associated with climate change are projected to increase. These indirect effects of climate on factors such as wildfires and insect outbreaks are likely to contribute to reduction of forest production. The interaction of climate change and these factors could create unprecedented conditions, the effects of which are very difficult to predict. Forests can take decades to re-establish after disturbances are caused by fire, insect outbreaks, and wind and ice storms. These effects are likely to become more important than the direct effects of climate itself in shaping future forest ecosystem structure and functioning. All of these changes will be influenced by the legacy of the logging in the 19th and 20th centuries and the more recent period of fire suppression that has led to dominance by an even-aged community of trees now reaching old age.

Modest increase in forest yields likely early in the century

Carbon dioxide fertilization

As discussed under agriculture, the projected increases in atmospheric carbon dioxide concentration are likely to increase forest growth due to a fertilization effect, but this will depend greatly on the type of forest and its environmental

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Fall colors illuminate a mountain forest.

conditions. The response of tree growth to elevated CO_2 also depends on the age of the trees; younger trees respond more strongly than older ones.[5] Maryland forests will likely absorb more CO_2 and retain more carbon in wood and soils as atmospheric CO_2 increases, but this will depend on the specifics of how climate changes and on such factors as the age of the forest and the degree of fertilization by nitrogen deposition. These factors are highly relevant when devising strategies to increase forest carbon sequestration for mitigation plans.

Atmospheric pollution

Forest growth and dynamics are affected by air pollution in two important ways: the toxic effects of ozone created by emissions of NOx and VOCs from power plants and vehicles, and the stimulatory effects of nitrogen deposited as a result of these NOx emissions. Nitrogen deposition in the eastern U.S. can exceed 10 kg of nitrogen per hectare (or 9 lbs per acre) per year and has increased 10 to 20 times above pre-industrial levels.[73] Although nitrogen deposition has declined recently in Maryland as result of air pollution controls[74], future emissions are uncertain. Forests are generally limited by nitrogen availability and increased deposition will enhance forest growth. However, if it increases too much, it can have negative effects on forests and on aquatic ecosystems that receive runoff from the forests. The interactions of elevated CO_2, temperature, precipitation, ozone pollution, and nitrogen deposition are likely to be important in determining forest growth and species composition, but the net result of these factors and their interactions is poorly understood. Continued nitrogen deposition on forests can have the result of stimulating the degradation of organic matter in soils by microbes, thus reducing any carbon sequestration resulting from faster growth in a CO_2-enriched world.

Combined effects of temperature, ozone, CO_2, and nitrogen deposition are difficult to predict

Insect outbreaks

Outbreaks of forest insects and diseases affect forest composition and production, leading to altered cycles of matter and energy, and changes in biodiversity and ecosystem services. Damage to Maryland forests caused by outbreaks of defoliating insects and other pests cost several million dollars per year.[75] Weather plays an important role in influencing outbreaks of serious forest insect pests, including the gypsy moth, southern pine beetle, hemlock woolly adelgid, spruce budworm, and western spruce budworm. Temperature affects the rate of insect life-cycle development rates, the synchronization of mass attacks that overcome tree defenses, and insect winter mortality rates. Climate also affects the insects indirectly through effects on the host trees. Drought stress, resulting from decreased precipitation and warming, reduces the trees' ability to resist insect attack.

Outbreaks and expansion of some non-native insect species, such as the hemlock woolly adelgid (Box 6.1), are known to be influenced by climate. The introduced gypsy moth has defoliated millions of acres of Maryland forests. Projections indicate that Maryland's changing climate is likely to increase the frequency and severity of gypsy moth outbreaks in the future.[76] Longer growing seasons and higher carbon dioxide concentrations might allow forests to recover more quickly after such disturbances. But defoliation disturbances affect carbon uptake, nutrient cycling, and stream hydrology, resulting in the loss of nitrogen from the forest where it is needed, to the Chesapeake Bay where it is harmful.[77]

Joanna Woerner

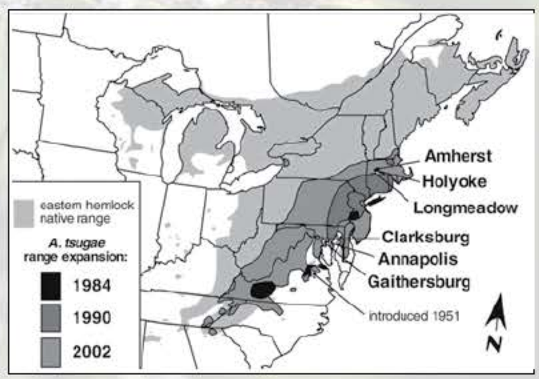
Industrial emissions.

NPS

Hemlock forest, ravaged by insect pests.

BOX 6.1 THE EASTERN HEMLOCK & WOOLLY ADELGID

The hemlock woolly adelgid, an aphid-like insect native to Asia, was first recorded in 1951 in Virginia, and has since spread, causing a severe decline in vitality and survival of eastern hemlock in North American forests (Box Figure 6.1). Once it arrives at a site, complete hemlock mortality is just a matter of time and damaged hemlock stands are replaced by black birch, black oaks, and other hardwoods. While plant biodiversity increases in the canopy and understory, several bird species, including the blue-headed vireo and Blackburnian warbler, have a high affinity for hemlock forests and are at risk as a result of adelgid expansion. Also, changes in the forest canopy affect hydrology and nutrient cycling, resulting in longer periods of dry streams, which, in turn, reduce the abundance of brook trout, brown trout and other fish. Low winter temperatures presently check the spread of the hemlock woolly adelgid, but increasing temperatures and the capacity of the adelgid to develop greater resistance to cold shock indicates that more hemlock forests will succumb in future years.



Box Figure 6.1. Expansion of the range of the hemlock woolly adelgid (*Adelges tsuagae*) with regard to the range of the eastern hemlock.[59]

www.duke.edu

Species composition

As the changing climate after the last Ice Age resulted in the northward shift in the distribution of tree species in eastern North America, 21st century warming will very likely result in the northward sift in the range of trees and forest types currently that exists in Maryland. Trees that need cold winter conditions (for example, sugar maples) or are susceptible to diseases or pests under warmer conditions will retreat northward, possibly replaced by species currently found south of Maryland. Plant hardiness zones for horticultural plants have recently been revised to take account of the changes in the potential ranges of garden plants that have already taken place (Figure 6.2).

By relating the preferred environmental conditions of various forest types to current temperature and precipitation, it has been possible

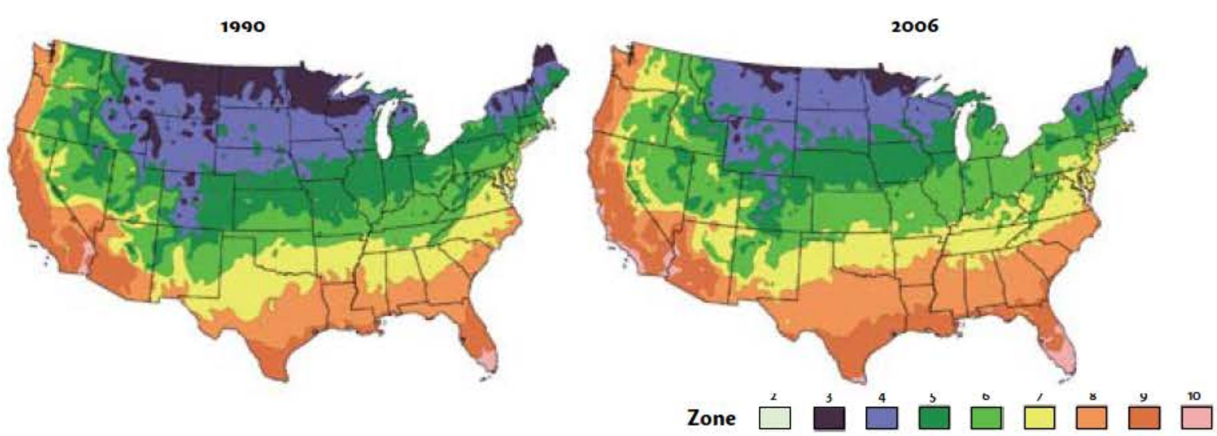


Figure 6.2. U.S. Department of Agriculture plant hardiness zones for 1990 compared to those delimited by the National Arbor Day Foundation's for 2006.

to estimate future ranges as climate changes in eastern North America.[55] Under a doubling of CO_2 concentrations—likely to be experienced in the latter half of the century under the low-emissions scenario—the maple-beech-birch forests of Allegany and Garrett counties are likely to disappear, replaced by oak-hickory forests. The oak-hickory forest type that presently characterizes most of the Piedmont and Coastal Plain west of the Chesapeake is likely to transition to an oak-pine forest.

The NECIA concluded that the region's species would shift northward by as much as 350 miles by the late-century under the lower emissions scenario, and as much as 500 miles under its higher emissions scenario. The NECIA projected that the maple-beech-birch forests that presently characterize most of Pennsylvania would move to northern Pennsylvania, and thus out of Western Maryland, under the lower emissions scenario and retreat to Upstate New York under its higher emissions scenario. In general, then, one would expect that by late-century, Maryland forests would look much like those in eastern Virginia and North Carolina do today, with many more pines.

Maple-beech-birch forests are likely to be eliminated from Western Maryland

Forest ecosystems

Forests provide many other benefits beyond the lumber and fiber. These ecosystem services, including watershed protection, water quality, flow regulation, wildlife habitat and diversity, climate regulation, carbon storage, air quality, recreational opportunities, and aesthetic fulfillment, are important for the well-being of Marylanders. The market values of few of these ecosystem services have been quantified, but they are nonetheless essential and irreplaceable. All of these services are subject to the direct and indirect effects of climate change as forest productivity and composition changes and disturbance by heat stress, seasonal drought, severe storms, fire, disease, and pest outbreaks increase.

The biodiversity of forest plants, animals, and microbes is also likely to be affected in ways that are difficult to predict let alone quantify.[78] Biodiversity is already being affected at the landscape, species, and genetic levels by a variety of human activities, including habitat loss and fragmentation, invasive species, and air pollution.[79] Climate change poses yet another stress that is likely to reduce biodiversity.[80]

Climate changes have been shown to affect the timing of critical processes of growth and reproduction (for example, flowering and fruiting) in thousands of plant and animal species around the world.[5,81] These changes can disrupt previously synchronized relationships among species (for example, pollination, prey availability for predators, and food sources for migrant birds). The reduction in population sizes caused by these adverse effects sets the stage for local or global extinctions of species.[82] The American Bird Conservancy estimated that habitat alterations due to climate change may force out 34 or more bird species from Maryland.

The most emblematic of birds that may no longer breed in Maryland because of the unsuitability of habitats is the state bird, the Baltimore oriole. The NECIA also projected that various migratory bird species with northerly or high altitude distributions, including the American goldfinch, purple finch, rose-breasted grosbeak, and black-capped chickadee would experience declines in abundance in the Northeast, while the tufted titmouse, northern cardinal, and indigo bunting have the potential to increase in both range and incidence.[7]

Summary of impacts on forests

Maryland forests are likely to experience a modest increase in productivity over the first half of the century as a result of longer growing seasons and elevated atmospheric carbon dioxide concentrations. Later in the century, the composition of Maryland forests is likely to undergo pronounced changes as the maple-beech-birch forests of Western Maryland begin to disappear and pine trees become more prominent in oak-hickory forests of central Maryland. Also, later in the century, heat stress, seasonal droughts, and outbreaks of pests and diseases are likely to diminish forest productivity,

University of Texas

Maryland's state bird, the Baltimore oriole.

particularly under the higher-emissions scenario. This could result in impairment of important ecosystem services that forests provide, including carbon sequestration, control of the water cycle, and maintenance of biodiversity. The extent to which and rate at which other tree species from the south would replace the current species and the services the present forests provide cannot be readily predicted.

NPS

Maryland forests provide many resources as well as recreational opportunities.

Section 7

COASTAL VULNERABILITY FROM SEA-LEVEL RISE & STORMS

KEY POINTS

- **Sea level in Maryland rose by 1 foot in the 20th century, partially because the land is sinking.**
  Coastal regions of Maryland have been sinking at about a rate of 6 inches per century and this should continue. Additionally, the average level of the sea in this region rose by about the same amount. As a result, Maryland has experienced considerable shoreline erosion and deterioration of coastal wetlands.

- **Sea-level rise is very likely to accelerate, inundating hundreds of square miles of wetlands and land.**
  Projections, that include accelerating melting of ice, extend to more than 1 foot by mid-century and 3 feet by late century. If the highest rates are realized under the higher emissions scenario, most tidal wetlands would be lost, about 200 square miles of land would be inundated, and an even greater sea-level rise would occur in subsequent centuries.

- **Rains and winds from hurricanes are likely to increase, but their frequency cannot be predicted.**
  The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with warming sea surface temperatures. This trend is likely to continue as ocean waters warm. Whether Maryland will be confronted with more frequent or powerful storms depends on storm tracks that cannot yet be predicted.

Mention effects of climate change in Maryland and most people would think first of the threat of coastal inundation due to sea-level rise and the increased risks of storm damage. The record storm surge flooding associated with the passage of Hurricane Isabel in 2003 is still fresh in the minds of Marylanders. With its 3,100 miles of tidal shoreline and extensive low-lying lands, especially on the Eastern Shore, Maryland's coastal zone is particularly vulnerable to climate change. Indeed, the central charge to the Adaptation and Response Working Group of the Commission on Climate Change is to "recommend strategies for reducing the vulnerability of the State's coastal, natural, and cultural resources and communities to the impacts of climate change, with an initial focus on sea-level rise and coastal hazards (e.g., shore erosion, coastal flooding)." The Commission is thus tasked with developing appropriate guidance to assist the State and local governments with identifying specific measures (e.g., local land use regulations and ordinances) to adapt to sea-level rise and increasing coastal hazards.

This section explores what we know about sea-level rise in Maryland and the Chesapeake Bay region, and applies the latest models and scientific results that provide insights into the sea-level rise that may be experienced during the present century and beyond. Projections are made for the higher and lower emission scenarios as has been done for temperature and precipitation in Section 3. The section further explores current scientific knowledge of the likely consequences of global warming for extratropical storms, such as Nor'easters, and the tropical cyclones that we know as hurricanes. The potential impacts on tidal wetlands, coastal lands and development, and storm surges are then evaluated.

SEAS RISING OR LAND SINKING?

As mentioned in Section 1, sea level rose rapidly as glaciers melted after the peak of the last Ice Age 20,000 years ago. At that time, the Atlantic shoreline was near the edge of the continental shelf, more than 80 miles off Ocean City, and the rivers ran across the present shelf to the sea. By 8,000 years ago, sea level had risen to the point of flooding the lower Susquehanna River valley, creating a tidal estuary, the nascent Chesapeake Bay (Figure 7.1).[83] The rate of sea-level rise during this period of rapid melting of glaciers was about 16 mm/year. (Throughout this discussion, metric units are used for annual rates to facilitate presentation and calculation, but rates over longer periods are converted to feet for ease in comprehension.) By 5,000 years ago, the rise of the ocean virtually ceased, but the Bay continued to deepen and expand, filling the lower valleys of the Potomac, Patuxent, Patapsco, Choptank, and other rivers. This was because the land was sinking as the bulging of the Earth's surface, resulting from the tremendous burden on the crust by the very thick glaciers that occupied what is now Hudson Bay and Quebec, subsided. This rate of subsidence was relatively rapid initially, but continues to this day as a slow-motion rebounding of an event that peaked 20,000 years ago.

Because different coastlines around the world are sinking at different rates—or actively rising in some previously glaciated or geologically active regions —sea-level rise experienced at specific places will differ, even with a comparable rising of the level of the ocean itself. It is, then, appropriate to refer to "relative sea-level rise"—the water level relative to the land at that place. This is typically estimated by tide gauges that have long been fixed in place. The tide gauge record for Baltimore, which is one of the nation's longest, shows that the water levels there are highly variable as a result of weather events, strong seasonal variations, and longer oscillations in the North Atlantic Basin. On the average, however, relative sea level increased approximately one foot over the 20th century (Figure 7.2). Note, however, that for the first 30 years of the record the rate of relative sea-level rise was slower, with a disproportionate part of the rise in the mean level coming since 1930.

Sea level at Baltimore rose by 1 foot during the 20th century, mostly since 1930

Analysis of many such tide gauge records from around the world, including those from more geologically stable locations, allowed the IPCC to conclude that the global mean sea-level rise, once the effects of land subsidence or emergence are removed, was approximately 1.8 mm/year between 1961 and 1993.[2] Relative sea level at Baltimore rose at a rate of about 3.5 mm/year, indicating the local rate of subsidence was 1.7 mm/year or roughly half a foot per century. The effects of regional land subsidence on relative sea-level rise is apparent

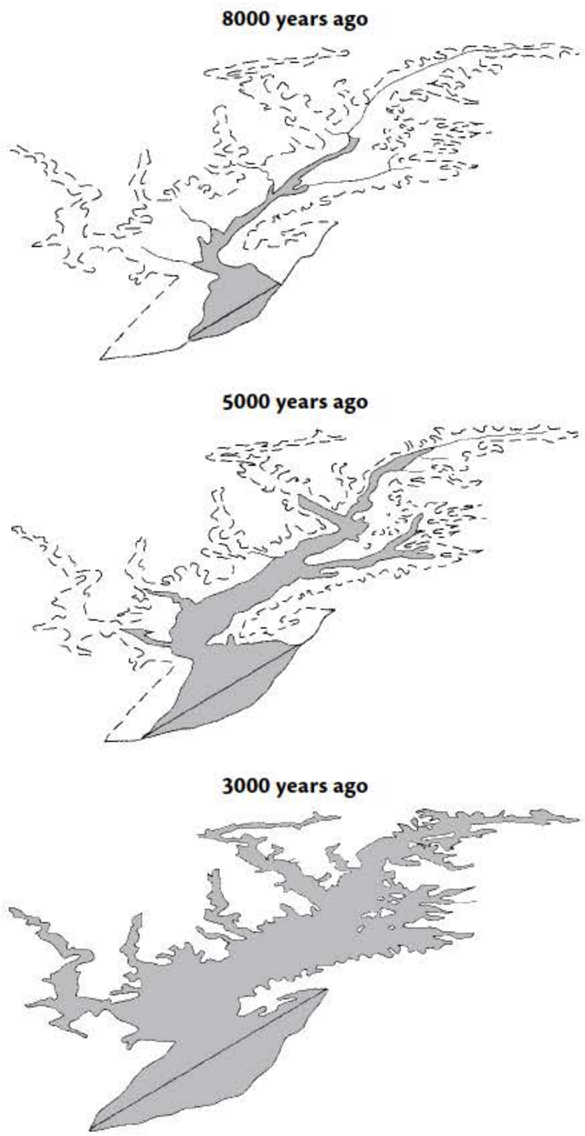


Figure 7.1. The rising ocean began to fill river valleys 8,000 years ago creating the general configuration of the Chesapeake Bay by 3,000 years ago.[83]

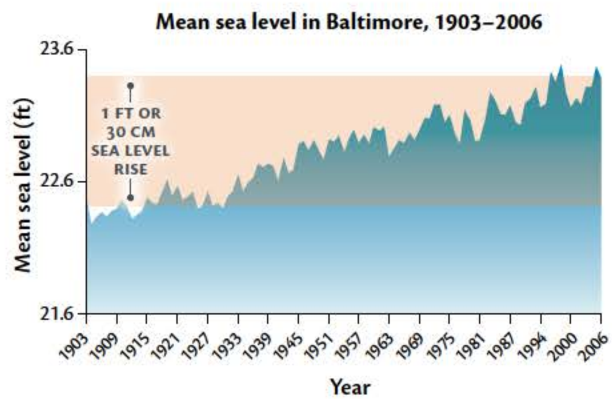
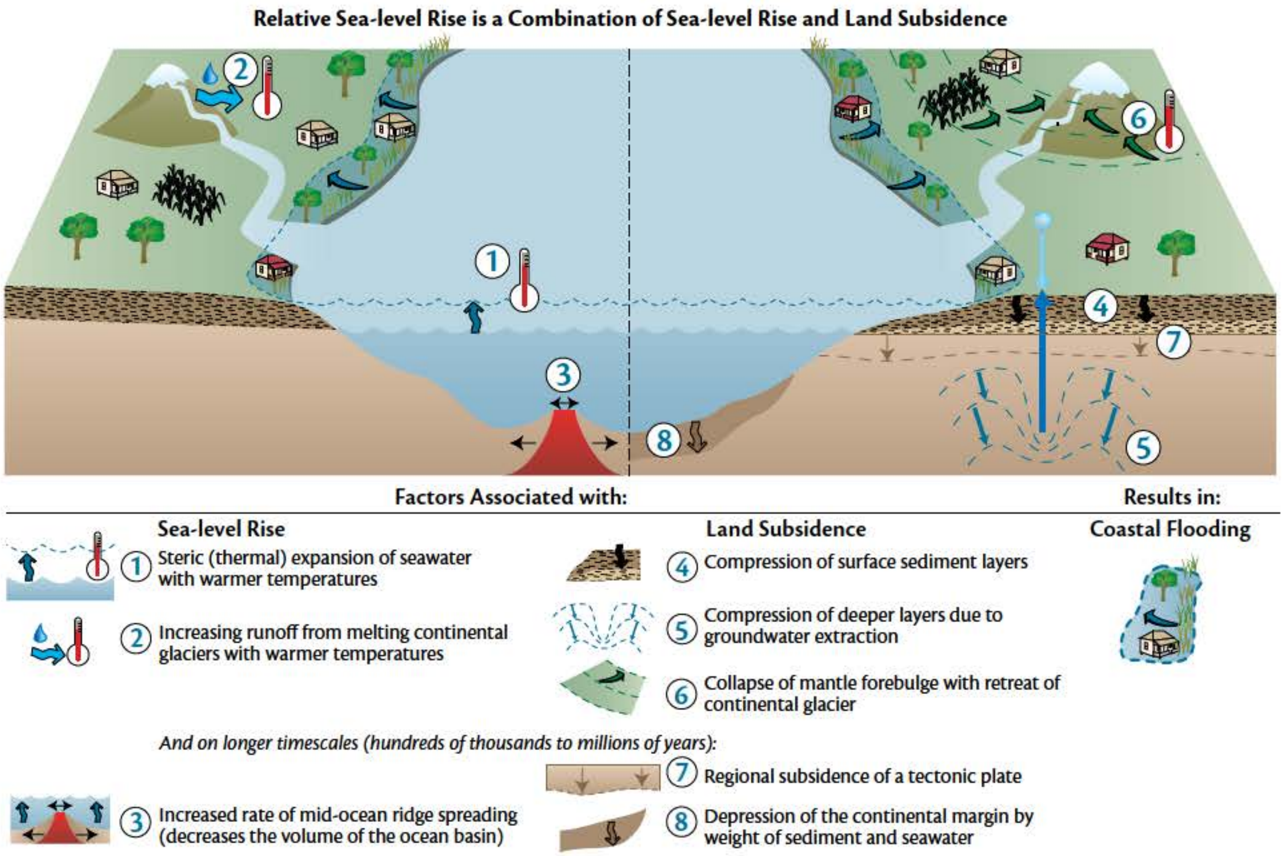


Figure 7.2. Tide gauge record for Baltimore.



by comparing tide gauge observations along the Atlantic coast (Figure 7.3).[84] Glaciated areas to the north experienced less relative sea-level rise than those located in the glacial forebulge region that are still subsiding. This subsidence (reflected by the difference between relative sea-level rise and the global mean) diminishes to the south of the Chesapeake Bay region. Note, however, that subsidence rates vary within the Bay region, with

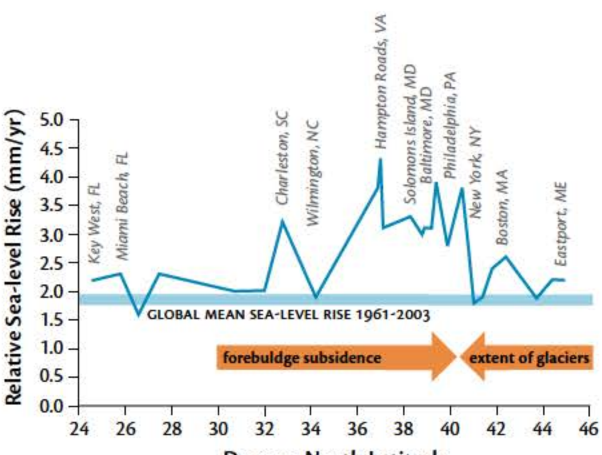


Figure 7.3. Relative sea level rise during the later 20th century along the U.S. Atlantic coast compared to the global mean sea level rise during 1961-2003 (band represents the confidence limits around the mean).[2]

Hampton Roads (Norfolk) experiencing a relative sea-level rise of 4.2 mm/year. This is likely the result of groundwater extraction from permeable rock or sediments, which can cause localized subsidence of the ground surface. Similar localized areas of greater subsidence resulting from large groundwater withdrawal may exist around Solomons and Cambridge, Maryland. However, for the Chesapeake Bay as a whole, the relative sea-level rise of about one foot during the 20th century resulted from near equal parts of subsidence and global sea-level rise. And, there is no reason to expect that the regional forebulge subsidence, which is in the process of adjusting over thousands of years, will be different than what was observed over the past century.

GLOBAL SEA-LEVEL RISE

The limited records available indicate that global sea level, adjusted for land movements, was nearly stable during the 19th century but began to increase around the turn of the century and then accelerate from the 1930s onward (Figure 7.4). Based on tide gauge data, the mean rate of sea-level rise was estimated by the IPCC to have been 1.8 mm/year between 1961-2003.[2] Since late 1992, there have been satellites deployed with the capability of very accurately measuring their altitude over the ocean's surface. Large numbers of measurements can be averaged over a 10-day period to develop precise maps of the surface of the ocean. Based on analysis changes in the ocean's elevation between 1993 and 2003, the IPCC noted a global average of 3.1 mm/year (black line in Figure 7.4), although the level of various regions of the ocean changed at different rates. While the degree to which the differences with sea-level rise estimates derived from tide gauges represent methodological differences or an actual acceleration of the rate of global sea-level rise has not been fully resolved, such an acceleration is consistent with the observed warming of the ocean surface and melting of glaciers, both of which expand the ocean's volume (Figure 7.5).

Sea-level rise during the recent past is caused primarily by expansion of the volume of the warming ocean and, secondly, by the observed melting of glaciers and ice caps. The melting of the massive polar ice sheets on Greenland and western Antarctica were only a small component of sea-level rise, although the contribution of Greenland seems to be growing. It is unlikely that the total melting of the Greenland Ice Sheet would occur this century and produce the kind of 25-foot inundations seen in popular dramatizations of sea-level rise, although this could happen sometime in the future.

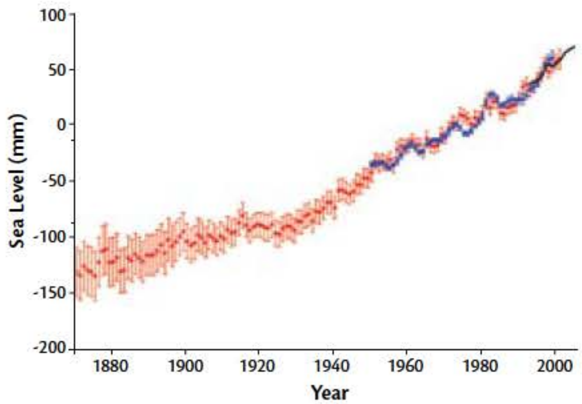


Figure 7.4. IPCC compilation of global data since 1870 shows acceleration of sea level rise during the 20th century.[2] The blue curve shows coastal tide gauge measurements since 1950 and the black curve is based on satellite altimetry.

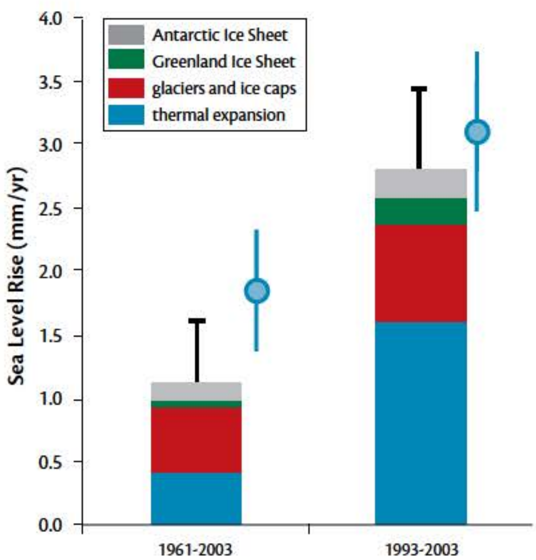


Figure 7.5. The IPCC attempted to estimate the factors responsible for increasing the ocean's volume, including thermal expansion and melting of glaciers and polar ice sheets.[2] These are compared with the global mean (dot) and range of observed sea-level rise. These estimates come closer to explaining the higher rates of sea level rise based on satellite observations during 1993-2003.

FUTURE SEA-LEVEL RISE

How much sea-level rise will Maryland experience over the coming century in a warming climate? The IPCC projected that global sea level would rise by 7 to 15 inches under the lower emissions (B1) scenario and 9 to 20 inches under the higher emissions (A2) scenario, although the IPCC specifically stated that these projections cannot "provide a best estimate or an upper bound for sea-level rise."[2] Adding to those projections the expectation that land subsidence in coastal Maryland would continue at the rate observed during the 20th century yields the relative sea-level rise projections labeled as IPCC projections in Figure 7.6. These projections suggest that Maryland would experience a rise in sea level ranging from just slightly more than the one foot experienced during the past century to more than twice that amount. However, the IPCC sea-level rise projections have been widely criticized as too conservative because they do not account for rapid changes in ice flow that could be experienced.

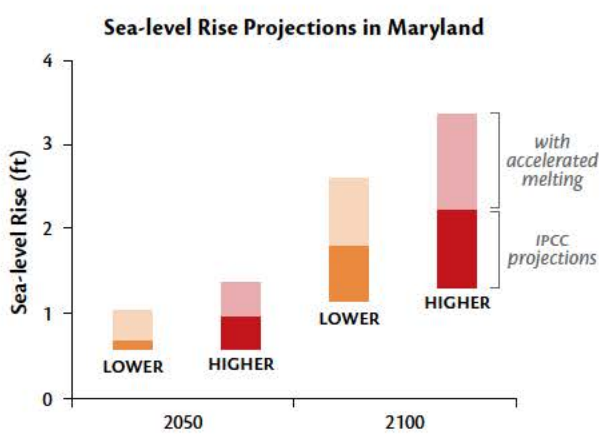


Figure 7.6. Projected relative sea level rise in Maryland during the 21st century under the higher and lower emissions scenarios.

The IPCC readily admitted that such effects were excluded because these ice flow dynamics could not reliably be modeled when its Fourth Assessment was being prepared and cautioned that sea-level rise could be higher as a result.

The melting of ice floating on the sea has no effect on sea level, much as ice cubes melting in a glass do not cause the glass to overflow. But, how much higher could sea-level rise if losses of ice that rests on land accelerate? This was estimated by examining three scientific reports appearing since the publication of the IPCC Fourth Assessment. They projected potential 21st century sea-level rise using three different methods. One used a statistical approach relating sea-level rise to observed temperature increase[85]; another assumed that the continuation of the rate of recently observed acceleration of ice loss, primarily from glaciers and ice sheets[86]; and a third estimated an upper limit of ice sheet contribution during the 21st century in projecting sea-level rise in the state of Washington.[87] The statistical model projected a mean increase of 34 inches in global sea level under the higher emissions (A2) scenario, compared to the IPCC projection of 9 to 20 inches. A word of caution, though, in that the statistical range of possibilities extended to 47 inches in the range of scenarios tested. Remarkably, the other two studies produced estimates of accelerated melting that, when added to the IPCC projections, resulted in very similar global sea-level rise at the end of the century under the higher emissions scenario. When coastal Maryland subsidence rates are taken into account, the additional relative sea-level rise based on the assumptions of these studies is represented in Figure 7.6 by the lighter-colored extensions above the darker-colored boxes that represent the IPCC projections. This suggests a sea-level increase of as little as 0.6 feet (probably unlikely because this is scarcely above the 20th century rate) to much as 1.3 feet could be experienced along the Maryland's coast by the middle of the century. By the end of the century, accelerated melting could produce a relative sea-level rise from 2.7 feet under the lower emissions scenario to 3.4 feet under the higher emissions scenario.

Accelerated ice melting could result in 3 feet of sea-level rise if emissions continue to increase

These adjusted estimates based on the IPCC projections should not be considered as model forecasts, but as reasonable bases for assessment and

A mature buffer zone helps reduce nutrient runoff from entering a saltmarsh on a tributary of the Chester River, Maryland.

planning that take account of the admitted high-end uncertainties in estimating future sea levels. They do not consider the upper bounds of the confidence limits presented in the statistical study, but can be used with confidence in concluding that it is likely that Maryland will experience sea-level rise of 2 feet by the end of the century. Further, this estimation indicates that, at this time, there is no scientific basis for projecting sea level rise of more than 4 feet during this century. Of course, sea-level rise will not stop at the end of the century and an important difference between the higher and lower emissions scenarios is that the higher emissions scenario is much more likely to move global temperatures over a threshold that would lead to the irreversible melt down of at least the Greenland Ice sheet, that would result, during succeeding centuries, in the 25-foot inundation of cities depicted in some frightening animations.

COASTAL WETLANDS

This section assesses the impacts of sea-level rise on shorelines and low lying lands. Section 8 will further explore the consequences of sea-level rise on the Chesapeake Bay and Maryland's Coastal Bays. An important part of these coastal ecosystems is, however, the coastal wetlands that fringe the estuaries. Maryland has some 200,000 to 285,000 acres of coastal wetlands[88] that provide critical nursery grounds for commercially important fisheries, important feeding grounds for migratory waterfowl, and home to furbearers and other wildlife. These wetlands buffer shorelines from erosion during storms, trap sediments and associated nutrients and pollutants, and provide a variety of outdoor recreational opportunities, such as sport fishing, hunting, kayaking, and bird-watching. The quantity and quality of these resources and opportunities available for future generations of Maryland residents will be directly affected by climate change.

Tidal wetlands will persist only if they build vertically through the accumulation in their soils of mineral (sand, silt, clay) and organic (plant material, especially plant roots) matter at a pace equal to or greater than sea-level rise—otherwise they will become submerged and convert to shallow open water habitat. In addition, given the generally shallow slopes over much of the Maryland coastal zone, those tidal wetlands that are able to keep pace with sea level will migrate and expand inland, but only so long as there are no barriers to migration (such as shore stabilization structures, houses, and roads).

As sea level rises, the fate of coastal wetlands in Maryland will be determined largely by how the needed build-up of soils is impacted by natural processes, human activities, and the effects of the changing climate. Changes in the river runoff and shoreline erosion would affect the mineral sediment available for soils. Droughts could affect the accumulation of organic matter. More intense storms and greater storm surge could erode wetlands, but also transport mineral sediments onto the wetlands

When sea level rises, tidal wetlands must build up the soil or migrate inland


Jane Thomas

The loss of wetlands at the Blackwater National Wildlife Refuge, Maryland, is due in part to sea-level rise, erosion, and subsidence.

and affect accumulation of organic matter by the negative effects of salt-water intrusion on plant growth.

Wetland survival during sea-level rise will vary among coastal wetlands depending on their location and the degree to which they are able to build up the soil surface. Marshes behind barrier islands on the seaside Eastern Shore increase their soil level vertically primarily as a result of sand driven over the islands during storms. An increase of storm intensity or frequency could build and expand the marshes as sea levels rise. Estuarine marshes depend more on organic matter and fine-grained resuspended sediments to build their soils. Without some significant source of mineral sediments such as discharge from a river, organic soils can only build so fast to keep up with sea level rise—beyond some threshold, the marshes begin to deteriorate as plants die because their roots become continuously inundated and wetlands convert to shallow ponds.

As sea level has risen in the Chesapeake Bay, the gradual inundation of the low lying land on the lower Eastern Shore has led to the formation of tidal marshes that are built atop submerged uplands, particularly in Dorchester and Somerset counties. Accretion rates in these marshes are typically less than the current rate of sea-level rise.[89] At the Blackwater National Wildlife Refuge, land surface adjustments related to shallow soil subsidence[90] and possibly to groundwater withdrawal[91] have locally increased the rate of relative sea-level rise, contributing to severe wetland loss.[89] In addition, the effect of local stressors on vegetation growth, including intense herbivory by nutria, burning of the marsh for wildlife management, and altered flooding and salinity patterns related to roads and other construction activities, may be limiting soil buildup needed to counteract sea-level rise, which contributes to severe wetland loss.

Coastal wetlands, such as at Blackwater National Wildlife Refuge, are already deteriorating

If sea level were to rise at 6 mm/year, most of the remaining wetlands would be converted to open water (Figure 7.7).[92] Marsh elevation is not accreting appreciably under present rates of sea-level rise.[86] Consequently, it is unlikely that these marshes could build additional soil to keep pace without some external sediment subsidy. The placement of sediment dredged from channel maintenance in the Chesapeake Bay is currently under evaluation as a way to sustain these drowning wetlands.

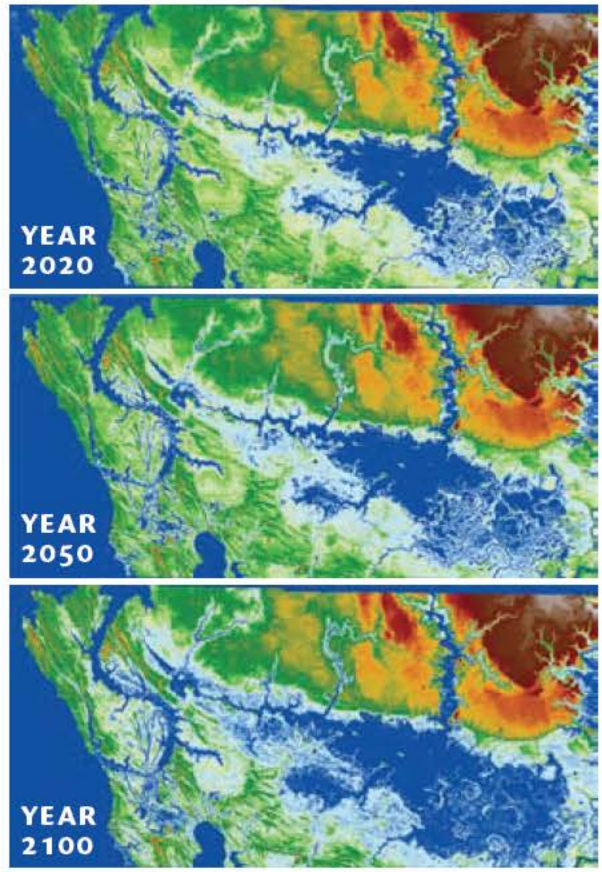


Figure 7.7. Projected inundation of coastal wetlands at Blackwater National Wildlife Refuge that would result from 6 mm/year sea level rise.[92]

Coastal responses to accelerated sea-level rise are difficult to predict over an area as large as Maryland, but a panel of wetland experts considered existing knowledge of responses and likely climate changes to project wetland survival for the Chesapeake Bay and Coastal Bays during this century.[93] Three relative sea-level rise scenarios were evaluated: 3 mm/year (approximating the current rate), 5 mm/year, and 10 mm/year. The fate of the wetlands was assigned to one of three possible outcomes: keeping pace, marginal (able to maintain elevation under optimal conditions, and loss (flood to the point of loss of

Intensive development and the loss of marsh impact the health of Maryland's Coastal Bays.

emergent vegetation). The findings summarized below are intended to provide a regional perspective and should not be applied to site-specific cases:

- **For the Maryland Coastal Bays:** marshes are able to keep pace with 3 mm/year of sea-level rise; at 5 mm/year, their ability to do this would be marginal and depend on the frequency of storms to mobilize and deliver sediments; and, at 10 mm/year, there would be marsh loss to shallow open water.
- **For the Chesapeake Bay:** estuarine marshes on the lower Eastern Shore are already experiencing high rates of loss and their survival is considered marginal at 3 mm/year and subject to substantial loss under either of the accelerated rates; estuarine marshes in the northern portion of Chesapeake Bay and on the western shore are keeping pace with 3 mm/year, but would be marginal at 5 mm/year and subject to loss at 10 mm/year; and, tidal freshwater marshes and swamps accumulate both mineral sediment and large quantities of plant organic and are considered sustainable under accelerated sea-level rise assuming salinities do not increase and sediment supplies are maintained.

To put these expert judgments in the context of the sea-level rise projections under the higher and lower emissions scenarios (Figure 7.6), based on the IPCC projections, the rate of sea-level rise over the first half of the century is likely to range from 3.5 to 5.8 mm/year, with the average for the higher emissions scenario 4.7 mm/year versus 3.8 mm/year under the lower emissions scenario. Except in tidal freshwater environments or where there is a significant supply of mineral sediments, the survivability of coastal wetlands is likely to be marginal, at least under the higher emissions scenario.

During the second half of the century, sea level is projected to rise, based on the IPCC, by an average of 4.8 mm/year under the lower emissions scenario versus 5.7 mm/year under the higher emissions scenario, however, the upper end of the range under higher emissions is 7.8 mm/year. Consequently, the difference in the path of global emissions of greenhouse gases is likely to determine whether there is marginal survivability of at least some of Maryland's tidal wetlands and the predominance of wetland loss. However, with accelerated melting, the rate of sea-level rise could exceed 10 mm/year by the middle of the century, resulting in loss of the substantial majority of Maryland's 430 square miles of tidal wetlands. While some new tidal wetlands will be created over land that is presently dry, the dry land and nontidal wetlands potentially available for inland migration is only about 10% of the area of existing tidal wetlands.[94]

A recently completed, parallel analysis by the National Wildlife Federation[94] also projected losses of a majority of the brackish marshes, tidal swamps, and estuarine beaches in the Chesapeake Bay under a 27-inch rise in sea level by the end of the century. Clearly, the intertidal habitats that are important to the characteristics and productivity of the Chesapeake Bay ecosystem are at risk as a consequence of global warming.

EROSION & INUNDATION

In addition to causing the deterioration and landward migration of coastal wetlands, projected sea-level rise will cause the erosion and retreat of shorelines and, ultimately, the inundation of presently dry land. Based on general estimates derived from the Maryland Department of Natural Resources airborne surveys using a highly accurate laser instrument called LIDAR (Figure 7.8), it is roughly estimated that over 180 square miles of land would be inundated by the end of the century under the higher emissions scenario, assuming the

Potential Innundation on Maryland's Eastern Shore

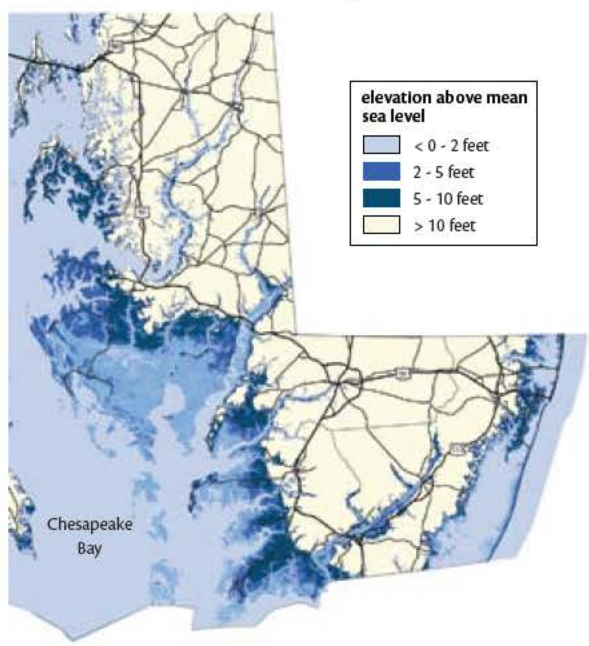


Figure 7.8. Extensive areas of wetlands and low-lying lands less than 2 feet above mean sea level (light blue) are likely to be innundated this century. Lands with elevations between 2 and 5 feet (medium blue) are also potentially at risk. Image based on aircraft LIDAR mapping by the Maryland Department of Natural Resources.

higher sea level rise rates driven by accelerated ice melting (Figure 7.6). If the growth of greenhouse gas emissions is not mitigated, the inundation of land could be more than 60% if the growth of emissions were reversed by mid century, based on comparison of sea-level rise projections under higher and lower emission scenarios. The extent of inundation of dry lands will, of course, be dependent on steps taken to respond to rising sea level, but these estimates reflect the amount of present land that will be below the level of normal spring high tides. One has to also keep in mind that as sea level rises, the volume of the Chesapeake Bay will increase and this will affect the normal range of the tides, in general, making the high tides a little higher (see Section 8).

Over 180 miles of land could be inundated if greenhouse gas emissions are not reduced

Most of the land subject to inundation is naturally located in the lowest lying parts of the State, notably along the Chesapeake Bay side of the lower Eastern Shore in Dorchester, Wicomico, and Somerset counties (Figure 7.8). Several islands (including Smith Island) and necks in this region, some inhabited, may be completely inundated or cut off within this century. Outside of this region, parts of Talbot, St. Mary's, Anne Arundel, and Baltimore counties are similarly susceptible. Assuming the projection included accelerated melting (resulting in sea-level rise to just over 3 feet; Figure 7.6), the homes of thousands of Marylanders would be lost. With a relative sea-level rise of just half that, which should be regarded as likely within the century, 264 miles of roadway, 226 miles of rail line, and 31% of the port facilities in Maryland would be at risk of inundation.

Eroding Chesapeake Bay shoreline.

In addition to inundation, of course, substantial shoreline erosion will very likely occur, but the distance of shoreline retreat will vary greatly by location, depending on the land forms, soils, exposure, structural protection, and other factors. Even shorelines characterized by high bluffs are susceptible to retreat due to undermining and slope failure. The barrier islands of Maryland's ocean shore already experience morphological changes through erosion and overwash. If sea-level rise accelerated to 5 mm/year, as projected under the higher emissions scenario sometime during the middle of the century, it is very likely that northern Assateague Island, south of Ocean City, would fragment with one or more new inlets opening to the Coastal Bays.[95] This would dramatically impact not only this National Seashore but also the Coastal Bays, by exposure to waves and storm surge.

STORMY WEATHER AHEAD?

The relationship between climate change and storms has received much attention after the devastation of Hurricane Katrina in 2005, which produced record storm surge and property loss and awakened the nation to its vulnerability. This relationship has been hotly debated within the scientific community, but another U.S. Climate Change Science Program (CCSP) synthesis report recently provided a consensus perspective based on the latest scientific results and analysis.[13] The Atlantic tropical storm and hurricane destructive potential increased since 1970 in association with warming Atlantic sea surface temperatures. And, it is likely that the annual numbers of tropical storms, hurricanes, and named hurricanes increased over the past 100 years during which the sea surface temperatures also increased. Also, it is very likely that the increase of greenhouse gases contributed to this ocean warming. The CCSP synthesis concluded that it is likely that hurricane rainfall and wind speeds will increase in response to global warming, but could not predict any change in frequency in hurricanes during this century. Two very recent studies have actually projected a decrease in hurricane and tropical storm frequency, but an increase in their wind intensity and rainfall.[96]

There has been a northward shift in the tracks of strong non-tropical storms, such as Nor'easters, but evidence is inconclusive in the Atlantic to draw conclusions about the strength of these storms. The CCSP synthesis concluded that there are likely to be more frequent strong non-tropical storms, with stronger winds and more extreme wave heights.

The degree to which Maryland will be confronted with more frequent or powerful storms depends heavily on the storm tracks, which scientists are not yet able to predict for future decades. However, because of the above projections of storm intensification and because hurricanes will be able to travel farther north as a result of the warming sea surface conditions, it is likely that Maryland will experience more powerful hurricanes or tropical storms and more powerful and frequent non-tropical storms than in the 20th century. It is not now possible, however, to quantify this increased risk.

While more intense storms (for example, with higher wind velocity and greater precipitation) generally produce greater storm surge (raising of the water level by high winds and reduced atmospheric pressure), the storm surge experienced depends greatly on the size, approach, and speed of the storm. For example, Hurricane Katrina produced much higher storm surge along the Mississippi Gulf Coast than Hurricane Camille, which hit more or less the same area with higher winds. Hurricane Isabel in 2003 produced record storm surges throughout much of the Chesapeake Bay because its path carried it up the western side of the Bay, with its counterclockwise winds driving water north all the way.[97] But, its storm surge was higher by about one foot than a large storm with a similar track that hit in the 1930s—the difference being the relative sea-level rise that had taken place since then (Figure 7.2). This means that assessments of future vulnerability to storm surges must take into account both the moving baseline of sea-level rise and the greater potential of more intense storms.

NASA

The 2003 Hurricane Isabel makes landfall on the Mid-Atlantic.

www.wetlandswatch.org

Flood damage caused by Hurricane Isabel, Benedict, Maryland.

Section 8

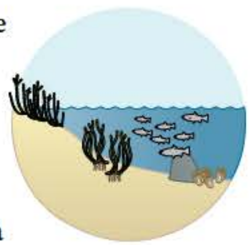
CHESAPEAKE BAY & COASTAL ECOSYSTEMS

KEY POINTS

➤ **Chesapeake and Coastal Bay restoration goals will likely be more difficult to achieve.**
Increased winter-spring runoff washing more nutrients into the bays, higher temperatures, and stronger density stratification tend to exacerbate water quality impairment, alleviation of which is the prime restoration objective. Nutrient loads would have to be reduced beyond current targets to achieve water quality requirements.

➤ **Living resources will very likely change in species composition and abundance with warming.**
A mixture of northern, cool water species and southern, warm water species currently resides in the Chesapeake Bay. Northern species such as soft shell clams and eelgrass are likely to be eliminated by later in the century. Southern species are very likely to increase in abundance because of milder winters.

➤ **As ocean water becomes more acidic, shellfish production could be affected.**
Increasing atmospheric carbon dioxide has already lowered pH, a trend that is very likely to continue. Recent research indicates that the rate at which oysters and other coastal shellfish build their calcium carbonate shells will likely be affected, but whether this would occur in Maryland waters has not been evaluated.



In many respects, the Chesapeake Bay defines Maryland, extending through the center of the state, providing abundant resources, rich cultures, a port to the world, and commanding a major commitment for its protection and restoration. The changing climate will have multiple and complex effects on the Chesapeake Bay as well as on Maryland's Coastal Bays and the nearshore ocean environment. Warming of water temperatures throughout the year, earlier warming and later cooling, changes in precipitation and freshwater runoff, sea-level rise, and stronger winds and tropical and non-tropical storms will affect these coastal ecosystems and economies, including navigation, energy, tourism, and fishing industries. As discussed in the previous section, sea-level rise is very likely to have major consequences for coastal wetlands and shorelines, but will also deepen the bays, affecting both water circulation and biota.

Climate change will complicate the effects of nutrient pollution, the reduction of which is a central objective of the restoration and protection of the bays. Milder winters could lead to increased disease and parasitism in coastal living resources and changes in the species able to live here. Not all effects on Maryland's coastal ecosystems and industries will necessarily be negative. Shorter winters could mean longer growth seasons for blue crabs and improved fishery yields. Reductions in the frequency of ice formation could allow oysters to grow along shorelines and in very shallow water, much as they do in South and North Carolina.

The projected changes in temperature, precipitation, droughts, and floods that would affect coastal ecosystems during the century are described in Section 4; the likely consequences of global climate change on sea levels and storm intensity are described in Section 7. It is very likely that temperature and sea level will increase with the limits projected in Figures 4.2 and 7.6, respectively. For the reasons discussed in Section 4, there is less confidence in the trends and extent of precipitation and runoff.

Moving the Chesapeake Bay south along the coast as depicted in Figure 4.7 is a way to put the warming of the Bay in context. The Bay is displaced by matching the projected future Bay summer-fall temperatures with those presently experienced in estuarine waters to the south.[98] Warming by 2050 under either emissions scenario is likely to change seasonal temperatures to those currently experienced in North Carolina estuaries. The emissions scenarios would make a big difference by the end of the century, however, with conditions approximating present day southern North Carolina under the lower emissions scenario but south Florida under the high emissions scenario!

But, the vision of the future Chesapeake Bay harboring shrimp and alligators should be counter-balanced with caution. Warming will likely not geographically shift ecosystems; the Chesapeake is not likely to be just like Pamlico Sound by the middle of the century, harboring the exact same fish, plants, and animals and supporting similar coastal industries. Rather, changes in these ecosystems cannot be fully predicted and will probably yield novel species combinations, ecosystem adjustments, and mixes of living resources. Differences in the physical environment (for example, tidal range) will continue and changes in river flows and salinity will also affect the future ecosystems. Furthermore, geographic barriers may exist for more southern species to invade the Chesapeake Bay as conditions favor their colonization and native species could adapt to new conditions if they occur gradually.

NUTRIENT POLLUTION

Over-enrichment by human nutrient inputs, or eutrophication, has degraded the entire Chesapeake Bay ecosystem in pervasive ways, and reducing nutrient pollution is the lynchpin of the Chesapeake Bay Program. The Chesapeake 2000 Agreement commits the Bay states and federal government to reduce nutrient inputs in order to restore the quality of tidal waters sufficient to remove them from their listing as impaired, and this was determined to require a 48% reduction of nitrogen loading and a 53% of phosphorus loading, derived from a 1985 base load.[99] Reversing and controlling eutrophication is also a central management objective for the Coastal Bays.[100] While nutrients are essential for productive estuaries, excess nutrients contribute to reduced water clarity, loss of submerged vegetation, and low oxygen in bottom waters during summer months (hypoxia or so-called "dead zones"; Figure 8.1). By affecting temperature, precipitation and runoff, sea level and winds, and possibly nutrient loading, climate change will affect the capacity of Maryland's estuaries to assimilate nutrients and recover from eutrophication.

Reducing nutrient pollution is critical for restoring Chesapeake and Coastal Bays

River flows, nutrients, and hypoxia

Freshwater inflows into the Chesapeake Bay affect salinity and circulation and, thereby, the distribution of organisms and the functioning of the ecosystem. Freshwater inflow typically peaks during the spring as snow melts and precipitation increases.[101] The spring flow delivers a pulse of nutrients that, along with light and rising temperatures, fuels a bloom of microscopic planktonic algae, particularly diatoms, in the upper- to mid-Bay.[93] The spring

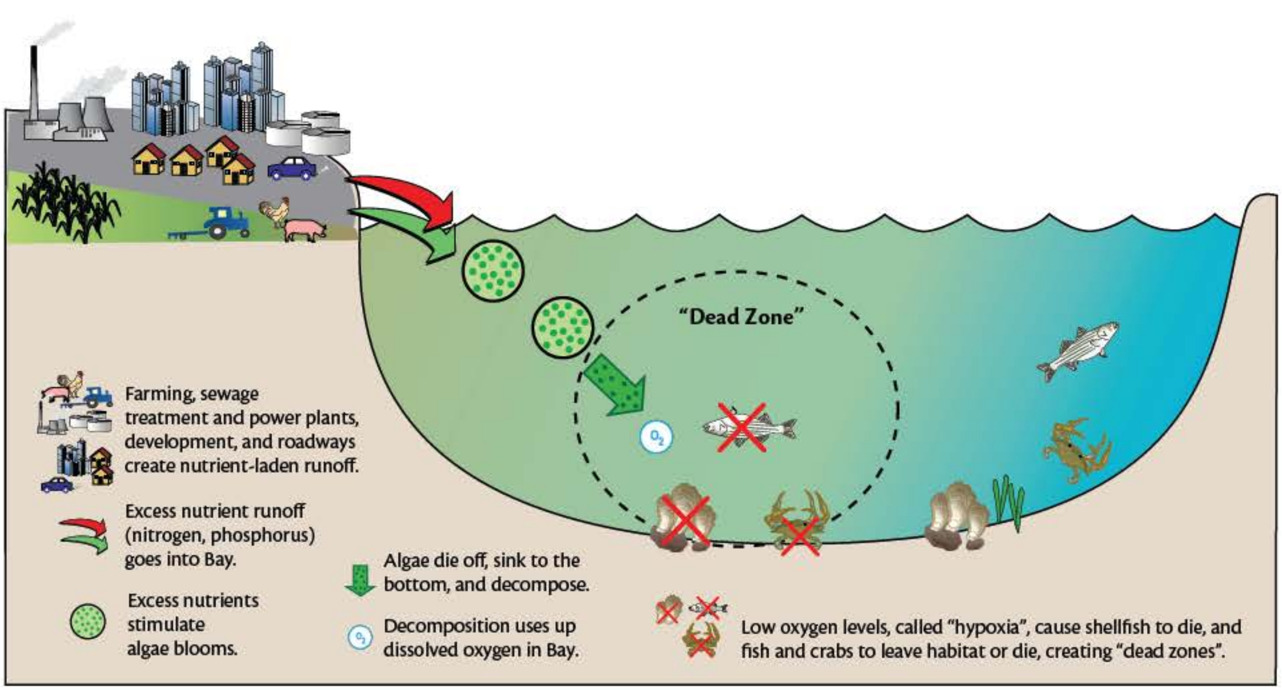


Figure 8.1. Processes contributing to severely low dissolved oxygen levels (hypoxia) in the Chesapeake Bay.

phytoplankton bloom, maintained by the nutrient input and sufficient mixing of the water column, is largely not consumed by zooplankton. Most of the biomass produced sinks to the bottom where it is eventually decomposed by bacteria as temperatures warm toward the summer. The respiration of bacteria consumes dissolved oxygen, which is not replenished by mixing because the bottom water is cooler and saltier, and therefore denser. This density stratification prevents reoxygenation of bottom waters, but when mixing events occur, the nutrients released by microbial decomposition stimulates more algal blooms, thus continuing a vicious cycle that maintains hypoxic (low oxygen) or anoxic (no oxygen) conditions.

Climate models project increasing winter temperatures (by an average of 4 and 7°F for lower and higher emissions scenarios, respectively; Figure 4.2) and rainfall (by about 10-13% under either scenario; Figure 4.8) over the century for Maryland. On the other hand, warming over the Susquehanna River Basin is very likely to reduce the storage of water in the form of snow in the watershed[7] and therefore even out the inflows to the Bay during the winter-summer period. A reduction in the peak spring inflows could result in a reduced spring phytoplankton bloom as nutrients would be delivered more evenly over the winter and spring. Warmer winter temperatures could cause an earlier occurrence of a smaller spring bloom centered in the upper Chesapeake Bay.

Dead zones are likely to expand with higher temperatures and precipitation

These outcomes are largely speculative and based on understanding of recent conditions, but illustrate the complexity of the physical, chemical, and biological process that regulate the production of organic matter in the nutrient-enriched Chesapeake Bay. Of course, these processes will also be subject to change as the climate changes. Temperature increases affect the production of phytoplankton biomass and the grazing of this

Caroline Wicks

An excess of nutrients can lead to large algal blooms that cover shorelines.

Jane Hawkey

Stormwater runoff from roads and parking lots enter Maryland waterways.

biomass by zooplankton.[102] A reduction in winter-spring phytoplankton biomass has been observed in Narragansett Bay, Rhode Island, during unusually warm winters.[103] In particular, and potentially quite significantly, if relative sea level were to increase by as much as 3 feet, as considered in Section 7, the volume of the Chesapeake Bay would increase by about 14%, shifting the salinity gradient, changing physical processes resulting from mixing of fresh and ocean water, and increasing the volume of bottom waters susceptible to hypoxia.

In spite of this complexity, climate change is likely to exacerbate hypoxia. Warmer waters can hold less oxygen to begin with, delivery of nutrients from the watershed would increase with increased precipitation and runoff, and salinity decreases and temperature increases may increase density stratification between surface and bottom waters. Considering these facts, it is more likely than not that hypoxia will worsen as a result of 21st century climate change unless greater reductions in nutrient loading are achieved and sustained. [104,105]

Harmful algal blooms

Harmful algal blooms (HABs) are a growing problem affecting aquatic ecosystems worldwide, including the Chesapeake Bay.[106] These blooms yield high densities of algae that negatively affect other organisms or produce toxins harmful to animals.[107] Humans may be affected by HAB toxins either through direct exposure or by consumption of seafood containing the toxins. The Chesapeake Bay and the Coastal Bays are home to several potential HAB-forming species, including dinoflagellates (e.g., *Pfiesteria piscicida, Prorocentrum minimum, Karlodinium micrum*), a raphidophyte (*Heterosigma akashiwo*) and a cyanobacterium (*Microcystis aeruginosa*).[108] HABs are commonly associated with nutrient over-enrichment, although many other factors affect their occurrence and prevalence. Some species of harmful dinoflagellates, such as *Prorocentrum*, and cyanobacteria (blue green algae) seem to be favored and grow faster under high temperature.[109]

Climate change is very likely to produce warm surface water temperatures and prolonged density stratification between surface and bottom waters conditions that favor dinoflagellate and blue green algal species, some of which are HAB-forming. But without more specific evidence and consideration of other moderating effects, such as predators and competitors, it is not possible to conclude that HABs will increase as a result of warmer temperatures alone. Nutrient inputs will remain the key factor in controlling algal blooms in the warmer bays.

Effects on harmful algal blooms are difficult to predict

Habitat squeeze

The high oxygen requirements for respiration under high temperatures and expansive dead zones act to reduce the habitats that can be used by fish such as striped bass, or rockfish as they are locally known. These factors may co-occur to the point of acute stress and fish kills, which already occur with some frequency in the Chesapeake Bay and in poorly flushed tidal creeks and canals in the Coastal Bays. Alternatively, the fish might swim away to avoid the stressful conditions in what might otherwise be preferred habitats. This can lead to increased risk of predation and capture by fishers or to increased competition within the reduced, remaining habitat (Figure 8.2). The high densities of fish in the few

Weems Creek fish kill due to low dissolved oxygen, June 2007.

Squeeze Zone for Striped Bass

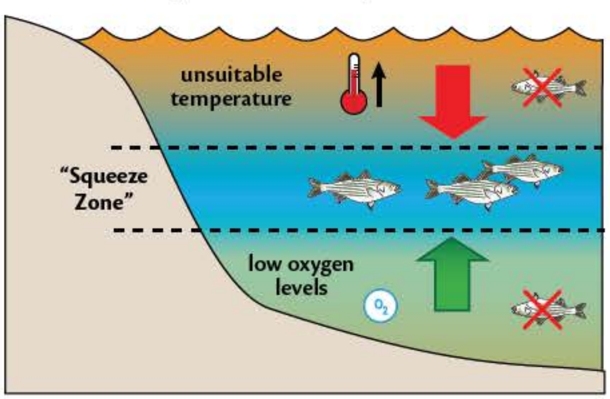


Figure 8.2. Climate change could compress the habitats suitable for striped bass by increasing surface water temperature to physiologically stressful levels and expanding the volume of bottom waters experiencing hypoxia or anoxia.

remaining suitable areas can also increase the risk of disease and parasitic infection or infestation, contributing additional stress to a fish that is already behaving, feeding and growing below par. Habitat squeezes in the Chesapeake Bay due to the degraded water quality and warming temperatures since 1950 may have already contributed to local extinctions of sturgeons, which are among the least tolerant Chesapeake Bay species to hypoxic summertime conditions.

Management implications

Although still far from reaching the restoration goals for the Chesapeake Bay, considerable reduction of nitrogen and phosphorus loads to the Bay has been accomplished though large public investments in waste treatment facilities and land management practices to reduce the runoff of nutrients. In addition to effects that climate change might have on hypoxia, harmful algal blooms, and habitat suitability, it could affect agricultural practices and forest health, and increase the frequency of flooding in ways that deliver more nutrients to the estuaries and worsen the symptoms of eutrophication as well as cause additional challenges in those sectors. If this happens, nutrient loads would have to be reduced beyond current targets in order to meet the water quality need to restore living resources.

Greater reductions in nutrient loads may be required to achieve restoration goals

ESTUARINE SEDIMENTS

The sediment that lines both the shoreline and the bottom of Chesapeake Bay and the Coastal Bays also shapes the varied habitats of its productive ecosystem. If this sediment remains on the shore or on the bottom and if inflowing rivers run clear, then the clarity and productivity of the Bay's waters are only limited by the nutrient supply and perhaps the stratification. However, if sediment is stirred into these waters, by waves, currents, and their associated turbulence, or delivered by muddy rivers, then it may deprive submerged vegetation of needed light, deprive oysters their ability to sustain viable reefs in the face of siltation, and alter the foraging or predation of animals dependent on visual cues. Because a portion of the bottom sediment is easily erodible, estuarine circulation creates a zone of maximum turbidity near the head of Chesapeake Bay.[110] Although this turbidity maximum is confined to a limited reach of the estuary, it constitutes an ecosystem crucial to early life stages of important fisheries.[111]

Over geological time, estuaries are ephemeral

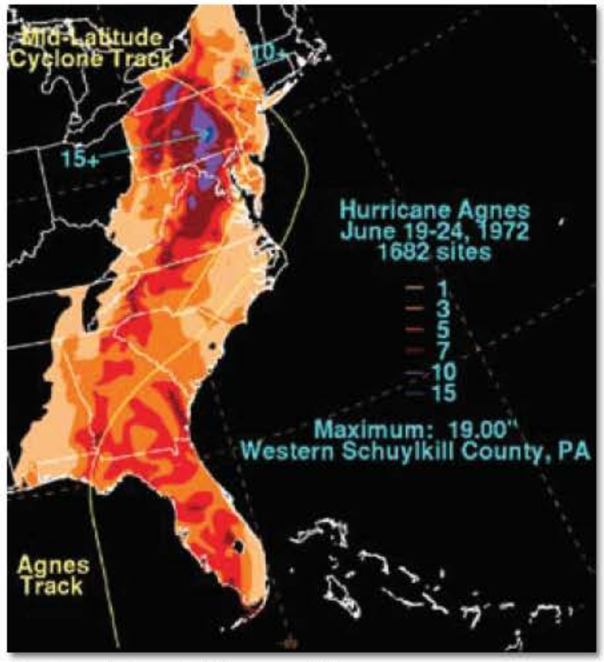
Jane Thomas

A plume of sediment, possibly from an adjacent construction site, fills a river.

features, ultimately losing the battle between sea-level rise which acts to create them and the movement of sediment off the land to fill their shallow depths. With the slowing of the rise of sea level 5,000 years ago (Figure 7.1), despite the fact that land subsidence was still raising the water levels, the filling of the Chesapeake Bay with sediments was also occurring, both from the head with sediments coming down the Susquehanna and the other great rivers and from the mouth with sand transported into the mouth of the Bay from the continental shelf. Land clearing during the 17th and 18th centuries resulted in large influx of sediments, filling in many smaller tributaries that were navigable during the colonial period. Continued relative sea-level rise a century ago, dominated by the sinking of the land rather than the rising of the ocean (see Section 7), eroded shorelines and upland deposits, bringing more sediments into the estuary. The gradual disappearance of Chesapeake Bay islands provides a graphic testament to this progression.[112]

The processes that control delivery of sediment to the Bay's waters—shoreline erosion, resuspension, or erosion in the watershed and subsequent delivery by rivers—are, in turn, controlled by the weather. As in other bodies of water, sediment transport in the Bay and its watershed occurs as a comparatively slow, inexorable process occasionally punctuated by episodes of wholesale erosion and deposition driven by violent storms. Hurricanes are especially effective because they combine extreme winds and extreme precipitation. As far as sediment is concerned, extreme precipitation is the greater concern because it rapidly erodes the watershed. Increased flashiness in runoff due to both land development and, more recently, attributable to climate change washes more sediment off the land surface and erodes stream beds. Storm-driven water flow can be devastatingly effective in moving large quantities of sediment in a short interval. As Hurricane Agnes passed through the Chesapeake watershed in 1972, dropping 3 to 6 inches of rain onto already saturated soils, some 31 million metric tons of sediment were swept into the Bay, depositing 40 years worth of sediments based on the average deposition rate.

The scale and geometry of Chesapeake Bay make it particularly vulnerable to tropical cyclones that travel a path with their center or eye moving on the west side of the Bay.[113] While eastern-track storms act to force water out of the Bay, these western storm tracks create destructive storm surges, such as occurred during the recent 2003 Hurricane Isabel. The linear nature of the Bay and its larger tributaries enables long fetches that allow efficient transfer of wind forces that drive these larger surges; these surges enhance the natural two-day oscillation of water level in the Bay.



NOAA

Hurricane Agnes rainfall accumulations.

As discussed in Section 7, global climate is very likely to accelerate sea-level rise and thus the erosion and inundation wetlands and low-lying lands. Erosion, as the shoreline retreats inland, will disperse sediment into the Chesapeake Bay and Coastal Bays, further contributing to the excess turbidity that limits light penetration. Stronger hurricanes and non-tropical storms, which are likely in this warming era, will increase the probably of sustained heavy downpours such as experienced during Hurricane Agnes. Such large storms that are accompanied by heavy and widespread precipitation throughout the watershed can have pervasive and lasting impacts on coastal ecosystems. Hurricane


J. Stein

Shoreline erosion from storms.

Agnes not only added a huge quantity of sediments to the Chesapeake Bay, but also added nutrients and organic matter, devastated oyster reefs and aquatic vegetation beds, and affected key species, with repercussions to the ecosystem lasting for decades.

LIVING RESOURCES

Present mixture of cool and warm species

The Chesapeake Bay is famous for its role in supporting spawning, nursery, and feeding habitats for diverse and important living resources. Historically, U.S. fisheries for shad, herrings, striped bass, menhaden, and oysters were centered here in the Chesapeake Bay. The Chesapeake Bay remains one of the most important nurseries for striped bass, croaker, eels, and blue crabs. The Atlantic menhaden fishery is now principally limited to the lower Chesapeake Bay, reflecting the productive feeding conditions that occur there during summer and fall months. Size, surrounding geography, tides, currents, and other physical features all contribute to the Chesapeake Bay's productive food webs. But the diversity and year-to-year abundances of living resources also depend heavily on the Chesapeake Bay's latitude and seasons. The Chesapeake Bay represents a transition zone between more southerly ranging temperate-subtropical species and more northern range boreal-temperate species. Interestingly, the Chesapeake Bay also shows the greatest seasonal temperature range of any other major U.S. Atlantic estuary. Therefore, in the future, warming in the Chesapeake will likely diminish the role of boreal-temperate species (Figure 8.3) and affect seasonal temperature fluctuations, which currently have an important role in nursery function and how food webs and fish communities are structured.[114]

Chesapeake Bay is a transition zone between northern and southern species

Shift to warm species

More northerly, cool temperature species such as eelgrass, soft shell clams, and sturgeons have already been in decline in the Chesapeake Bay. Soft shell clams occur at their southern limit in the Chesapeake Bay and their Maryland landings have declined from over 6 million pounds in the 1960s to less than 300,000 pounds in recent years.[115] Trends of diminished production of soft shell clams in Europe are related to climate, with poor juvenile production linked to warming at the southern extreme of its range in the Netherlands portion of the Wadden Sea.[116] Warming in the Chesapeake and Coastal Bays, coupled with existing stresses due to disease, pollution, and sediments, is likely to eliminate commercial harvests of the once economically important soft shell clam in the coming decades and may extinguish its local populations all together. As indicated below, warming will also confound efforts to restore eelgrass and sturgeons, compounding the other stresses, such as turbid waters and hypoxia, presently limiting their recovery.

Atlantic croaker is a subtropical fish that is already making significant inroads in temperate estuaries like the Chesapeake and Delaware Bay. Croaker juveniles can reside during winter months in Mid-Atlantic estuaries but can occasionally experience lethally cold temperatures, particularly to the north. During recent decades, more moderate winter temperatures in the Chesapeake Bay have increased juvenile growth and survival. Indeed during the last twenty years, Chesapeake landings

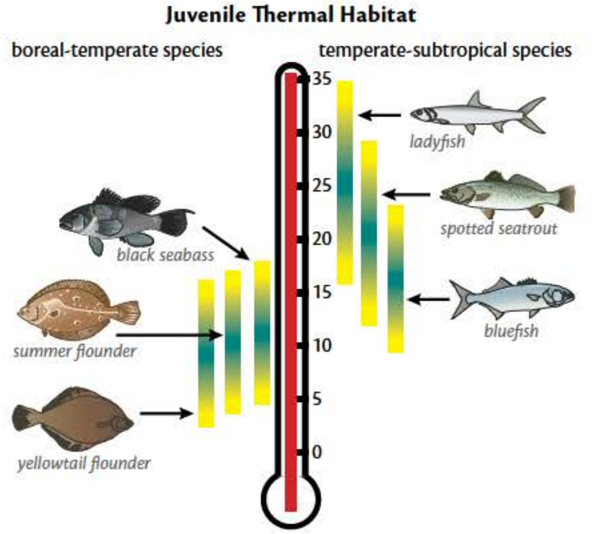


Figure 8.3. Thermal ranges for juvenile fishes native to U.S. Atlantic coastal waters (temperature in degrees C).[114]

Atlantic croakers are expanding their range in the Mid-Atlantic.

of Atlantic croaker have increased ten-fold to 8.6 million pounds in 2006 and now exceed commercial landings for striped bass (3.6 million pounds).[117]

The Atlantic croaker belongs to the drum family, which also include black drum, red drum, weakfish, spotted and speckled sea trout, spot, and Northern and Southern kingfish. Other members of this family of fishes, together with other more sub-tropical species, are likely to become more frequent and longer term visitors to the Chesapeake Bay. Fish species that already occur in Virginia coastal waters that should also become more prevalent and abundant with increased coastal water temperature include southern flounder, cobia, spadefish, Spanish mackerel, mullet, tarpon, and pinfish. On the other hand, more temperate species such as yellow perch, white perch, striped bass, black sea bass, tautog, summer and winter flounders, silver hake, and scup will be stressed by warming of the coastal waters.

Milder winters could also allow brown and pink shrimp to complete their life cycles in the Chesapeake and Coastal Bays, where they are now only occasional summertime visitors. These shrimp are abundant in North Carolina (e.g., Pamlico Sound), where they support important fisheries. Establishment of shrimp populations in the Chesapeake Bay could result in important commercial opportunities in the future, but would also have important but unpredictable effects on both the prey and predators of shrimp.

Warming could also favor the establishment of invasive populations of nonnative species. This is particularly true for species from distant parts that hitchhiked on or in the ballast water of ships. Also, species may escape captivity and establish local populations. For example, the beautiful lionfish, a native of the Indo-Pacific and popular with salt-water aquarists, was inadvertently introduced in Florida in the early 1990s and has expanded its range northward to North Carolina, achieving populations equal in number to those of native groupers.[118] Adding an additional species, such as the lionfish, to the mix has the potential to adversely affect native fishes through competition for prey and habitat and by directly eating native juveniles. With warming of coastal ocean temperatures, the lionfish is expected to continue a northward range expansion (Figure 8.4). Similarly, warmer waters may aid the spread (accidental or otherwise) of northern snakehead fish, which now occurs in the Potomac River[119], to other parts of the Chesapeake watershed.

Warmer winter temperatures could open the door to more non-native, invasive species

Figure 8.4. Locations in the Atlantic Ocean where lionfish have been reported as of May 2003.

Changed seasonality

Several important fish species show cycles of dominance that are the opposite of each other. Bluefish were abundant in the 1970s and 1980s but then declined during the recent period of high striped bass abundance. These cycles are thought to be due to the seasonal patterns of temperature and precipitation. Winter and early spring conditions seem particularly important in 'setting the clock' for patterns of juvenile production observed during the subsequent summer and fall seasons. Cold winter temperatures and high winter flows are associated with high abundance later in the year of juvenile Atlantic silversides (an important forage fish), striped bass, white perch, and Atlantic needlefish.[120] Species associated with the converse—low winter flows and high winter temperatures—include bluefish, spot, bay anchovy, and northern puffer.

Striped bass from the Chesapeake Bay.

Shifts between these two groups occur even when winter temperatures differ less than 2°F, well within the range of warming projected in the next fifty years. Species will adapt to some degree to changing environmental changes, but because this will require generational time scales, lowered abundance of the group of species that includes striped bass are likely for the Chesapeake Bay.

Milder winters would lead to longer growing seasons for species such as sea grasses, oysters, blue crab, eels, white perch, and the resident portion of the striped bass population. Blue crabs become functionally dormant during winter months when temperatures drop below 50°F. Below 41°F in bottom waters, winter temperatures become lethal.[121] Winter temperature projections indicate a 20% reduction in the number of days with less than 50°F by 2050 and, under the higher emissions scenario, a 36% reduction by 2100. The projections suggest that by mid-century there would be no severe winters with more than a week of water temperatures below 41°F. These warmer conditions are likely to shorten the time it takes for blue crabs to grow and reproduce, leading to increased productivity and yield to commercial fisheries. Of course, this assumes that there would be sufficient prey for blue crabs and that warming during the summer does not reduce the growth rate or increase the death rate as a result of greater disease incidence or expanded hypoxia.

Milder winters could mean longer growing seasons for species such as blue crabs

The degree to which the Chesapeake Bay freezes over is already much reduced in comparison to fifty years ago. The reduced occurrence of ice in shoreline habitats could permit oysters to colonize sheltered shorelines and very shallow waters to form reefs that emerge at low tide, much as they do now in North Carolina. Such reefs could provide new opportunities for restoration and aquaculture by enabling access and enforcement of protection of rebuilding or leased bottom reefs.

Warming and the shifting of seasons are likely to affect migration and spawning behaviors of Chesapeake Bay fish. Striped bass, shads and other fish that migrate into the Chesapeake for spring spawning will likely shift their arrival times to earlier dates. Such a shift is already apparent in migrating fish in other regions. Spawning migrations by Atlantic salmon in the Connecticut River are now over ten days earlier than in 1978.[122] American shad migrated five weeks earlier in 1993 than in 1949 in the Columbia River.[123] Changes in timing of spawning migrations by adult fish can influence early survival and growth of their offspring. For instance, fish larvae in the Chesapeake Bay rely on spring plankton blooms to support their growth and development. Early spawning migrations by adults could result in a 'mismatch' [124] between spawning and plankton blooms needed to support the growth and survival of larvae (Figure 8.5).

Another type of mismatch that can occur is between migration timing and fishing regulations. If changes in the timing of migration are sufficiently large, they may impact the timing and duration of a fishing season. For example, the Maryland 'trophy' striped bass recreational season targets post-spawning individuals. Here, early spawning could effectively reduce the fishing season if the season has a fixed start date. In response to increasing temperatures, management agencies may need to explore temperature-specific regulations, rather than fixed fishing seasons.

The Great Shellfish Bay

Native Americans referred to it as Chesepiooc, or

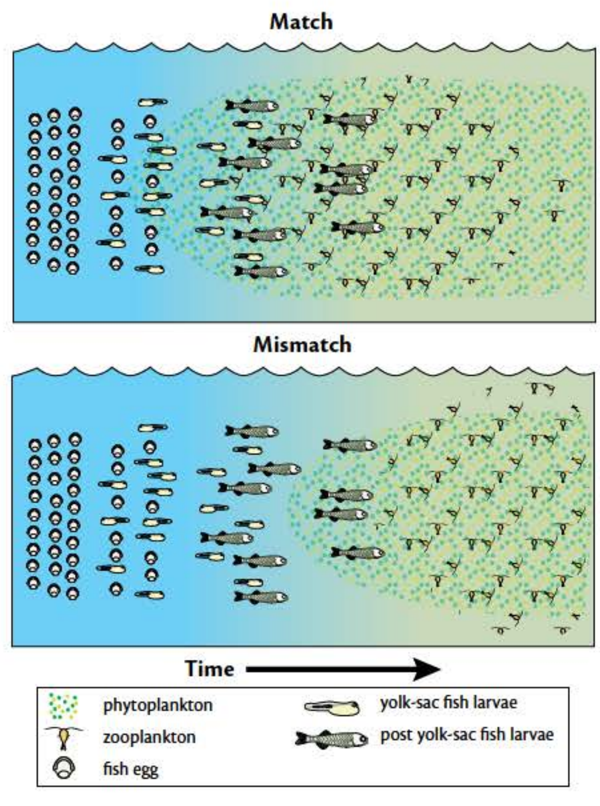


Figure 8.5. Matching of first-feeding fish larvae with the timing of zooplankton peak abundance. A match occurs when spawning is well-timed and there is overlap between the occurrence of first feeding larvae and peaks in zooplankton abundance and favors early growth and survival. Mismatches of timing and location correspond to poor growth and survival conditions.

great shellfish bay, because of the vast abundance of oysters that once characterized the Chesapeake Bay. Decimated initially by overharvesting that resulted in removal of their reefs themselves and later by introduced diseases, native oysters are present at a very small fraction of their original abundance. Substantial efforts are underway to try to determine how to increase oyster aquaculture and to restore oyster reefs for the role they play in providing habitat for other organisms and clearing up estuarine waters by their filter feeding.

Variations in climate have always been important in determining the success of oysters. Temperature and precipitation—through its effect on salinity—affect reproduction, the development of larvae, and the survival of newly settled oyster spat. Still, through the 1970s, the abundance of juvenile oysters in one year was heavily influenced by the abundance of the adult parents the year before.[125] Recently, it appears that at such low abundance, the number of adults has relatively little influence on the number of juveniles, which is now predominantly determined by water temperature and particularly salinity.[126] If higher river runoff regularly lowers Bay salinity, fewer juvenile oysters would be expected to survive, but if sea-level rise increases the volume of the Bay sufficiently to increase salinity, the reverse would be true.

The two prevalent oyster diseases, commonly called Dermo and MSX, are also likely to respond to climate change. Dermo epidemics are more severe in Chesapeake Bay after dry and warm winters. Increased water temperatures cause more rapid cell growth by the Dermo parasite once it has infected an oyster.[127] As conditions have warmed, Dermo has extended farther up the East Coast, even to New England.[128] But it may be the case that the Chesapeake Bay is already warm enough so that temperature is not a factor limiting Dermo epidemics except under higher salinity conditions. MSX is also more prevalent in oysters after dry and warm winters and less so following cold winters (less than 37°F) and under low salinity.[129] Successive cold winters keeps MSX in check, but, as this becomes less likely with the warming waters of the Chesapeake Bay and Coastal Bays, this disease is likely to remain at least as prevalent if not more so.

Warmer conditions have allowed oyster diseases to spread

Overall, the net effects of climate change on oyster populations, aquaculture, and restoration are difficult to project. They will depend not only on the direct effects of salinity and temperature on oyster growth and survival, but importantly on how the changing conditions affect the prevalence and virulence of the disease organisms, which warmer conditions should favor. Still, it should be remembered that native oyster populations prosper in Gulf Coast estuaries, which experience higher temperatures and more variable salinities.

Aquatic vegetation

Submerged aquatic vegetation (vascular plants that live underwater) constitutes a very important component of the Chesapeake Bay and Coastal Bay ecosystems. These plants increase water quality in shallow water areas by reducing the resuspension of sediment and releasing oxygen to the sediments, thereby enhancing nutrient recycling. The vegetation provides habitat for many animals, including blue crabs, which use it as a refuge from predators during early life.[130] There is currently a worldwide decline in coastal submerged plants, or seagrasses, including in the Chesapeake Bay and Coastal Bays.[131] Much

NOAA

Oyster reef, Chesapeake Bay.

Jane Hawkey

Aquatic vegetation provides habitat for juvenile fish and crabs.

of this loss is a result of nutrient over-enrichment, which increases shading by phytoplankton and stimulates the growth of algae on the blades of vegetation, thereby reducing the light needed for photosynthesis.[93]

Aquatic vegetation requires suitable temperature, salinity, nutrients, and, in particular, light.[132] Climate change could affect, directly or indirectly, all of these variables. As in the case of fish and other animal species, aquatic plant species have different latitudinal distributions that are closely related to their temperature tolerance. The dominant aquatic plant species under the higher salinity conditions of the lower Chesapeake Bay and the Coastal Bays is eelgrass (*Zostera marina*), a boreal-temperate species with a southern limit of distribution in North Carolina.[133] Largely as a result of declining water quality and increased light limitation, eelgrass has become much less abundant in Maryland bays. During the high salinity and high water clarity conditions that existed in the 1960s, eelgrass was found as far up the Chesapeake Bay as Kent Island, but now is largely limited to the Tangier Sound region (Figure 8.6), where it provides valuable habitat for early juvenile blue crabs and refuge for the highly vulnerable soft stages of adults.

Eelgrass is at risk of elimination and other species will replace it

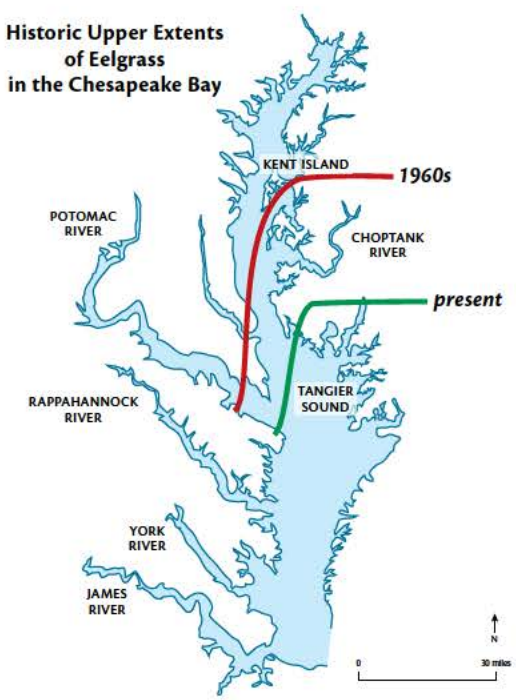


Figure 8.6. Changes in the distribution of eelgrass (*Zostera marina*) in the Chesapeake Bay.

At high summer temperatures, eelgrass photosynthesis cannot keep pace with its respiration and the plant loses its leaves and even its below-ground rhizomes may die.[134] During unusually hot summers, for example in 2005, the dieback of eelgrass was extensive and recovery in the following year was dependent on the bank of seeds left in the sediment. Because eelgrass seeds do not remain viable for over a year, if there were a succession of hot summers, eelgrass populations could be eliminated from the Bay. Consequently, the outlook for eelgrass in the warming bays is not promising. By mid-century, it is as likely as not that eelgrass beds will no longer exist in the Chesapeake Bay under the lower emissions scenario, and likely that it will be functionally eliminated under the higher emissions scenario. It is very likely that eelgrass will be completely extirpated by the end of the century under either scenario. It is possible, however, that shoalgrass (*Halodule beaudettei*), a subtropical species that is abundant in higher salinity portions of North Carolina's sounds could colonize the Chesapeake Bay and Coastal Bays as the winters warm. However, it does not tolerate low salinity as much as eelgrass and, thus, its distribution in the upper Bay would be more limited. Shoalgrass is also more ephemeral and provides less robust habitat than eelgrass.

As sea level continues to rise, increasing water depths will reduce the light available to aquatic vegetation where it presently occurs. However, the vegetation could migrate shoreward and even occupy areas that are presently tidal wetlands or dry land. However, as wetlands erode away, hard clay-rich deposits often remain, a consolidated remnant of older wetland soils. These clay deposits are not suitable soils for submerged vegetation and until covered by a veneer of sand will not be colonized.[135] With the increased volume of the Chesapeake Bay because of accelerated sea-level rise, higher salinity conditions are likely to extend farther up the Bay. While greater intrusion of salinity may be beneficial to seagrasses such as eelgrass and shoalgrass (if it successfully colonizes the Bay), it could constrict the habitat suitable for plants originating from fresh waters, such as redhead grass and sago pondweed, that are prevalent in lower salinity regions, where aquatic vegetation is currently expanding as water quality improves.[93]

While the net effects of climate change on aquatic vegetation are difficult to predict because of the complex and interacting effects of temperature, salinity, water quality, and sea level, it is very likely that the biomass, species composition, and distribution of aquatic vegetation in the Chesapeake Bay and Coastal Bays will be significantly affected by climate change.

OCEAN ACIDIFICATION

In addition to its greenhouse effect, the increase in the concentration of carbon dioxide in the atmosphere is gradually acidifying, or lowering the pH, of the ocean. Much of the carbon dioxide that is released from human activities is actually taken up by the ocean, moderating its effect on global warming. However, when carbon dioxide dissolves in sea water, it decreases its pH. From the beginning of the industrial era, pH has declined about 0.1 units from its normal 8.18, and may decline by a further 0.3 to 0.5 units by 2100.[2] While this will not make the oceans actually acidic (below 7 pH units), such a decline in pH affects the ability of organisms to create shells or skeletons of calcium carbonate because lowering the pH decreases the concentration of the carbonate ions that are required.

Ocean acidification is the sleeper issue of global change, because not only are the potential effects on the world's coral reefs profound, but the process of acidification also reduces the ocean's capacity to absorb more carbon dioxide from the atmosphere. The effects of ocean acidification have just recently been receiving attention, most of which is focused on corals and the plankton of the open ocean. Recent studies have shown that mollusks that are ecologically and economically important in coastal waters may be vulnerable to the effects of ocean acidification. Mussel and oyster calcification rates were projected to decline by 25 and 20%, respectively by the end of the century[136], as well as the ability of oyster larvae to form their thin shells when pH was reduced to 7.4 through addition of carbon dioxide.[137]

Declining ocean pH affects ability of oysters and other shellfish to form shells

Research on the processes and effects of acidification in Mid-Atlantic estuaries and coastal waters has scarcely begun. Important questions remain regarding the interaction of the bicarbonate created when carbon dioxide dissolves in these waters with other chemical constituents. This will affect the level of acidity likely to be experienced and the effects that might be realized not only on mollusks, but also crustaceans, starfish, and other organisms that create calcareous skeletons.

Holly Weiss

Maryland beach.

Ben Fertig

The native eastern oyster, *Crassostrea virginica*.

Section 9

HUMAN HEALTH

KEY POINTS

- **Health risks due to heat stress are very likely to increase if emissions are not reduced.**
  Under the higher emissions scenario, in particular, heat waves are projected to greatly increase risks of illness and death before the end of the century, with an average of 24 days per summer exceeding 100°F. Some, but not all, of these increased risks can be reduced by air conditioning and other adaptation measures.

- **Respiratory illnesses are likely to increase, unless air pollution is greatly reduced.**
  More ozone, responsible for multiple respiratory illnesses, is formed under prolonged, high temperatures. Releases of air pollutants (nitrogen oxides and volatile organic compounds) that cause ozone to be formed have been declining, but would have to be reduced much more to avoid a reversal in progress toward achieving air quality standards.

- **Increased risks of pathogenic diseases are less likely.**
  The mortality due to vector-borne and non-vector borne diseases in the United States is low because of public health precautions and treatment. Climate change might affect the exposure of Marylanders to pathogens such as the West Nile virus, but precautions and treatment could manage this risk.

Human well-being is obviously affected by the weather and the changing climate will have multiple ramifications for human health as well as comfort and enjoyment. Human health has the greatest sensitivity to climate change with regard to heat stress; the effects of storms that generate floods and extremely high winds; air pollution effects, particularly as they cause or exacerbate asthma and other respiratory maladies; and diseases caused by pathogens that are borne by insects and other vectors, water, and food.[138] The risk of storms and floods are addressed earlier in this assessment. Here the potential impacts of climate change-related heat waves, air quality, and pathogenic diseases on human health in Maryland are evaluated.

HEAT WAVES

Global warming is likely to result in substantially higher temperatures both in winter and summer in Maryland. While there could be some benefits in terms of reduced deaths from cardiovascular disease (for example, as result of milder winters) Maryland's population experiences very few deaths with its temperate climate related to extreme winter temperatures. Rather, most assessments in the United States have appropriately focused on the health risks of extreme heat. In six out of ten recent years, heat has been the leading weather-related killer in the United States.[7]

Concerns about the increased health risks from heat waves caused by global warming are not far-fetched. The death of an estimated 35,000 people, attributable to the August 2003 heat wave in Europe, was a sobering experience.[139] Parts of France experienced seven consecutive days with temperatures more than 104°F and 14,800 people died in that country alone. The situation in Europe

NOAA

Dawn brings on the day's heat.

was particularly acute because the population was not acclimated to warm summers and there was little air conditioning. Most of those who died were elderly. Closer to home, a 1995 heat wave in Chicago resulted in an estimated 696 deaths.[140] While the European heat wave was related to unusual weather patterns and not primarily to climate change, climate models predict frequent summer conditions not unlike those in 2003 during the latter part of the 21st century, indicating that, for many purposes, the 2003 event can be used as an analog of future summers in climate impact assessments.[141]

Heat stress can result in illnesses caused by heat cramps, fainting, heat exhaustion, and heatstroke and result in death.[142] Except for cramps, heat-related illnesses are the result of the body's failure to regulate its internal temperature. Our bodies respond to hot weather by an increase in blood circulation and increase in perspiration, both in an attempt to rid the body of heat. The effectiveness of such heat loss is reduced when air temperature and humidity increase. The ability to increase circulation may be limited by heart rate and the blood volume, which is reduced because of the loss of body fluids.

Several factors can increase the risk of heat-related illness. Both individuals over 65 and the very young are at higher risk because they have less ability to control internal temperatures and are more susceptible to dehydration. Reduced physical fitness, obesity, existing illnesses, and the use of medicinal drugs such as stimulants and beta-blockers all increase the risk of heat stress. Individuals not acclimated to high temperature or suffering from exertion are also more susceptible. City dwellers, particularly those of lower economic status who cannot afford air conditioning, are at greater risk because of the urban heat island effect, where buildings and paved surfaces hold the heat well into the night.[143] Many of those who die of heat stress live alone and do not seek treatment or are not discovered until it is too late. And most of those who die in urban areas as a result of heat stress succumb during the night, when temperatures are expected to rise even more than during the daytime.[42]

The average annual frequency of days with a maximum temperature exceeding 90°F in Maryland is projected to grow gradually over the century, but more dramatically later in the century. Near the end of the century under the lower emissions scenario, the model averages project about 64 days per year would exceed 90°F and 10 days per year would exceed 100°F (Figure 4.4). Under the higher emissions scenario, these numbers would grow to 95 and 24 days per year, respectively. These numbers would be higher in urban areas due to the urban 'heat island' effect. These projections are generally similar to those derived by the Northeastern Climate Impacts Assessment for Philadelphia (Figure 9.1).[7] Put another way, these projections indicate that toward the end of the century under the high emissions scenario, it would be a rare summer day when the high temperature did not top 90°F and there would be nearly a month where temperatures reached 100°F. A considerable increase in 90°F days is very likely inevitable, even if greenhouse gas emissions were reduced around the middle of the century (lower

With continued growth in emissions, 24 days per summer are projected to exceed 100°F

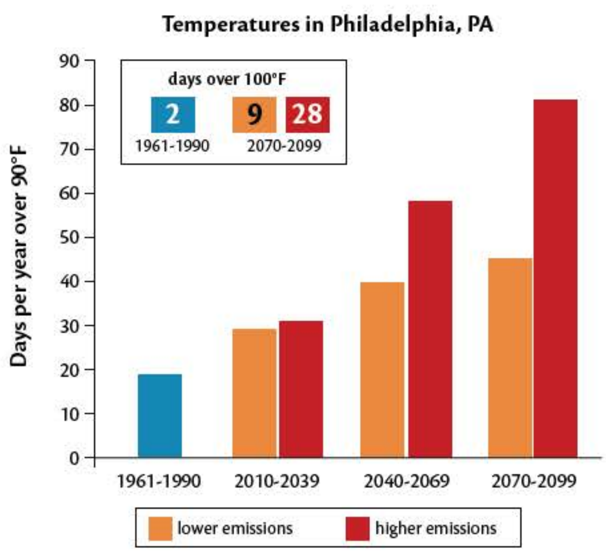


Figure 9.1. Model projections of number of days per year that the maximum temperatures would exceed 90°F and 100°F in Philadelphia according the NECIA.[7] The higher emissions scenario employed assumed more rapid growth of greenhouse gas emissions than the higher emissions scenario in this assessment.

Andrea Hetherington

Cooling off in the intense summer heat.

emissions scenario), but only about half as many 100°F days would occur if emissions were reduced.

Of course, as the frequency of very hot days increases so does the likelihood that there will be a successive number of these days, i.e., a heat wave. Based on the model projections, there is a high probability that, late in the century, heat waves with daily temperatures exceeding 90°F would last more than 60 days is high under the higher emissions scenario. Under the low emissions scenario in most years, heat waves would not exceed 20 days. The difference between the scenarios is even greater for severe heat waves such as experienced in Europe in 2003 (successive days with temperature exceeding 100°F).

Based on these temperature and heat wave projections, Maryland is likely to confront substantially increased heat-related health risks by the mid-century and beyond. By late in the century under the high emissions scenario, this situation is likely to become very serious, with life threatening conditions developing nearly every year, particularly in the Baltimore and Washington urban areas because of the urban heat island effect and more at-risk individuals living there. Beyond threatening life for the most vulnerable, these oppressive conditions would curtail outdoor activities and diminish productivity in commercial activities requiring outdoor work. Under the lower emissions scenario, heat-related health risks would increase substantially from the present condition but much less so than with the unmitigated growth in emissions.

Heat-related health risks likely to increase significantly in urban environments

Of course, there are steps that can be taken to lower these health risks. Within limits, acclimation to higher outdoor temperatures and various adaptation measures can lower the incidences of heat-related deaths. Adaptation measures include effective early warning and response plans for heat waves, air conditioning, and better education about personal precautions, such as drinking more fluids, wearing light colored and loose fitting clothing, and limiting outdoor activity. Over the longer term, building codes can be designed to reduce the urban heat island effect, for example, by increasing the tree canopy and including reflective or green roofs. More frequent and severe heat waves will very likely increase requirements for air conditioning, extend the air-conditioning season, and increasing peak-load electricity demands at the very time there will be a premium on energy conservation to mitigate greenhouse gas emissions.

AIR QUALITY

Global climate change could affect human respiratory health by changing levels of air pollutants and the types and levels of pollen. For the United States, impacts of climate change on ground level, or tropospheric, ozone are much more likely to be more important than for other air pollutants. This is due to the importance of high temperature in the formation of ozone as well as the large areas of the country currently affected by ozone levels exceeding national standards (Figure 9.2). Central Maryland is among the most affected regions in the nation.

Ozone can affect human health by irritation of the respiratory system, reducing lung function, aggravation of asthma by increasing sensitivity to allergens, increased susceptibility to respiratory infections, and inflammation and damage to the lining of the lungs, causing chronic obstructive pulmonary disease (COPD). Effects can range from coughing and shortness of breath to permanent

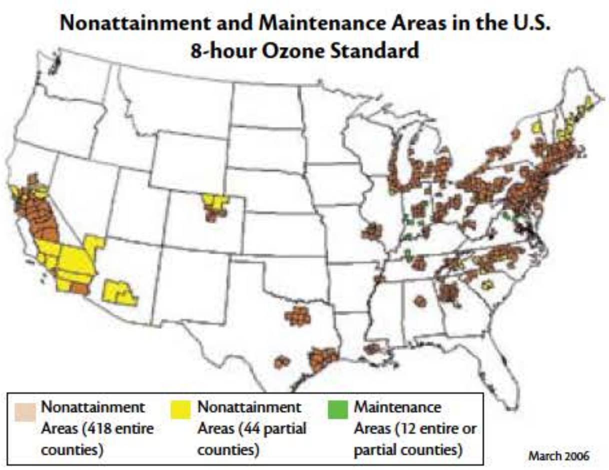


Figure 9.2. Counties not attaining the 8-hour ozone standard include most Maryland counties.

University of North Carolina

Physicians review lung x-rays.

scaring of the lungs and even death. Central Maryland has some of the highest incidence of asthma and acute respiratory illness in the country. It is estimated that about 2,000 Marylanders die each year because of chronic lower respiratory illnesses.

Maryland has made substantial progress in controlling air pollution. Baltimore and Washington areas are on a path leading to compliance with the National Ambient Air quality Standards (NAAQS) by 2009, but changes in the global background could reverse this progress and require even deeper reductions of the pollutants responsible for ozone formation. Human activities do not emit ozone per se, but our activities result in the release to the atmosphere nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs). NOx and CO are emitted mainly by the combustion of fossil fuels and VOCs are emitted from incomplete combustions of fuels and the evaporation of petroleum fuels and chemicals and by certain plants. These compounds react with oxygen in the atmosphere in the presence of sunlight to create ozone (O_3; Figure 9.3).

The process of ozone formation depends on high air temperatures, which explains why we do not have ozone alerts during the winter even though emissions of NOx and VOCs are just as high then. As Figure 9.4 shows, there is a clear relationship between the maximum temperature at the Baltimore-Washington International Airport (BWI) and ozone concentrations in the Baltimore non-attainment area.[144] Furthermore, heat waves (multiple successive days with very high temperatures) create the optimum conditions for ozone formation. This is apparent in the Baltimore non-attainment area where the number of days where ozone concentrations exceed the 8-hour "Code Orange" standards in a year shows close relationship with the number of days where maximum temperatures exceed 90°F (Figure 9.5).

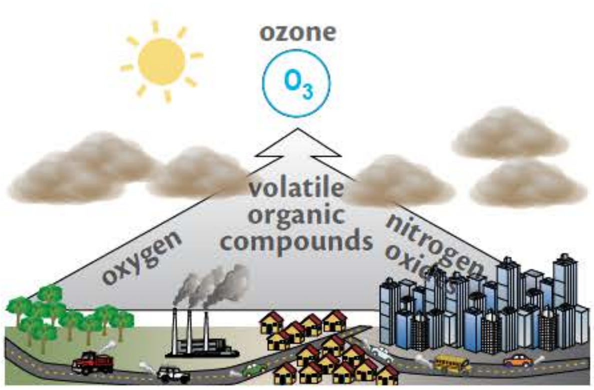


Figure 9.3. Ozone is created by the chemical reaction of air pollutants in the presence of sunlight.

The top image shows the reduced visibility (25 miles) in the downtown Washington, D.C. area in July 2006. The bottom image was taken in October 2005 where the visual range was 55 miles.

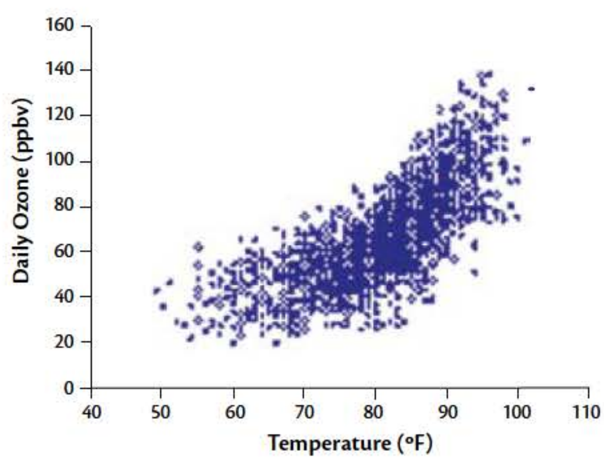


Figure 9.4. More ozone is formed under higher temperatures. Peak 8-hour ozone concentrations in the Baltimore region for May-September, 1994-2004, compared to maximum temperature at BWI Airport.[138]

Climate change is also likely to decrease the occurrence of cyclonic waves (low pressure system with associated weather fronts), thus lengthening

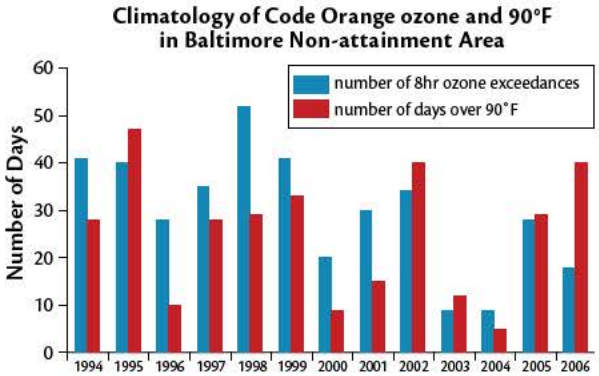


Figure 9.5. Heat waves (multiple days with temperatures exceeding 90°F) increase the buildup of ground-level ozone.

the duration of stagnant, high pressure events (hot and hazy periods) and delay the onset of cold fronts that clean up air pollution episodes.[145] Such smog episodes not only decrease the visual range but can also cause human illness and death due to higher concentrations of fine particulate matter. The persistent Bermuda High leads to weak or stagnant winds, high daytime temperatures, and intense UV radiation reaching the Earth's surface. Pollution and VOCs build up from gasoline vapors and even trees, particularly pines and oaks that are favored by global warming. All of this is exacerbated by the urban heat island effect.[146]

Ozone alert days likely to grow, requiring more aggressive reduction of air pollution

Based on the increase in summer temperatures and heat waves and these changes in weather patterns, scientists have projected anything from a 3-5 ppb[147] to a 10-20 ppb[148] increase in 8-hour average ozone concentrations over the eastern United States by the end of the century, assuming emissions of the ozone-precursor pollutants remain constant. One recent study projected a 28% increase in the average number of days exceeding 8-hour ozone standards for Baltimore and a 50% increase for Washington, D.C. by 2050.[149] On the other hand, if emissions of NOx are reduced by 50%, then ozone concentrations could, according to another study, actually decline by 11-28% despite the warming conditions.[150] The decline in observed ozone concentrations in the Baltimore region for given temperature ranges (Figure 9.6) provides clear evidence of the importance of reducing precursor emissions.

In summary, it is very likely that without significant additional reductions in air pollution by NOx and VOCs, ground level ozone concentrations

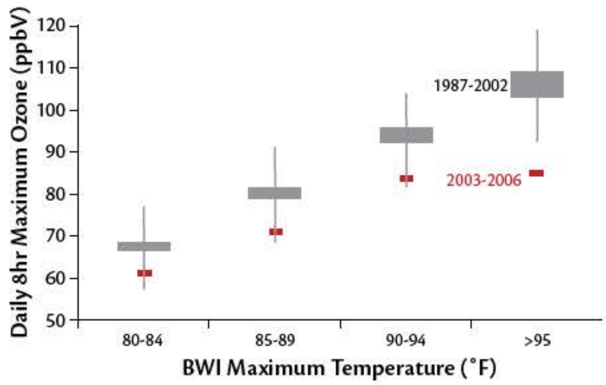


Figure 9.6. Maximum ozone concentrations have declined for each temperature range in recent years as a result of the reduction of emissions of air pollutants.

will increase and pose additional health risks to people residing in central Maryland. In addition to mitigation by reducing pollutant emissions, adaptive responses are similar to those for heat stress: warning systems, air conditioning, avoiding exertion and outdoor activity, and increasing tree cover.

Maryland Power Plant Research Program, MD DNR

There are 34 power plants operating in Maryland as of 2006.

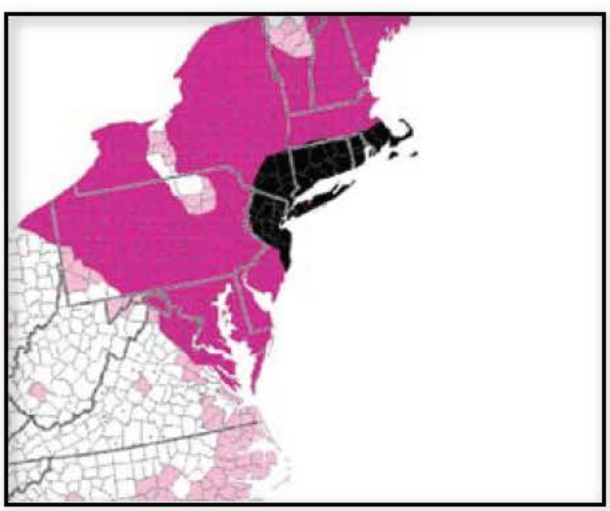
PATHOGENIC DISEASES

Climate change can increase human exposure and vulnerability of diseases caused by pathogenic microorganisms.[138] These include diseases borne by various animal vectors, such as malaria, dengue, Lyme disease, and encephalitis, a type of which may be caused by the West Nile virus. Global warming could increase the range or abundance of the animal vectors. Climate change could also affect exposure to non-vector borne diseases such as hantavirus, cryptosporidiosis, and cholera. The incidence and associated mortality of most of these diseases in the United States is relatively low because of public health precautions and the availability of treatment. For Maryland, the increased risks due to heat stress and respiratory impairment are likely to be more serious than for pathogenic diseases.

Moreover, it is difficult to project how climate changes would impact pathogenic transmission and human health because of the complexity of climatic effects on vectors and other environmental factors.[138] Cryptosporidiosis is an intestinal disease caused by a bacterium that is abundant in livestock feces and can be transported during high rainfall events. The bacterium is small and resistant to chlorination, making it difficult to kill or filter out of water supplies. Lyme disease has become the most important vector-borne diseases in the United States and a large majority of cases occurs in the Northeast, although it is less prevalent in Maryland than in the states to the north. The ticks that transmit Lyme disease prefer cooler temperatures during the summer, so the projected warming could reduce tick populations and disease risk.[7] Continued encroachment of suburbs into former woodlands presents a far greater risk for contraction of Lyme disease. Outbreaks of West Nile virus in humans seem to occur when extreme heat and drought are followed by heavy rains. It is thought that birds that host the virus migrate to wetter areas during the drought and the mosquitoes that normally prey on birds switch to humans when they hatch following the rains.[7]

University of Maryland

Heavy rains and coastal flooding combined with warm weather provides perfect conditions for an explosion of mosquitoes.



American Lyme Disease Foundation, Inc.

The dark pink area, which includes most of Maryland, represents a medium density of host-seeking ticks that have been shown to be infected with Lyme disease bacteria.

Section 10

IMPLICATIONS FOR MITIGATION & ADAPTATION

KEY POINTS

- **Reduction of greenhouse gas emissions has substantial benefits for Maryland.**
  Mitigation of global emissions by mid-century would very likely result in significantly lower sea-level rise, reduced public health risks, fewer extreme weather events, less decline in agricultural and forest productivity, and loss of biodiversity and species important to the Chesapeake Bay. Even more serious impacts beyond this century would be avoided.

- **Develop adaptation strategies for human health, water resources, and restoration of bays.**
  Adaptation strategies to reduce coastal vulnerability should plan for a 2 to 4 foot rise in sea level during the century. The Commission should evaluate additional adaptation strategies related to human health, water resources, forest management, and restoration of the Chesapeake Bay and Maryland's Coastal Bays.

- **Organize and enhance Maryland's capacity for monitoring and assessment of climate impacts.**
  A more extensive, sustained, and coordinated system for monitoring the changing climate and its impacts is required. Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to mitigation and adaptation.

This assessment of the impacts of climate change on Maryland was undertaken as one of three integrated components of the Plan of Action of Maryland's Commission on Climate Change. To that end, it is appropriate to draw implications from the impacts assessment to inform the other efforts to mitigate climate change by reducing greenhouse gas emissions and to adapt to changes likely, thereby reducing Maryland's vulnerability. This concluding section briefly summarizes the findings of the impacts assessment related to those two objectives.

MITIGATION

Reducing emissions soon is required

The Intergovernmental Panel on Climate Change has demonstrated that on a global scale, there are likely to be large changes in climate and substantial and serious effects on natural ecosystems, resources, and human populations and societies.[3] The IPCC showed that some of these changes are inevitable because they have already begun and cannot easily be stopped, even with dramatic and immediate reductions in greenhouse gas emissions. However, the path that humankind will follow in either continuing to increase those emissions or reducing them will have a large effect on the extent of climate change and magnitude of its consequences.

This assessment seeks to identify both those changes in Maryland that are likely inevitable and those changes that can be avoided with action to reduce emissions through the use of the lower and higher emissions scenarios. A point made earlier bears repeating: the higher emissions scenario is not

Improved fuel economy and less vehicles on the road could provide some reduction in greenhouse gas emissions.

and does not represent a ceiling nor the most extreme changes that are likely, and the lower emissions scenario is not a floor and does not represent the minimum effects that may be achievable. Currently, emissions are growing faster than the higher scenario assumes. The IPCC estimated that it would require early reductions of global greenhouse gas emissions of 50 to 85% by 2050 to constrain the increase in the global mean temperature to 3.6 to 4.5°F,[3] a level of warming generally thought to have dangerous consequences, and would, therefore, still have many negative consequences as this report attests. Under the lower emissions scenario used in this assessment, the emissions in 2050 would be declining but still be about 30% higher than today. For that reason, the IPCC is planning to develop scenarios incorporating earlier and more dramatic emission reductions in its future assessments.

For the most part, the projections of impacts under the lower and higher emissions scenarios are similar or only modestly different at the middle of the 21st century. This is hardly surprising because the cumulative emissions are little different between the two scenarios by that point in time (Figure 3.3). The differences become starker towards the end of the century, even though the lower emissions scenario shows only about a 50% reduction in emissions by that time. Thus, the lower emissions scenario projections represent what might be considered the maximum change that could be expected if the mitigation strategies now being advanced in international negotiations are implemented. With that in mind, the following are some of the more severe impacts projected for late 21st century climate change in Maryland that could potentially be avoided by global action to reduce greenhouse gas emissions during the first half of century:

- Sea-level rise of up to 3.5 feet as opposed to less than 2 feet; the loss of virtually all coastal wetlands; inundation of more than 100 square miles of presently dry land and loss of the homes of thousands of Marylanders; and the likely initiation of a 20-feet or more rise in sea level in later centuries as a result of unstoppable melting of polar ice sheets.
- Heat waves lasting most of the summer, with an average of 30 days each summer exceeding 100°F (like Phoenix but with high humidity) creating life-threatening conditions in Maryland's urban environments during most years; and increased respiratory health risks due to ground-level ozone concentrations unless pollution emissions are dramatically reduced.

Wikipedia Commons

Record energy use and heat waves often coincide.

- More extreme rainfall events, but also longer lasting summer droughts, not unlike the unusual conditions seen in Maryland over the past year.
- Declines in agricultural productivity, which may be initially enhanced due to warmer temperatures and higher carbon dioxide concentrations, as a result of severe heat stress and the summer droughts.
- Reduced forest productivity and ability to sequester carbon, after a modest increase during the first half of the century, as a result of heat stress, seasonal droughts, and outbreaks of pests and diseases; the loss of maple-beech-birch forests of Western Maryland and an increase in pine trees in the landscape of the rest of the state; and the withdrawal of northern bird species such as the Baltimore oriole from Maryland.
- The permanent loss of important species such as eelgrass and soft shell clams from the Chesapeake Bay; highly stressful summer conditions for striped bass and other fish as the dead zone expands and surface waters heat up; and a substantially more difficult challenge in restoring the health of the Bay by reducing nutrient pollution.

Limiting the projected impacts in this assessment to the 21st century undervalues the full benefits of mitigation of greenhouse gas emissions taken early in the century. The impacts of unmitigated climate change will not stabilize in 2100 but continue beyond, in some cases at an accelerated pace. In fact, some responses have a long lag effect, meaning that the effects will continue to grow over centuries.[2] This is particularly true for sea-level rise


NASA/Wallops

This image shows the calving front, or break-off point into the ocean, of Helheim Glacier, located in southeast Greenland. The image, taken in May 2005, shows high calving activity associated with faster glacial flow. This glacier is now one of the fastest moving glaciers in the world.

because of the slow process of warming the ocean and the continued melting of polar ice sheets. If emissions continue to grow at the pace of the higher emissions scenario or greater, it is likely that the climate system will be committed to an accelerated melt down of the polar ice sheets over the next few centuries that could not be stopped by reducing greenhouse gas emissions. Lest one think that is such a long time in the future, remember that European colonization of Maryland began 374 years ago and Maryland became a state 227 years ago.

Impacts of climate change will not stabilize in 2100, and sea level will continue to rise

Changing conditions affect mitigation

Conditions will change in ways that affect mitigation options. For example, forests that are stressed by heat and low soil moisture during the summer will cease to take up and hold (or sequester) carbon from the atmosphere. Instead, they will tend to release stored carbon back into the atmosphere as carbon dioxide. Heat stress will increase the demand for air conditioning and extend the cooling season. At times, air conditioning will not be a luxury, but a matter of survival. This would offset mitigation savings through energy conservation and increase peak electricity demand, which determines the generation capacity required.

Some of the projected climate changes are likely to make the accomplishment of present environmental objectives more difficult, for example, attaining ozone concentration standards by reducing air pollution or achieving the Chesapeake Bay restoration goals by reducing nutrient agricultural and urban runoff of nutrients and sediments. However, most of the projected impacts of climate change will not be realized until the middle of the century or later, and some are not yet very predictable. Therefore, there is ample opportunity to continue to pursue those environmental objectives aggressively because this would lessen the impacts of climate change later on. Freezing action due to the uncertain effects of climate change would result in unavoidable and more severe consequences.

ADAPTATION

Sea-level rise and coastal vulnerability

Based on the current scientific understanding of the complex processes that will affect future sea level as considered in the projections of this assessment, it is prudent to plan now for one foot of relative sea level rise by the middle of the century and at least two feet by the end of the century. For major, long life-time investments in property and infrastructure, it would be prudent to consider an additional margin of safety by planning for a four foot rise in sea level. New observations of the global and local rates of sea level rise, new scientific understanding of the processes of melting of polar ice sheets, and improved capabilities for long-range storm forecasting could alter this advice, but more severe impacts are not likely to be realized until the second half of the century. Consequently, plans and policies should be periodically reevaluated with regard to this emerging understanding and the progress in reducing greenhouse gas emissions.

Subsequent adaptation strategies

The Maryland Commission on Climate Change will


Adrian Jones

Coastal development is vulnerable to sea-level rise and storm surge.

continue to evaluate adaptation strategies in addition to sea-level rise and coastal vulnerability over the next year or more. Although detailed evaluation of adaptation options is beyond the scope of this report, the assessments provided here should serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health (heat and respiratory stress), water resources (particularly emphasizing the Potomac Basin, groundwater resources, and reducing the effects of urbanization on flooding and stream health), forest management (changing sequestration potential and managing forest succession, diseases and pests), and restoration of the Chesapeake Bay and Maryland's Coastal Bays (building on the recent analysis of the Scientific and Technical Advisory Committee of the Chesapeake Bay Program). These issues are ripe for further evaluation by the Commission.

Monitoring, assessment, and forecasting

In general, there is insufficient monitoring of Maryland's climate, environmental conditions, and resources to characterize their present state and variability. Now that we realize that all of these are changing and will be changing more rapidly in the future, a better system of observations is required—one that is reliably continuous, strategically targeted, and thoroughly integrated. Reliable observations, interpreted with scientific understanding, and innovative models can dramatically reduce uncertainty about the path of climate change in Maryland and its consequences, allowing us to make better informed and wise decisions about the State's future. It is clear that traditional approaches to adaptation will not suffice in a future that no longer resembles the past. Climate models can be downscaled to incorporate locally important phenomena, such as urban heat island and forest cover effects, and resolve important differences across our slice of the Mid-Atlantic landscape.

Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to mitigation and adaptation. There is already considerable, world-recognized expertise within our public and private universities on which to build. And, Maryland has the unmatched advantage of the location of the Goddard Space Flight Center, which leads the National Aeronautics and Space Administration's earth science program at Greenbelt; headquarters of the National Oceanic and Atmospheric Administration's line offices at Silver Spring; and National Weather Service's Climate Prediction Center soon to be relocated to College Park. Marshalling and enhancing this capacity for continually improving climate impact assessment would greatly benefit not only our State of Maryland, but our planet, Earth.

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Jane Hawkey

Turk's Cap lily, a native of the Chesapeake Bay watershed.

16 Comments on sea level and storm surge report.pdf

From:	Patrick Gonzalez NPS
To:	Maria Caffrey
Cc:	Maria Caffrey; Patrick Gonzalez UC
Subject:	Comments on sea level and storm surge report
Date:	Tuesday, October 04, 2016 10:27:39 PM
Attachments:	Sea Level Change Report Draft for Review September 2016 PG.docx

Hi Maria,

Congratulations on finishing the draft of your technical report! It represents a lot of hard work.

You'll find attached the document with recommended edits tracked in Word. I found no major issues. You'll see that most of the edits related to using the word "projected" for future estimates that are dependent on emissions scenarios and use of the conditional voice (could, might) when talking about the future. I did not have time to add explanatory comments for each edit - I know that you'll easily grasp the rationale behind individual edits. You can call me on my personal cell phone [redacted] for any questions.

All the best,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
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....

....
From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Re: Sea level and storm surge report
Date: October 3, 2016 at 3:09:30 PM PDT
To: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>

No worries. Thanks for taking the time to do this.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Oct 3, 2016 at 4:06 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria - I'm going through the report and will get to you before too long. Thanks for your patience.
>
> Patrick
>
> ---
>
> **From:** "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
> **Subject: Re: Sea level and storm surge report**
> **Date:** September 28, 2016 at 10:02:19 AM PDT
> **To:** Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
>
> Patrick,
>
> No problem. You don't need to hurry it. I can wait until Monday. I'm attending the Geological Society of America meeting this week, so I have other things I can do with my time. I just thought I might take a poke at some edits during my downtime between papers.
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Wed, Sep 28, 2016 at 11:00 AM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:
>
>> Hi Maria,
>>
>> I'm sorry for the delay in reviewing your report. I travelled, then gave two presentations, then was on leave. If you can wait until tomorrow, I can make suggestions to the Word document though track changes.
>>
>> Patrick

From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Re: Sea level and storm surge report
Date: September 28, 2016 at 9:01:10 AM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hi Patrick,

Do you have any edits you would like to suggest for the final report? I'm starting to make changes based on Amanda's comments, but I wanted to see if you have anything to add before I start going through it.

Cheers,

Maria Caffrey, PhD

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On Fri, Sep 2, 2016 at 3:04 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Amanda, Patrick,
>
> Here is the draft report. I have included an excel spreadsheet for your comments so I don't have to try and combine four versions of track changes from everyone (I'll be emailing Rob and Steve for their comments separately). Please try to get your reviews back to me by 9/16/16.
>
> Have a great labor day weekend!
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
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> Energy and Minerals * Active Processes and Hazards * Geologic Heritage

16 1 Attachment Sea Level Change Report Draft for Review Sept.pdf

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Change in the National Park Service: Sea Level and Storm Surge Projections for 118 National Park Service Units

Natural Resource Data Series NPS/XXXX/NRDS—2016/XXX

ON THIS PAGE
Driftwood washed up on the shoreline of Redwood National Park
Photograph courtesy of Maria Caffrey, University of Colorado

ON THE COVER
Fort Point National Historic Site and the Golden Gate Bridge, California
Photograph courtesy of Maria Caffrey, University of Colorado

Sea-Level Change in the National Park Service

Sea Level and Storm Surge Projections for 118 National Park Service Units

Natural Resource Data Series NPS/XXXX/NRDS—2016/XXX

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NT: More authors will be added. Pending their approval.

September 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Climate Change Response Program website (http://nps.gov/orgs/ccrp/index.htm), and the Natural Resource Publications Management website (http://www.nature nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

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Photo 1. Point Reyes National Seashore. Photo credit: Maria Caffrey.

Abstract/Executive Summary

Photo 2. Basement flooding in the visitor center at Rosie the Riveter WWII Home Front National Historical Park. This photograph was taken approximately 12 years after the establishment of the park. Photo credit: Maria Caffrey.

Changing relative sea levels and potential increasing storm surges due to anthropogenic climate change present many challenges to land managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service to combine, compare, and contrast different sea-level change projections from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios using National Oceanic and Atmospheric Administration (NOAA) storm surge models. This report covers how these models are used to project sea level change in ~~protect~~ coastal units that have recently recovered from storm damage, such as the Statue of Liberty in New York. Both the IPCC and NOAA have established their own climate change scenarios, however this research will be the first to combine these results to show how storm surge could propagate in the future using bathtub models. These scenarios result in significantly different inundation outcomes. In addition to using multiple sea level and storm surge scenarios; multiple time horizons (2030, 2050 and 2100) were studied. The National Capital Region is projected ~~expected~~ to experience the highest average rate of sea level change by 2100, although the coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is also projected~~expected~~ to experience the highest storm surges based on historical data and NOAA storm surge models.

These results have far reaching implications for adaptation and mitigation strategies for lands managed by the National park Service.

Acknowledgments

This project was funded using funds from the NPS Servicewide Comprehensive Call (FY2013–2015) and was augmented by funds from the Natural Resource Stewardship and Science Directorate's Geologic Resources Division and Climate Change Response Program. We would like to thank the members of the communication advisory team (Lynda Bell, Ann Gallagher, Will Elder, Janet Cakir, Stanton Enonmoto, Matt Holly, Shawn Norton, Larry Perez, and Ryan Stubblebine) and science advisory team (Amanda Babson, Patrick Gonzalez, Steve Nerem, and Rob Thieler) for their time and input into this project.

We would also like to thank the Susan Teel and Caroline Rohe at Gulf Islands National Seashore for their assistance designing two waysides. Likewise, we also thank Julie Whitbeck, Aleutia Scott, Kristy Wallisch, and Stacy Meyers for helping design, review, and install a wayside at Jean Lafitte National Historical Park and Preserve. Elizabeth Rogers and Kathy Krause helped design a wayside for Fire Island National Seashore.

We would also like to thank xxx for their assistance in editing and reviewing this document.

List of Terms

The following list of terms are defined here as they will be used in this report.

Flooding: The temporary impoundment of water on the land.
Inundation: The permanent impoundment of water on what had once been dry land.
Isostatic rebound: A change in land level caused by a change in loadings on the Earth's crust. The most common cause of isostatic rebound is the loading of continental ice during the Last Glacial Maximum in North America. The North American land surface is still moving after the melting of this continental ice in an effort to return to equilibrium with its original pre-loading state.
National Park Service unit: Property owned or managed by the National Park Service.
Relative sea level: Where the water level can be found compared to some reference point on land. This term is most frequently used in discussion of *changes* in relative sea level. A change in relative sea level could be caused by a change in water volume or a change in land level (or some combination of these two factors).
Sea level: The average level of the seawater surface.
Sea-level change: This term is frequently used in reference to *relative* sea-level change. This is the product of two main factors, 1) an increase in the volume of ocean water, and 2) a change in land level. These two factors can be broken down further into other drivers that will be discussed in greater detail in other sections. This term is sometimes mistakenly confused with the term *sea-level rise*.
Sea-level rise: An increase in sea level. This is the result of an increase in ocean water volume caused principally by melting continental ice and thermal expansion. This term is not to be confused with increasing *relative* sea level, which can also be caused by decreasing land levels.

Introduction

Global sea levels are rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), the onset of anthropogenic climate change has significantly increased the rate of global sea-level rise (Grinsted et al. 2009, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). ~~As~~ If human activities continue to release carbon dioxide (CO_2) into the atmosphere, ~~we can expect the~~ Earth's atmosphere ~~to~~ will continue to warm over the next century (IPCC 2013, Mearns et al. 2013, Melilo et al. 2014). As the atmosphere warms we anticipate sea levels to also rise; however, the rate of warming depends on a number of factors that have been categorized by the Intergovernmental Panel on Climate Change (IPCC) into four different representative concentration pathways (RCPs; ~~Meinshausen~~ Moss et al. 2010~~1~~). These RCPs are newly defined climate change scenarios that were first introduced in the IPCC's most recent climate change report (IPCC 2013) and will form the basis of this report. The aim of this report is to ~~discuss~~ present combined estimates of ~~how anthropogenic climate change will impact our coastal zone via~~ sea-level change, due to climate change, and storm surge. As temperatures change, sea levels will rise due to a number of factors that will be discussed in greater detail; however, while sea levels are incrementally rising we can also expect periods of coastal flooding caused by coastal storms and hurricanes to exacerbate the growing problem of coastal inundation (see list of terms).

Comment [PG1]: Moss, R H , J A Edmonds, K A Hibbard, M R Manning, S K Rose, D P van Vuuren, T R Carter, S Emori, M Kainuma, T Kram, G A Meehl, J F B Mitchell, N Nakicenovic, K Riahi, S J Smith, R J Stouffer, A M Thomson, J P Weyant, and T J Wilbanks 2010 The next generation of scenarios for climate change research and assessment Nature 463: 747-756

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion of damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to anthropogenic climate change but the storm surge occurred over a sea whose level has risen due to climate change. While the amount of damage from this storm might seem to be extreme, we can expect a 1/100 year storm surge to cost $2–5 billion and a 1/500 year storm surge to cost $5–11 billion (Aerts et al. 2013). Looking ahead to the future we can expect storms to become more intense (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea-level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline.

Peek et al. (2015) estimated that the cost of sea-level rise in 40 National Park Service units could be in excess of $40 billion if these units were exposed to one-meter of sea-level rise. The aim of this report is to examine 118 coastal park units to; 1) quantify ~~precisely how much~~projections of sea-level rise ~~they can expect~~ over the next century based on the latest IPCC (2013) models, and 2) how could storm surge generated by hurricanes could also impact these parks.

Format of This Report

This report is separated into five sections: introduction, methods, results, discussion, and conclusion. Results per park will be presented alphabetically by region. The 118 park units studied for this project cover six administrative regions: the Northeast, Southeast, National Capital, Intermountain, Pacific West, and Alaska. Funding for this project did not include projected changes in lake levels, although we recognize that interior waterways and lakes, especially the Great Lakes, are also vulnerable to climate change. Further explanation on how to access the data from this project can be found in the methods sections and accompanying appendices.

Frequently Used Terms

Definitions of the most basic terms used in this report can be found on page viii. However, some terms require some greater explanation for their use. We are following the advice of Flick et al. (2012) in differentiating between the terms *flooding* and *inundation*. While many choose to use these terms interchangeably, we use the term flooding to describe the temporary placement of water on land. This is usually the result of storm activity and other short-lived events, such as periodic tidal action, and will therefore be used here in reference to the effects of a storm surge on land. Inundation is used to refer to the gradual permanent submergence of land that will occur due to sea-level rise.

Furthermore, the terms sea-level rise and sea-level change are also used differently. Sea-level rise refers only to rising water levels resulting from an increase in global ocean volumes. In most parts of the United States this increase in water volume will lead to increasing relative sea levels. However, in some parts of the country relative sea level is *decreasing* due to isostatic rebound. Figure 1 shows current sea level trends based on tide gauge records for United States that span at least 30-years of data.

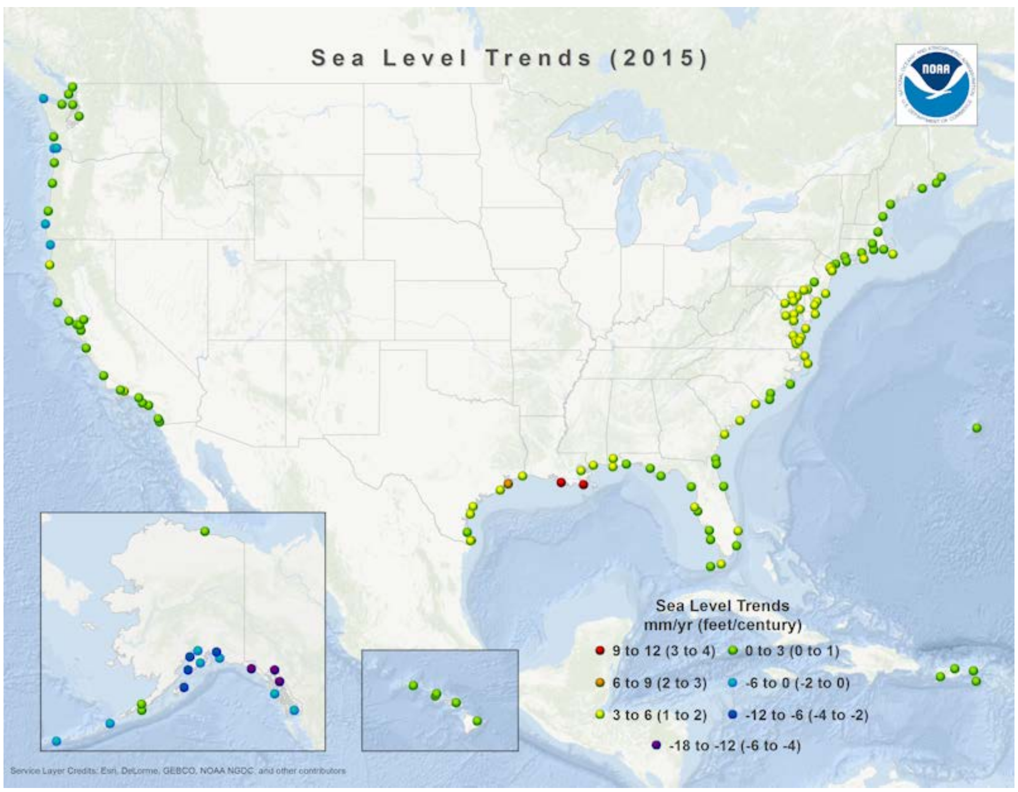

Figure 1. Sea level trends for the United States based on Zervas (2009). Trends are calculated for 2015 relative to global mean sea level. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change. Yellow to red dots are experiencing greater than the global average (primarily driven by regional subsidence) and blue to purple dots are stations that are experiencing less than the global average (due to isostatic rebound or other tectonically-driven factors). Source: https://tidesandcurrents.noaa.gov/sltrends/slrmap.htm

The Southeast Region of Alaska is experiencing a decrease in relative sea level. Alaska's crust is still rebounding following the melting of large volumes of ice that had been stored on land for centuries to millennia. Alaska is also very tectonically complex with a large number of faults that contribute to this crustal motion. Even though the volume of water in this region is increasing, the rate of sea-level rise is not enough to keep up with the rate of land-based movement resulting in a decrease in relative sea level. Whether the rate of land-based motion will continue throughout this century will be discussed in further detail in other chapters; however, this is why we use the term *sea-level change* as a more inclusive term that better reflects regions that will experience a decrease in relative sea level (at least in the early part of this century) as well as those that will have to deal with increasing relative sea levels.

Methods

This report reflects the work of a three-year project that began in 2013. 118 National Park Service units were selected after consultation with regional managers who identified which units they considered to be vulnerable to sea level change and/or storm surge (Appendix C). Funding for this project required the following:

1. Calculate rates of sea level change over multiple time horizons for each park unit.
2. Estimate potential exposure to storm surge using the National Oceanographic and Atmospheric Administration (NOAA) Sea, Lakes, and Overland Surge from Hurricanes (SLOSH) Model.
3. Create waysides communicating about the impact of climate change in the coastal zone for three National Park Service units.

A wayside is an exhibit designed to be installed outside for visitors to find out more information about a particular subject (https://www nps.gov/hfc/products/waysides/). Four waysides were created for three National Park Service units: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore. These parks were selected after consulting with regional managers who recommended units that they felt had a need for a communication product and had communication staff who were available to work with staff at the University of Colorado in the design. The finished wayside designs are in Appendix D. Each wayside design is different because each wayside was customized to reflect the messaging and/or themes of each unit.

Sea-Level Rise Data

Sea-level rise is the product of a number of factors at work. As human~~s~~ activities release ~~more~~ CO_2 and other greenhouse gases into the atmosphere, mean global temperatures ~~will~~ increase (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). Rising global temperatures cause ice located on land and in the sea to melt. While the melting of sea ice is problematic from an oceanographic perspective (primarily because it will alter water temperatures and salinity), it is the melting of ice that is currently stored on land that will have the greatest impact on global sea levels.

Melting sea ice is not a cause of sea-level rise. Water level does not change when sea ice (ice wholly contained within water and not supported by land) melts. The phase shift of water from ice to liquid water does not displace an additional volume of water.

However, the melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise. As ocean waters warm the density of these waters will also change causing thermal expansion. Thermal expansion is responsible for approximately 39% of sea level rise while melting ice contributed a further 47% from 1993 to 2010 (IPCC 2013). Other factors that also need to be considered are listed in Table 1.

Table 1. Observed global mean sea level budget (mm/yr) over multiple time horizons (IPCC 2013).

Source	1901–1990	1971–2010	1993–2010
Thermal expansion	—	0.08	1.1
Glaciers except in Greenland and Antarctica[a]	0.54	0.62	0.76
Glaciers in Greenland	0.15	0.06	0.10[b]
Greenland ice sheet	—	—	0.33
Antarctic ice sheet	—	—	0.27
Land water storage	-0.11	0.12	0.38
Total of contributions	**—**	**—**	**2.8**
Observed	**1.5**	**2.0**	**3.2**
Residual[c]	0.5	0.2	0.4

[a]Data until 2009, not 2010.
[b]This is not included in the total because these numbers have already been included in the Greenland ice sheet.
[c]This is calculated as observed global mean sea level rise – modeled glaciers – observed land water storage. See table 13.1 in IPCC (2013) for more details.

Sea level rise projections for this project follow a *process-based model* approach. This process-based approach generates data based on the underlying processes that are responsible for sea level rise. This is in contrast to *semi-empirical* models that use observations in combination with any number of other variables or theoretical considerations, which in some cases include expert elicitations (surveys or interviews with other professionals to gauge their opinion) (Rahmstorf 2010, Orlic and Pasaric 2013). The IPCC cites a number of semi-empirical projections in their most recent report (IPCC 2013), but they choose to use coupled atmosphere-ocean general circulation models (AOGCM). AOGCMs are able to simulate the processes of change rather than relying on statistical inferences that make up the semi-empirical approach. AOGCMs are considered a process-based technique, although some variables may have been derived using semi-empirical methods (IPCC 2013).

Local sea-level rise numbers for 2050 and 2100 were taken directly from the IPCC (2013) downscaled AOGCM regional climate model (RCM). Many park units also require estimates for shorter time horizons that fit more closely with the expected lifetime of various projects, so sea level rise projections for 2030 were calculated using IPCC RCM data for each sea level rise driver shown in Table 2 downscaled to 2030 for each RCP. All projections results are relative to the period 1986–2005 (see Appendix C for further discussion).

Comment [PG2]: Specify here the spatial resolution

Table 2. Median values for projections of global mean sea level and its contributions in meters for 2100 (IPCC 2013).

	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Thermal expansion	0.15	0.20	0.22	0.32
Glaciers	0.11	0.13	0.14	0.18
Greenland ice sheet surface mass balance[a]	0.03	0.05	0.05	0.10
Antarctic ice sheet surface mass balance	-0.02	-0.03	-0.03	-0.05
Greenland ice sheet rapid dynamics	0.04	0.04	0.04	0.05
Antarctic ice sheet rapid dynamics	0.08	0.08	0.08	0.08
Land water storage	0.05	0.05	0.05	0.05
Sea level rise	0.44	0.53	0.55	0.74
Greenland ice sheet	0.08	0.09	0.09	0.15
Antarctic ice sheet	0.06	0.05	0.05	0.04
Ice-sheet rapid dynamics	0.12	0.12	0.12	0.14

[a]Changes in ice mass derived through direct observation and satellite data.

The standard error (σ) for each site estimate was not calculated because it was beyond the scope of this project. However, it can be calculated using the following equation and data available from the IPCC (2013 supplementary material):

Eq 1. $$\sigma_{tot}^2 = \left(\sigma_{steric/dyn} + \sigma_{smb\_a} + \sigma_{smb\_g}\right)^2 + \sigma_{glac}^2 + \sigma_{IBE}^2 + \sigma_{GIA}^2 + \sigma_{LW}^2 + \sigma_{dyn\_a}^2 + \sigma_{dyn\_g}^2$$

Where: *steric/dyn* = the global thermal expansion uncertainty plus dynamic sea surface height; *smb_a* = the Antarctic ice sheet surface mass balance uncertainty; *smb_g* = the Greenland ice sheet surface mass balance uncertainty; glac = glacier uncertainty; *IBE* = the inverse barometer effect uncertainty; *LW* is the land water uncertainty; *dyn_a* = Antarctica ice sheet rapid dynamics uncertainty; and, *dyn_g* = Greenland ice sheet rapid dynamics uncertainty.

Comment [PG3]: Insert here "GIA = "

Initial data were exported as GeoTIFF files that could be manipulated in ArcGIS as simple bathtub models. A weighted average by shoreline was calculated for park boundaries that overlapped more than one data cell. A standard bathtub model approach was used to show the effects of sea level rise on top of mean higher high water. Areas of inundation and flooding are denoted in the maps in the blue. Additional low-lying areas that could be potentially inundated or flooded are shown in green

Comment [PG4]: It would be good if you briefly described this

(Figure 2). These low-lying areas do not appear to have any inlet or other pathway for water, although they should still be considered vulnerable to exposure to either groundwater seepage or potential flooding via breaching. The lack of high-resolution DEMs and time constraints prevented us from attempting a dynamic modeling approach (see limitations below). Maps were created to illustrate inundation for all park units for 2050 and 2100 under RCP4.5 and RCP8.5.

Figure 2. An example of how areas of inundation appear in ArcGIS. In this example for the Toms Cove area of Assateague National Seashore, areas of inundation (RCP4.5 2050) are shown in blue. Other low lying areas that are blocked from inundation by some impediment are shown in green.

Storm Surge Data

NOAA SLOSH data estimate potential storm surge height (NOAA 2016). The NOAA SLOSH model is comprised of the following three products (P-Surge, MEOW, and MOMs) that utilize three different modeling approaches (probabilistic, deterministic, and composite) to estimate storm surge.

P-Surge (also known as the tropical cyclone storm surge probabilities product) uses a probabilistic approach by examining past events to estimate the storm surge generated by a cyclone that is present and within 72-hours of landfall. It statistically evaluates National Hurricane Center data (calculated in part using a deterministic approach) including the official projected cyclone track and historical forecasting errors. It also incorporates astronomical tide calculations and variations in the radius of maximum wind into this estimate. These rates of motion variables are then fit to a Cartesian or polar (depending on the location) grid (Jalesnianski et al. 1992).

Comment [PG5]: Add "digital elevation models"

Comment [PG6]: It would be good to increase the contrast between the inundation color and the sea color

The Maximum Envelope of Overwash Water (MEOW) calculates flooding using past P-Surge data to create a composite estimate of the potential storm surge generated by a hypothetical storm. This product generates a worst-case scenario based on a hypothetical storm category that includes forward speed, trajectory of the storm when it strikes the coastline, and initial (mean vs. high) tide level that will also incorporate any historical uncertainty from previous landfall forecasts.

The final SLOSH product is the MOM (Maximum of MEOWs) model. MOM is a further composite approach that uses the forward speed, trajectory, and initial tide level data that is also used by MEOW to create a worst-of-the-worst scenario (or "perfect storm"). Storms are simulated for 32 regions (also known as operational basins, Figure 3) defined by NOAA. Data was imported into ArcGIS using the SLOSH display program. Maps were generated showing storm surge for all possible Saffir-Simpson hurricane categories for each site. While most sites had data for Saffir-Simpson hurricane categories 1–5, a few sites, such as Acadia National Park, were missing the highest category. NOAA did not model this scenario because it is considered extremely unlikely at a location that far north in the Atlantic Ocean.

SLOSH MOM was used to estimate potential storm surge in 79 coastal park units. Unfortunately MOM data do not exist for the remaining 39 units, so we supplemented this with data from Tebaldi et al. 2012 wherever possible. Tebaldi et al. (2012) used 55 long-term tide gauge records to calculate potential sea level and storm surge estimates. We used the current 50-year and 100-yr return level data from their paper for any parks near to a tide gauge. Unfortunately we were unable to use either Tebaldi et al. (2012) or SLOSH MOM data for the Alaskan, Guam, and American Samoa park units.

Figure 3. An example of the extent of an operational basin shown in NOAA's SLOSH display program. The black area is the full extent of the operational basin for Chesapeake Bay.

Storm surge models were combined with the mapped sea level rise data to get a rough idea of how these regions could be exposed to flooding occurring later in the century on top of inundation. We used historical hurricane data from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010) to ascertain the highest Saffir-Simpson category hurricane to strike within 10 miles of each park unit. We then used the MOM estimate for a storm surge one category higher than anything that had struck the park historically (based data spanning 1842–2014; Appendix E, Table E3). By using one storm category higher than historical data we hoped to approximate what could happen as storms are expected to be more intense due to anthropogenic climate change in the future (Emanuel 2005, Webster et al. 2005, Mendelsohn et al. 2012). However we would recommend caution in using these combined maps for any detailed planning due to the limitations that will be discussed further in the following section of this report.

Limitations

While every effort has been made to use the best available data and techniques, all projects of this nature have limitations that should be clearly delineated to ensure that these data are interpreted correctly.

Every effort has been made to incorporate any parks, such as Harriet Tubman Underground Railroad National Monument, that were established after work began, although some maps might be missing due to lack of available boundary data in new units.

We used a bathtub modeling approach to map the extent of sea level rise and storm surge over every unit. Bathtub modeling simply simulates how high up or inland water will go under different climate scenarios. It does not take into account changes in topography or other environmental or manmade systems that will occur in response to encroaching water. While bathtub models are the most widely used technique for modeling inundation, it is also a more passive technique of simulating how sea level rise will impact a landscape (Storlazzi et al. 2013). Dynamic models could model changes in flow around buildings or estimate how topographic features such as dune systems will migrate in response to inundation and flooding; but dynamic models also vary in their methods, which can be a severe limitation if trying to standardize data for comparison and management.

Even though SLOSH MOM has the widest geographic storm surge coverage of any model in the US, storm surge data are not available for every part of the coastline. Every effort has been made by this project to bridge any gaps where SLOSH MOM does not exist. While the Tebaldi et al. (2012) data cover the California, Oregon, Washington, and southern Alaskan coastlines, ~~it does not give any information for the~~they do not cover northern Alaskan, American Samoan, or Guam coastlines. These coastlines are vulnerable to storm surge but we could not find data that we were satisfied were accurate enough to be included in our mapping efforts. Furthermore, combined sea level and storm surge maps are only intended as a rough guide of how flooding by storm surge on top of permanent inundation due sea level rise and should be used with caution. As more of the coastline becomes inundated we can expect coastal flooding to also change accordingly. The SLOSH model is a probabilistic approach that uses previous storms to estimate future storm surge. It cannot take into account any changes in future basin morphology that could affect the fluid dynamics and propagation of coastal flooding.

SLOSH MOM is modeled using mean sea level (0 m NAVD88) and what NOAA terms "high tide" (which is not tied to the local tidal datum, but is actually a round number based on the average high tide for the region that was modeled). Jalesnianski et al. (1992) estimate surge estimates to be accurate +/- 20%, although Glahn et al. (2009) discuss how others have found the P-Surge model to be more accurate than originally estimated. All of these things must be kept in mind when using these numbers for mapping.

Land Level Change

It is important to include changes in land level while interpreting changes in sea level. The IPCC (2013) does not include changes in relative sea level in their calculations of sea-level change. Our sea level rise results do not include how changes in land level will change over time. Land level change is an important variable when calculating relative sea level. Land levels have changed over time in response to numerous factors. Changes in various land-based loadings, such as ice sheets during the last glacial maximum, on the continents has been a significant cause of land level change in the U.S. Post-glacial isostatic rebound is the result of this pressure placed on the Earth's crust by the ice sheets and is still causing land levels to change. Land level can also be altered by other factors such tectonic shifts particularly along Alaska and continental U.S. Pacific coastline. The aforementioned drivers can often prompt either a relative increase or decrease in land level depending on location. Other factors such as aquifer drawdown and the draining of coastal swamps can create decreases in relative land level.

Quantifying how land levels are changing is difficult given the paucity of data available prior to modern satellite data. This data need will be relieved by the release of a NASA study on land-based movement in 2017 (Nerem per. comm.). This NASA report will provide numbers for land-based movement across the country. These numbers should be incorporated with the sea-level rise numbers in this report once they are released in 2017. These numbers can be combined with the numbers in this report in the following equation (after Lentz et al. 2016):

Eq. 2 $aE = E_0 - e_i + R$

Where; a*e* is the adjusted elevation, E_0 is the initial land elevation, e_i is the future sea level for either 2030, 2050, or 2100, and R is the current rate of land movement due to isostatic adjustments.

In the interim, tide gauges can provide data regarding changes in land level, but should be used cautiously. We have listed tide gauge data for the rate of change in land level for tide gauges nearest to all units for this study in Appendix E; however, only Fort Pulaski National Monument and Fort Point National Historic ~~Point~~ Site have a long-term tide gauge on site. This lack of nearby long-term data can limit the accuracy of these numbers if they are applied to sea level change projections for almost all other parks units. Land level changes were only reported for long-term tide gauges that had at least thirty years of data in order to ensure a statistically robust dataset. Based on these limited records we estimate that seven park units are currently experiencing decreasing relative sea levels (Figure 4; Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords

Comment [PG7]: The NOAA gauge is in Golden Gate National Recreation Area

National Park, Lake Clark National Park, Sitka National Historical Park), although we cannot be certain of this number given that many of park units are some distance from a tide gauge. We expect the release of the NASA data (Nerem per comm.) to help refine these estimates.

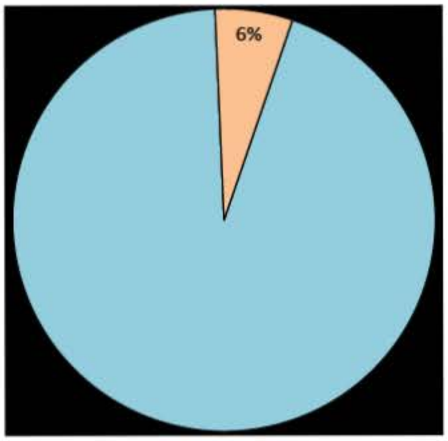

Figure 4. The estimated percentage of park units that currently experience decreasing relative sea levels (orange) versus those with increasing relative sea level (blue).

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It is strongly recommended that you discuss the applicability of these land level numbers with a natural resources manager or similar expert to ensure that the nearest tide gauge to your project site is appropriate. In selecting an appropriate tide gauge to use a number of variables must be taken including oceanographic setting, length of the record, completeness of data, and geography of the coastline. A decision was made by the science team for this project to not set a threshold for how close a park unit should be to a long-term tide gauge based on the aforementioned considerations.

Where to Access the Data

All GIS data from this project will be uploaded on www.irma.gov for archiving by park. Non-GIS users can access the data discussed in this report using our online map viewer at:

[redacted]

A website discussing this project is available at the following address:

https://www.nps.gov/subjects/climatechange/sealevelchange

The raw IPCC (2013) data can be downloaded using the following link:

http://ipcc.ch/report/ar5/wg1/docs/ar5_wg1_ch13sm_datafiles.zip

Results

Sea level and storm surge maps are in Appendices A and B. A full list of the 118 park units used for this study can be found in Appendix D along with a table listing sea level rise projections per park unit. Following the methods outlined above we found that sea level rise ~~will~~ projections average between 0.45m (RCP2.6) and 0.67 m (RCP8.5) by 2100. However, this number masks how these ~~data~~ projections will vary geographically. Figure 5 describes these ~~data~~ projections in more detail by breaking down sea level estimates by region. The error bars in Figure 5 denote the standard deviation for each average per region, which further reveals how these numbers can vary. A high standard deviation and range signals that sea level estimates vary between units, whereas a low standard deviation and small range are be expected in smaller regions where sea level rise estimates do not cover such a large geographic area.

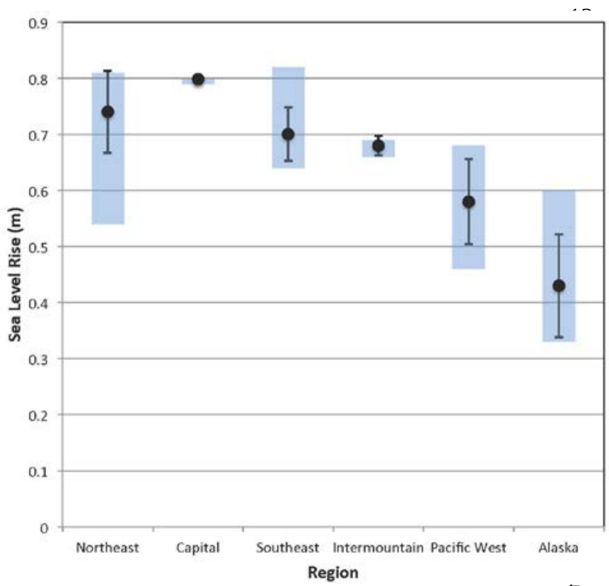


Figure 5. Projected future sea level by region for 2100 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region. These averages do not include the impact of land movement.

Based on the averages per region we found that the shoreline within the National Capital Region is ~~expected~~ projected to experience the highest sea level rise (0.80 m RCP8.5 2100), although this number does not include changes in land level over the same time interval. The shoreline near Wright Brothers National Memorial in the Southeast Region has the highest overall projected sea level rise (0.82 m RCP8.5 2100). Glacier Bay Preserve and Klondike Gold Rush National Historical Park are tied for lowest projected sea level rise at 0.33 m using RCP8.5 for 2100. The Alaska Region also has the highest standard deviation among park units. The National Capital Region conversely has very little standard deviation due to the compact nature of the region that meant that all of the parks units listed fell within the same raster cell. This is not to say that all of the parks will experience exactly the same amount of sea level rise, but that the IPCC model projected that sea levels could rise up to an average 0.80 m (RCP8.5) above waterline for that region by 2100. These differences among the

National Capital parks is illustrated in our sea level rise maps which will be discussed in further detail in the National Capital section of this report.

Comparing RCP8.5 data for 2030 and 2050 (Figures 4 and 5, respectively) shows the National Capital Region tied with the Northeast Region in 2030 based on average projected sea level rise, however the National Capital Region ranks highest in 2050. The Alaska Region ranks lowest for all three time intervals followed by the Pacific Northwest region, Intermountain Region, and Southeast Region. The Northeast Region comes ranks second highest for 2050 and 2100.

Figure 6. Projected future sea level by region for 2030 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region.

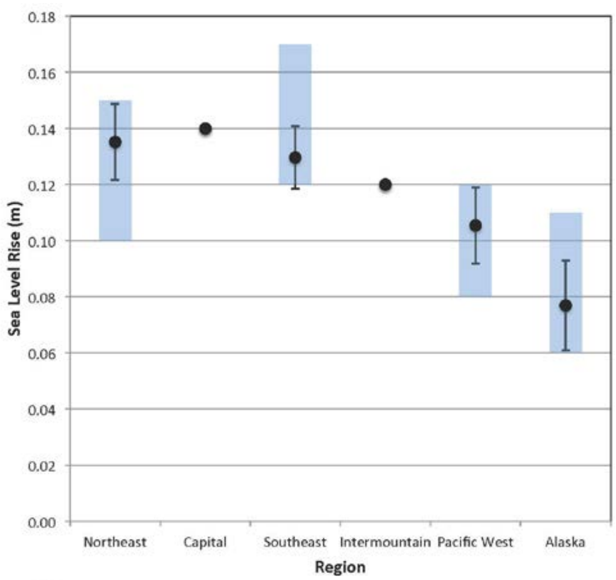
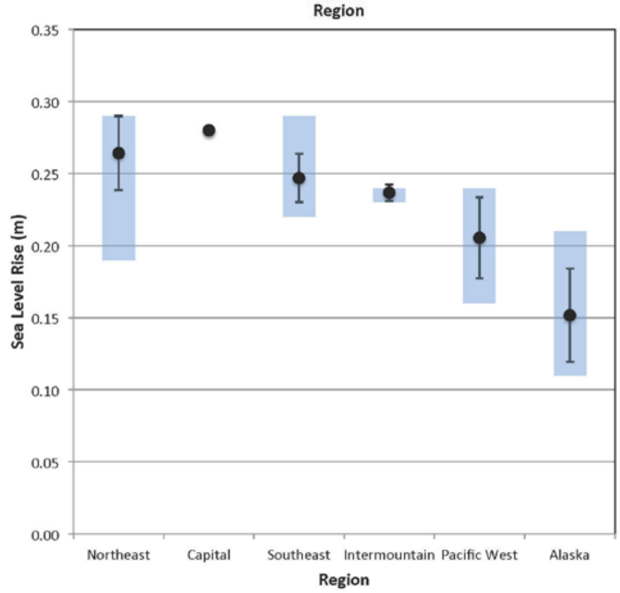


Figure 7. Projected future sea level by region for 2050 under RCP8.5. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region.



Storm surge was mapped for 79 park units. Storm surge data were combined with sea level rise projections to approximate how much area could be exposed to flooding on top of inundation. We used data for one storm category higher than the highest historical storm for our combined maps. Table E3 in Appendix E lists the highest historical storm for each park unit. 31 park units did not have a historical storm path travel within 10 miles of their boundaries, so a Saffir-Simpson hurricane 1 was simulated for these locations. The lack of a historical storm does not mean that these parks are not subject to strong storms. It may merely be that these parks are in regions that either do not have extensive historical records or they experience strong storms that are classified differently, such as nor'easters.

The Southeast Region has the strongest historical storms (average of highest recorded storm categories = 2.79), followed by the Intermountain Region (average = 2.33), National Capital Region (average = 1.90), and the Northeast (average = 1.03). None of the historical data intersected with the 10 miles buffers around the Alaska region parks. The Pacific West Region has experienced some tropical depressions, particularly in Hawaii, but most of their storm surges are driven by other phenomena, such as midlatitude cyclones or extreme tides (sometimes colloquially referred to as a king tide). The strongest (highest winds) and most intense (lowest pressure at landfall) recorded historical storm to have impacted a park unit was the "Labor Day Hurricane" that passed within 10 miles of Everglades National Park in 1935. However, while this storm may have been the highest intensity storm it is certainly not the most damaging or costly storm in National Park Service history.

Northeast Region

Figure 8 shows ~~how~~ the range of sea level projections for the Northeast Region for 2100. It is projected to average between 0.49 m (RCP2.6) and 0.74 m (RCP) of sea level rise by the end of the century. Colonial National Historical Park, Fort Monroe National Monument, and Petersburg National Battlefield are all tied for the coastline with the highest projected sea level rise in 2050 and 2100. They are also tied along with Edgar Allen Poe National Historic Site, Fort McHenry National Monument and Historic Shrine, Independence National Historical Park, and Thaddeus Kosciusko National Memorial as parks near coastline with the highest projected sea level rise for 2030. However, while these parks may have ranked highly, so caution should be used when analyzing these results. Many of these parks do not have coastline and so these projections are based on sea level rise for the coastline adjacent to these parks. The maps in Appendix A show how these projected numbers will impact each of these parks. Colonial National Historical Park, Fort McHenry, and Fort Monroe National Monument are the only park units that contain coastline with their boundaries.
Acadia National Park had the lowest projected rates of sea level rise for 2030 (0.08–0.10 m), 2050 (0.14–0.19 m), and 2100 (0.28–0.54).

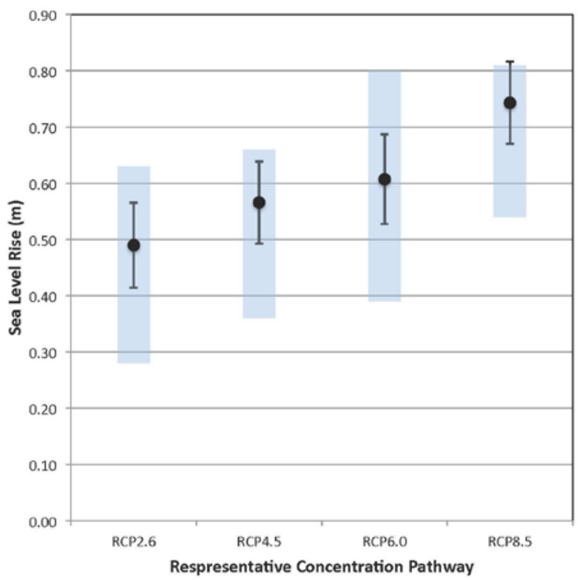


Figure 8. Projected future sea level by 2100 for the Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each category.

The highest recorded storm to have travelled within 10 miles of any of the 29 parks units identified for study was an officially unnamed hurricane in 1869 known colloquially as Saxby's Gale that was classified as a Saffir-Simpson 3 hurricane. The storm path passed Boston National Historical Park and Roger Williams National Memorial. Figure 9 shows the estimated extent of a storm surge from category 3 hurricane striking Boston Harbor Islands National Recreation Area at mean tide.

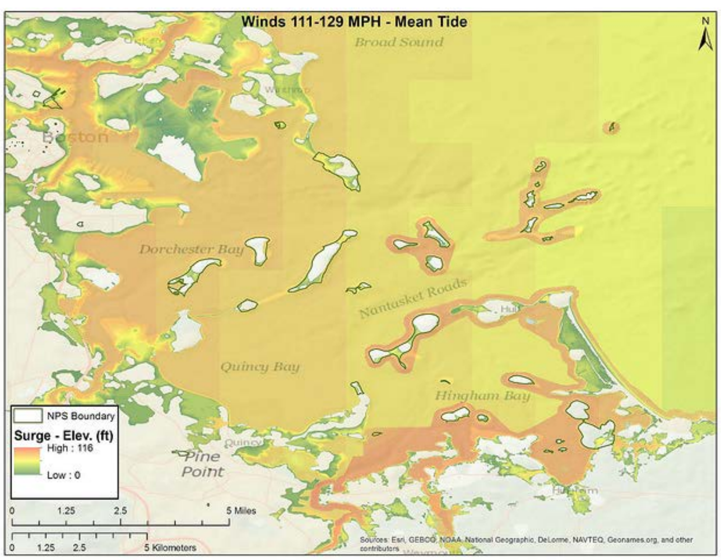


Figure 9. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at mean tide near Boston Harbor Islands National Recreation Area.

Southeast Region

The southeast region can expect to have some of the more intense (highest Saffir-Simpson storm category) storm over this century. Historically, the region has the highest intensity storms; although Everglades National Park has recorded a category 5 hurricane within 10 miles of its boundary, Figure 10 shows how it would only need to be struck by category 2 hurricane to completely flood the park.

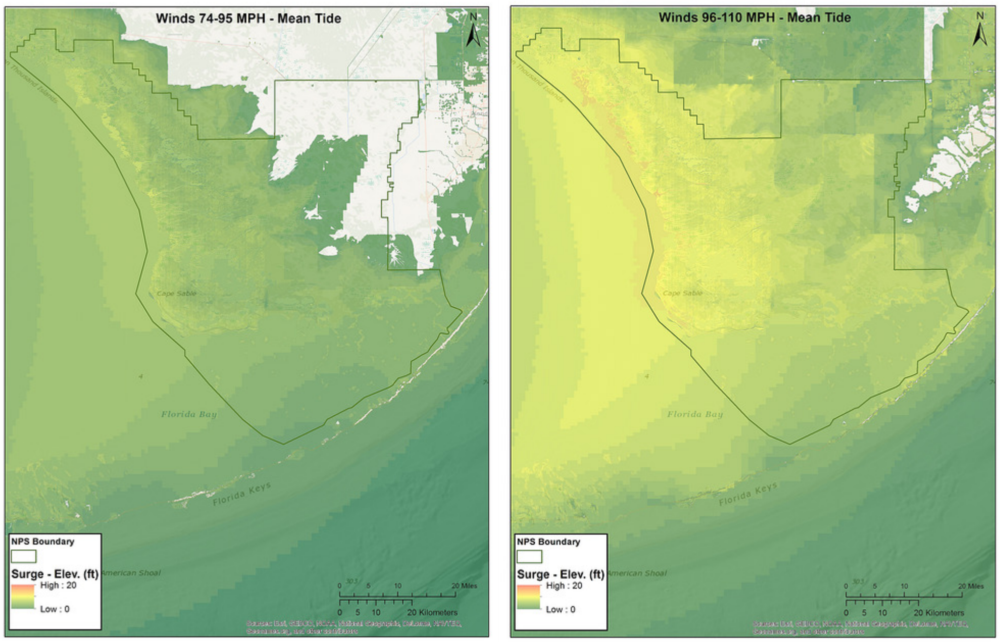


Figure 10. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide.

Combining such large storm surges with sea level rise highlights how exposed many of the Southeast Region park units are. It should also be considered that sea level rise projections do not include changes in land level. We recommend waiting for the forthcoming NASA report (Nerem per comm.) on land level before applying any numbers for planning; however, using table E1 from Appendix E as a rough guide changing land level for parks near tide gauges can be evaluated. The Eugene Island, Louisiana tide gauge's current rate of sea level rise is the highest in the country at 9.65 mm/yr owing in part to the large rate of subsidence in the region (Figure 1). Using the nearest tide gauge to Jean Lafitte National Historical Park and Preserve (Grand Isle, Louisiana, gauge 8761724) we can estimate that land will subside by 7.60 mm/yr. Applying this estimate of subsidence (using a baseline of 1992) to our RCP8.5 projections, the park could experience approximately 0.41 m of *relative* sea level rise by 2030 followed by 0.69 m by 2050 and 1.50 m by 2100.

Our projections list Wright Brothers National Memorial’s nearest coastline as having the greatest sea level rise by 2100 (0.82 m RCP8.5), but given the elevation of the park, this will still not inundate a large area of the memorial. However this could be more of a problem if this rise in water level is combined with other factors, such as a storm surge. The park will be almost completely flooded if a category 2 or higher hurricane strikes on top of the inundation from sea level rise.

Nearby Cape Hatteras and Cape Lookout National Seashores are projected to experience up to 0.79 m and 0.76 m, respectively (RCP8.5) of sea level rise by 2100. Both of the aforementioned units have shoreline as part of their boundaries, which means these rises in sea level will result in large areas of inundation. While these national seashores may rank slightly lower than Wright Brothers National Memorial for sea level rise, they serve as example of how caution must be used when using these numbers to assess which park units are most vulnerable to sea level rise. Other factors, such as percent of exposed land, changes in land movement, and adaptive capacity must also be taken into account for vulnerability analysis (Peek et al. 2015).

National Capital

National Capital Region has very little variability in projected sea level rise because all of the park units selected for study are all adjacent to the same section of coastline that was modeled. Their proximity also explains why they all share the same storm history. Despite these similarities, the way these numbers will impact each individual park unit will vary based on the topography of Washington D.C. The strongest storm to ever pass within 10 miles of the National Capital Region parks was as Saffir-Simpson category 2 hurricane that struck the city in 1878. While 1878 storm caused relatively little damage, we can expect a significantly larger amount of damage if a similar storm struck the city again. Figure 11 shows the extent of flooding created a Saffir-Simpson category 2 hurricane. A storm surge measuring more than 3 m could travel up the Potomac River causing large amounts of flooding.

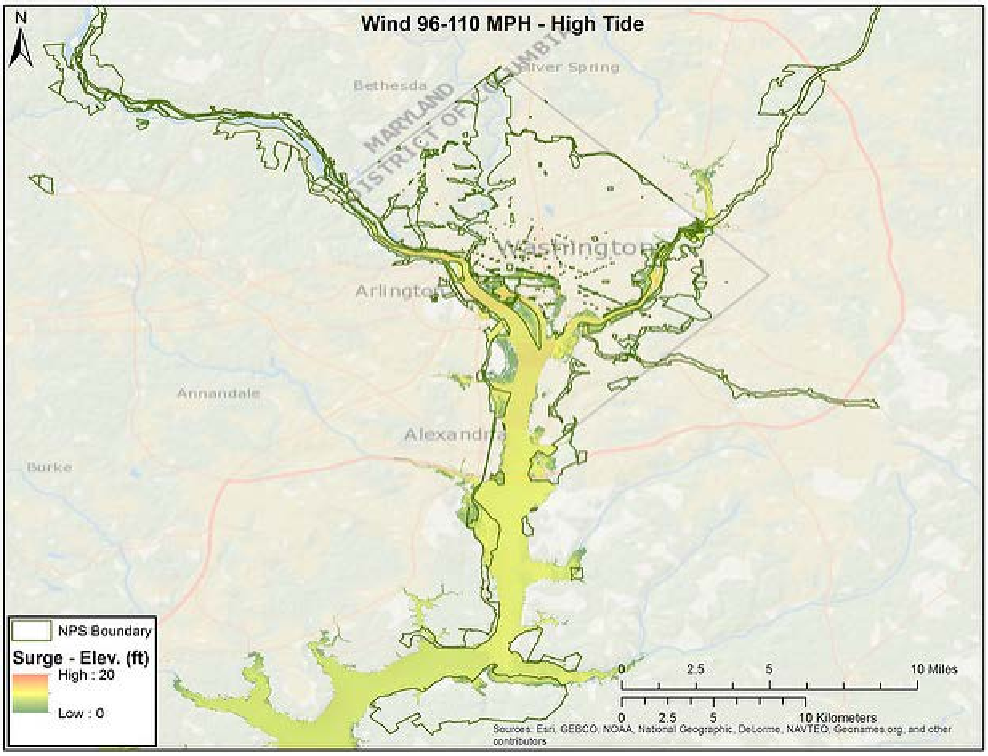


Figure 11. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide.

IPCC/SLOSH models showed either storm surge or sea level rise (or some combination of the two) impacting every park nominated for study with the exception of Harpers Ferry National Historical Park. Our mapping efforts revealed that Harpers Ferry National Historical Park located approximately 149 m above sea level is unlikely to experience any impacts of sea level rise due to its elevation and is unlikely to be damaged by storm surge from a hurricane from its relatively protected location behind several dams along the Potomac and Shenandoah Rivers. Harpers Ferry is potentially vulnerable to other climate change impacts, such as changing temperatures and precipitation.

Sea level rise alone is not expected to spread very far into Washington D.C., although a large section on the east side of Theodore Roosevelt Island ~~will~~ could be inundated. However, storm surge flooding on top of this sea level rise would have widespread impacts.

Intermountain Region

The Intermountain Region covers mostly inland park units stretching from Texas to Montana. Only three park units in Texas could be nominated for a study of this nature: Big Thicket National Preserve, Palo Alto Battlefield National Historical Park, and Padre Island National Seashore. Padre

Island National Seashore is likely to experience the greatest effects of sea level and storm surge out of the three park units. Sea level is projected to rise 0.46–0.69 m (RCP2.6–8.5, Figure 12) by 2100. The same amount of sea level rise is projected for the shoreline near Palo Alto Battlefield National Historical Park, but it is not ~~expected~~ projected to stretch inland enough to reach the park. Palo Alto Battlefield National Historical Park has no history of being within 10 miles of any hurricane, making the site unlikely to be flooded by storm surge. SLOSH MOM models for the park unit show that that the region would have to have either a Saffir-Simpson category 4 hurricane striking at high tide or a category 5 hurricane striking at any tide in order for the park to experience any storm surge. Whereas Figure 13 shows how Padre Island National Seashore located on the shoreline to the east of Palo Alto Battlefield National Historical Park has been within 10 miles of a category 4 hurricane. SLOSH MOM data show that another category 4 hurricane that would likely flood almost the entire island if it struck again.

There is some potential for storm surge to travel up the Neches River and flood the southernmost part of Big Thicket National Preserve, although storm surge defenses in Beaumont, Texas to the south of the preserve are likely to buffer it from any surge. It is more likely that a hurricane would cause flooding over a wider area of the park via precipitation.

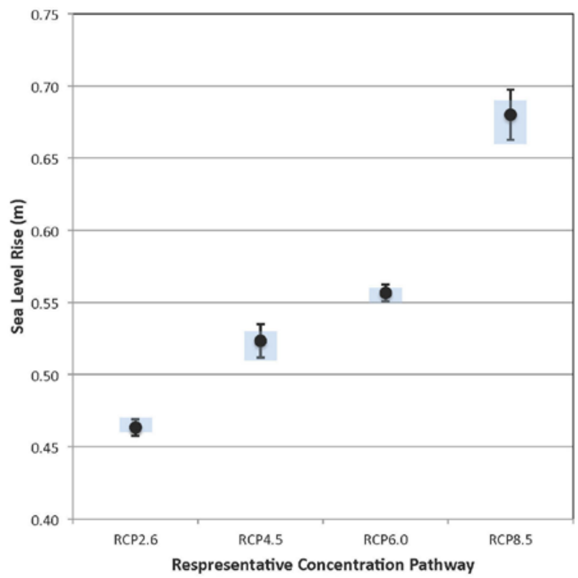


Figure 12. Projected future sea level by 2100 for the Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each category.

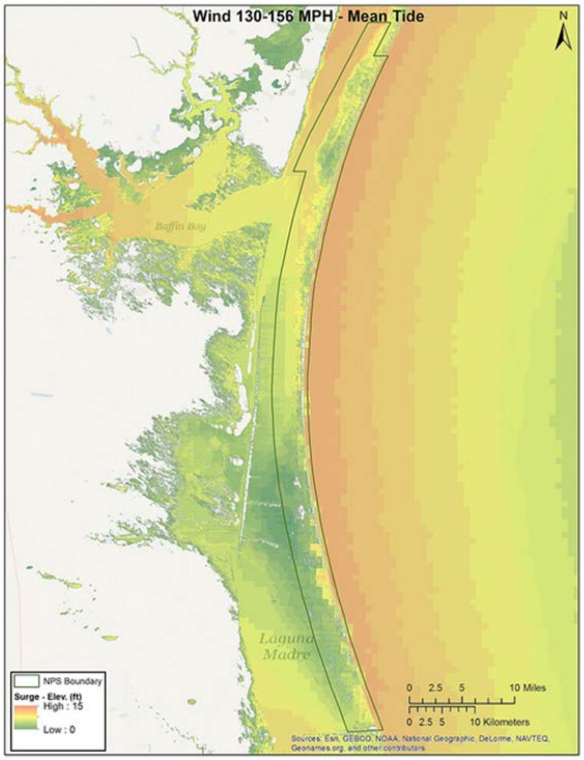


Figure 13. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore.

Pacific West Region

The Pacific West Region identified 24 park units that could be vulnerable to sea level rise and/or storm surge. These units are located over a large area comprising California, Oregon, Washington, Hawaii, American Samoa, and Guam. The average projected sea level rise range is ~~between~~ 0.40–0.58 m (RCP2.6–8.5) by 2100 for the whole region; however, there is a large standard deviation between these numbers (0.04 m and –0.08 m for RCP2.6 and RCP–8.5, respectively) that belies how the park-specific projections vary across the region. War in Pacific National Historical Park in Guam has the highest projected sea level rise at 0.68 m (RCP8.5) by 2100. War in Pacific National Historical Park is also tied for highest projected sea level rise with almost all of the Hawaiian park units in 2030 and 2050.

At the other end of the spectrum the park units located around Washington’s Olympic Peninsula (Ebey’s Landing National Historical Reserve, Olympic National Park, and San Juan Island Historical Park) rank lowest for projected sea level rise. Sea level is projected to rise much more slowly in this region reaching a maximum 0.46 m (RCP8.5) by 2100. This is a region that is subject to tectonic shifts as well as continuing land movement due to isostatic rebound that further complicate sea level projections. Long-term tide gauge records at Neah Bay, Washington (gauge 9443090) and Tofino, Canada (gauge 822-116) show relative sea levels as currently decreasing while tide gauges in Port Angeles, Washington (gauge 9444090), Victoria, Canada (gauge 822-101), and Seattle, Washington (gauge 9447130) show it to be increasing (Zervas 2009). Our projections show sea level in this region to rise throughout this century, although the release of the forthcoming NASA report (Nerem per comm.) could shed more light on this matter.

Modeling for storm surge is complicated by the lack of hurricanes to have stuck many of the parks in this region. Instead we chose to use data from Tebaldi et al. (2012) that includes anomalous surges that could be created by storms as well as other factors (sometimes referred to as king tides). Based on the Tebaldi et al. (2012) data, La Jolla, California (gauge 9410230) has the lowest 100-year storm surge measuring 0.95 m and Toke Point, Washington (gauge 9440910) has the highest 100-year storm surge (1.96 m) in the Pacific West Region. Tebaldi et al. (2012) did not analyze storm data for Hawaii, Guam, or American Samoa, although IBTrACS (Knapp et al. 2010) does have hurricane records for these areas. Only tropical depressions have been recorded within 10 miles almost all of the selected Hawaiian park units (Haleakala National Park, Hawaii Volcanoes National Park, Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puukohola Heiau National Historic Site, and World War II Valor in the Pacific National Monument).

Alaska Region

The Alaska Region has the lowest average projected sea level rise (0.28–0.43 m by 2100) compared to the five regions described above. Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park in southeastern Alaska share the lowest projected sea level rise (0.33 m RCP8.5 2100) while Bering Land Bridge National Preserve on the west coast of the state has the highest projected sea level rise (0.60 m RCP8.5 2100).

Figure 1 shows how current relative sea levels vary across the state. Land levels are rapidly rising in the southeast of the region due to isostatic rebound and other tectonic shifts. Current rates of relative sea level change in Skagway, Alaska are the lowest in the country; decreasing at an average rate of 17.59 mm/yr (Zervas 2009). The net result of these increasing land levels is decreasing relative sea levels for at least the early part of this century. Despite melting ice and other factors outlined in Table 1 that are adding to our ocean waters volume, the amount of rising water is not sufficient to keep up with the land level. Seven park units (Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park) have been identified as potentially having decreasing relative sea levels based on the nearest tide gauge data to each of these parks. None of these parks have long-term tides gauges that have data spanning at least thirty years. A great strength of using the IPCC (2013) process-based model approach is that, unlike many other semi-empirical models, it does not rely on long-term tide gauge records to statistically predict future sea levels. However, our sea level projections do not at this time include changes in land level. The numbers we supply here are for how much we can expect the water volume to rise near to each of these park units. Table E1 shows how land levels are changing at long-term tide gauges across the country. However, given that all of these park units are located far from a tide gauge and that the region is relatively geologically complex, we would not recommend using the land movement numbers from the nearest tide gauge for any of the Alaskan parks.

Storm surge is also very difficult to model for this region. Historically, many of the parks had sea ice along the coastline that helped protect these parks from storm surge. Consequently NOAA does not have SLOSH MOM models for this region. IBTrACS data (Knapp et al. 2010) show a few storm paths that have moved towards the region, but these types of storms typically do not make landfall once they move over colder waters. Alaska does hold the record for the highest intensity (lowest central pressure) storm (Duff 2015). A downgraded super typhoon, Nuri, struck Adak Island, Alaska in 2014 with recorded winds gusting up to 122 mph. It is unfortunately impossible to determine an average or peak historical storm surge without adequate tide gauge data.

Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/yr, although this rate accelerated over the later part of the century. Slangan et al. (2016) found that the release of anthropogenic greenhouse gases has been the primary driver of global sea level change since 1970 as the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/yr (Cazenave et al. 2014, Fasullo et al. 2016).

The IPCC (2013) ~~expects~~ projects this rate will increase and ~~predicts~~ projects global average sea levels to increase by 0.40–0.63 m (RCP2.6–8.5) by 2100. We used regional sea level projections from the IPCC (2013) generated for 2050 and 2100 in combination with our own downscaled projections for 2030 to estimate how much sea level rise 118 coastal national park units could experience in the future. Our ~~are~~ projections are based on the new representative concentration pathways (~~Meinshausen~~ Moss et al. 2010~~1~~, Figure 14) and use a process based model approach.

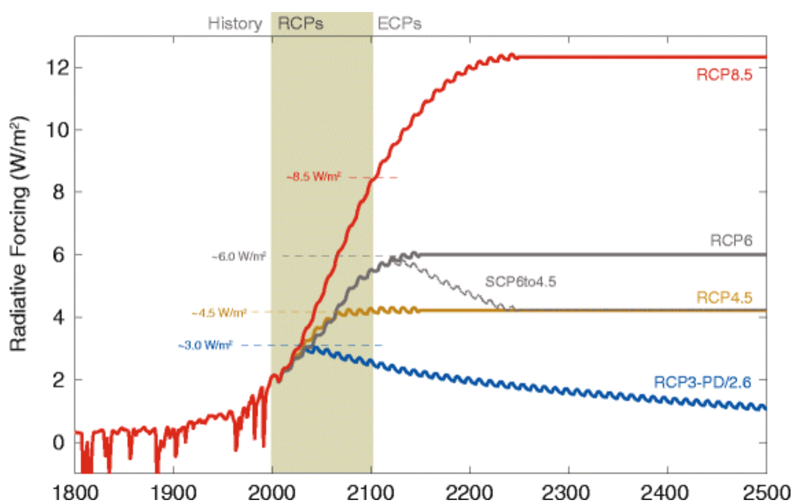


Figure 14: Radiative forcing for each of the Representative Concentration Pathways (RCPs). RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are higher than RCP6.0 (gray line) in the early part of this century.

Source: Meinshausen et al. 2011.

There are numerous academic articles that use mostly semi-empirical models (Rahmstorf 2007) to estimate sea level rise for a number of regions across the U.S. The IPCC (2013) lists a number of semi-empirical sea level estimates, all of which create estimates of future sea level that are higher than the IPCC (2013) approach. The differences to these approaches can be attributed to a number of factors. For example, some of the older papers may have higher sea level estimates because they are based on the older IPCC SCRES scenarios (e.g. Vermeer and Rahmstorf 2009, Grinsted et al. 2010, Jevrejeva et al. 2010). Other papers may augment their sea level projections with "expert elicitations" where experts are polled on how much they think sea level (or a related factor) could rise in the future (e.g. Bamber and Aspinall 2013, Jevrejeva et al. 2014, Horton et al. 2014). Others have published articles criticizing the IPCC sea level estimates as being too conservative or underestimating rates of future sea level change (e.g. Kerr 2013, Horton et al. 2014). These criticisms were addressed by Church et al. (2013) and so they will not be discussed in detail here. Recent analyses by Clark et al. (2015) further supports the findings of the IPCC.

A key strength of these methods has been that this research applies a unified approach to identify how sea level change will impact all coastal park units across the National Park System, rather than relying on sea level data generated for specific regions. Our analyses revealed that the National Capital Region is projected to be the region to experience then greatest increase in sea level (not taking into account changes in land level). This rise will impact each of the region's units in different ways depending on the elevation of the individual unit, but it could be catastrophic if combined with a storm surge from a storm such as the category 2 hurricane in 1878.

At the individual park level IPCC projections reveal the sea level along the coastline adjacent to Wright Brothers National Memorial could rise up 0.82 m (RCP8.5) by 2100, which could lead to significant flooding if combined with a storm surge. The Southeast Region as a whole is generally susceptible to inundation and flooding due to its low-lying nature in many places, particularly in the Cape Hatteras/Cape Lookout National Seashores region. Our sea level rise maps highlight how much all of these park units will be impacted.

However these estimates do not factor in changing land levels. We are expecting the latest state-of-the-art land level estimates to be released by NASA in 2017. In the meantime we can roughly estimate relative sea level change for a small number of parks based on current rates of subsidence gathered from nearby long-term tide gauge data. We expect Jean Lafitte National Historical Park and Preserve to have the greatest relative sea level increase based on the current rate of land movement. Our sea level projections agree with current sea level trends that the southeast Alaska region is experiencing the least amount of sea level rise of anywhere in the National Park System.

Sallenger et al. (2012) discussed how storm surge combined with sea level rise could create a 1000-km long "hotspot" along the North Atlantic coast from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. Our projections also found that to be the case. We mapped future inundation caused by sea level change combined with flooding caused by a storm measuring one storm category higher than historical for each park unit, assuming an intensification of future storm surge (Webster 2005, Mingfang 2015). We found that almost all of the coastal park units would be flooded under these conditions.

It is unknown exactly to what degree future storm surge will impact the Alaskan park units. A~~Storm~~ ~~a~~ccurate long-term (>30 years) storm surge data do not exist for the Alaska region. Even if such data did exist it would be not be analogous to future conditions in the regions as sea ice that had previously protected the shores for many of the western Alaska park units melts to reveal an easily erodible coastline (Frey et al. 2015). The warming of ocean waters in the Gulf of Alaska and Pacific Ocean could also make it more conducive for more storms like Typhoon Nuri to travel north without losing as energy as they once did.

The Pacific West Region shows a lot of variability among parks. A recent report by Golden Gate National Recreation Area (2016) goes into detail regarding what some of these park units are doing to plan for climate change. The National Research Council report for California, Washington, and Oregon (2012) has been cited frequently as a resource on sea level rise in the region, but it does not cover the entire administrative region that is managed by the Pacific West Region. War in Pacific National Historical Park in Guam ranks first as having the highest projected sea level rise amongst the units administered by the Pacific West Region.

Island park units in general are especially exposed to the impacts of sea level change and storm surge. Many of the barrier island parks, such as Fire Island National Seashore, Assateague National Seashore, Palo Alto Battlefield National Historical Park, Gulf Islands National Seashore and Cape Hatteras National Seashore are all projected to experience sea level rises over 0.69 m by 2100 (RCP8.5). This sea level rise combined with storm surge could be especially difficult for isolated island park units, such as the Caribbean park units, National Park of American Samoa, and War in Pacific National Historical Park where access to aid in the event of a natural disaster may not be immediately available.

Conclusions

Projections of sea level change and storm surge due to anthropogenic climate change in 118 coastal park units administered by the National Park Service are presented in this report. Historical storm surge data showed the Southeast Region to have experienced the most intense hurricanes, which could lead to even greater storm surges in the future if storms become stronger (Webster 2005, Mingfang 2015). Sea level rise is projected to generally be greatest in the National Capital Region, although some low-lying parks, such as Everglades National Park and park units in the Outer Banks of North Carolina and Gulf Coast will continue to be challenged by this issue.

Sea level and storm surge will vary geographically, resulting in unique challenges for adaptation and management. It is important to acknowledge that sea level change will impact some parts of Alaska differently to the rest of the country. Northwest Alaska can expect relative sea levels to increase over time, while southeast Alaska relative sea levels will likely continue to decrease over the first part of this century followed by an increase in relative sea level by the end of the century.

This project is an important first step in assessing how changes in sea level and storm surge due to anthropogenic climate change will impact our national park units. By combining projected sea level with storm surge data we can start to examine how these two separate variables can exacerbate the impact of each other over time. It is clear that more research can be done on these complex issues to assess how these changes will impact individual parks as well as the wider regions. Looking ahead, these data have applications for a number of future projects related to both natural and cultural resources as well as the planning and management of infrastructure.

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Appendix A

Sea-level change Maps

The following maps were created by this project to illustrate the impact of storm surge for all of the parks that have SLOSH data. These maps were created by this project using NOAA data. For further information regarding our methods refer to methods section on page 4. Digital versions of these maps will be available at www.irma.gov and [redacted] webappviewer/index html?id=b0089512f1ee4117bc57224b97f74ecc

[Maps will be inserted after they have been reviewed]

Appendix B

Storm Surge Maps

The following maps were created by this project to illustrate the impact of storm surge for all of the parks that have SLOSH data. These maps were created by this project using NOAA data. For further information regarding our methods refer to section xxx. Digital versions of these maps will be available at www.irma.gov and https://www flickr.com/photos/125040673@N03/albums/with/72157663665097941. Maps are arranged alphabetically by unit name.

[Maps will be added after they have been reviewed]

Appendix C

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with regional managers. Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.

Q. Who originally identified which park units should be used in this study?

A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. Where did you use data used by Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to help plug some of these gaps in our data network for park units in California, Oregon, Washington, and southern Alaska.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012). The following parks used Tebaldi et al. (2012) data: Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into that region.

Q. Why are the storm surge maps in NAVD88?

That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on projections for some parks?

The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America. It uses a fixed value for the height of the sea level. While this is a popular datum for mapping, it has the limitation that it is based on the tidal benchmark for Rimouski, Canada. As you move further away from this benchmark you can expect actual sea level to differ from the reference benchmark. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

All parks are different, as are all projects. Your choice of scenario may depend on many different factors. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. 2009. Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). The standard error of the IPCC is explained in greater detail in the chapter 13 supplementary material in AR5 (IPCC 2013).

Comment [PG9]: It would be good to give ranges of the IPCC standard errors

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent an average storm surge number. As described above there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, El Niño and La Niña years will impact sea level. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of man-made structures, such as levees and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. Permanent inundation will change the way waves propagate within a basin in the future. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www nhc noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bath tub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact Rebecca Beavers for assistance. It may be possible to downscale projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing between sources.

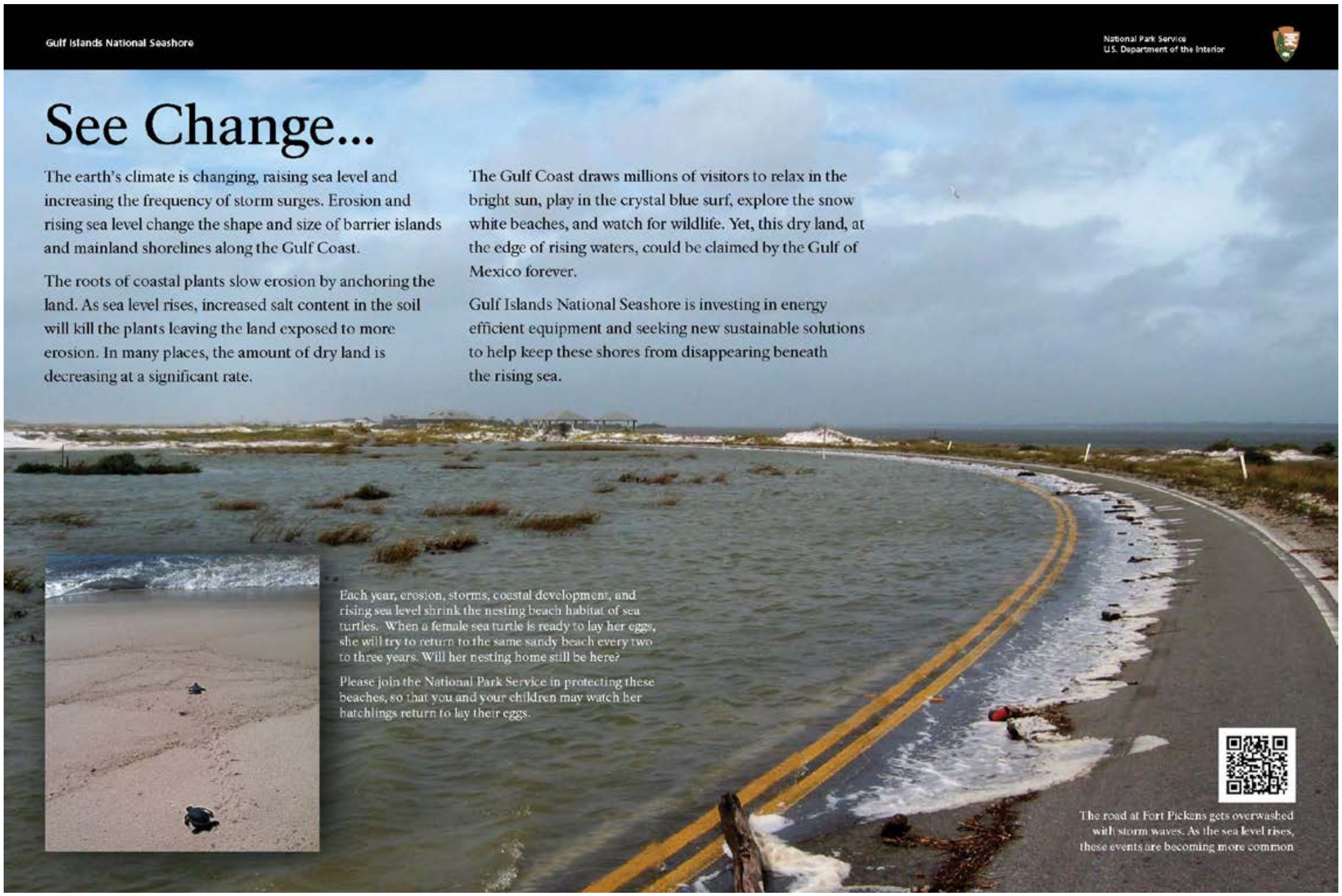
Q. What are other impacts from sea-level rise that parks should consider?

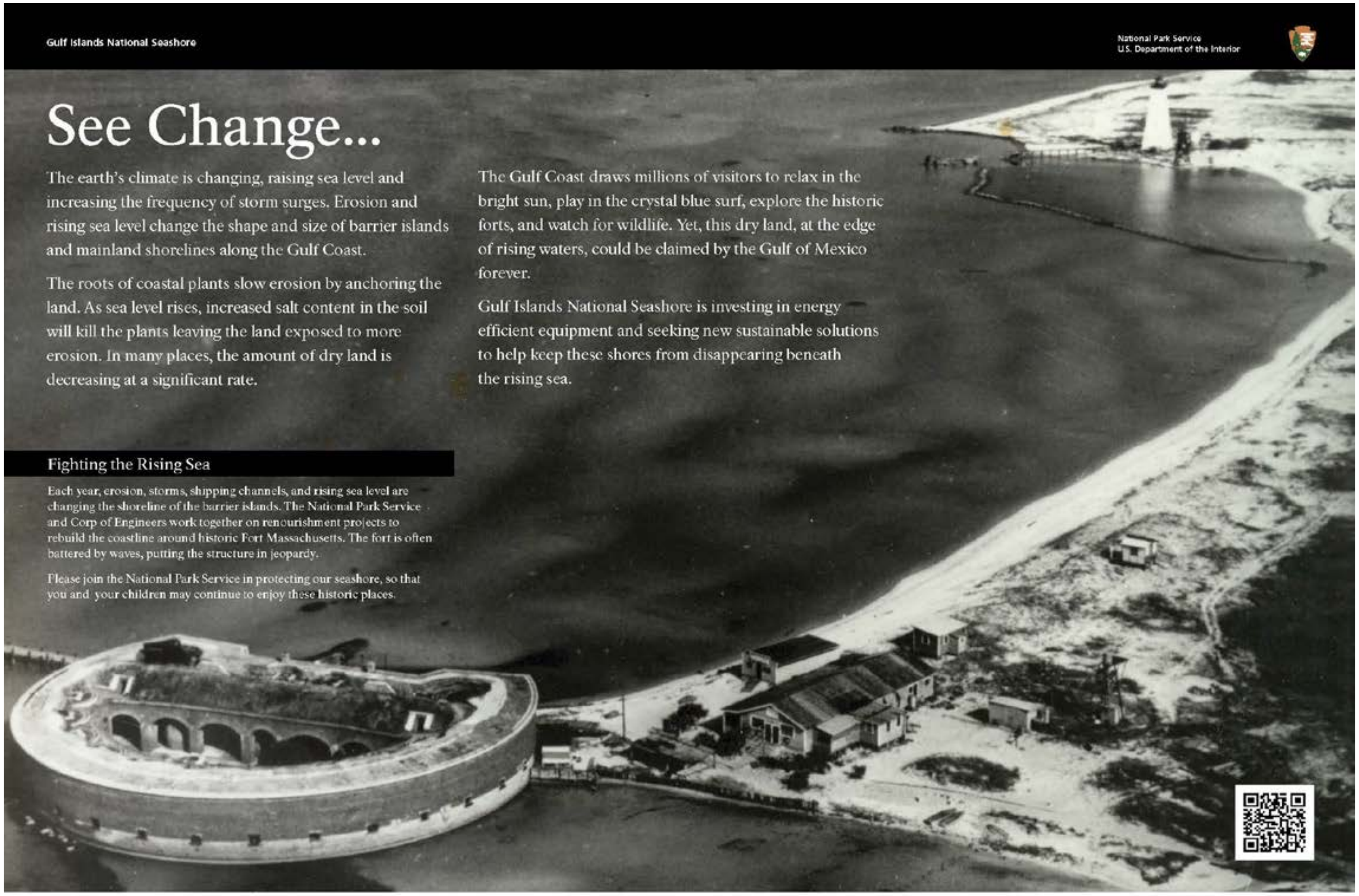
A. Impacts from sea-level rise could include, but are not limited to, destroyed cultural resources, damage to above ground infrastructure, difficulty accessing buried infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems.

Appendix D

Waysides

The following pages show the final designs for waysides that were installed in parks as part of the funding for this project. Gulf Islands National Seashore received two waysides that were received in 2015. Jean Lafitte National Historical Park and Preserve and Fire Island National Seashores waysides were installed in 2016.


Gulf Islands National Seashore
National Park Service
U.S. Department of the Interior
See Change...
The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.
The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.
The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the snow white beaches, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.
Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.
Each year, erosion, storms, coastal development, and rising sea level shrink the nesting beach habitat of sea turtles. When a female sea turtle is ready to lay her eggs, she will try to return to the same sandy beach every two to three years. Will her nesting home still be here?
Please join the National Park Service in protecting these beaches, so that you and your children may watch her hatchlings return to lay their eggs.
The road at Fort Pickens gets overwashed with storm waves. As the sea level rises, these events are becoming more common


Gulf Islands National Seashore
National Park Service
U.S. Department of the Interior
See Change...
The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.
The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.
The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the historic forts, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.
Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.
Fighting the Rising Sea
Each year, erosion, storms, shipping channels, and rising sea level are changing the shoreline of the barrier islands. The National Park Service and Corp of Engineers work together on renourishment projects to rebuild the coastline around historic Fort Massachusetts. The fort is often battered by waves, putting the structure in jeopardy.
Please join the National Park Service in protecting our seashore, so that you and your children may continue to enjoy these historic places.

Sinking Land, Rising Water

This is the Barataria Basin, built of soil washed to this area by the Mississippi River. This soil is still compacting and sinking, a process called subsidence. Most of the Barataria Preserve is less than two feet above sea level, and its subsidence rate is nearly half an inch a year.

Meanwhile, glaciers and polar ice sheets are melting and our warming climate is heating oceans everywhere, making their waters expand just like water does when you heat it on the stove. Everywhere on the planet, the oceans are a little higher every day.

The combination of the Barataria Basin's sinking land and global sea level rise means that the ocean is creeping in faster here than almost anywhere else in North America.

- Floods are becoming more frequent and lasting longer
- Coastal wetlands are disappearing as land sinks and water rises
- Less land is available to buffer Gulf of Mexico storms
- Storm and flooding threats to homes, communities, and infrastructure like highways, ports, and energy facilities are increasing
- Salt water from the Gulf is moving into freshwater wetlands, killing the plants that hold the land together
- Death of plants, animals, and microbes that cannot tolerate increased flooding or salt water

The photo shows two feet of flooding on Barataria Boulevard after Hurricane Isaac in August 2012. The map shows predicted consequences of 18 inches of sea level rise in the preserve; blue areas would be flooded and brown areas would remain land.


Fire Island National Seashore
National Park Service
U.S. Department of the Interior
See Change In A Changing Climate
Natural landscape change can be nearly imperceptible on a barrier island, as the wind and waves gradually shape the shoreline, beach, and dunes. Natural changes can also be obvious and happen quickly during storms like hurricanes and nor'easters. Looking ahead, storms will have a greater impact on Fire Island due to climate change.
When we burn fossil fuels, carbon dioxide is released into the atmosphere and acts like a heat trapping blanket around our planet. Heat that would normally escape from the atmosphere is retained, warming the Earth, and changing climate patterns. As ocean waters warm and ice on land melts, sea level rises and impacts Fire Island and coastlines all over the world. The future of this barrier island is in jeopardy due to these human-induced climate change effects.
Fire Island protects mainland Long Island against storms and is a stunning setting for recreation, education, and inspiration. It also provides critical habitat for plants and wildlife. We must do what we can to protect this special place. By using renewable energy sources and reducing our dependence on fossil fuels, we can take steps today to preserve barrier island systems and processes, and help build natural resilience to future storms and sea-level rise.
Storm Stories
On October 29, 2012, Hurricane Sandy struck Fire Island National Seashore and changed the lay of the land. During the storm high water and large waves scoured sand from the beach and dunes, moved sand across the width of the island, and carved the breach, pictured here, through the barrier island. The storm was the strongest in recorded history to make landfall in this region.
To learn more about how climate change is impacting the Seashore, please visit www.nps.gov/fiis/learn/climatechange.htm
Background photo credit: C. Flagg

Appendix E

Data Tables

Table E1. The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (yrs)[†]	Rate of Subsidence (mm/yr)
Northeast Region				
Acadia National Park	Bar Harbor, ME (8413320)	N	60	0.750
Assateague Island National Seashore[‡]	Lewes, DE (8557380)	N	88	1.660
Boston Harbor Islands National Recreation Area	Boston, MA (8443970)	N	86	0.840
Boston National Historical Park	Boston, MA (8443970)	N	86	0.840
Cape Cod National Seashore	Woods Hole, MA (8447930)	N	75	0.970
Castle Clinton National Monument	New York, The Battery, NY (8518750)	N	151	1.220
Colonial National Historical Park	Sewells Point, VA (8638610)	N	80	2.610
Edgar Allen Poe National Historic Site	Philadelphia, PA (8545240)	N	107	1.060
Federal Hall National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
Fire Island National Seashore	Montauk, NY (8510560)	N	60	1.230
Fort McHenry National Monument and Historic Shrine	Baltimore, MD (8574680)	N	105	1.330
Fort Monroe National Monument[‡]	Sewells Point, VA (8638610)	N	80	2.610
Gateway National Recreation Area[*‡]	Sandy Hook, NJ (8531680)	N	75	2.270
General Grant National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
George Washington Birthplace National Monument[‡]	Solomons Island, MD (8577330)	N	70	1.830
Governors Island National Monument[‡]	New York, The Battery, NY (8518750)	N	151	1.220
Hamilton Grange National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
Harriet Tubman Underground Railroad National Monument	Cambridge, MD (8571892)	N	64	1.900
Independence National Historical Park	Philadelphia, PA (8545240)	N	107	1.060
New Bedford Whaling National Historical Park	Woods Hole, MA (8447930)	N	75	0.970
Petersburg National Battlefield[‡]	Sewells Point, VA (8638610)	N	80	2.610
Roger Williams National Memorial	Providence, RI (8454000)	N	69	0.300

Sagamore Hill National Historic Site	Kings Point, NY (8516945)	N	76	0.670
Saint Croix Island International Historic Site‡	Eastport, ME (8410140)	N	78	0.350
Salem Maritime National Historic Site	Boston, MA (8443970)	N	86	0.840
Saugus Iron Works National Historic Site	Boston, MA (8443970)	N	86	0.840
Statue of Liberty National Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
Thaddeus Kosciuszko National Memorial	Philadelphia, PA (8545240)	N	107	1.060
Theodore Roosevelt Birthplace National Historic Site	New York, The Battery, NY (8518750)	N	151	1.220

Southeast Region				
Big Cypress National Preserve	Naples, FL (8725110)	N	42	0.270
Biscayne National Park‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
Buck Island Reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Canaveral National Seashore	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620
Cape Hatteras National Seashore*‡	Beaufort, NC (8656483)	N	54	0.790
Cape Lookout National Seashore	Beaufort, NC (8656483)	N	54	0.790
Castillo De San Marcos National Monument‡	Mayport, FL (8720218)	N	79	0.590
Charles Pinckney National Historic Site	Charleston, SC (8665530)	N	86	1.240
Christiansted National Historic Site‡	San Juan, Puerto Rico (9755371)	N	45	-0.202
Cumberland Island National Seashore‡	Fernandina Beach, FL (8720030)	N	110	0.600
De Soto National Memorial	St. Petersburg, FL (8726520)	N	60	0.920
Dry Tortugas National Park‡	Key West, FL (8724580)	N	94	0.500
Everglades National Park*‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
Fort Caroline National Memorial‡	Fernandina Beach, FL (8720030)	N	110	0.600
Fort Frederica National Monument‡	Fernandina Beach, FL (8720030)	N	110	0.600
Fort Matanzas National Monument‡	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620
Fort Pulaski National Monument	Fort Pulaski, GA (8670870)	Y	72	1.360
Fort Raleigh National Historic Site‡	Beaufort, NC (8656483)	N	54	0.790
Fort Sumter National Monument‡	Charleston, SC (8665530)	N	86	1.240
Gulf Islands National	Dauphin Island, AL	N	41	1.220

Seashore*‡	(8735180) Pensacola, FL (8729840)	N	84	0.330
Jean Lafitte National Historical Park and Preserve‡	Grand Isle, LA (8761724)	N	60	7.600
Moores Creek National Battlefield‡	Wilmington, NC (8658120)	N	72	0.430
New Orleans Jazz National Historical Park‡	Grand Isle, LA (8761724)	N	60	7.600
Salt River Bay National Historical Park and Ecological Preserve‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
San Juan National Historic Site	San Juan, Puerto Rico (9755371)	N	45	-0.020
Timucuan Ecological and Historic Preserve‡	Fernandina Beach, FL (8720030)	N	110	0.600
Virgin Islands Coral reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Virgin Islands National Park‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
Wright Brothers National Memorial‡	Sewells Point, VA (8638610)	N	80	2.610

National Capital Region				
Anacostia Park	Washington, DC (8594900)	N	83	1.340
Chesapeake and Ohio Canal National Historical Park	Washington, DC (8594900)	N	83	1.340
Constitution Gardens	Washington, DC (8594900)	N	83	1.340
Fort Washington Park	Washington, DC (8594900)	N	83	1.340
George Washington Memorial Parkway	Washington, DC (8594900)	N	83	1.340
Harpers Ferry National Historical Park	Washington, DC (8594900)	N	83	1.340
Korean War Veterans Memorial	Washington, DC (8594900)	N	83	1.340
Lincoln Memorial	Washington, DC (8594900)	N	83	1.340
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Washington, DC (8594900)	N	83	1.340
Martin Luther King Jr. Memorial	Washington, DC (8594900)	N	83	1.340
National Mall	Washington, DC (8594900)	N	83	1.340
National Mall and Memorial Parks	Washington, DC (8594900)	N	83	1.340
National World War II Memorial	Washington, DC (8594900)	N	83	1.340
Piscataway Park	Washington, DC (8594900)	N	83	1.340
Potomac Heritage National	Washington, DC	N	83	1.340

Scenic Trail	(8594900)			
President's Park (White House)	Washington, DC (8594900)	N	83	1.340
Rock Creek Park	Washington, DC (8594900)	N	83	1.340
Theodore Roosevelt Island Park	Washington, DC (8594900)	N	83	1.340
Thomas Jefferson Memorial	Washington, DC (8594900)	N	83	1.340
Vietnam Veterans Memorial	Washington, DC (8594900)	N	83	1.340
Washington Monument	Washington, DC (8594900)	N	83	1.340

Intermountain Region				
Big Thicket National Preserve‡	Sabine Pass, TX (8770570)	N	49	3.850
Palo Alto Battlefield National Historical Park‡	Port Isabel, TX (8779770)	N	63	2.160
Padre Island National Seashore*	Padre Island, TX (8779750)	N	49	1.780

Pacific West Region				
Cabrillo National Monument	San Diego, CA (9410170)	N	101	0.370
Channel Islands National Park‡	Santa Monica, CA (9410840)	N	74	-0.280
Ebey's Landing National Historical Reserve‡	Friday Harbor, WA (9449880)	N	73	-0.580
Fort Point National Historic Site	San Francisco, CA (9414290)	Y	110	0.360
Fort Vancouver National Historic Site‡	Astoria, OR (9439040)	N	82	-2.100
Golden Gate National Recreation Area	San Francisco, CA (9414290)	N	110	0.360
Haleakala National Park*‡	Kahului, HI (1615680)	N	60	0.510
Hawaii Volcanoes National Park*‡	Hilo, HI (1617760)	N	80	1.470
Kaloko-Honokohau National Historical Park‡	Hilo, HI (1617760)	N	80	1.470
Lewis and Clark National Historical Park	Astoria, OR (9439040)	N	82	-2.100
National Park of American Samoa	Pago Pago, American Samoa (1770000)	N	59	0.370
Olympic National Park*‡	Seattle, WA (9447130)	N	109	0.540
Point Reyes National Seashore‡	San Francisco, CA (9414290)	N	110	0.360
Port Chicago Naval Magazine National Memorial‡	Alameda, CA (9414750)	N	68	-0.780
Pu'uhonua O Honaunau National Historical Park*‡	Hilo, HI (1617760)	N	80	1.470
Puukohola Heiau National Historic Site*‡	Hilo, HI (1617760)	N	80	1.470
Redwood National and State	Crescent City, CA	N	74	-2.380

Parks	(9419750)			
Rosie the Riveter WWII Home Front National Historical Park*	Alameda, CA (9414750)	N	68	-0.780
San Francisco Maritime National Historical Park	San Francisco, CA (9414290)	N	110	0.360
Santa Monica Mountains National Recreation Area	Santa Monica, CA (9410840)	N	74	-0.280
War in the Pacific National Historical Park	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
World War II Valor in the Pacific National Monument[‡]	Honolulu, HI (1612340)	N	102	-0.180

Alaska Region				
Aniakchak Preserve*[‡]	Unalaska, AK (9462620)	N	50	-7.250
Bering Land Bridge National Preserve[‡]	No data	No data	No data	No data
Cape Krusenstern National Monument[‡]	No data	No data	No data	No data
Glacier Bay National Park*[‡]	Juneau, AK (9452210)	N	71	-14.620
Glacier Bay Preserve*[‡]	Juneau, AK (9452210)	N	71	-14.620
Katmai National Park[‡]	Seldovia, AK (9455500)	N	43	-11.420
Kenai Fjords National Park[‡]	Seward, AK (9455090)	N	43	-3.820
Klondike Gold Rush National Historical Park[‡]	Skagway, AK (9452400)	N	63	-18.960
Lake Clark National Park[‡]	Seldovia, AK (9455500)	N	43	-11.420
Sitka National Historical Park[‡]	Sitka, AK (9451600)	N	83	-3.710
Wrangell – St. Elias National Park[‡]	Cordova, AK (9454050)	N	43	3.450
Wrangell – St. Elias National Preserve[‡]	Cordova, AK (9454050)	N	43	3.450

[†]Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

[‡]It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Northeast Region					
Acadia National Park	2030	0.08	0.09	0.09	0.10
	2050	0.14	0.16	0.16	0.19
	2100	0.28	0.36	0.39	0.54
Assateague Island National Seashore[§]	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Boston Harbor Islands National Recreation Area	2030	0.11[‡]	0.11	0.11[‡]	0.11
	2050	0.19[‡]	0.20	0.20[‡]	0.22
	2100	0.37[‡]	0.45	0.50[‡]	0.62
Boston National Historical Park	2030	0.11[‡]	0.11	0.11[‡]	0.11
	2050	0.19[‡]	0.20	0.20[‡]	0.22
	2100	0.37[‡]	0.45	0.50[‡]	0.62
Cape Cod National Seashore[§]	2030	0.13	0.15	0.13	0.15
	2050	0.23	0.27	0.23	0.29
	2100	0.45	0.51	0.57	0.69
Castle Clinton National Monument*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Colonial National Historical Park	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81
Edgar Allen Poe National Historic Site*	2030	0.16[‡]	0.15	0.15[‡]	0.14
	2050	0.27[‡]	0.27	0.27[‡]	0.28
	2100	0.54[‡]	0.62	0.68[‡]	0.79
Federal Hall National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Fire Island National Seashore[§]	2030	0.14	0.14	0.14	0.14
	2050	0.25	0.26	0.25	0.27
	2100	0.50	0.58	0.62	0.76
Fort McHenry National Monument and Historic Shrine	2030	0.16[‡]	0.15	0.15[‡]	0.14
	2050	0.27[‡]	0.27	0.27[‡]	0.28
	2100	0.54[‡]	0.62	0.68[‡]	0.79
Fort Monroe National Monument	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway 2.6	4.5	6.0	8.5
Gateway National Recreation Area	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
General Grant National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
George Washington Birthplace National Monument	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Governors Island National Monument	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Hamilton Grange National Memorial*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Harriet Tubman Underground Railroad National Monument	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Independence National Historical Park*	2030	0.16‡	0.15	0.15‡	0.14
	2050	0.27‡	0.27	0.27‡	0.28
	2100	0.54‡	0.62	0.68‡	0.79
New Bedford Whaling National Historical Park*	2030	0.13	0.13	0.12	0.13
	2050	0.22	0.23	0.22	0.25
	2100	0.45	0.53	0.55	0.70
Petersburg National Battlefield*	2030	0.16	0.15	0.15	0.15
	2050	0.27	0.28	0.27	0.29
	2100	0.55	0.64	0.67	0.81
Roger Williams National Memorial*	2030	0.13	0.13	0.12	0.13
	2050	0.22	0.23	0.22	0.25
	2100	0.45	0.53	0.55	0.70
Sagamore Hill National Historic Site	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Saint Croix Island International Historic Site	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.26	0.26	0.27
	2100	0.52	0.59	0.64	0.76
Salem Maritime National Historic Site	2030	0.11‡	0.11	0.11‡	0.11
	2050	0.19‡	0.20	0.20‡	0.22
	2100	0.37‡	0.45	0.50‡	0.62
Saugus Iron Works National Historic Site	2030	0.11‡	0.11	0.11‡	0.11

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Saugus Iron Works National Historic Site	2050	0.19[‡]	0.20	0.20[‡]	0.22
	2100	0.37[‡]	0.45	0.50[‡]	0.62
Statue of Liberty National Monument	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Thaddeus Kosciuszko National Memorial*	2030	0.16[‡]	0.15	0.15[‡]	0.14
	2050	0.27[‡]	0.27	0.27[‡]	0.28
	2100	0.54[‡]	0.62	0.68[‡]	0.79
Theodore Roosevelt Birthplace National Historic Site*	2030	0.15	0.14	0.14	0.14
	2050	0.26	0.25	0.25	0.27
	2100	0.52	0.58	0.62	0.77
Southeast Region					
Big Cypress National Preserve[§]	2030	0.13	0.13	0.12	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.46	0.54	0.55	0.69
Biscayne National Park	2030	0.14[‡]	0.13	0.12	0.12
	2050	0.24[‡]	0.23	0.21	0.24
	2100	0.47[‡]	0.53	0.53	0.68
Buck Island Reef National Monument	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
Canaveral National Seashore	2030	0.14[‡]	0.13	0.13[‡]	0.12
	2050	0.25[‡]	0.24	0.24[‡]	0.24
	2100	0.50[‡]	0.54	0.59[‡]	0.68
Cape Hatteras National Seashore	2030	0.15[‡]	0.15	0.15	0.14
	2050	0.26[‡]	0.28	0.28	0.28
	2100	0.53[‡]	0.63	0.68	0.79
Cape Lookout National Seashore[§]	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.27
	2100	0.53	0.61	0.65	0.76
Castillo De San Marcos National Monument	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
Charles Pinckney National Historic Site*	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Christiansted National Historic Site	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
Cumberland Island National Seashore	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
De Soto National Memorial	2030	0.14	0.13	0.13	0.13

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
De Soto National Memorial	2050	0.24	0.24	0.23	0.25
	2100	0.48	0.56	0.57	0.72
Dry Tortugas National Park[§]	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.24
	2100	0.47	0.54	0.56	0.69
Everglades National Park[§]	2030	0.13	0.13	0.12	0.17
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.54	0.68
Fort Caroline National Memorial	2030	0.14	0.13	0.13	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.56	0.56	0.70
Fort Frederica National Monument	2030	0.14	0.13	0.12	0.12
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.54	0.54	0.69
Fort Matanzas National Monument	2030	0.14	0.13	0.13	0.13
	2050	0.23	0.24	0.22	0.24
	2100	0.47	0.56	0.56	0.70
Fort Pulaski National Monument[§]	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Fort Raleigh National Historic Site	2030	0.15[‡]	0.15	0.15	0.14
	2050	0.27[‡]	0.28	0.28	0.28
	2100	0.53[‡]	0.63	0.68	0.79
Fort Sumter National Monument	2030	0.14	0.14	0.13	0.13
	2050	0.25	0.25	0.24	0.25
	2100	0.49	0.57	0.59	0.72
Gulf Islands National Seashore[§]	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.48	0.55	0.57	0.70
Jean Lafitte National Historical Park and Preserve[†§]	2030	0.14	0.13	0.13	0.12
	2050	0.24	0.23	0.23	0.24
	2100	0.48	0.54	0.56	0.68
Moores Creek National Battlefield*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.27
	2100	0.53	0.61	0.65	0.76
New Orleans Jazz National Historical Park*	2030	0.14	0.13	0.13	0.12
	2050	0.24	0.23	0.23	0.24
	2100	0.48	0.54	0.56	0.68
Salt River Bay National Historic Park and Ecological Preserve	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.23
	2100	0.44	0.50	0.51	0.64
San Juan National Historic Site	2030	0.12	0.12	0.11	0.12
	2050	0.22	0.22	0.20	0.22
	2100	0.43	0.49	0.50	0.64

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway 2.6	4.5	6.0	8.5
Timucuan Ecological and Historic Preserve	2030	0.14	0.13	0.13	0.13
	2050	0.24	0.24	0.23	0.25
	2100	0.47	0.56	0.56	0.70
Virgin Islands Coral Reef National Monument	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.51	0.64
Virgin Islands National Park[§]	2030	0.13	0.12	0.11	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.51	0.64
Wright Brothers National Memorial*	2030	0.15[‡]	0.16	0.16	0.15
	2050	0.27[‡]	0.29	0.28	0.29
	2100	0.53[‡]	0.65	0.70	0.82

National Capital Region					
Anacostia Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Chesapeake & Ohio Canal National Historical Park[§]	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.62	0.66	0.79
Constitution Gardens*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Fort Washington Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
George Washington Memorial Parkway[§]	2030	0.15[‡]	0.15	0.15[‡]	0.14
	2050	0.26[‡]	0.27	0.26[‡]	0.28
	2100	0.53[‡]	0.62	0.66[‡]	0.79
Harpers Ferry National Historical Park*[§]	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.62	0.66	0.79
Korean War Veterans Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Lincoln Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Martin Luther King Jr. Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

		Representative Concentration Pathway			
Park Unit	**Year**	**2.6**	**4.5**	**6.0**	**8.5**
National Mall*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
National Mall & Memorial Parks*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
National World War II Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Piscataway Park*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Potomac Heritage National Scenic Trail	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
President’s Park (White House)*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Rock Creek Park	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Theodore Roosevelt Island Park	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Thomas Jefferson Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Vietnam Veterans Memorial*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80
Washington Monument*	2030	0.15	0.15	0.15	0.14
	2050	0.26	0.27	0.26	0.28
	2100	0.53	0.63	0.66	0.80

Intermountain Region					
Big Thicket National Preserve*	2030	0.14[‡]	0.12	0.12[‡]	0.12
	2050	0.23[‡]	0.23	0.22[‡]	0.23
	2100	0.47[‡]	0.51	0.55[‡]	0.66
Palo Alto Battlefield National Historical Park*[§]	2030	0.13	0.13	0.13	0.12
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.56	0.69
Padre Island National Seashore[§]	2030	0.13	0.13	0.13	0.12
	2050	0.23	0.23	0.22	0.24
	2100	0.46	0.53	0.56	0.69

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway 2.6	4.5	6.0	8.5
Pacific West Region					
Cabrillo National Monument	2030	0.10	0.10	0.09	0.10
	2050	0.17	0.17	0.17	0.19
	2100	0.35	0.40	0.41	0.53
Channel Islands National Park§	2030	0.11	0.11	0.10	0.10
	2050	0.20	0.19	0.18	0.20
	2100	0.39	0.44	0.46	0.57
Ebey's Landing National Historical Reserve	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46
Fort Point National Historic Site	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
Fort Vancouver National Historic Site*	2030	0.12	0.11	0.11	0.10
	2050	0.21	0.20	0.19	0.19
	2100	0.42	0.45	0.47	0.55
Golden Gate National Recreation Area§	2030	0.11	0.10	0.10	0.10
	2050	0.19	0.18	0.17	0.19
	2100	0.37	0.42	0.43	0.54
Haleakala National Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Hawaii Volcanoes National Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Kalaupapa National Historical Park§	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.66
Kaloko-Honokohau National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Lewis and Clark National Historical Park§	2030	0.12	0.10	0.10	0.10
	2050	0.20	0.19	0.18	0.19
	2100	0.40	0.44	0.46	0.53
National Park of American Samoa	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.52	0.65
Olympic National Park§	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
Point Reyes National Seashore[§]	2030	0.11	0.10	0.10	0.10
	2050	0.19	0.19	0.18	0.19
	2100	0.38	0.43	0.45	0.55
Port Chicago Naval Magazine National Memorial	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
Pu'uhonua O Honaunau National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.50	0.52	0.67
Puukohola Heiau National Historic Site	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.24
	2100	0.44	0.51	0.52	0.67
Redwood National and State Parks	2030	0.12	0.11	0.10	0.10
	2050	0.20	0.19	0.18	0.20
	2100	0.40	0.44	0.46	0.56
Rosie the Riveter WWII Home Front National Historical Park	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
San Francisco Maritime National Historical Park	2030	0.11	0.10	0.10	0.10
	2050	0.18	0.18	0.17	0.19
	2100	0.37	0.41	0.43	0.53
San Juan Island National Historical Park	2030	0.10	0.09	0.09	0.08
	2050	0.17	0.16	0.16	0.16
	2100	0.34	0.37	0.39	0.46
Santa Monica Mountains National Recreation Area[§]	2030	0.12	0.11	0.10	0.11
	2050	0.20	0.20	0.19	0.20
	2100	0.40	0.45	0.46	0.58
War in the Pacific National Historical Park	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.22	0.24
	2100	0.44	0.51	0.54	0.68
World War II Valor in the Pacific National Monument[§]	2030	0.13	0.12	0.12	0.12
	2050	0.22	0.22	0.21	0.23
	2100	0.44	0.50	0.52	0.67

Alaska Region					
Aniakchak Preserve[§]	2030	0.09[‡]	0.09	0.09	0.09
	2050	0.15[‡]	0.17	0.16	0.18
	2100	0.31[‡]	0.38	0.40	0.51
Bering Land Bridge National Preserve[§]	2030	0.11	0.11	0.10	0.11

Table E2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	Representative Concentration Pathway			
		2.6	4.5	6.0	8.5
	2050	0.18	0.19	0.18	0.21
	2100	0.37	0.44	0.45	0.60
Cape Krusenstern National Monument[§]	2030	0.10	0.10	0.10	0.10
	2050	0.17	0.18	0.17	0.20
	2100	0.35	0.42	0.43	0.58
Glacier Bay National Park[†§]	2030	0.07	0.06	0.06	0.06
	2050	0.11	0.11	0.11	0.12
	2100	0.23	0.25	0.28	0.34
Glacier Bay Preserve[†]	2030	0.06	0.06	0.06	0.06
	2050	0.11	0.11	0.11	0.11
	2100	0.22	0.24	0.27	0.33
Katmai National Park[§]	2030	0.09	0.08	0.08	0.08
	2050	0.15	0.15	0.15	0.16
	2100	0.31	0.34	0.37	0.47
Katmai National Preserve[†§]	2030	0.09	0.08	0.08	0.08
	2050	0.15	0.15	0.14	0.16
	2100	0.30	0.33	0.34	0.45
Kenai Fjords National Park[†§]	2030	0.09[‡]	0.08	0.08[‡]	0.08
	2050	0.15[‡]	0.14	0.14[‡]	0.15
	2100	0.30[‡]	0.33	0.34[‡]	0.44
Klondike Gold Rush National Historical Park*[†§]	2030	0.06[‡]	0.06	0.06[‡]	0.06
	2050	0.11	0.11	0.11[‡]	0.11
	2100	0.22	0.24	0.27	0.33
Lake Clark National Park*[†]	2030	0.08	0.08	0.07	0.08
	2050	0.14	0.14	0.13	0.15
	2100	0.29	0.32	0.33	0.43
Sitka National Historical Park[†]	2030	0.08	0.07	0.07	0.07
	2050	0.14	0.14	0.13	0.14
	2100	0.28	0.31	0.33	0.41
Wrangell - St. Elias National Park[§]	2030	0.07	0.06	0.06	0.07
	2050	0.12	0.12	0.11	0.12
	2100	0.23	0.26	0.8	0.35
Wrangell – St. Elias National Preserve*[§]	2030	0.07	0.06	0.06	0.06
	2050	0.12	0.12	0.11	0.12
	2100	0.23	0.26	0.29	0.35

[*]Parks that do not have shoreline These numbers are for the nearest shoreline to the park

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century Refer to section methods for more information

‡No data was available for this scenario Data from an adjacent cell was used in lieu

§Parks that cover two or more cells Data were averaged between these parks based on percentage of shoreline in each cell Adjacent cells were used in cases where boundaries crossed into null data cells

Table E3. IBTrACS data (Knapp et al. 2010) was used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Park Unit	Highest Recorded Hurricane Within 10 mi
Northeast Region	
Acadia National Park	Hurricane, Saffir-Simpson category 1
Assateague Island National Seashore	Hurricane, Saffir-Simpson category 1
Boston Harbor Islands National Recreation Area	Hurricane, Saffir-Simpson category 2
Boston National Historical Park	Hurricane, Saffir-Simpson category 3
Cape Cod National Seashore	Hurricane, Saffir-Simpson category 2
Castle Clinton National Monument	Hurricane, Saffir-Simpson category 1
Colonial National Historical Park	Tropical storm
Edgar Allen Poe National Historic Site	Extratropical storm
Federal Hall National Memorial	Hurricane, Saffir-Simpson category 1
Fire Island National Seashore	Hurricane, Saffir-Simpson category 2
Fort McHenry National Monument and Historic Shrine	Tropical storm
Fort Monroe National Monument	Tropical storm
Gateway National Recreation Area	Hurricane, Saffir-Simpson category 1
General Grant National Memorial	Hurricane, Saffir-Simpson category 1
George Washington Birthplace National Monument	Extratropical storm
Governors Island National Monument	Hurricane, Saffir-Simpson category 1
Hamilton Grange National Memorial	Hurricane, Saffir-Simpson category 1
Harriet Tubman Underground Railroad National Monument	Tropical storm
Independence National Historical Park	Extratropical storm
New Bedford Whaling National Historical Park	Extratropical storm
Petersburg National Battlefield	Hurricane, Saffir-Simpson category 2

Roger Williams National Memorial	Hurricane, Saffir-Simpson category 3
Sagamore Hill National Historic Site	Hurricane, Saffir-Simpson category 2
Saint Croix Island International Historic Site	Hurricane, Saffir-Simpson category 2
Salem Maritime National Historic Site	Hurricane, Saffir-Simpson category 1
Saugus Iron Works National Historic Site	Hurricane, Saffir-Simpson category 1
Statue of Liberty National Monument	Hurricane, Saffir-Simpson category 1
Thaddeus Kosciuszko National Memorial	Extratropical storm
Theodore Roosevelt Birthplace National Historic Site	Hurricane, Saffir-Simpson category 1

Southeast Region	
Big Cypress National Preserve	Hurricane, Saffir-Simpson category 4
Biscayne National Park	Hurricane, Saffir-Simpson category 4
Buck Island Reef National Monument	Hurricane, Saffir-Simpson category 2
Canaveral National Seashore	Hurricane, Saffir-Simpson category 2
Cape Hatteras National Seashore	Hurricane, Saffir-Simpson category 3
Cape Lookout National Seashore	Hurricane, Saffir-Simpson category 3
Castillo De San Marcos National Monument	Hurricane, Saffir-Simpson category 3
Charles Pinckney National Historic Site	Hurricane, Saffir-Simpson category 4
Christiansted National Historic Site	Hurricane, Saffir-Simpson category 4
Cumberland Island National Seashore	Hurricane, Saffir-Simpson category 4
De Soto National Memorial	Hurricane, Saffir-Simpson category 1
Dry Tortugas National Park	Hurricane, Saffir-Simpson category 4
Everglades National Park	Hurricane, Saffir-Simpson category 5
Fort Caroline National Memorial	Hurricane, Saffir-Simpson category 2
Fort Frederica National Monument	Hurricane, Saffir-Simpson category 1
Fort Matanzas National Monument	Hurricane, Saffir-Simpson category 1
Fort Pulaski National Monument	Hurricane, Saffir-Simpson category 2
Fort Raleigh National Historic Site	Hurricane, Saffir-Simpson category 2
Fort Sumter National Monument	Hurricane, Saffir-Simpson category 4

Gulf Islands National Seashore	Hurricane, Saffir-Simpson category 4
Jean Lafitte National Historical Park and Preserve	Hurricane, Saffir-Simpson category 2
Moores Creek National Battlefield	Hurricane, Saffir-Simpson category 1
New Orleans Jazz National Historical Park	Hurricane, Saffir-Simpson category 2
Salt River Bay National Historic Park and Ecological Preserve	Hurricane, Saffir-Simpson category 4
San Juan National Historic Site	Hurricane, Saffir-Simpson category 3
Timucuan Ecological and Historic Preserve	Hurricane, Saffir-Simpson category 2
Virgin Islands Coral Reef National Monument	Hurricane, Saffir-Simpson category 3
Virgin Islands National Park	Hurricane, Saffir-Simpson category 3
Wright Brothers National Memorial	Hurricane, Saffir-Simpson category 2

National Capital Region	
Anacostia Park	Hurricane, Saffir-Simpson category 2
Chesapeake & Ohio Canal National Historical Park	Hurricane, Saffir-Simpson category 2
Constitution Gardens	Hurricane, Saffir-Simpson category 2
Fort Washington Park	Hurricane, Saffir-Simpson category 2
George Washington Memorial Parkway	Hurricane, Saffir-Simpson category 2
Harpers Ferry National Historical Park	Extratropical storm
Korean War Veterans Memorial	Hurricane, Saffir-Simpson category 2
Lincoln Memorial	Hurricane, Saffir-Simpson category 2
Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Hurricane, Saffir-Simpson category 2
Martin Luther King Jr. Memorial	Hurricane, Saffir-Simpson category 2
National Mall	Hurricane, Saffir-Simpson category 2
National Mall & Memorial Parks	Hurricane, Saffir-Simpson category 2
National World War II Memorial	Hurricane, Saffir-Simpson category 2
Piscataway Park	Hurricane, Saffir-Simpson category 2
Potomac Heritage National Scenic Trail	Hurricane, Saffir-Simpson category 2
President’s Park (White House)	Hurricane, Saffir-Simpson category 2

Rock Creek Park	Hurricane, Saffir-Simpson category 2
Theodore Roosevelt Island Park	Hurricane, Saffir-Simpson category 2
Thomas Jefferson Memorial	Hurricane, Saffir-Simpson category 2
Vietnam Veterans Memorial	Hurricane, Saffir-Simpson category 2
Washington Monument	Hurricane, Saffir-Simpson category 2

Intermountain Region	
Big Thicket National Preserve	Hurricane, Saffir-Simpson category 3
Palo Alto Battlefield National Historical Park	No recorded historical storm
Padre Island National Seashore	Hurricane, Saffir-Simpson category 4

Pacific West Region	
Cabrillo National Monument	Tropical depression
Channel Islands National Park	No recorded historical storm
Ebey's Landing National Historical Reserve	No recorded historical storm
Fort Point National Historic Site	No recorded historical storm
Fort Vancouver National Historic Site	No recorded historical storm
Golden Gate National Recreation Area	No recorded historical storm
Haleakala National Park	Tropical depression
Hawaii Volcanoes National Park	Tropical depression
Kalaupapa National Historical Park	Tropical depression
Kaloko-Honokohau National Historical Park	Tropical depression
Lewis and Clark National Historical Park	No recorded historical storm
National Park of American Samoa	No recorded historical storm
Olympic National Park	No recorded historical storm
Point Reyes National Seashore	No recorded historical storm
Port Chicago Naval Magazine National Memorial	No recorded historical storm
Pu'uhonua O Honaunau National Historical Park	No recorded historical storm
Puukohola Heiau National Historic Site	Tropical depression

Redwood National and State Parks	No recorded historical storm
Rosie the Riveter WWII Home Front National Historical Park	No recorded historical storm
San Francisco Maritime National Historical Park	No recorded historical storm
San Juan Island National Historical Park	No recorded historical storm
Santa Monica Mountains National Recreation Area	No recorded historical storm
War in the Pacific National Historical Park	No recorded historical storm
World War II Valor in the Pacific National Monument	Tropical depression

Alaska Region	
Aniakchak Preserve	No recorded historical storm
Bering Land Bridge National Preserve	No recorded historical storm
Cape Krusenstern National Monument	No recorded historical storm
Glacier Bay National Park	No recorded historical storm
Glacier Bay Preserve	No recorded historical storm
Katmai National Park	No recorded historical storm
Katmai National Preserve	No recorded historical storm
Kenai Fjords National Park	No recorded historical storm
Klondike Gold Rush National Historical Park	No recorded historical storm
Lake Clark National Park	No recorded historical storm
Sitka National Historical Park	No recorded historical storm
Wrangell - St. Elias National Park	No recorded historical storm
Wrangell – St. Elias National Preserve	No recorded historical storm

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities

NPS XXXXXX, September 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

19 Re_ Sea level and storm surge report co-author.pdf

From:	Caffrey, Maria
To:	Patrick Gonzalez NPS
Subject:	Re: Sea level and storm surge report co-author
Date:	Wednesday, October 05, 2016 11:38:29 AM

I'll be sure to include this information. Thanks!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
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On Wed, Oct 5, 2016 at 11:36 AM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> Thank you for the offer to be a co-author. I would be honored to be included.
>
> Please include my two affiliations:
>
> National Park Service
> Climate Change Response Program
> 130 Mulford Hall
> Berkeley, CA 94720-3114
>
> University of California, Berkeley
> Department of Environmental Science, Policy, and Management
> 130 Mulford Hall
> Berkeley, CA 94720-3114
>
> Thanks,
>
> Patrick
>
> ....
>
> **From:** "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
> **Subject: Re: Comments on sea level and storm surge report**
> **Date:** October 5, 2016 at 7:47:11 AM PDT
> **To:** Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
>
> Hi Patrick,

Thanks for getting this back to me. I really appreciate you taking the time to review this. I know you're very busy at the moment. I'm looking forward to getting this report out and then turning my attention to putting this into an academic publication.

With regards to authorship, would you like to be co-author on this? You've spent so much time working on this giving me advice throughout the life of the project and helping with text.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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On Tue, Oct 4, 2016 at 10:26 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> Congratulations on finishing the draft of your technical report! It represents a lot of hard work.
>
> You'll find attached the document with recommended edits tracked in Word. I found no major issues. You'll see that most of the edits related to using the word "projected" for future estimates that are dependent on emissions scenarios and use of the conditional voice (could, might) when talking about the future. I did not have time to add explanatory comments for each edit - I know that you'll easily grasp the rationale behind individual edits. You can call me on my personal cell phone (b) (6) [redacted] for any questions.
>
> All the best,
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Department of Environmental Science, Policy, and Management
> University of California, Berkeley
> 130 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
@pgonzaleztweet
http://www.patrickgonzalez.net
....

....
From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Re: Sea level and storm surge report
Date: October 3, 2016 at 3:09:30 PM PDT
To: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>

No worries. Thanks for taking the time to do this.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
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On Mon, Oct 3, 2016 at 4:06 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria - I'm going through the report and will get to you before too long. Thanks for your patience.
>
> Patrick
>
> ———
>
> **From:** "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
> **Subject: Re: Sea level and storm surge report**
> **Date:** September 28, 2016 at 10:02:19 AM PDT
> **To:** Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
>
> Patrick,
>
> No problem. You don't need to hurry it. I can wait until Monday. I'm attending the Geological Society of America meeting this week, so I have other things I can do with my time. I just thought I might take a poke at some edits during my downtime between papers.

Maria Caffrey, PhD

Research Associate, University of Colorado
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On Wed, Sep 28, 2016 at 11:00 AM, Patrick Gonzalez NPS
<patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> I'm sorry for the delay in reviewing your report. I travelled, then gave two presentations, then was on leave. If you can wait until tomorrow, I can make suggestions to the Word document though track changes.
>
> Patrick
>
> ____
>
> **From:** "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
> **Subject: Re: Sea level and storm surge report**
> **Date:** September 28, 2016 at 9:01:10 AM PDT
> **To:** Patrick Gonzalez <patrick_gonzalez@nps.gov>
>
> Hi Patrick,
>
> Do you have any edits you would like to suggest for the final report? I'm starting to make changes based on Amanda's comments, but I wanted to see if you have anything to add before I start going through it.
>
> Cheers,
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
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>
> On Fri, Sep 2, 2016 at 3:04 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov>

wrote:

Amanda, Patrick,

Here is the draft report. I have included an excel spreadsheet for your comments so I don't have to try and combine four versions of track changes from everyone (I'll be emailing Rob and Steve for their comments separately). Please try to get your reviews back to me by 9/16/16.

Have a great labor day weekend!

Maria Caffrey, PhD

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NPS Geologic Resources Division http://nature.nps.gov/geology
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20 Re_ FAQs.pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Re: FAQs
Date: Wednesday, October 05, 2016 12:38:48 PM
Attachments: Frequently Asked Questions_draft October 2016_RLB edits.docx

---

See suggested revisions.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/adaptation.htm

On Wed, Oct 5, 2016 at 12:23 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Should I take out the second question (see attached)?
>
> It will be uploaded as a PDF.
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
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20 1 Attachment Frequently Asked Questions_draft October 2016.pdf

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with and approval of regional managers. ~~Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.~~

~~*Q. Who originally identified which park units should be used in this study?*~~

~~A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).~~

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. Where did you use data used by Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to ~~help plug some of these gaps in our~~provide data ~~network~~ for park units in California, Oregon, Washington, and southern Alaska.). The following parks used Tebaldi et al. (2012) data: Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012~~). The following parks used Tebaldi et al. (2012) data: Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.~~ These parks are:

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into that region.

Q. Why are the storm surge maps in NAVD88?

That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on projections for some parks?

The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America. It uses a fixed value for the height of the sea level. While this is a popular datum for mapping, it has the limitation that it is based on the tidal benchmark for Rimouski, Canada. As you move further away from this benchmark you can expect actual sea level to differ from the reference benchmark. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

All parks are different, as are all projects. Your choice of scenario may depend on many different factors. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. 2009. Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). IPCC global sea level rise projections range between 0.26 m (RCP2.6 minimum likely range) and 0.82m (RCP8.5 maximum likely range) by 2100. The standard error of the IPCC is explained in greater detail in the chapter 13 supplementary material in AR5 (IPCC 2013).

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent an average storm surge number. As described above there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, El Niño and La Niña years will impact sea level. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of man-made structures, such as levees and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. Permanent inundation will change the way waves propagate within a basin in the future. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www.nhc.noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bath tub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact ~~Rebecca Beavers~~park, region, or Climate Change Response Program staff for assistance. It may be possible to downscale projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing between sources.

Q. What are other impacts from sea-level rise that parks should consider?

A. Impacts from sea-level rise could include, but are not limited to, increased erosion, damaged cultural resources, damage to above and below ground infrastructure, difficulty accessing inundated infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems. For more information on the topic, please see the Coastal Adaptation Strategies Handbook at: http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

21 Re_ FAQs(1).pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: FAQs
Date: Wednesday, October 05, 2016 1:08:23 PM

Thanks!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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On Wed, Oct 5, 2016 at 12:38 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> See suggested revisions.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
> http://www.nps.gov/subjects/climatechange/adaptation.htm
>
> On Wed, Oct 5, 2016 at 12:23 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:
>
> > Should I take out the second question (see attached)?
> >
> > It will be uploaded as a PDF.
> >
> > Maria Caffrey, PhD
> >
> > Research Associate, University of Colorado
> > NPS Partner, Geologic Resources Division
> > Office: (303) 969-2097
> > Cell: (303) 518-3419
> >
> > NPS Geologic Resources Division http://nature.nps.gov/geology
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23 Re_ Nov. 7.pdf

From: Caffrey, Maria
To: Patrick Gonzalez NPS
Subject: Re: Nov. 7
Date: Monday, October 31, 2016 1:05:48 PM

That works for me. Woohoo, we found a time! Thanks for helping me work this out.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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On Mon, Oct 31, 2016 at 1:01 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> If 12 PM MST (11 AM PST) is OK in your schedule, I can talk then.
>
> Patrick
>
> ---
>
> **From:** "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
> **Subject: Re: Availability next week?**
> **Date:** October 31, 2016 at 11:57:43 AM PDT
> **To:** Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
>
> Boy, you're super busy. How does Monday 11/7 look for you? Rebecca won't be able to join us, but Amanda and I are both free after 9 am MST (8 am PST).
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Mon, Oct 31, 2016 at 12:03 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:
>
>> Hi Maria,

I have a work session with my graduate student researcher 10-1 PDT, then a National Climate Assessment telephone call 1-2:30 PM PDT (5:30 PM EDT) on Friday. Oh no - I am at Golden Gate NRA all day Nov. 9. The only other time then is 9 AM PDT on Friday.

Patrick

From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Re: Availability next week?
Date: October 31, 2016 at 9:56:36 AM PDT
To: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>

Hi Patrick,

I'm afraid Rebecca and Amanda are tied up until 12 PST (1 pm MST, 3 pm EST) on Friday. Do you have any time in your afternoon to talk? I could move it to Wednesday 11/9 if that doesn't work for you.

Amanda would like us to completely remove the combined maps/data. She says that she can't recommend the report to her region if it is not removed.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
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On Mon, Oct 31, 2016 at 10:13 AM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> On Thursday, I will be on a bus then a train returning from Yosemite. I do not know my schedule yet. Cell phone service is not continuous until the later part of the trip. So, Friday is a better day if possible, perhaps 9 AM PDT - 10 AM MDT - 12 PM EDT.
>
> If not, I think it would be good to have a panel of three maps: Sea level only, storm surge only, combined.
>
> Thanks,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
130 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
@pgonzaleztweet
http://www.patrickgonzalez.net
....

From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Availability next week?
Date: October 27, 2016 at 2:03:16 PM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hi Patrick,

I was wondering if you might be available to chat next week with me and Amanda Babson (and maybe Rebecca depending on her availability)? Amanda has some concerns regarding whether we should (b) (5) [redacted]. I know we have discussed this before, but she would like that (b) (5) [redacted].

I think the report should be ready to go out for external review within the next week or so, so it would be good to discuss this issue before it goes out.

Thanks,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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24 Sea level viewer.pdf

From: Caffrey, Maria
To: Patrick Gonzalez; Amanda Babson
Subject: Sea level viewer
Date: Monday, November 07, 2016 12:25:23 PM

Here is the viewer for reference: (b) (5) [redacted]

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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26 Re_ Summary of combined maps conversation.pdf

From: Patrick Gonzalez NPS
To: Maria Caffrey
Subject: Re: Summary of combined maps conversation
Date: Monday, November 07, 2016 4:28:38 PM

Hi Maria,

I'm glad that you found my input useful. I agree with your plan. I also (b) (5) [redacted] and can mention that to Rebecca.

Patrick

———

From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Subject: Summary of combined maps conversation
Date: November 7, 2016 at 12:00:45 PM PST
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hi Patrick,

Thanks again for taking the time to talk today. It was super useful to have your insight in this matter. After talking this over with Amanda we decided on the following:

1. (b) (5) [redacted]
2. (b) (5) [redacted]
3. (b) (5) [redacted].

Rebecca joined us later in the conversation. She feels that (b) (5) [redacted] I voiced my objection to that, but she feels that (b) (5) [redacted] My money is up in March, so I will leave this for other folks to figure out the most appropriate way to release them.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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27 Fwd_ Report for your review.pdf

From:	Caffrey, Maria
To:	Rebecca Beavers
Subject:	Fwd: Report for your review
Date:	Monday, November 14, 2016 8:37:51 AM
Attachments:	Instructions to Reviewers.docx Reviewer comments_insert last name here.xlsx Suggested Reviewers.docx

---

Rebecca,

Here is the email confirming that Amanda has the new report.

I'm also copying those files I mentioned in my previous email. All of these files are also available on the n drive at: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
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---------- Forwarded message ----------
From: **Babson, Amanda** <amanda_babson@nps.gov>
Date: Wed, Nov 9, 2016 at 7:06 PM
Subject: Re: Report for your review
To: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>

Hey, I can accept dropbox files now, great. I won't get a chance to take a look soon, but thanks for sending and for responding to my review. No worries on my part about sending it out for external review without me getting a 2nd look. Good to hear you've got a SLOSH reviewer. Hope you get helpful input.
Amanda

On Wed, Nov 9, 2016 at 5:45 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Amanda,
>
> I'm attaching a link to a copy of the report (it's too big to email). Rebecca has decided that the document needs to be fast tracked so it can get published by the end of December, so we are going to have to send it out for external review immediately. Sorry I couldn't give you time to review it by yourself before sending it out for external. Let me know if I have addressed all of your key concerns.

https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
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--
Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile)

27 1 Attachment Instructions to Reviewers.pdf

Instructions to Reviewers:

You have been asked to review the “Sea Level and Storm Surge Projections for 119 National Park Service Units”. This report will be released as part of a three year project with the University of Colorado. The aim of the report is to combine sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Do not make edits in word.

Please return your review to us by COB December 16th.

Thank you for agreeing to review this important dataset.

27 2 Attachment Reviewer comments_insert last name here_1.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

27 3 Attachment Suggested Reviewers.pdf

Suggested Reviewers

Bob Glahn, NOAA/National Weather Service, Meteorological Development Laboratory.
E-mail: harry.glahn@noaa.gov

John Fasullo, UCAR.
Email: fasullo@ucar.edu

Claudia Tebaldi, Climate Central (formerly UCAR).
Email: ctebaldi@climatecentral.org

Back-up
Chris Zervas, NOAA Tides and Currents.
Email: chris.zervas@noaa.gov

28 Request review by Dec 14 for NPS SL.SS Report.pdf

From: Beavers, Rebecca
To: harry.glahn@noaa.gov
Subject: Request review by Dec 14 for NPS SL.SS Report
Date: Tuesday, November 15, 2016 12:00:26 PM
Attachments: Reviewer comments insert last name here.xlsx

Hi Bob:

Thank you for taking the time to speak with me today. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Thank you for agreeing to review this important dataset for management of our coastal National parks.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

28 1 Attachment Reviewer comments_insert last name here_2.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

30 Request review by Dec 14 for NPS SL.SS Report(1).pdf

From:	Beavers, Rebecca
To:	ctebaldi@climatecentral.org
Subject:	Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:06:27 PM
Attachments:	Reviewer comments insert last name here.xlsx

Hi Claudia:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: (b) (5) [redacted]
(b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

30 1 Attachment Reviewer comments_insert last name here_4.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

31 Request review by Dec 14 for NPS SL.SS Report(2).pdf

From:	Beavers, Rebecca
To:	chris.zervas@noaa.gov
Subject:	Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:08:49 PM
Attachments:	Reviewer comments insert last name here.xlsx

HI Chris:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

31 1 Attachment Reviewer comments_insert last name here_5.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

32 Re_ Request review by Dec 14 for NPS SL.SS Report.pdf

From:	Harry Glahn
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:12:24 PM

I only got something with a lot of lines on it. no report.

On 11/15/2016 2:00 PM, Beavers, Rebecca wrote:

> Hi Bob:
>
> Thank you for taking the time to speak with me today. Please let me know if this is a feasible task for you to complete for the National Park Service.
>
> Instructions to Reviewers:
>
> I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.
>
> Some of the data can be viewed using an online viewer:
> (b) (5) (b) (5) [redacted]
>
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>
> The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Thank you for agreeing to review this important dataset for management of our coastal National parks.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

33 Fwd_ Request review by Dec 14 for NPS SL.SS Report(1).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:22:55 PM

1st reviewer confirmed!

Bob is reviewing a hard copy of the report. I gave him permission to mail back the hard copy! (I had to walk him through downloading from dropbox so he could print! He does not work from the computer screen.

---------- Forwarded message ----------
From: **Harry Glahn** <harry.glahn@noaa.gov>
Date: Tue, Nov 15, 2016 at 12:11 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

I only got something with a lot of lines on it. no report.

On 11/15/2016 2:00 PM, Beavers, Rebecca wrote:

Hi Bob:

Thank you for taking the time to speak with me today. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer:
(b) (5) [redacted]

(b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Thank you for agreeing to review this important dataset for management of our coastal National parks.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

34 Request review by Dec 14 for NPS SL.SS Report(3).pdf

From:	Beavers, Rebecca
To:	Doug Marcy - NOAA Federal
Subject:	Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:27:03 PM
Attachments:	Reviewer comments insert last name here.xlsx

Hi Doug:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service. we need one reviewer with experience with applications of SLOSH Results.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

34 1 Attachment Reviewer comments_insert last name here_6.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

35 Re_ Request review by Dec 14 for NPS SL.SS Report(1).pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Tuesday, November 15, 2016 12:34:36 PM

Tebaldi could review the "storm surge data" subsection in the Methods (p 6-8) and the Pacific West region results subset (p 20-21) -- that's where we used her data.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Tue, Nov 15, 2016 at 12:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> If Tebaldi reviewed a subset of the report, what would that be?
>
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
>
> ---------- Forwarded message ----------
> From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
> Date: Tue, Nov 15, 2016 at 12:23 PM
> Subject: Re: Request review by Dec 14 for NPS SL.SS Report
> To: claudia tebaldi <ctebaldi@climatecentral.org>
>
> Could we discuss your input on a small section of the report that uses your method for pacific parks?
>
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
>
> On Tue, Nov 15, 2016 at 12:09 PM, claudia tebaldi <ctebaldi@climatecentral.org> wrote:
>
>> I apologize but I do not have the time in the next month to do this.
>> You may try Benjamin Strauss at Climate Central, bstrauss@climatecentral.org.

On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Hi Claudia:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

36 Re_ Request review by Dec 14 for NPS SL.SS Report(2).pdf

From:	claudia tebaldi
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 12:53:19 PM

Hi Rebecca

I graduated in '97.

I'd be happy to look art a specific section of the report.

On Tue, Nov 15, 2016 at 12:25 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Claudia:
>
> also... what is your connection with duke statistics? I am a Duke Ph.D From '99 (geology/oceanography) based at Duke Marine Lab.
>
> Cheers,
> rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Tue, Nov 15, 2016 at 12:23 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > Could we discuss your input on a small section of the report that uses your method for pacific parks?
> >
> > Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> > National Park Service | Geologic Resources Division I Climate Change Response Program
> > 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
> >
> > On Tue, Nov 15, 2016 at 12:09 PM, claudia tebaldi <ctebaldi@climatecentral.org> wrote:
> >
> > > I apologize but I do not have the time in the next month to do this.
> > > You may try Benjamin Strauss at Climate Central, bstrauss@climatecentral.org.
> > >
> > > On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
> > >
> > > > Hi Claudia:
> > > >
> > > > Thank you for your time to consider this review. Please let me know if this is a

feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer:
(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

37 Fwd_ Request review by Dec 14 for NPS SL.SS Report(2).pdf

From:	Beavers, Rebecca
To:	Steve Nerem
Cc:	Caffrey, Maria
Subject:	Fwd: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 3:02:43 PM
Attachments:	Reviewer comments_insert last name here.xlsx

Hi Steve:

if you could encourage John to do this review, it would be greatly appreciated. I have not had the privilege of meeting him, so this may seem a little bit out of "left field" for him.

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Tue, Nov 15, 2016 at 12:04 PM
Subject: Fwd: Request review by Dec 14 for NPS SL.SS Report
To: fasullo@ucar.edu

Hi John:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled “Sea Level and Storm Surge Projections for 118 National Park Service Units”. This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

37 1 Attachment Reviewer comments_insert last name here_7.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

38 Re_ Request review by Dec 14 for NPS SL.SS Report(3).pdf

From:	Beavers, Rebecca
To:	claudia tebaldi
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 3:11:27 PM
Attachments:	Reviewer comments_insert last name here.xlsx

Hi Claudia:

Specific sections of the report for your review are defined by PI- Dr. Maria Caffrey (see forwarded email) as "Tebaldi could review the "storm surge data" subsection in the Methods (p 6-8) and the Pacific West region results subset (p 20-21) -- that's where we used her data."

Can I ask what your main duties are at Climate Central? Brian Khan is my main POC at Climate Central.

Thank you for reviewing these sections.

Cheers,
rebecca

---------- Forwarded message ----------
From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
Date: Tue, Nov 15, 2016 at 12:34 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Tebaldi could review the "storm surge data" subsection in the Methods (p 6-8) and the Pacific West region results subset (p 20-21) -- that's where we used her data.

> On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > Hi Claudia:
> >
> > Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
> >
> > Instructions to Reviewers:
> >
> > I request your review of a report for the National Park Service entitled “Sea Level and Storm Surge Projections for 118 National Park Service Units”. This report will

be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

38 1 Attachment Reviewer comments_insert last name here_8.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

39 Re_ Request review by Dec 14 for NPS SL.SS Report(4).pdf

From:	claudia tebaldi
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, November 15, 2016 4:15:14 PM

I work at NCAR in Boulder but I am a science fellow at Climate Central, mainly to advise on science issues as they come up, comment on research direction, collaborate still on SLR/storm surge analysis.

On Tue, Nov 15, 2016 at 3:11 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Claudia:
>
> Specific sections of the report for your review are defined by PI- Dr. Maria Caffrey (see forwarded email) as "Tebaldi could review the "storm surge data" subsection in the Methods (p 6-8) and the Pacific West region results subset (p 20-21) -- that's where we used her data."
>
> Can I ask what your main duties are at Climate Central? Brian Khan is my main POC at Climate Central.
>
> Thank you for reviewing these sections.
>
> Cheers,
> rebecca
>
> ---------- Forwarded message ----------
> From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
> Date: Tue, Nov 15, 2016 at 12:34 PM
> Subject: Re: Request review by Dec 14 for NPS SL.SS Report
> To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
>
> Tebaldi could review the "storm surge data" subsection in the Methods (p 6-8) and the Pacific West region results subset (p 20-21) -- that's where we used her data.
>
> > On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
> >
> > > Hi Claudia:
> > >
> > > Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer:
(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

40 Re_ Request review by Dec 14 for NPS SL.SS Report(5).pdf

From:	Doug Marcy - NOAA Federal
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Wednesday, November 16, 2016 6:30:05 AM

Hi Rebecca,

I got your voicemail. I would be glad to review the report. Your voicemail indicated you wanted me to review the storm surge section. I assume this entire report (link provided) is what you need reviewed?

Was this based on any of the work that Lynda Bell and Jeremy Cantor were doing in NC? We had a call with them a while back.

I may run this by the folks at NHC, if they have time to review. I have been engaging Jamie Rhome about SLR + Surge for other clients too (DHS).

Doug

On Tue, Nov 15, 2016 at 2:27 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Doug:
>
> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service. we need one reviewer with experience with applications of SLOSH Results.
>
> Instructions to Reviewers:
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> Some of the data can be viewed using an online viewer: [redacted]
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> The report itself can be downloaded from: https://www.dropbox.com/sh/scf

iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

--
Doug Marcy
NOAA Office for Coastal Management
2234 S. Hobson Avenue
Charleston, SC 29405
843-740-1334
doug.marcy@noaa.gov
coast.noaa.gov

41 Report currently through review.pdf

From:	Maria Caffrey
To:	Steve Nerem
Cc:	Rebecca Beavers
Subject:	Report currently through review
Date:	Wednesday, November 16, 2016 11:27:40 AM

Hi Steve,

I know you are super busy right now getting your funding proposal together, but I wanted to keep you in the loop on the SLR/SS project report that is currently going through external review.

Here is a link to the newest version of the report:
https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

I know that you didn't have time to review it before, but here is a copy so you can look at it while the external reviewers are reading it. Please let me know if you have any comments/edits by December 12th. We are now pushing to get this report out by the end of the year.

Thanks,

Maria Caffrey, PhD
Research Associate
Geological Sciences,
UCB 399,
2200 Colorado Ave,
Boulder, CO 80309

Office: (303) 969-2097
Cell: (303) 518-3419
Web: mariacaffrey.com

42 Re_ Request review by Dec 14 for NPS SL.SS Report(6).pdf

From:	Beavers, Rebecca
To:	Chris Zervas - NOAA Federal
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Thursday, November 17, 2016 1:10:53 PM

Thank you! Have a fantastic vacation.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Thu, Nov 17, 2016 at 12:20 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:

> Hi Rebecca,
> Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.
>
> Chris
>
> On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> HI Chris:
>>
>> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
>>
>> Instructions to Reviewers:
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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

43 Fwd_ Request review by Dec 14 for NPS SL.SS Report(3).pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Request review by Dec 14 for NPS SL.SS Report
Date: Thursday, November 17, 2016 1:11:07 PM

FYI

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Chris Zervas - NOAA Federal** <chris.zervas@noaa.gov>
Date: Thu, Nov 17, 2016 at 12:20 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca,
Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.

Chris

On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> HI Chris:
>
> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
>
> Instructions to Reviewers:
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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

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http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

44 Re_ Report currently through review.pdf

From:	Steve Nerem
To:	Maria Caffrey
Cc:	Rebecca Beavers
Subject:	Re: Report currently through review
Date:	Thursday, November 17, 2016 8:20:18 PM

Maria,

I looked it over and thought it looked pretty good, but there was one major thing (#3 below) that I think you should strongly consider changing:

#1. In your List of Terms, it is not common practice to call “sea level change” relative sea level change. Sea level change is a generic term that could be relative sea level change (as measured by a tide gauge) or it could be absolute sea level change (as measured by a satellite altimeter).

#2. I think some readers will find Figures 4-6 misleading, because they will interpret the spread as uncertainty, when they in fact just represent variability in the region. I know you explain this in the text, but some people will just look at the figures.

#3. The IPCC global projections are really given as a range, and you only report the central value. For example, the global projections for RCP8.5 range from 50 cm to 98 cm if I remember correctly. I wouldn’t think of this as an error - it really represents the range of the projections given by the IPCC based on 90% confidence. Without using the ranges, you really aren’t using the IPCC projections correctly. Instead of thinking of it as an error, think of it as the IPCC giving you the 90% probability of where the sea level rise will fall for 2100 (between 50 and 98 cm).

I know the regional projections don’t come with ranges, but you could simply scale them based on the global numbers (e.g. if the central value is 74 cm, then you would multiply the regional numbers by 50/74 to get the low end and 98/74 to get the high end). Perhaps you can add these ranges to the figures.

In effect, you are misrepresenting the IPCC projections, so I feel this is something you should fix (or you will have people criticize your interpretation of the IPCC projections). While this may seem like a major change, I think you can implement it pretty easily. I would just remove Eq 1 and discussion - it’s not important if you use the ranges as I’ve discussed.

Thanks,

Steve

> On Nov 16, 2016, at 11:27 AM, Maria Caffrey <maria.caffrey@colorado.edu> wrote:
>
> Hi Steve,
>
> I know you are super busy right now getting your funding proposal together,

but I wanted to keep you in the loop on the SLR/SS project report that is currently going through external review.

Here is a link to the newest version of the report:
https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

I know that you didn't have time to review it before, but here is a copy so you can look at it while the external reviewers are reading it. Please let me know if you have any comments/edits by December 12th. We are now pushing to get this report out by the end of the year.

Thanks,

Maria Caffrey, PhD
Research Associate
Geological Sciences,
UCB 399,
2200 Colorado Ave,
Boulder, CO 80309

Office: (303) 969-2097
Cell: (303) 518-3419
Web: mariacaffrey.com

45 Re_ Request review by Dec 14 for NPS SL.SS Report(7).pdf

From:	Doug Marcy - NOAA Federal
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Wednesday, November 23, 2016 12:27:37 PM
Attachments:	NPS_marcy_comments.xlsx

my comments. I didn't get into the gory details of the numbers etc..in the Appendices but rather looked at it from a more general sense with overarching method comments.

Hope this helps. Let me know if you all have questions.

Doug

On Tue, Nov 15, 2016 at 2:27 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Doug:
>
> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service. we need one reviewer with experience with applications of SLOSH Results.
>
> Instructions to Reviewers:
>
> I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.
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>
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>
> The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not

make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
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http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

--
Doug Marcy
NOAA Office for Coastal Management
2234 S. Hobson Avenue
Charleston, SC 29405
843-740-1334
doug.marcy@noaa.gov
coast.noaa.gov

45 1 Attachment NPS_marcy_comments.pdf

Page Number(s)	Line Number Beginning	Line Number Ending
3	18	20
5	23	24
3	33	whole section
3	33	whole section
3	33	whole section
6	15	whole section

6	15	whole section
9	9	10
9	16	16
10	31	36
12	11	27
22	12	whole section
6	15	mapping
Datums		

Comment
Mentions the SLOSH modeling used but not the Tebaldi et al, 2012 data that is mentioned later for West Coast.
Is this the NOAA method used for their SLR viewer? Potenially site the mapping method used. Marcy, D., Brooks, W., Draganov, K., Hadley, B., Haynes, C., Herold, N., McCombs, J., Pendleton, M., Ryan, S., Schmid, K., Sutherland, M., and Waters, K. (2011) New Mapping Tool and Techniques for Visualizing Sea Level Rise and Coastal Flooding Impacts. Solutions to Coastal Disasters 2011: pp. 474-490. doi: 10.1061/41185(417)42
Im sure you may get this question from other reviewers. Why use the lower IPCC estimates of SLR that really don't take into account more aggressive ice melt scenarios. Most Federal Agencies are/or have agreed to use the Parris et al, 2012 (input to the 3rd National Climate Assessment) scenarios or at least other similar scenarios such as the NRC west coast scenarios or the USACE scenarios. Also these have been used by DOD more recently and updated in their Coastal Assessment Regional Scenario Working Group (CARSWG). https://www.serdp-estcp.org/content/download/38961/375873/version/3/file/CARSWG+SLR+FINAL+April+2016.pdf The FEMA TMAC future conditions mapping report points to these scnenarios as does the E.O. 13690 - Federal Flood Risk Management Standard (FFRMS) - Climate Informed Science Approach.
It is not very clear if local subsidence was taken into account for all of these sites? The SLR scenarios should be based on locals relative sea level rise. At the very least, choosing closest tide gauge and using the USACE SLR Calculator would result in more accurate local scenarios if you were to use the NCA scenarios, or just use the subsidence values in the equations to extrapolate future sea level rise. I fear not taking into account local subsidence will result in number too low for the future scenarios.
The highest SLR scenario used is the RCP 8.5 by 2100 which only estimates ~0.8m of Sea Level Rise. The upper end of the NCA3 scenarios was 2.0m and the NCA4 range is likley to go up to 2.5m for the 2100 worse case RCP 8.5 scenario. I think your SLR estimates are too low for future planning.
Please check the descriptions of the P-Surge, MEOWS, and MOMs. P-Surge is used for probabalistic real-time runs during landfalling storms and produces an exceedence probablilty. The MEOWS and MOMS in the SLOSH display program were not derived from P-Surge and have no probability associated with them. The MEOWS are a worst case basin snapshot for a particular storm category, forward speed, trajectory, and initial tide level, incorporating uncertainty in forecast landfall location. These products are compiled when a SLOSH basin is developed or updated. MEOWs are not storm specific and are available to view in the SLOSH display program for all operational basins. No single hurricane will produce the regional flooding depicted in the MEOWs. Instead, the product is intended to capture the worst case high water value at a particular location for hurricane evacuation planning. MOMS provide a worst case snapshot for a particular storm category under "perfect" storm conditions. Each MOM considers combinations of forward speed, trajectory, and initial tide level. These products are compiled when a SLOSH basin is developed or updated. As with MEOWs, MOMs are not storm specific and are available to view in the SLOSH display program for all operational basins. No single hurricane will produce the regional flooding depicted in the MOMs. Instead, the product is intended to capture the worst case high water value at a particular location for hurricane evacuation planning. The MOMs are also used to develop the nation's evauation zones. Long story short is that MOMS are used for worse case evacuation planning and are not in any way related to the 100 year or 1% chance storm and thus should not be compared to the Tebaldi et al, 2012

Using MOMs can be problematic because in the SLOSH display program there are often mean tide and high tide runs, but the various basins ran different amounts of tide and different tide scenarios, based on what the State Partners wanted modeled for their state Hurricane Evacuation Study. Also where basins overlap there will be non-matching values. Choosing the correct basin value is often a judgement call. NHC has recently put out a National MOM product and they are working on a version 2 and they plan to make the GIS data available. I suggest you contact NHC and try to access this data to improve your study results. http://noaa.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=b1a20ab5eec149058bafc059635a82ee http://www.nhc.noaa.gov/news/20141106_pa_natlSurgeMap.pdf
Tebaldi uses MHW to reference the extreme surge values…and the mapping for the SLR projections was relateive to MHHW. Make sure datums are consistent.
SLOSH uses a multiple scenario approach…not probabalistic.
The Storm surge layers were not in the map viewer. I could not find where to download the GIS data. Also I noticed the maps for the high SLR scenario for RCP 8.5 are comparible to the NOAA SLR viewer maps for around 2FT above MHHW. I think this is too low of a scenario for 2100 planning. We have reached 2FT above MHHW during high frequency king tide / perigean tide events in Charleston, SC.
Figure 4. Does this include the Gulf Coast? Seems like the number should be much higher in the Gulf based on the very high SLR trends in Louisiana vs. the East Coast.
Discussion: need to add a description of the difference between using SLOSH MOMs worse case scenarios and Tebaldi numbers for West Coast. These really are not comparible. The Tebaldi numbers are based on the work of NOAA (Zervis) which are based on 1% water levels at the tide gauges. These numbers will also not match FEMA coastal flood studies because wave effects are not included. The SLOSH MOMs are often way higher than the 1% flood. For example, in Charleston, SC the 1% chance water level at the Charleston tide gauge is ~7.5FT. The category 1 MOM is that high. Going out to Cat 2-5 will produce surge value way above the 1% chance. So comparing SLOSH vs. Tebaldi numbers isn't really valid. One is based on probalistic analysis of historical data and the other is on 4500 or so scenario runs and having a cumlative peek value. In many cases in the east and gulf coast the 1% chance FEMA BFE is only a Cat 1 to Cat 2 MOM value.
How were the SLOSH results mapped? There are methods out there from the USACE for doing this for HES studies. http://www.northerngulfinstitute.org/impact/resources/inundationWorkshop/scott.pdf
SLR mapping was done using MHHW but was that converted to NAVD88 to match the DEMs? Just wanting to make sure all the map legend values are showing correct height relative to the same datum for both sets of

47 Re_ Request review by Dec 14 for NPS SL.SS Report(8).pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Monday, November 28, 2016 9:37:21 AM

Thanks!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Nov 28, 2016 at 9:34 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Review from Doug Marcy is attached.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> ---------- Forwarded message ----------
> From: **Doug Marcy - NOAA Federal** <doug.marcy@noaa.gov>
> Date: Wed, Nov 23, 2016 at 12:25 PM
> Subject: Re: Request review by Dec 14 for NPS SL.SS Report
> To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
>
> my comments. I didn't get into the gory details of the numbers etc..in the Appendices but rather looked at it from a more general sense with overarching method comments.
>
> Hope this helps. Let me know if you all have questions.
>
> Doug
>
> On Tue, Nov 15, 2016 at 2:27 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Hi Doug:
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>> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service. we need one reviewer with experience with applications of SLOSH Results.

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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--
Doug Marcy
NOAA Office for Coastal Management
2234 S. Hobson Avenue
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doug.marcy@noaa.gov
coast.noaa.gov

48 Re_ Request review by Dec 14 for NPS SL.SS Report(9).pdf

From:	Harry Glahn
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Wednesday, November 30, 2016 2:06:54 PM
Attachments:	review_sea_level_storm_surge_park_service_11_30_16.rtf

Rebecca,

Attached is my review in MS Word. I would be glad to discuss any items in the review or report you wish. I will likely not be at my desk, so leave a message and I will contact you.

bg

On 11/15/2016 2:00 PM, Beavers, Rebecca wrote:

Hi Bob:

Thank you for taking the time to speak with me today. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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(b) (5) [redacted] (b) (5) [redacted]

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Thank you for agreeing to review this important dataset for management of our coastal National parks.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

48 1 Attachment review_sea_level_storm surge_park_service_11_3.pdf

REVIEW OF "SEA LEVEL AND STORM SURGE PROJECTIONS
FOR 118 NATIONAL PARK SERVICE UNITS"

Bob Glahn

This report covers the very difficult subject of trying to forecast relative water level rise in national park units by considering sea level changes, land subsidence or otherwise, and storm surge. In so doing, the MOMs generated with the SLOSH model developed by the Meteorological Development Laboratory (MDL) and the National Hurricane Center (NHC) of the National Weather Service (NWS), NOAA, are used where possible.

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1) SLOSH can be, and has been, run over approximately 32 basins and MOMs created where sufficient past hurricane data exist. Where MOMs are not available, other methods of estimating storm surge were used. There did not seem to be a clear distinction early on that surge of both tropical and extratropical storms was being considered. In fact, the introduction talks specifically of Hurricane Sandy, and concludes with "The aim of this report . . . projections of sea-level rise. . . and 2) how could storm surge generated by hurricanes could also impact these parks." (The second "could" should be omitted.) This implies to me, only storm surge generated by hurricanes is considered, but the report is not limited to that. It should be made clear in the introduction that storm surge by extratropical storms is also being considered. (

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<u>More Minor Comments</u>:

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General – There are instances where a period after a sentence is followed by only one space. You could search.

49 Fwd_ Request review by Dec 14 for NPS SL.SS Report(5).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Request review by Dec 14 for NPS SL.SS Report
Date:	Wednesday, November 30, 2016 2:20:54 PM
Attachments:	review_sea_level_storm surge_park_service_11_30_16.rtf

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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Harry Glahn** <harry.glahn@noaa.gov>
Date: Wed, Nov 30, 2016 at 2:04 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Rebecca,

Attached is my review in MS Word. I would be glad to discuss any items in the review or report you wish. I will likely not be at my desk, so leave a message and I will contact you.

bg

On 11/15/2016 2:00 PM, Beavers, Rebecca wrote:

> Hi Bob:
>
> Thank you for taking the time to speak with me today. Please let me know if this is a feasible task for you to complete for the National Park Service.
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Thank you for agreeing to review this important dataset for management of our coastal National parks.

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50 Re_ Request review by Dec 14 for NPS SL.SS Report(10).pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Wednesday, November 30, 2016 2:21:44 PM

Thanks.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Wed, Nov 30, 2016 at 2:20 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Date: Wed, Nov 30, 2016 at 2:04 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

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http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

51 SL Communication Team Review of Final Report.pdf

From: Beavers, Rebecca
To: Janet Cakir; Larry Perez; Holly, Matt; Shawn Norton
Cc: Caffrey, Maria
Subject: SL Communication Team Review of Final Report
Date: Monday, December 05, 2016 1:29:38 PM
Attachments: Reviewer comments insert last name here.xlsx

SL Communication Team Members:

As discussed on November 30, I request your review of the report entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.

For NPS reviewers, we are interested in any wording changes that may make this material more accessible to more NPS staff.

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Cheers,

rebecca

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51 1 Attachment Reviewer comments_insert last name here_9.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

52 Ocean_Coastal Staff Review of Final NPS Sea Lev....pdf

From:	Beavers, Rebecca
To:	Babson, Amanda; Janet Cakir; Catherine Toline; Eva DiDonato; York, Linda; Tahzay Jones; John Goldsmith; Patrick Malone; Tom Olliff; Julia F Brunner; Cliff McCreedy; Diane Pavek
Cc:	Caffrey, Maria
Subject:	Ocean/Coastal Staff Review of Final NPS Sea Level and Storm Surge Projections Report
Date:	Tuesday, December 06, 2016 2:28:56 PM
Attachments:	Reviewer comments_insert last name here.xlsx

NPS Ocean/Coastal/Climate Change Staff based in a WASO or Regional Office:

I request your review of the report entitled “Sea Level and Storm Surge Projections for 118 National Park Service Units”. This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge (SL/SS) projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.

For NPS reviewers, we are interested in any wording changes in pp. vii-25 and "Appendix B: Frequently Asked Question" on pp. B1-4 that may make this material more accessible to more NPS staff.

The report can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word. **Please return your review by COB December 27th. Early submission of your review would be greatly appreciated. Please cc: maria_caffrey@partner.nps.gov on your response.**

Also of interest, yet not covered by this review:

- Some of the SL/SS data can be viewed using an online viewer: (b) (5) [redacted] The online viewer will undergo separate review. ArcGIS is currently available by request.
- A CCRP webinar on this topic by Dr. Maria Caffrey from October 13, 2016 is available at: http://share.inside.nps.gov/sites/nrss/div/ccrp/webinar/Forms/AllItems.aspx?RootFolder=%2Fsites%2Fnrss%2Fdiv%2Fccrp%2Fwebinar%2FRecordings%20and%20Presentation%20Files%2F2016-10-13%20CC%20Webinar%2C%20Maria%20Caffrey%20-%20Exposure%20to%20Sea%20Level%20Change%20and%20Storm%20Surge

Cheers,

rebecca

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52 1 Attachment Reviewer comments_insert last name here_10.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

53 Re_ SL Communication Team Review of Final Report.pdf

From:	Perez, Larry
To:	Beavers, Rebecca
Cc:	Holly, Matt; Caffrey, Maria
Subject:	Re: SL Communication Team Review of Final Report
Date:	Wednesday, December 07, 2016 11:41:29 AM
Attachments:	Reviewer comments Perez 2016-12-7.xlsx

Rebecca & Maria,

A few comments attached from me for your consideration.

GREAT job and I look forward to seeing this released!!

-L

On Mon, Dec 5, 2016 at 1:29 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

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Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
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Office: 970-267-2136
Email: larry_perez@nps.gov

2016 National Park Service CENTENNIAL | NATIONAL PARK SERVICE

Centennial Goal: Connect with and create the next generation of park visitors, supporters, and advocates.

53 1 Attachment Reviewer comments_Perez 2016-12-7.pdf

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24	7	

Comment
This is a very well-written report: your methods and results are easy to follow, and appropriate "side boards" are placed on relevant content for consideration by the reader. The document was clearly crafted with good attention to detail--bravo!
It should be noted that estimates from Aerts et al. are specific to NYC. Also, this sentence is a bit wonky: t sets up an impending contradiction ("While the amount of damage from this storm might seem to be extreme…") then provides damage estimates that reinforce just how extreme it was by comparison.
Reword 2 to read something like "show how storm surge generated by hurricanes…"
Change page number to "ix"
Recommend increasing the size of the figure enough to make the credit line in the lower left corner legible
From "...find out more information..." to "learn"
To keep the subject of both paragraphs cosistent and clear, consider swapping the final phrase of line 3 with the opening phrase of line 4.
Consider shortening statements regarding the implication of sea-ice into a single, succinct paragraph, and move mention of the implications of land-based ice to the very end of the paragraph as a final transitional thought. And is it proper to say here that the loss of land-based ice contributes to sea-level change?
Unless this table is reference elsewhere (perhaps to demonstrate the increasing rate of rise) it is a poor tool for illustrating additional drivers of SLR, as the language is obtuse. Unless referenced elsewhere, I recommend removing the table and addressing additional drivers in short form in the text.
The question could be asked (and probably should be addressed): why did we filter historic storm intensity using only a 10-mile window (especially given the relative size and large swings in movement observed from past tropical systems?) Coupled with guidance to plan for "one hurricane category highter", this leads to surprisingly conservative recommendations for units in San Juan and peninsular Florida.
"inputted" or "imported", perhaps?
Recommend rewording to: "Changes in various land-based loadings on the continents—such as ice sheets during the last glacial maximum—have been a significant cause of land level change in the U.S.
This line is also a bit confusing: post-glacial isostatic rebound is the result of pressure being *removed* from the
Currently, it looks like this is being made available only in Appendix A.
Appendix D?
Currently, the sea level change data for regions is rolled out/discussed in this order: 2100, 2030, 2050. For reader clarity, I recommend these results be presented chronologically.
recommend: "…path passed *present-day* Boston National…"
recommend: "…indicate the potential height and extend of storm surge generated by…"
In reading this, it occurs to me that additional caveats might be necessary (i.e. a nod to the influence of storm direction.) Given SLR projections for the region, complete inundation of EVER might be possible for storms approaching from the west of southwest, but would still be highly unlikely for storms approaching from the east or southeast. This dynamic is also apropos in discussing several other SE region parks.
Change "then" to "the"
I defer to better knowledge, but would suspect that it is more accurate to say: "…discussed how changes in ocean circulation (resulting from warming temperatures and changing salinity) could create…"
change "regions" to "region"
change "as energy" to "energy"

54 Re_ SL Communication Team Review of Final Report(1).pdf

From:	Caffrey, Maria
To:	Perez, Larry
Cc:	Beavers, Rebecca; Holly, Matt
Subject:	Re: SL Communication Team Review of Final Report
Date:	Wednesday, December 07, 2016 11:46:04 AM

Wow, you're so quick. Thanks!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Wed, Dec 7, 2016 at 11:40 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Rebecca & Maria,
>
> A few comments attached from me for your consideration.
>
> GREAT job and I look forward to seeing this released!!
>
> -L
>
> On Mon, Dec 5, 2016 at 1:29 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> SL Communication Team Members:
>>
>> As discussed on November 30, I request your review of the report entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.
>>
>> For NPS reviewers, we are interested in any wording changes that may make this material more accessible to more NPS staff.
>>
>> Some of the data can be viewed using an online viewer: (b) (5) [redacted] (b) (5) [redacted]
>>
>> The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLo S1jL9_vonekjha?dl=0
>>
>> The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 16th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

2016 National Park Service. CENTENNIAL

NATIONAL PARK SERVICE

Centennial Goal: Connect with and create the next generation of park visitors, supporters, and advocates.

55 Fwd_ SL Communication Team Review of Final Report.pdf

From:	Beavers, Rebecca
To:	Ann Gallagher
Cc:	Caffrey, Maria
Subject:	Fwd: SL Communication Team Review of Final Report
Date:	Monday, December 12, 2016 10:22:21 AM
Attachments:	Reviewer comments insert last name here.xlsx

Hi Ann:

I apologize for leaving you off the most recent science team call for the sea level and storm surge projections project. You will be included in future calls.

Comments received by Dec 22 would be greatly appreciated on the targeted sections of the draft as described below.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Mon, Dec 5, 2016 at 1:29 PM
Subject: SL Communication Team Review of Final Report
To: Janet Cakir <janet_cakir@nps.gov>, Larry Perez <larry_perez@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Shawn Norton <Shawn_Norton@nps.gov>
Cc: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>

SL Communication Team Members:

As discussed on November 30, I request your review of the report entitled “Sea Level and Storm Surge Projections for 118 National Park Service Units”. This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.

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Please return your review by COB December 16th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

55 1 Attachment Reviewer comments_insert last name here_11.pdf

Page Number(s)	Line Number Beginning	Line Number Ending

Comment

56 Re_ SL Communication Team Review of Final Report(2).pdf

From: Beavers, Rebecca
To: Gallagher, Ann
Cc: Caffrey, Maria
Subject: Re: SL Communication Team Review of Final Report
Date: Monday, December 12, 2016 10:25:29 AM

Thank you!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, Dec 12, 2016 at 10:24 AM, Gallagher, Ann <ann_gallagher@nps.gov> wrote:

> I will take a look! I was staring to wonder if I had been sending things to the spam folder; not living up to my end of the bargain. So glad you've got me on the list, now!
>
> Yours,
> Ann
>
> Ann M. Gallagher, M.S.
> ISA Certified Arborist® MA-5484A
> Science Education Coordinator
> Natural Resources & Science, National Capital Region
> 4598 MacArthur Blvd, NW
> Washington, DC 20007
> Phone: 202-339-8320
> Cell: 240-461-6171
> Fax: 202-282-1031
>
> Click Here to share your feedback on the assistance I provided to you today
>
> On Mon, Dec 12, 2016 at 12:22 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Hi Ann:
>>
>> I apologize for leaving you off the most recent science team call for the sea level and storm surge projections project. You will be included in future calls.
>>
>> Comments received by Dec 22 would be greatly appreciated on the targeted sections of the draft as described below.
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division I Climate Change Response Program
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> ---------- Forwarded message ----------

From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Mon, Dec 5, 2016 at 1:29 PM
Subject: SL Communication Team Review of Final Report
To: Janet Cakir <janet_cakir@nps.gov>, Larry Perez <larry_perez@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Shawn Norton <Shawn_Norton@nps.gov>
Cc: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>

SL Communication Team Members:

As discussed on November 30, I request your review of the report entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.

For NPS reviewers, we are interested in any wording changes that may make this material more accessible to more NPS staff.

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Please return your review by COB December 16th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

57 Fwd_ Request review by Dec 14 for NPS SL.SS Report(6).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Request review by Dec 14 for NPS SL.SS Report
Date:	Thursday, December 15, 2016 2:33:39 PM

Tebaldi review

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **claudia tebaldi** <ctebaldi@climatecentral.org>
Date: Thu, Dec 15, 2016 at 1:39 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca

apologies for the delay in getting back to you. I read the brief subsections that you wanted me to double check and everything looks OK, BUT I did not find any mention that the numbers we produced in our 2012 article in terms of storm surge levels are referred to mean high water (MHW) not the zero datum or mean sea level. I may have missed that however, not having read the report in its entirety.I just did a search through the document for "mean high water" and "MHW" and nothing came up. Also, I haven't looked at the data itself that you are making available, I just read the text in the report.Let me know if you wanted me to do something different.

All the best from the AGU circus!

Claudia

PS FYI, Climate Central through its surging seas program made available projections based on different scenarios (for example for the West Coast based on an NRC report that was published after our paper in ERL, by the National Research Council, with Phil Mote at the helm). Also available are slightly updated estimates of storm surges that we worked on at a later time, using observational records that, for some gauges, are longer than the ones used in that paper. Unfortunately at this time I do not have with me the numbers based on that work, but if you are interested I can dig them out next week. Or you can get in touch with Ben Strauss at Climate Central, who has all those numbers.

On Tue, Nov 15, 2016 at 11:23 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Could we discuss your input on a small section of the report that uses your method for pacific parks?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Nov 15, 2016 at 12:09 PM, claudia tebaldi <ctebaldi@climatecentral.org> wrote:

I apologize but I do not have the time in the next month to do this.
You may try Benjamin Strauss at Climate Central, bstrauss@climatecentral.org.

On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Hi Claudia:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: (b) (5) [redacted]

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

58 Re_ Request review by Dec 14 for NPS SL.SS Report(11).pdf

From:	Beavers, Rebecca
To:	Chris Zervas - NOAA Federal
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Thursday, December 15, 2016 3:20:32 PM

Hi Chris:

Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.

We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Thu, Nov 17, 2016 at 12:20 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:

> Hi Rebecca,
> Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.
>
> Chris
>
> On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > HI Chris:
> >
> > Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
> >
> > Instructions to Reviewers:
> >
> > I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and

the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

59 Fwd_ Request review by Dec 14 for NPS SL.SS Report(7).pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Request review by Dec 14 for NPS SL.SS Report
Date: Thursday, December 15, 2016 3:21:28 PM

FYI- This would be a 4th external peer review if the review is completed by 12/21.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Thu, Dec 15, 2016 at 3:20 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: Chris Zervas - NOAA Federal <chris.zervas@noaa.gov>

Hi Chris:

Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.

We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Thu, Nov 17, 2016 at 12:20 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:

> Hi Rebecca,
> Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.
>
> Chris
>
> On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> HI Chris:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

60 Request review by Dec 21 for NPS SL.SS Report.pdf

From:	Beavers, Rebecca
To:	John Fasullo
Subject:	Request review by Dec 21 for NPS SL.SS Report
Date:	Thursday, December 15, 2016 3:25:47 PM

Hi John:

I realize I did not hear back form you about this request sent 1 month ago. Steve Nerem has been an NPS advisor to this project and recommended you as a reviewer of the application of the IPCC Sea level model to this product for coastal units of the National Park Service.

Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.

We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Nov 15, 2016 at 12:04 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi John:
>
> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
>
> Instructions to Reviewers:
>
> I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.
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http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

61 Fwd_ Request review by Dec 21 for NPS SL.SS Report.pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Request review by Dec 21 for NPS SL.SS Report
Date: Thursday, December 15, 2016 3:29:20 PM

FYI- this would be a 5th external peer review. John has yet to confirm he can serve as a reviewer. Did you follow-up with Steve to request this review from John?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Thu, Dec 15, 2016 at 3:25 PM
Subject: Request review by Dec 21 for NPS SL.SS Report
To: John Fasullo <fasullo@ucar.edu>

Hi John:

I realize I did not hear back form you about this request sent 1 month ago. Steve Nerem has been an NPS advisor to this project and recommended you as a reviewer of the application of the IPCC Sea level model to this product for coastal units of the National Park Service.

Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.

We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Nov 15, 2016 at 12:04 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi John:
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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

62 SL_SS report External Peer Review Status.pdf

From:	Beavers, Rebecca
To:	John Gross; Caffrey, Maria; Caffrey, Maria
Subject:	SL/SS report External Peer Review Status
Date:	Thursday, December 15, 2016 3:34:58 PM
Attachments:	SL_SS Caffrey Report_External Peer Reviewers_Status 12152016.docx

SL/SS report External Peer Review Status

3 reviews received. 2 reviews pending with closing date for reviews extended to 12/22.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

62 1 Attachment SL_SS Caffrey Report_External Peer Reviewers_.pdf

Sea Level and Storm Surge Projections
External Peer Review Status

Peer Reviews Received

1. **Harry R (Bob) Glahn,** NOAA/National Weather Service, Meteorological Development Laboratory. sent email 11/15; **review received 11/30**
    a. E-mail: harry.glahn@noaa.gov
    b. 301-4279085 x 279463
2. **Claudia Tebaldi,** Climate Central (formerly UCAR). sent email 11/15; **review received 12/15**
    a. Email: ctebaldi@climatecentral.org
    b. *Research Scientist, Climate Central, Princeton, NJ, & NCAR, Boulder, CO*
    c. http://www.climatecentral.org/
    d. (b) (6) [redacted]
    e. http://www.image.ucar.edu/~tebaldi/
3. **Doug Marcy** SLOSH msg 11/15; sent email 11/15; **review received 11/23**
    a. **doug.marcy@noaa.gov**
    b. (843) 740-1334
    c. NOAA- NOS

Peer Reviews Pending

4. Chris Zervas, NOAA Tides and Currents. msg 11/15; sent email 11/15; follow-up email on 12/15
    a. Email: chris.zervas@noaa.gov
    b. 240-533-0589
5. John Fasullo, UCAR. Voice msg 11/15; sent email 11/15; follow-up email on 12/15
    a. 303-497-1712
    b. Email: fasullo@ucar.edu

63 Fwd_ Request review by Dec 21 for NPS SL.SS Report(1).pdf

From:	Beavers, Rebecca
To:	Steve Nerem
Subject:	Fwd: Request review by Dec 21 for NPS SL.SS Report
Date:	Friday, December 16, 2016 9:39:13 AM

Hi Steve:

We need an external reviewer for the Sea Level section of this report. Who do you recommend?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **John Fasullo** <(b) (6) [redacted]
Date: Fri, Dec 16, 2016 at 9:11 AM
Subject: Re: Request review by Dec 21 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca,

Thanks for getting back to me. I have been on travel for all but 4 days since your original email and alas am off again this morning to take my family skiing for a long weekend. Given this I don't see a window of opportunity to contribute to this review. Please keep me in mind for future work however as I would relish the opportunity to contribute to the National Park Service's mission.

Sincerely,
John

> On Dec 15, 2016, at 3:25 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> Hi John:
>
> I realize I did not hear back form you about this request sent 1 month ago. Steve Nerem has been an NPS advisor to this project and recommended you as a reviewer of the application of the IPCC Sea level model to this product for coastal units of the National Park Service.
>
> Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.
>
> We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Nov 15, 2016 at 12:04 PM, Beavers, Rebecca
<rebecca_beavers@nps.gov> wrote:

Hi John:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer:
(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

64 Re_ Coastal Adaptation and Sea Level Change Pro....pdf

From:	Babson, Amanda
To:	Beavers, Rebecca
Subject:	Re: Coastal Adaptation and Sea Level Change Program Briefs
Date:	Friday, December 16, 2016 11:02:07 AM

Hi Rebecca,
If you send Word version, I can suggest language, but here are some suggestions:

Suggested changes in italics:
The NPS *published* a Coastal Adaptation Strategies Handbook *and a companion Case Studies Report*
for coastal area park response to effects associated with storms
and sea level rise. *add link*

Suggested additional bullet, or to add to a vulnerability assessment one:
The University of Rhode Island Coastal Resources Center is developing vulnerability assessment methods integrating across natural resources, cultural resources and facilities, piloting it at Colonial National Historical Park.

This is a stylistic thing, but for the SLR& storm change, I prefer to start out Background with SLR info (rather than 1.5 sentences before you get to it). Would be more user friendly to have title/heading of Category 2 hurricane instead of the wind speed. I'm assuming Maria is suggesting updates to reflect publication details from the will be completed in 2016.

On Mon, Dec 12, 2016 at 2:45 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Can you send me any edits you would like to see on the coastal adaption brief? Is Wednesday a reasonable time frame?
>
> I'll send you the revised version from maria for your final OK, too.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> ---------- Forwarded message ----------
> From: **Stubblebine, Ryan** <ryan_stubblebine@nps.gov>
> Date: Mon, Dec 12, 2016 at 8:31 AM
> Subject: Coastal Adaptation and Sea Level Change Program Briefs
> To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
>
> Rebecca and Maria,
>
> It is that time of year again when we like to update our program briefs. I really need

some help from you two! The coastal adaptation and sea level change briefs are attached. If you wouldn't mind just perusing them and offering some changes for 2016, I would really appreciate it. There is no need to rewrite the entire brief, we would just like to update with current information. I hope you have a great holiday!

--
Respectfully,

Ryan Stubblebine
Interpretive Specialist
Climate Change Response Program
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
(970) 225-3542- Office
(970) 218-7468- Cell

--
Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile)

65 Re_ SL_SS report External Peer Review Status.pdf

From: Gross, John
To: Beavers, Rebecca
Subject: Re: SL/SS report External Peer Review Status
Date: Friday, December 16, 2016 12:20:33 PM

Thanks for the update. Looks like it's getting close!

johng

On Thu, Dec 15, 2016 at 3:34 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> SL/SS report External Peer Review Status
>
> 3 reviews received. 2 reviews pending with closing date for reviews extended to 12/22.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

--
John Gross, PhD
Climate Change Ecologist, NPS

66 Re_ Ocean_Coastal Staff Review of Final NPS Sea....pdf

From:	Babson, Amanda
To:	Beavers, Rebecca
Subject:	Re: Ocean/Coastal Staff Review of Final NPS Sea Level and Storm Surge Projections Report
Date:	Monday, December 19, 2016 3:56:44 PM

That makes sense, thanks.
Amanda

On Mon, Dec 19, 2016 at 5:53 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> HI Amanda:
>
> This is your opportunity to review in your regional office role. It is up to you if you review again or not.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Mon, Dec 19, 2016 at 3:50 PM, Babson, Amanda <amanda_babson@nps.gov> wrote:
>
>> Hi Rebecca, Just checking - were you and Maria looking for me to take a 2nd look at this to see how my previous comments were addressed, or were you including me so I could see who all was included in the review?
>> Thanks,
>> Amanda
>>
>> On Tue, Dec 6, 2016 at 4:28 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>>
>>> NPS Ocean/Coastal/Climate Change Staff based in a WASO or Regional Office:
>>>
>>> I request your review of the report entitled “Sea Level and Storm Surge Projections for 118 National Park Service Units”. This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge (SL/SS) projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.
>>>
>>> For NPS reviewers, we are interested in any wording changes in pp. vii-25 and "Appendix B: Frequently Asked Question" on pp. B1-4 that may make this material more accessible to more NPS staff.
>>>
>>> The report can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0
>>>
>>> Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word. **Please return your review by COB December 27th. Early submission of your review would be greatly appreciated. Please cc: maria_caffrey@partner.nps.gov on your response.**

Also of interest, yet not covered by this review:

- Some of the SL/SS data can be viewed using an online viewer: [redacted] The online viewer will undergo separate review. ArcGIS is currently available by request.
- A CCRP webinar on this topic by Dr. Maria Caffrey from October 13, 2016 is available at: http://share.inside nps.gov/sites/nrss/div/ccrp/webinar/Forms/AllItems.aspx?RootFolder=%2Fsites%2Fnrss%2Fdiv%2Fccrp%2Fwebinar%2FRecordings%20and%20Presentation%20Files%2F2016-10-13%20CC%20Webinar%2C%20Maria%20Caffrey%20-%20Exposure%20to%20Sea%20Level%20Change%20and%20Storm%20Surge

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

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Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
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(401) 874-6015
(401) 932-9812 (mobile)

--
Amanda L. Babson, PhD
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Northeast Region
National Park Service
University of Rhode Island Bay Campus
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Narragansett, RI 02882
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(401) 932-9812 (mobile)

67 Re_ Ocean_Coastal Staff Review of Final NPS Sea...(1).pdf

From:	Beavers, Rebecca
To:	Babson, Amanda
Cc:	Caffrey, Maria
Subject:	Re: Ocean/Coastal Staff Review of Final NPS Sea Level and Storm Surge Projections Report
Date:	Wednesday, December 21, 2016 4:23:06 PM

Thank you for this review.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Dec 21, 2016 at 1:37 PM, Babson, Amanda <amanda_babson@nps.gov> wrote:

> Hi Maria and Rebecca, Thanks for the opportunity to review again, but I looked through and appreciate that Maria responded to my previous review and don't have major comments for this round.
> One minor typo as I looked back through the NER section p. 14 line 21 is missing 8.5 after 0.74 m (RCP).
> Happy Holidays!
> Amanda
>
> On Tue, Dec 6, 2016 at 4:28 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> NPS Ocean/Coastal/Climate Change Staff based in a WASO or Regional Office:
>>
>> I request your review of the report entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge (SL/SS) projections for 118 coastal park units. These sea level and storm surge projections were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. A separate, concurrent external peer review will evaluate technical elements in how these datasets have been applied and discussed.
>>
>> For NPS reviewers, we are interested in any wording changes in pp. vii-25 and "Appendix B: Frequently Asked Question" on pp. B1-4 that may make this material more accessible to more NPS staff.
>>
>> The report can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0
>>
>> Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word. **Please return your review by COB December 27th. Early submission of your review would be greatly appreciated. Please cc: maria_caffrey@partner.nps.gov on your response.**
>>
>> Also of interest, yet not covered by this review:

- Some of the SL/SS data can be viewed using an online viewer: [redacted] The online viewer will undergo separate review. ArcGIS is currently available by request.
- A CCRP webinar on this topic by Dr. Maria Caffrey from October 13, 2016 is available at: http://share.inside nps.gov/sites/nrss/div/ccrp/webinar/Forms/AllItems.aspx?RootFolder=%2Fsites%2Fnrss%2Fdiv%2Fccrp%2Fwebinar%2FRecordings%20and%20Presentation%20Files%2F2016-10-13%20CC%20Webinar%2C%20Maria%20Caffrey%20-%20Exposure%20to%20Sea%20Level%20Change%20and%20Storm%20Surge

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

--
Amanda L. Babson, PhD
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University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile)

68 Re_ Request review by Dec 14 for NPS SL.SS Report(12).pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Thursday, December 22, 2016 9:20:42 AM

Thanks! I've added a copy of it to the n drive and will address these comments.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Thu, Dec 15, 2016 at 2:33 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Tebaldi review
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> ---------- Forwarded message ----------
> From: **claudia tebaldi** <ctebaldi@climatecentral.org>
> Date: Thu, Dec 15, 2016 at 1:39 PM
> Subject: Re: Request review by Dec 14 for NPS SL.SS Report
> To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
>
> Hi Rebecca
>
> apologies for the delay in getting back to you. I read the brief subsections that you wanted me to double check and everything looks OK, BUT I did not find any mention that the numbers we produced in our 2012 article in terms of storm surge levels are referred to mean high water (MHW) not the zero datum or mean sea level. I may have missed that however, not having read the report in its entirety.I just did a search through the document for "mean high water" and "MHW" and nothing came up. Also, I haven't looked at the data itself that you are making available, I just read the text in the report.Let me know if you wanted me to do something different.
>
> All the best from the AGU circus!
>
> Claudia

PS FYI, Climate Central through its surging seas program made available projections based on different scenarios (for example for the West Coast based on an NRC report that was published after our paper in ERL, by the National Research Council, with Phil Mote at the helm). Also available are slightly updated estimates of storm surges that we worked on at a later time, using observational records that, for some gauges, are longer than the ones used in that paper. Unfortunately at this time I do not have with me the numbers based on that work, but if you are interested I can dig them out next week. Or you can get in touch with Ben Strauss at Climate Central, who has all those numbers.

On Tue, Nov 15, 2016 at 11:23 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Could we discuss your input on a small section of the report that uses your method for pacific parks?
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Tue, Nov 15, 2016 at 12:09 PM, claudia tebaldi <ctebaldi@climatecentral.org> wrote:
>
>> I apologize but I do not have the time in the next month to do this.
>> You may try Benjamin Strauss at Climate Central, bstrauss@climatecentral.org.
>>
>> On Tue, Nov 15, 2016 at 12:06 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>>
>>> Hi Claudia:
>>>
>>> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.
>>>
>>> <u>Instructions to Reviewers:</u>
>>>
>>> I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess

whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer:
(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

69 Re_ Request review by Dec 14 for NPS SL.SS Report(13).pdf

From:	Chris Zervas - NOAA Federal
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Friday, December 23, 2016 2:58:14 PM
Attachments:	Reviewer comments_Zervas.xlsx

Hi Rebecca,

I apologize for being so late in submitting my review.

Hope you enjoy your holidays,
Chris

On Thu, Dec 15, 2016 at 5:20 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Chris:
>
> Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.
>
> We need your review to demonstrate a robust external peer review and thank you in advance for your time.
>
> Cheers,
> rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Thu, Nov 17, 2016 at 12:20 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:
>
>> Hi Rebecca,
>> Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.
>>
>> Chris
>>
>> On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>>
>>> HI Chris:
>>>
>>> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

Some of the data can be viewed using an online viewer: (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scfiwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

69 1 Attachment Reviewer comments_Zervas.pdf

Page Number(s)	Line Number Beginning	Line Number Ending
1 (Introduction)	1	
2	18 (Figure caption)	18
2	19 (Figure caption)	19
4	6	6
4	19	28
21	37	40

Comment
Since you have chosen the IPCC projections over the semi-empirical approach, you should probably briefly mention that other agencies have put forward a range of planning curves for coastal managers including semi-empirical-based curves which rise more rapidly. I see you that you have a paragraph about this in the Discussion section (page 23 line 1), but a sentence or two at the beginning would help.
Substitute 'for 2015' with 'using all available data including 2015'
Cross out 'relative to global mean sea level'. A trend is not relative to any level.
Substitute 'ice wholly contained within water and not supported by land' with 'ice wholly supported by water'
This paragraph is another place to note that the semi-empirical approach can result in projected levels over twice as high as the IPCC's process-based approach.
This is an important point.   Most of southern Alaska is rising rapidly with spatially and temporally variable rates. Therefore, the present-day vertical land motion must be measured directly at the parks in order to make any

70 Re_ Request review by Dec 14 for NPS SL.SS Report(14).pdf

From: Beavers, Rebecca
To: Chris Zervas - NOAA Federal
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Friday, December 23, 2016 3:01:06 PM

Thank you for this review. Happy Holidays.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, Dec 23, 2016 at 2:56 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:

> Hi Rebecca,
>
> I apologize for being so late in submitting my review.
>
> Hope you enjoy your holidays,
> Chris
>
> On Thu, Dec 15, 2016 at 5:20 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Hi Chris:
>>
>> Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.
>>
>> We need your review to demonstrate a robust external peer review and thank you in advance for your time.
>>
>> Cheers,
>> rebecca
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division I Climate Change Response Program
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> On Thu, Nov 17, 2016 at 12:20 PM, Chris Zervas - NOAA Federal <chris.zervas@noaa.gov> wrote:
>>
>>> Hi Rebecca,
>>> Thank you for asking me to review your report. I think I should be able to do it by Dec 14 as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.
>>>
>>> Chris

On Tue, Nov 15, 2016 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

HI Chris:

Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service.

Instructions to Reviewers:

I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.

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(b) (5) [redacted] (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program

303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

71 Fwd_ Request review by Dec 14 for NPS SL.SS Report(8).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria; Caffrey, Maria
Subject:	Fwd: Request review by Dec 14 for NPS SL.SS Report
Date:	Friday, December 23, 2016 3:02:00 PM
Attachments:	Reviewer comments_Zervas.xlsx

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Chris Zervas - NOAA Federal** <chris.zervas@noaa.gov>
Date: Fri, Dec 23, 2016 at 2:56 PM
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca,

I apologize for being so late in submitting my review.

Hope you enjoy your holidays,
Chris

On Thu, Dec 15, 2016 at 5:20 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi Chris:
>
> Can you provide this review by 12/21? We have extended some reviewer deadlines until that date.
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>
> Cheers,
> rebecca
>
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> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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as I will be returning from a one week vacation on Dec 2. It might be a good idea to send me reminder the week before the due date.

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303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

71 1 Attachment Reviewer comments_Zervas_1.pdf

Page Number(s)	Line Number Beginning	Line Number Ending
1 (Introduction)	1	
2	18 (Figure caption)	18
2	19 (Figure caption)	19
4	6	6
4	19	28
21	37	40

Comment
Since you have chosen the IPCC projections over the semi-empirical approach, you should probably briefly mention that other agencies have put forward a range of planning curves for coastal managers including semi-empirical-based curves which rise more rapidly. I see you that you have a paragraph about this in the Discussion section (page 23 line 1), but a sentence or two at the beginning would help.
Substitute 'for 2015' with 'using all available data including 2015'
Cross out 'relative to global mean sea level'. A trend is not relative to any level.
Substitute 'ice wholly contained within water and not supported by land' with 'ice wholly supported by water'
This paragraph is another place to note that the semi-empirical approach can result in projected levels over twice as high as the IPCC's process-based approach.
This is an important point.   Most of southern Alaska is rising rapidly with spatially and temporally variable rates. Therefore, the present-day vertical land motion must be measured directly at the parks in order to make any

72 Re_ Request review by Dec 21 for NPS SL.SS Report.pdf

From:	Steve Nerem
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 21 for NPS SL.SS Report
Date:	Wednesday, December 28, 2016 11:55:26 AM

Rebecca,

Here are some names, but I think it's going to be tough to find people with the time to do it properly.

Billy Sweet, NOAA
Eric Leuliette, NOAA
Don Chambers, University of South Florida
Phil Woodworth, retired, PSMSL
Carmen Boening, JPL
Ben Hamlington, Old Dominion University

Steve

On Dec 16, 2016, at 9:39 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Hi Steve:

We need an external reviewer for the Sea Level section of this report. Who do you recommend?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **John Fasullo** <[redacted]>
Date: Fri, Dec 16, 2016 at 9:11 AM
Subject: Re: Request review by Dec 21 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca,

Thanks for getting back to me. I have been on travel for all but 4 days since your original email and alas am off again this morning to take my family skiing for a long weekend. Given this I don't see a window of opportunity to contribute to this review. Please keep me in mind for future work however as I would relish the opportunity to contribute to the National Park Service's mission.

Sincerely,
John

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We need your review to demonstrate a robust external peer review and thank you in advance for your time.

Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Dr. R. Steven Nerem, Professor
Colorado Center for Astrodynamics Research
Dept of Aerospace Engineering Sciences
431UCB
University of Colorado
Boulder, Colorado 80309

Ph. 303-492-6721
Fax 303-492-2825
Cell 303-641-0057
nerem@colorado.edu

73 Fwd_ Request review by Dec 21 for NPS SL.SS Report(2).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria; Caffrey, Maria
Subject:	Fwd: Request review by Dec 21 for NPS SL.SS Report
Date:	Tuesday, January 03, 2017 7:32:01 PM

FYI- unless you need an external reviewer on this topic, I will call the review complete with 4 external peer reviews.

I have no further comments from NPS regions, oceans staff, etc.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Steve Nerem** <nerem@colorado.edu>
Date: Wed, Dec 28, 2016 at 11:55 AM
Subject: Re: Request review by Dec 21 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Rebecca,

Here are some names, but I think it's going to be tough to find people with the time to do it properly.

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> National Park Service | Geologic Resources Division I Climate Change Response Program

303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **John Fasullo** <[redacted]
Date: Fri, Dec 16, 2016 at 9:11 AM
Subject: Re: Request review by Dec 21 for NPS SL.SS Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca,

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Sincerely,
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>
> Cheers,
> rebecca
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> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division I Climate Change Response Program
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Please return your review by COB December 14th. Early

submission of your review would be greatly appreciated.

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National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) |
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Dr. R. Steven Nerem, Professor   Ph. 303-492-6721
Colorado Center for Astrodynamics Research   Fax 303-492-2825
Dept of Aerospace Engineering Sciences   Cell 303-641-0057
431UCB
University of Colorado   nerem@colorado.edu
Boulder, Colorado 80309

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74 Re_ Request review by Dec 14 for NPS SL.SS Report(15).pdf

From: Maria Caffrey
To: Beavers, Rebecca
Subject: Re: Request review by Dec 14 for NPS SL.SS Report
Date: Wednesday, January 04, 2017 9:35:45 AM

Will do. Thanks!

Maria Caffrey, PhD
Research Associate
Geological Sciences,
UCB 399,
2200 Colorado Ave,
Boulder, CO 80309

Office: (303) 969-2097
Cell: (303) 518-3419
Web: mariacaffrey.com

From: Beavers, Rebecca <rebecca_beavers@nps.gov>
Sent: Tuesday, January 3, 2017 7:30:41 PM
To: Maria Caffrey
Subject: Re: Request review by Dec 14 for NPS SL.SS Report

Please send the final version to the science team and the communication team with cc: to John Gross as a last call with edits due by Noon Tuesday, Jan 10. If no edits by then (also when I am back in the office), I'll work with you on publishing.

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Jan 3, 2017 at 7:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> great!
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Tue, Jan 3, 2017 at 7:23 PM, Maria Caffrey <maria.caffrey@colorado.edu> wrote:
>
>> Yes. I've already made the changes and saved a copy of the comments on the n drive.
>>
>> Maria Caffrey, Ph.D.

Office: (303) 969-2097
Cell: (303) 518-3419
mariacaffrey.com

On Jan 3, 2017, at 7:22 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Did you get the comments?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, Dec 23, 2016 at 5:07 PM, Maria Caffrey
<maria.caffrey@colorado.edu> wrote:

> Thanks. I don't see an attachment on this, but I'm on my phone so maybe it'll show up on my computer later.
>
> Cheers
>
> Maria Caffrey, Ph.D.
>
> Office: (303) 969-2097
> Cell: (303) 518-3419
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> On Dec 23, 2016, at 3:02 PM, Beavers, Rebecca
> <rebecca_beavers@nps.gov> wrote:
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
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> Date: Fri, Dec 23, 2016 at 2:56 PM
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<Reviewer comments_Zervas.xlsx>

75 Re_ Request review by Dec 21 for NPS SL.SS Report(1).pdf

From:	Maria Caffrey
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 21 for NPS SL.SS Report
Date:	Wednesday, January 04, 2017 9:38:52 AM

Sounds good. Looks like John just can't do it.

I could ask Billy Sweet to look it over, but he was someone who had applied for the sea level position in OCRB. I don't know if that would be an issue (probably not because Billy seems very professional based on the few emails we've exchanged).

Maria Caffrey, PhD
Research Associate
Geological Sciences,
UCB 399,
2200 Colorado Ave,
Boulder, CO 80309

Office: (303) 969-2097
Cell: (303) 518-3419
Web: mariacaffrey.com

From: Beavers, Rebecca <rebecca_beavers@nps.gov>
Sent: Tuesday, January 3, 2017 7:32:01 PM
To: Caffrey, Maria; Maria Caffrey
Subject: Fwd: Request review by Dec 21 for NPS SL.SS Report

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Dr. R. Steven Nerem, Professor — Ph. 303-492-6721
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Dept of Aerospace Engineering Sciences — Cell 303-641-0057
431UCB
University of Colorado — nerem@colorado.edu
Boulder, Colorado 80309

76 Re_ Sea level_storm surge project report.pdf

From:	Caffrey, Maria
To:	Cat Hoffman
Cc:	Rebecca Beavers
Subject:	Re: Sea level/storm surge project report
Date:	Tuesday, January 17, 2017 3:55:43 PM

Hi Cat,

I'm not sure if you have gotten around to reading the report yet. I need to send it out ASAP (within the next day or two). I'm assuming that you're ok to be kept on as an author on this. Can you confirm that you want to be a co-author?

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Wed, Jan 11, 2017 at 1:57 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Hi Cat,
>
> I wanted to share with you the sea level/storm surge project report that Rebecca and I have been working on. It's a rather large file that is too big to attach to an email, so I've included a link to it:
>
> https://drive.google.com/open?id=0BxhhWNH7lJJwU2hXWUJQTUZWbTQ
>
> We have spent a lot of time putting the report through review, but I think it's almost ready to go public. We are aiming to release it by the end of this month. I really appreciate all of the support that I've received from CCRP on this project and I was wondering if you would like to be a co-author on it?
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> Congratulations on the promotion too. That's excellent news.
>
> Cheers,
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NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

77 Fwd_ Sea level_storm surge project report.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Sea level/storm surge project report
Date:	Wednesday, January 18, 2017 8:55:15 AM

Did you ask or consider Amanda as an author. I think she had far more input than Cat. Still think it is good to keep Cat- more ownership we can show in NPS the better.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
Date: Tue, Jan 17, 2017 at 3:55 PM
Subject: Re: Sea level/storm surge project report
To: Cat Hoffman <cat_hawkins_hoffman@nps.gov>
Cc: Rebecca Beavers <rebecca_beavers@nps.gov>

Hi Cat,

I'm not sure if you have gotten around to reading the report yet. I need to send it out ASAP (within the next day or two). I'm assuming that you're ok to be kept on as an author on this. Can you confirm that you want to be a co-author?

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>
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>
> https://drive.google.com/open?id=0BxhhWNH7lJJwU2hXWUJQTUZWbTQ

We have spent a lot of time putting the report through review, but I think it's almost ready to go public. We are aiming to release it by the end of this month. I really appreciate all of the support that I've received from CCRP on this project and I was wondering if you would like to be a co-author on it?

Congratulations on the promotion too. That's excellent news.

Cheers,

Maria Caffrey, PhD

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NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

78 Re_ Sea level_storm surge project report(1).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Re: Sea level/storm surge project report
Date:	Wednesday, January 18, 2017 3:38:15 PM

In a CCRP call this afternoon, I told both amanda & cat that you would follow- up with them on some final details that need to be confirmed before the report is published. We need to check with Larry on 508 compliance for the report, too.

I have one more report review to complete by COB and will let you know when I am done. Tomorrow AM ~ 9:30 am should be OK if you want to schedule a time.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Jan 18, 2017 at 8:56 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> I did ask Amanda, but she never replied (I guess because of her initial issues with the report). I'll email her again and ask.
>
> Do you have some time today to discuss the Great Lakes?
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Wed, Jan 18, 2017 at 8:55 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > Did you ask or consider Amanda as an author. I think she had far more input than Cat. Still think it is good to keep Cat- more ownership we can show in NPS the better.
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> > Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> > National Park Service | Geologic Resources Division
> > 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
> >
> > ---------- Forwarded message ----------
> > From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
> > Date: Tue, Jan 17, 2017 at 3:55 PM

Subject: Re: Sea level/storm surge project report
To: Cat Hoffman <cat_hawkins_hoffman@nps.gov>
Cc: Rebecca Beavers <rebecca_beavers@nps.gov>

Hi Cat,

I'm not sure if you have gotten around to reading the report yet. I need to send it out ASAP (within the next day or two). I'm assuming that you're ok to be kept on as an author on this. Can you confirm that you want to be a co-author?

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https://drive.google.com/open?id=0BxhhWNH7lJJwU2hXWUJQTUZWbTQ

We have spent a lot of time putting the report through review, but I think it's almost ready to go public. We are aiming to release it by the end of this month. I really appreciate all of the support that I've received from CCRP on this project and I was wondering if you would like to be a co-author on it?

Congratulations on the promotion too. That's excellent news.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

79 Re_ Sea level_storm surge project report(2).pdf

From:	Hoffman, Cat
To:	Caffrey, Maria
Cc:	Rebecca Beavers; Perez, Larry
Subject:	Re: Sea level/storm surge project report
Date:	Thursday, January 26, 2017 9:43:32 AM

yes, definitely can get comments to you by then.

On Thu, Jan 26, 2017 at 9:42 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Hi Cat,
>
> Thanks for getting back to me. I'm glad you agreed to be co-author.
>
> I can take a few more comments if you think you can get them back to me somewhat soon. Feel free to share this with Ray. I can incorporate comments from him too. I'd really like to get this out by the end of February, so could I get the comments back by the end of next week?
>
> Thanks,
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Thu, Jan 26, 2017 at 9:29 AM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>
>> Hi Maria -- I'm glad that Rebecca sent a "nudge" to me through Larry yesterday -- things definitely fall below my radar, particularly lately with several short-turnaround transition tasks that are coming in.
>>
>> I would like to be a co-author on the report, although if you feel I haven't contributed enough, it won't insult me if you decide not to include me!
>>
>> Ray is organizing a cross-directorate meeting next week to talk about our profile and messaging around our work. I'll know more after that about how we can move forward with this report.
>>
>> In the meantime, are you still open to some comments on the document?
>>
>> On Tue, Jan 17, 2017 at 3:55 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:
>>
>>> Hi Cat,
>>>
>>> I'm not sure if you have gotten around to reading the report yet. I need to send it

out ASAP (within the next day or two). I'm assuming that you're ok to be kept on as an author on this. Can you confirm that you want to be a co-author?

Cheers,

Maria Caffrey, PhD

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> https://drive.google.com/open?id=0BxhhWNH7lJJwU2hXWUJQTUZWbTQ
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> We have spent a lot of time putting the report through review, but I think it's almost ready to go public. We are aiming to release it by the end of this month. I really appreciate all of the support that I've received from CCRP on this project and I was wondering if you would like to be a co-author on it?
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--

> > ***Cat Hawkins Hoffman***
> > **National Park Service**
> >
> > **Chief, NPS Climate Change Response Program**
> > **1201 Oakridge Drive**
> > **Fort Collins, CO 80525**
> > **cat_hawkins_hoffman@nps.gov**
> > **970-225-3567**
> >
> > Adaptation websites: public, NPS managers
> > Climate Change Response Resources

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

80 press material for SS_SL paper.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	press material for SS_SL paper
Date:	Thursday, January 26, 2017 2:04:02 PM

N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Press examples

We will likely need to draft a similar key messages, comms worksheet and press release for your paper.

The key messages will be needed first to accompany the paper when it is sent to WASO Comms.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

81 Peer review manager update_ Caffrey Sea level_s....pdf

From: Beavers, Rebecca
To: John Gross
Subject: Peer review manager update: Caffrey Sea level/storm surge report
Date: Tuesday, January 31, 2017 1:40:28 PM

Hi John:

Cat is making her revisions to the final version of the sea level/ storm surge projections report that now addresses internal and external peer review comments. She anticipated providing her comments to us by friday.

I'll send the draft Manuscript Submittal Form to you approx early next week for review and comment along with 1) the final version of the paper and 2) the spreadsheet we have for tracking comments and responses to comments.

Thanks.

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

82 Re_ Peer review manager update_ Caffrey Sea lev....pdf

From:	Beavers, Rebecca
To:	Gross, John
Subject:	Re: Peer review manager update: Caffrey Sea level/storm surge report
Date:	Tuesday, January 31, 2017 3:08:03 PM

I like [redacted]. Will be [redacted] & will wave hello!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Jan 31, 2017 at 3:01 PM, Gross, John <john_gross@nps.gov> wrote:

> Hi Rebecca,
>
> Glad to hear you're getting out! The backcountry is has been equally good. What I meant to say is that I'm leaving for [redacted] (Feb. 8th).
>
> I'm at [redacted]. Among my wife's family, we've been sharing pics using [redacted] sharing, if you're using [redacted]
>
> Cheers,
> johng
>
> On Tue, Jan 31, 2017 at 2:57 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > Thank you! Nice picture. I was [redacted]. Snow has been awesome.
> >
> > Still have not made it backcountry this season, [redacted] wants to try this spring and is ready for snowshoeing up & skiing down slopes inbounds at loveland. (Have to pack the boots & skis to change in lodge for her)!
> >
> > What is your private email & I'll send you some fun videos?
> >
> > Enjoy [redacted]
> >
> > Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> > National Park Service | Geologic Resources Division
> > 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
> >
> > On Tue, Jan 31, 2017 at 2:32 PM, Gross, John <john_gross@nps.gov> wrote:
> >
> > > Hi Rebecca,
> > >
> > > Thanks for the update. I'm off to [redacted]. I'm hoping to work a few

hours on Monday and will work a full day Tuesday, so if you don't get it to me before then, don't push too hard because I won't see it until the following week. Regardless, I'll push this out the door ASAP once I get it.

Hope you've been getting out. I've been enjoying some AWESOME skiing!!

Cheers,
johng

On Tue, Jan 31, 2017 at 1:40 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Hi John:
>
> Cat is making her revisions to the final version of the sea level/ storm surge projections report that now addresses internal and external peer review comments. She anticipated providing her comments to us by friday.
>
> I'll send the draft Manuscript Submittal Form to you approx early next week for review and comment along with 1) the final version of the paper and 2) the spreadsheet we have for tracking comments and responses to comments.
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> Thanks.
>
> -rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

--
John Gross, PhD
Climate Change Ecologist, NPS

--
John Gross, PhD
Climate Change Ecologist, NPS

83 Manuscript submittal forms.pdf

From:	Caffrey, Maria
To:	Rebecca Beavers
Subject:	Manuscript submittal forms
Date:	Monday, February 06, 2017 2:51:49 PM
Attachments:	Manuscript_Submittal_Form 2017.docx NRR_Author_Template_V4.0.docx

Rebecca,

I have attached the manuscript submittal form for the sea level/storm surge report. I've filled it out as much as I can. We will have to add the report numbers later along with a date for the program managers approval. Cat is still reviewing the document, but she she should get it back to us this week. I haven't attached the final report because I will need to include Cat's edits once I get them back, but I thought it would be good to get the manuscript submittal forms ready. Hopefully this should all be ready for the next step in a week or so.

I have the majority of the reviewer comments in spreadsheets that I could upload onto the drive for John to review if he would like me to. I've made notes next to each comment explaining how we tackled each comment. I have a couple reviews that are in a PDF format because the reviewer preferred to email their comments. I have a document that explains my replies to each of Bob Glahn's lengthycomments, but I don't have anything for the smaller emailed comments from Claudia Tebaldi and Steve Nerem.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
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Energy and Minerals * Active Processes and Hazards * Geologic Heritage

83 1 Attachment Manuscript_Submittal_Form 2017.pdf

Manuscript Submittal Form and Checklist

Fields marked by an asterisk are required

SECTION 1.

1. Manuscript submitter - the person submitting this manuscript for publication, e.g., project manager, author, editor

* **Name: Maria A. Caffrey**

* **Mailing Address (street, city, state, zip): National Park Service, Geologic Resources Division, 12795 West Alameda Parkway, Lakewood, CO 80228**

* **Phone:** 303-969-2097

* **Email: maria_a_caffrey@partner.nps.gov**

2. Title and author(s)

* **Title of manuscript:** Sea level and storm surge projections for 118 national park units

* **Authors (complete table)**

Author List Order	First Name	Middle Initial (optional)	Last Name
First	**Maria**	**A.**	**Caffrey**
Second	**Rebecca**	**L.**	**Beavers**
Third	**Patrick**	Click here to enter text.	**Gonzalez**
Fourth	**Cat**	Click here to enter text.	**Hawkins-Hoffman**
Fifth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Sixth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Seventh	Click here to enter text.	Click here to enter text.	Click here to enter text.
Eighth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Ninth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Tenth	Click here to enter text.	Click here to enter text.	Click here to enter text.

3. * Report Series - select series that is appropriate for the manuscript

☐ **Natural Resource Data Series (NRDS) (proceed to sections 2 and 4 below)**

Intended for the timely release of basic data sets and routine data summaries that are based on data collection and data management methods documented in established, peer-reviewed protocols. While QA procedures have been completed to assure the accuracy of raw data values, *analysis or interpretation of the data has not been completed and should not be included in NRDS manuscripts.* (see NRDS guidance and tips)

☒ **Natural Resource Report (NRR) series (proceed to sections 3 and 4 below)**

Intended for comprehensive information and analysis about natural resources and related topics concerning lands managed by NPS. NRR manuscripts may include quantitative data that are accompanied by analysis and/or interpretation; procedural documents such as protocols and standard operating procedures; planning or policy information; and/or resource management information.

Note: If the manuscript meets criteria for 'Highly Influential Scientific or Scholarly Information' as defined by the OMB Peer Review Bulletin (i.e., provides the sole or major component of information used in decision-making; or, by itself, leads to a change in the direction of decision-making or to a decision that creates a clear and substantial impact on important public policies or private sector decisions), publication should not occur in the NRR.

SECTION 2. NRDS Manuscript

This section applies only if you are publishing in the **Natural Resource Data Series**.

No peer review is required for these reports; however, program management review is recommended.

*** Citation or link (preferred) to protocol associated with report:**

n/a

SECTION 3. NRR Manuscript

This section applies only if you are publishing in the **Natural Resource Report** *series*. This series requires peer review.

This section should be completed by the program manager who is assuming responsibility for the content of the manuscript. **Note**: Authors can never hold the role of Program Manager or Peer Review Manager for a manuscript.

Current NPS peer review guidance requires that NPS scientific and scholarly activities comply with OMB Final Information Quality Bulletin for Peer Review (2004; 70 FR 2664-2677), and NPS Director's Order (DO) #11B: Ensuring Quality of Information Disseminated by the National Park Service.

Peer review of the manuscript must comply with the NPS Interim Guidance on Peer Review. If the manuscript is submitted by or on behalf of the Inventory and Monitoring Division, it must also adhere to IMD-specific guidance

3.1. Peer Review Manager

The peer review manager oversees the peer review process of this report, and assumes responsibility for the manuscript fully meeting NPS peer review guidance. Manuscripts submitted by the Inventory and Monitoring Division must also meet the latest version of the IMD Peer Review Policy (NPS-only).

The peer review manager recommends, to the program manager, the technical acceptance of the manuscript in a written record documenting the process. The peer review manager is also responsible for maintaining all records associated with the peer review process, including correspondence, comments, and responses.

*** Peer Review Manager Name: John Gross**

*** Title: Climate Change Ecologist**

3.2. Peer Review Summary

Briefly describe the major review comments addressed, and areas of the report that were revised during the peer review conducted by the Peer Review Manager.

Peer review was carried out using both internal and external reviewers. Reviewers were selected based on their expertised in one or more fields relating to coastal climate change, sea level change, or storm surge. The following people reviewed the document: Amanda Babson (NPS), Ann Gallagher (NPS), Larry Perez (NPS), Steve Nerem (University of Colorado), Bob Glahn (emeritus, NOAA), Doug Marcy (NOAA), Chris Zarvas (NOAA), Rob Thieler (USGS), and Claudia Tebaldi (Climate Central). All peer review comments have been compiled in either spreadsheets as PDFs. Desciptions of how each comment was addressed is included in the spreadsheets. Comments covered the entire report. Peer reviewers were not supplied the GIS data referenced in this report. The GIS data will undergo a separate review.

Provide confirmation that peer and management review comments have been adequately incorporated into the final manuscript.

The report authors were responsible for the incorporation of peer and management comments into the final manuscript. These edits were reviewed by peer review manager John Gross to ensure that their edits adequately addressed the peer and management comments.

☐ Yes
☒ No

Does the manuscript include any sensitive or commercially valuable information that may potentially jeopardize a park resource or that might justify a management review by a qualified individual? If yes, please explain

Click here to enter text.

☐ Yes
☒ No

Is there policy-sensitive material in the manuscript that might justify a management review by an appropriate reviewer who can verify consistency with or clear and appropriate relation to NPS policy? A management review should be conducted if any material might not be consistent with NPS policy. If one of the reviewers is qualified to conduct such a review and has already done so, please explain.

Click here to enter text.

SECTION 4. Approval and Publication

4.1 Program Manager Approval

The NPS program manager has final authority to approve publication of the manuscript, and assumes responsibility for this report's adherence to scientific integrity, administrative and policy standards.

*** Program Manager Name: Cat Hawkins-Hoffman**

*** Title: Chief, Climate Change Response Program**

*** Date Approved for Publication:** Click here to enter text.

4.2. Report Numbers and Data Store Record Owners

Provide the name and email address of additional NPS employees who should receive the final publication review notice from the series manager, and who should review the associated NPS Data Store record.

Name: Click here to enter text.

Email: Click here to enter text.

Name: Click here to enter text.

Email: Click here to enter text.

The following information is completed by the publication series manager.

Report Series Number: Click here to enter text.

Technical Information Center (TIC) number: Click here to enter text.

NPS Data Store Reference Code: Click here to enter text.

Comments:
Click here to enter text.

This completed form is archived through the Natural Resource Publication Series. Archived forms are available to NPS management and other U.S. Government oversight entities upon request.

Series Manager – Fagan Johnson (Fagan_johnson@nps.gov, 970-267-2190)

83 2 Attachment NRR_Author_Template_V4.0.pdf

About This Template

This template is intended for use by authors who are preparing a final draft of a report that will be sent to a dedicated NPS layout expert (who will format the report to meet NRR Full Template standards). *Do not use this template if you do not have access to such an expert and intend to submit the report for publication yourself.* Instead, prepare your report using the NRR Full Template.

Not sure how to do something as instructed in the template? Click on the hyperlinks provided. **Note:** Most links in this document will only work if all five files in the NRR_Template_4.0.zip file are unzipped into the same drive folder.

How to Use This Template

1) Prepare your report using this template and MS Word 2013 or later.
2) Provide the title, authors, and cover image(s) on the following 3-4 pages.
3) Prepare your report using the basic template examples that begin on the *First Order Heading Example* chapter.
   a) Use the MS Word Styles built into this template (style names that begin with "*nrps* ") for all text elements throughout the report (Rules/Guidance – see all text elements built into this template for working examples, and the See the NRR Full Template for additional examples).
      i) To see the Styles, go to the Home tab, find the tile that says "Styles," and click on the little arrow in the lower right-hand corner.
      ii) All headings should be applied in a logical order (styles *nrps Heading 1–6*; first-order headings come first, followed by second-order headings, etc.).
   b) All pages must be in single-column layout.
   c) Always include an abstract or executive summary (see full template Abstract or Executive Summary)
   d) Always include a brief introduction or similar section (see full template Introduction)
   e) Make sure that the written content of your entire report is characterized by the following.
      i) Correct and consistent grammar, punctuation, capitalization, and spelling
      ii) Straightforward, concise, and natural wording
      iii) Defined acronyms and abbreviations (at first usage)
      iv) Findings were clearly and coherently presented
   f) All graphics (photographs, maps, charts, etc.) should (Rules/Guidance)
      i) If the graphics show data results or analysis, facts, or contextual information (maps, charts, etc.), they should be added to the report as figures and referenced in the text section immediately before the figure (see full template Figure 1, Figure 2, Figure 3, Figure 4, and Figure 5).
      ii) If they are purely decorative graphics (i.e., photos and images that do not show data results or analysis, facts, or contextual information), they should not be treated as figures or referenced in the text in most cases (see full template Example 1 and Example 2).
      iii) Be added directly to the page (not still housed in an external file).
      iv) Stay within the page margins (Rules/Guidance).

v) Be in-line with text (no text wrapping around the graphic or the caption).

vi) Be easy for the reader to discern and all major text attributes (legends, major feature labels, etc.) must be legible.

vii) Be saved as separate graphics files whenever possible and made available upon request by the NRPM support staff.

(1) Prior to importing them into MS Word, photos and like images (.jpg, .png, etc.) should be saved as separate files that are close to the same dimensions displayed on the MS Word page (inches wide and tall) at 300-600 ppi/dpi (pixels per inch / dots per inch).

(2) MS Office charts or Draw elements (saved in stand-alone MS Word or Excel files; charts should be the same size as will be used on the actual page).

(3) All vector-based graphics (should be saved to Adobe Illustrator (.ai) or Scalable Vector Graphics formats (.svg – supported by most GIS, statistics, and plot generating software)).

h) Tables should
(Rules/Guidance – see full template Table 1, Table 2, Table 3, Table 4, and Table 5)

i) Always be MS Word tables added directly to the page (not pictures of tables, or tables still housed in external files, or other treatments that only "look like" tables).

ii) Always have multiple columns and rows. Single-column content should be added as lists.

iii) Stay within the page margins (Rules/Guidance).

iv) Not be split into multiple tables when the table spans multiple pages (this will be done for you later).

v) Have consistent layout schemes (borders, backgrounds, table notes, etc.) throughout all chapters.

vi) Not be nested inside of other tables or text boxes.

vii) Not have a single-column (please use bulleted or numbered lists instead).

2) Authors should use this copy for peer review and editing (review of all content and language).

3) When you have a final draft that is ready for final layout and editing, send the report to a dedicated NPS layout expert who will reformat each page of the report to meet full template standards.

4) Work with the NPS peer review manager and the NRR layout editor to make sure that the final report meets NRPM peer review standards and to publish the report.

Information for Cover Pages (Required)

Item	Information
Report title	Sea Level And Storm Surge Projections for 118 National Park Units
Report subtitle	
Author 1 name, organization name, city, state	Maria A. Caffrey, Department of Geological Sciences, University of Colorado, UCB 399, Boulder, CO 80309-0399

Item	Information
Author 2 name, organization name, city, state	Rebecca L. Beavers, National Park Service, Geologic Resources Division, P.O. Box 25287, Denver, CO 80225-0287
Author 3 name, organization name, city, state	Patrick Gonzalez, National Park Service, Climate Change Response Program, 1201 Oakridge Drive, Suite 200, Fort Collins, CO 80205
Author 4 name, organization name, city, state	Cat Hawkins-Hoffman, National Park Service, Climate Change Response Program, 1201 Oakridge Drive, Suite 200, Fort Collins, CO 80205
Author 5 name, organization name, city, state	
Author 6 name, organization name, city, state	

Add more author rows as needed

Cover Photo or Image (Required)

Please click on the line between these instructions and the table shown just below, then insert a cover photo (Insert/Picture) and complete the table (Rules/Guidance).

Item	Information
Cover photo caption	Driftwood washed up on the shoreline of Redwood National Park. Photograph courtesy of Maria Caffrey, University of Colorado
Cover photo credit (Rules/Guidance on how to credit images, photos, and artwork)	Maria Caffrey

Inside Cover Photo or Image (optional)

You may also provide a photo for the inside cover (which is the back of the cover page). If desired, please insert that photo on the line between these instructions and the table shown just below, and then complete the table (Rules/Guidance).

Item	Information
Inside Cover photo caption	Fort Point National Historic Site and the Golden Gate Bridge, California. Photograph courtesy of Maria Caffrey, University of Colorado.
Inside Cover photo credit (Rules/Guidance on how to credit images, photos, and artwork)	Maria Caffrey

After completing the tables shown above, begin your report on the following page. If desired, don't forget to include an Acknowledgements section and an Executive Summary. Please contact your layout person or Fagan Johnson with any questions about this template or the publications process.

First Order Heading Example (Style: *nrps Heading 1*)

Use the MS Word Styles built into this template (style names that begin with "*nrps* ") for all text elements throughout the report (Style *nrps Normal* - Rules/Guidance for using Styles - see template text elements for working examples - see the NRR Full Template for additional examples).

Second Order Heading Example (Style: *nrps Heading 2*)

All headings should be applied in a logical order (styles *nrps Heading 1–6*; first-order headings come first, followed by second-order headings, etc.).

Third Order Heading Example (Style: nrps Heading 3)

Lorem ipsum aliquet tincidunt bibendum ultrices mi himenaeos, auctor elit justo consequat litora tempor, faucibus quis elementum platea quisque tristique sapien consectetur dictumst eu porta diam sodales platea.

Fourth Order Heading Example (Style: *nrps Heading 4*)

Platea lacinia elementum lacus feugiat scelerisque cursus commodo, cras dui congue quisque blandit elit dolor tortor.

Fifth Order Heading Example (Style: nrps Heading 5)

Interdum auctor tempor aenean duis bibendum ipsum dapibus primis suscipit, est dictumst dui adipiscing aliquam adipiscing nec mi vitae (Table 1).

Table 1. Example of a basic table (Rules/Guidance for tables).

Terrestrial resource	Indicator	Agency	Source
Big Meadows area	Vegetation	National Park Service	Shenandoah I&M Program
	Deer	National Park Service	Shenandoah I&M Program
Native vegetation	Seedling density	National Park Service	Shenandoah I&M Program
	Canopy cover	National Park Service	Shenandoah I&M Program
	Rare plant species	National Park Service	Shenandoah I&M Program
Non-native vegetation	Occurrence frequency	National Park Service	Shenandoah I&M Program

Sixth Order Heading Example (Style: nrps Heading 6)

Consectetur gravida etiam facilisis nostra semper magna, libero proin fermentum aenean iaculis orci ad, vehicula ut consectetur malesuada ut donec sed donec fermentum magna dapibus urna vulputate mi mauris auctor hendrerit netus, proin cras auctor aenean ac varius scelerisque dictum quis pulvinar sociosqu, tempor curabitur integer maecenas quis aenean consequat purus fringilla nostra present (Figure 1).

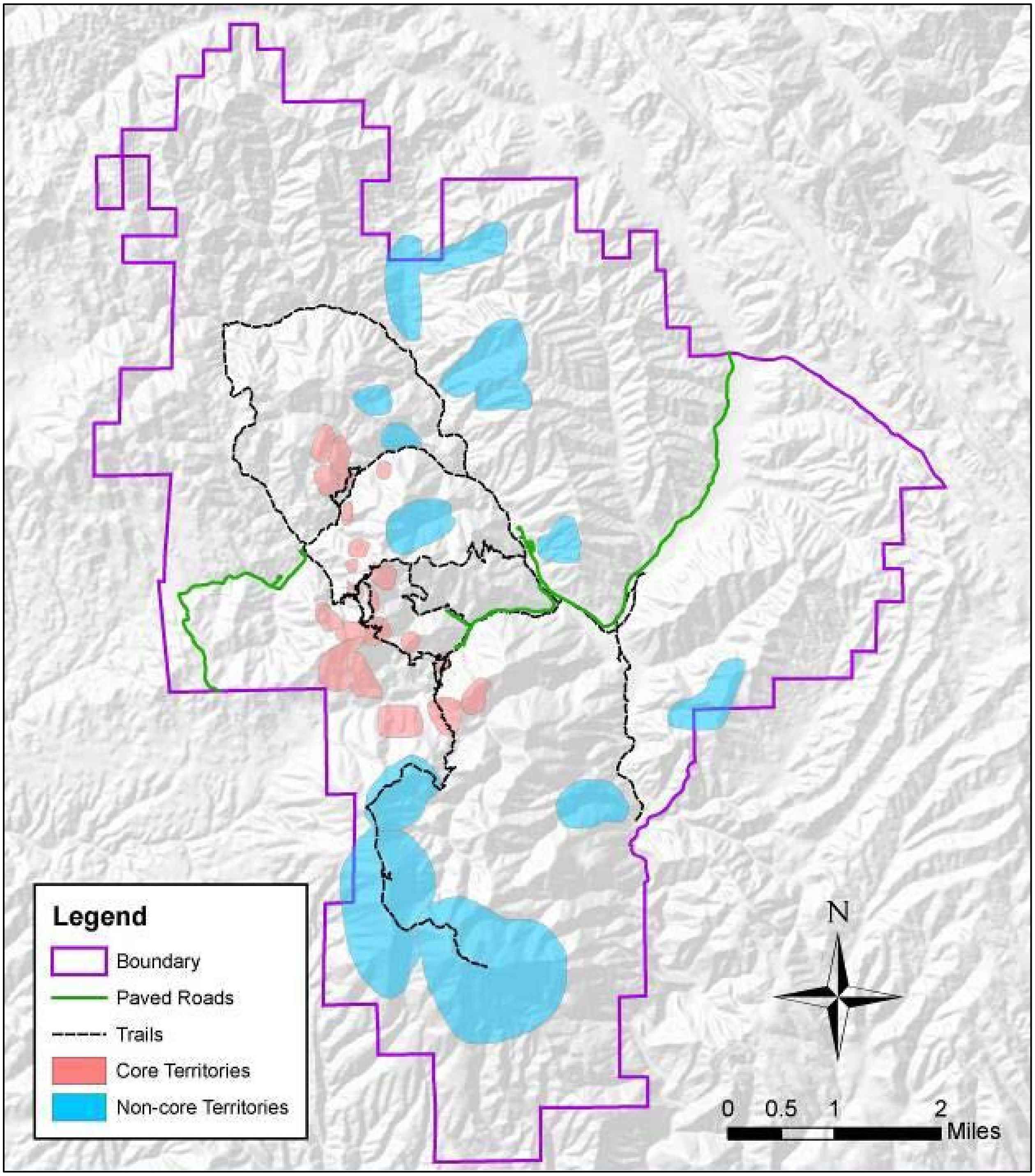

Figure 1. Example of a map that takes up the entire width of the page (suggested for most maps in NRR reports) (Style: *nrps Figure caption*, Rules/Guidance for maps; Rules/Guidance for graphic captions; and Rules/Guidance for how to credit images, photos, and artwork).

84 Re_ Manuscript submittal forms.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Re: Manuscript submittal forms
Date:	Monday, February 06, 2017 2:52:56 PM

Thank you!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

On Mon, Feb 6, 2017 at 2:51 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Rebecca,
>
> I have attached the manuscript submittal form for the sea level/storm surge report. I've filled it out as much as I can. We will have to add the report numbers later along with a date for the program managers approval. Cat is still reviewing the document, but she she should get it back to us this week. I haven't attached the final report because I will need to include Cat's edits once I get them back, but I thought it would be good to get the manuscript submittal forms ready. Hopefully this should all be ready for the next step in a week or so.
>
> I have the majority of the reviewer comments in spreadsheets that I could upload onto the drive for John to review if he would like me to. I've made notes next to each comment explaining how we tackled each comment. I have a couple reviews that are in a PDF format because the reviewer preferred to email their comments. I have a document that explains my replies to each of Bob Glahn's lengthycomments, but I don't have anything for the smaller emailed comments from Claudia Tebaldi and Steve Nerem.
>
> Cheers,
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology

85 NRSS_CCRP Outlook Submissions.pdf

From:	Perez, Larry
To:	Bill Commins; Jennifer Wyse
Cc:	Cat Hoffman
Subject:	NRSS/CCRP Outlook Submissions
Date:	Friday, February 10, 2017 3:00:55 PM

Bill & Jen,

In an effort to help consolidate our reporting, I'm sending you both these submissions from CCRP for your respective purposes. Please let me know if this new method of reporting will work for you going forward.

Many Thanks,

Larry

P.S. I hope to one day work at Mordor National Park, Jen ;)

3-Week Outlook

On February 14-15, Colonial National Park, Northeast Region, and the Climate Change Response Program will host the final in the 3-part workshop series to assess vulnerability across natural resources, cultural resources, and facilities. The effort is being coordinated in partnership with the University of Rhode Island. (Contact: Amanda Babson, 401-874-6015)

Beginning February 29, the Climate Change Response Program will host *Interpreting Climate Change*, a three-day virtual workshop for communications personnel on interpreting climate change with park audiences. The curriculum familiarizes attendees with audience segmentation trends, best practices, and potential program themes.(Contact Larry Perez, 970-267-2136)

Sometime early March, the Climate Change Response Program and Geological Resources Division will release a peer-reviewed report on projections of sea level and storm surge for 118 coastal parks. (Contact: Rebecca Beavers, 303-987-6945)

General Updates

No Updates.

Technical Assistance and Training

No Updates.

Papers, Presentations, and Meetings

(CCRP) New Article Published in *Science*: Dr. Patrick Gonzalez coauthored an article published February 10 in the journal *Science*. The article provides a framework for using deep time to inform conservation under climate change, illustrated in part by examples from Joshua Tree, Yellowstone, and other national parks around the world. The article abstract can be viewed here. (Contact: Patrick Gonzalez at patrick_gonzalez@nps.gov or 510-643-9725.)

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200

Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

86 Re_ NRSS_CCRP Outlook Submissions.pdf

From:	Cat Hoffman
To:	Wyse, Jennifer
Cc:	Perez, Larry; Bill Commins
Subject:	Re: NRSS/CCRP Outlook Submissions
Date:	Sunday, February 12, 2017 12:36:08 PM

It's been peer reviewed, and will be an NR Technical report

Cat

sent from my iPhone

On Feb 12, 2017, at 12:34 PM, Cat Hoffman <cat_hawkins_hoffman@nps.gov> wrote:

> The report discusses methods used by Dr Maria Caffrey to develop sea level rise and storm surge projections (maps) for all NPS coastal units, for the IPCC emissions scenarios. Having it available in 3 weeks might be optimistic but we wanted to send the info just in case.
>
> I'm working on final edits this afternoon and will send you the draft so you can see what it's about.
>
> Cat
>
> sent from my iPhone
>
> On Feb 12, 2017, at 11:34 AM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:
>
>> I hit send a bit too soon. Do we have any other details on the sea level rise/storm surge report?
>>
>> **********************
>> Jennifer Wyse
>> 202-208-4272
>>
>> FIND YOUR PARK
>>
>> On Sun, Feb 12, 2017 at 1:33 PM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:
>>
>>> Thanks Larry!
>>>
>>> **********************

Jennifer Wyse
202-208-4272

FIND YOUR PARK

On Fri, Feb 10, 2017 at 5:00 PM, Perez, Larry
<larry_perez@nps.gov> wrote:

Bill & Jen,

In an effort to help consolidate our reporting, I'm sending you both these submissions from CCRP for your respective purposes. Please let me know if this new method of reporting will work for you going forward.

Many Thanks,

Larry

P.S. I hope to one day work at Mordor National Park, Jen ;)

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General Updates

No Updates.

Technical Assistance and Training

No Updates.

Papers, Presentations, and Meetings

(CCRP) New Article Published in *Science*: Dr. Patrick Gonzalez coauthored an article published February 10 in the journal *Science*. The article provides a framework for using deep time to inform conservation under climate change, illustrated in part by examples from Joshua Tree, Yellowstone, and other national parks around the world. The article abstract can be viewed here. (Contact: Patrick Gonzalez at patrick_gonzalez@nps.gov or 510-643-9725.)

Larry Perez, Communications Coordinator
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Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

87 Sea level rise report.pdf

From:	Hoffman, Cat
To:	Maria Caffrey
Cc:	Rebecca Beavers; Patrick Gonzalez
Subject:	Sea level rise report
Date:	Sunday, February 12, 2017 4:51:55 PM

Hi Maria -- here are comments and suggested edits for the sea level rise report. Thanks for your patience.

Cat

Sea Level Change Report Draft After External Re...

--

Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

88 Re_ NRSS_CCRP Outlook Submissions(1).pdf

From:	Hoffman, Cat
To:	Wyse, Jennifer
Cc:	Larry Perez
Subject:	Re: NRSS/CCRP Outlook Submissions
Date:	Sunday, February 12, 2017 4:57:28 PM

Here is the sea level rise report, with edits and comments that I just sent back to Maria Caffrey. The report has been peer reviewed for methodology and conclusions; my edits are largely for clarity.

Although it's possible, I'm not sure that the final version will be available in 3 weeks, so this could be an even earlier "heads up."

Sea Level Change Report Draft After External Re...

Cat

On Sun, Feb 12, 2017 at 1:02 PM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:

> Thanks Cat!
>
> *********************
>
> Jennifer Wyse
> 202-208-4272
>
> FIND YOUR PARK
>
> On Sun, Feb 12, 2017 at 2:36 PM, Cat Hoffman <cat_hawkins_hoffman@nps.gov> wrote:
>
> > It's been peer reviewed, and will be an NR Technical report
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> > Cat
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> > sent from my iPhone
> >
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> > > I'm working on final edits this afternoon and will send you the draft so you can see what it's about.
> > >
> > > Cat
> > >
> > > sent from my iPhone

On Feb 12, 2017, at 11:34 AM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:

I hit send a bit too soon. Do we have any other details on the sea level rise/storm surge report?

****

Jennifer Wyse
202-208-4272

On Sun, Feb 12, 2017 at 1:33 PM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:

Thanks Larry!

****

Jennifer Wyse
202-208-4272

On Fri, Feb 10, 2017 at 5:00 PM, Perez, Larry <larry_perez@nps.gov> wrote:

Bill & Jen,

In an effort to help consolidate our reporting, I'm sending you both these submissions from CCRP for your respective purposes. Please let me know if this new method of reporting will work for you going forward.

Many Thanks,

Larry

P.S. I hope to one day work at Mordor National Park, Jen ;)

3-Week Outlook

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(Contact: Amanda Babson, 401-874-6015)

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Sometime early March, the Climate Change Response Program and Geological Resources Division will release a peer-reviewed report on projections of sea level and storm surge for 118 coastal parks. (Contact: Rebecca Beavers, 303-987-6945)

General Updates

No Updates.

Technical Assistance and Training

No Updates.

Papers, Presentations, and Meetings

(CCRP) New Article Published in *Science*: Dr. Patrick Gonzalez coauthored an article published February 10 in the journal *Science*. The article provides a framework for using deep time to inform conservation under climate change, illustrated in part by examples from Joshua Tree, Yellowstone, and other national parks around the world. The article abstract can be viewed here. (Contact: Patrick Gonzalez at patrick_gonzalez@nps.gov or 510-643-9725.)

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FIND YOUR PARK

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

89 Sea Level Change Report Draft After External Re....pdf

From: Cat Hoffman (via Google Drive)
To: maria_a_caffrey@partner.nps.gov
Cc: patrick_gonzalez@nps.gov; rebecca_beavers@nps.gov
Subject: Sea Level Change Report Draft After External Reviewer Edits January 11 2017_CHH Feb 12, 2016.docx
Date: Sunday, February 12, 2017 5:00:06 PM

Cat Hoffman has shared the following document:

W Sea Level Change Report Draft After External Reviewer Edits January 11 2017_CHH Feb 12, 2016.docx

Open

90 Re_ NRSS_CCRP Outlook Submissions(2).pdf

From: Jennifer Wyse
To: Hoffman, Cat
Cc: Larry Perez
Subject: Re: NRSS/CCRP Outlook Submissions
Date: Monday, February 13, 2017 8:27:25 AM

Thank you! Good catch!

Sent from my iPhone

On Feb 13, 2017, at 10:17 AM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:

> Thanks for working on this and for the call a moment ago. This is a good addition. One thought -- you might remove the second use of the word "projections" in the sentence you added.
>
> On Mon, Feb 13, 2017 at 6:45 AM, Wyse, Jennifer <jennifer_wyse@nps.gov> wrote:
>> Thank you Cat!
>>
>> I added a sentence to the 3 week out report entry:
>>
>> In early to mid-March, the National Park Service will release a peer-reviewed report on projections of sea level rise and storm surge projections for 118 and 79 coastal parks (respectively). The results are intended to inform park planning, and adaptation and mitigation strategies for lands managed by the National Park Service.
>>
>> Does that work for you all?
>>
>> Thanks!
>>
>> Jen
>>
>> **********************
>> Jennifer Wyse
>> 202-208-4272
>>
>> FIND YOUR PARK
>>
>> On Sun, Feb 12, 2017 at 6:57 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>>> Here is the sea level rise report, with edits and comments that I just sent back to Maria Caffrey. The report has been peer reviewed for methodology and conclusions; my edits are largely for clarity.
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>>> Although it's possible, I'm not sure that the final version will be available in 3 weeks, so this could be an even earlier "heads up."

Sea Level Change Report Draft After External Re...

Cat

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Thanks Cat!

****

Jennifer Wyse
202-208-4272

FIND YOUR PARK

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It's been peer reviewed, and will be an NR Technical report

Cat

sent from my iPhone

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sent from my iPhone

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Jennifer Wyse
202-208-4272

FIND YOUR PARK

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> Thanks Larry!
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> Jennifer Wyse
> 202-208-4272
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> FIND YOUR PARK
>
> On Fri, Feb 10, 2017 at 5:00 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Bill & Jen,
>>
>> In an effort to help consolidate our reporting, I'm sending you both these submissions from CCRP for your respective purposes. Please let me know if this new method of reporting will work for you going forward.
>>
>> Many Thanks,
>>
>> Larry
>>
>> P.S. I hope to one day work at Mordor National Park, Jen ;)
>>
>> ## 3-Week Outlook
>>
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>>
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Change, a three-day virtual workshop for communications personnel on interpreting climate change with park audiences. The curriculum familiarizes attendees with audience segmentation trends, best practices, and potential program themes.(Contact Larry Perez, 970-267-2136)

Sometime early March, the Climate Change Response Program and Geological Resources Division will release a peer-reviewed report on projections of sea level and storm surge for 118 coastal parks. (Contact: Rebecca Beavers, 303-987-6945)

General Updates

No Updates.

Technical Assistance and Training

No Updates.

Papers, Presentations, and Meetings

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FIND YOUR PARK

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National Park Service

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Adaptation websites: public, NPS managers
Climate Change Response Resources

--
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Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

91 Re_ NRSS Weekly Outlook Report - Week of 02_13_....pdf

From:	Perez, Larry
To:	Rebecca Beavers; Cat Hoffman
Subject:	Re: NRSS Weekly Outlook Report - Week of 02/13/2017
Date:	Monday, February 13, 2017 7:54:26 PM

Cat and I did, Rebecca, in order to provide as much notice as possible up the line.

We will continue to update the anticipated release date as it becomes clearer.

Thanks,

L

On Mon, Feb 13, 2017 at 6:58 PM, Rebecca Beavers <rebecca_beavers@nps.gov> wrote:

> Did you submit the 3 week out item for the SLR report? I did not. The report has not cleared NRSS pubs review so may not be quite 3 weeks out.
>
> Sent from my Verizon Wireless 4G LTE smartphone
>
> -------- Original message --------
> From: "Perez, Larry" <larry_perez@nps.gov>
> Date: 02/13/2017 4:19 PM (GMT-07:00)
> To: Amanda Babson <amanda_babson@nps.gov>, Amanda Carlson <amanda_carlson@partner.nps.gov>, Amanda Hardy <amanda_hardy@nps.gov>, Amber Childress <amber_childress@partner.nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>, "Cakir, Janet" <janet_cakir@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, David Lawrence <david_james_lawrence@nps.gov>, gregor_schuurman <gregor_schuurman@nps.gov>, "Gross, John" <john_gross@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Rockman, Marcia (Marcy)" <marcy_rockman@nps.gov>, Ryan Stubblebine <ryan_stubblebine@nps.gov>, S Olliff <tom_olliff@nps.gov>, William Dozier <michael_dozier@nps.gov>, "Wood, Melanie" <melanie_wood@nps.gov>
> Subject: NRSS Weekly Outlook Report - Week of 02/13/2017
>
> Team,
>
> The latest NRSS Outlook Report is attached below.
>
> Please have any submissions to me by COB Thursday.
>
> Thanks,
>
> L
>
> ---
>
> Larry Perez, Communications Coordinator

Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

92 Re_ Request review by Dec 14 for NPS SL.SS Report(16).pdf

From:	Doug Marcy - NOAA Federal
To:	Beavers, Rebecca
Subject:	Re: Request review by Dec 14 for NPS SL.SS Report
Date:	Tuesday, February 28, 2017 8:25:28 AM

Rebecca,

Did these comments help? did this ever get published?

Thanks. Hope you are well.

Doug

On Wed, Nov 23, 2016 at 2:25 PM, Doug Marcy - NOAA Federal <doug.marcy@noaa.gov> wrote:

> my comments. I didn't get into the gory details of the numbers etc..in the Appendices but rather looked at it from a more general sense with overarching method comments.
>
> Hope this helps. Let me know if you all have questions.
>
> Doug
>
> On Tue, Nov 15, 2016 at 2:27 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Hi Doug:
>>
>> Thank you for your time to consider this review. Please let me know if this is a feasible task for you to complete for the National Park Service. we need one reviewer with experience with applications of SLOSH Results.
>>
>> Instructions to Reviewers:
>>
>> I request your review of a report for the National Park Service entitled "Sea Level and Storm Surge Projections for 118 National Park Service Units". This report will be released as part of a three year project with the University of Colorado. The report provides sea level and storm surge estimates for 118 coastal park units. These sea level and storm surge estimates were generated by the Intergovernmental Panel on Climate Change (IPCC) and the NOAA. You have been chosen as a reviewer because of your expertise in this matter; you are not expected to review to whether using these datasets was an appropriate choice for this project, but we would like you to assess whether there are any technical errors in how these datasets have been applied and discussed.
>>
>> Some of the data can be viewed using an online viewer: (b) (5) [redacted]

The report itself can be downloaded from: https://www.dropbox.com/sh/scf iwntlliasfh0/AAAOMFgFZLoS1jL9_vonekjha?dl=0

The online viewer will undergo separate review. ArcGIS is currently available by request. Use the attached excel spreadsheet to record your comments/suggested edits. Please do not make edits in word.

Please return your review by COB December 14th. Early submission of your review would be greatly appreciated.

Cheers,

rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division I Climate Change Response Program
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

--
Doug Marcy
NOAA Office for Coastal Management
2234 S. Hobson Avenue
Charleston, SC 29405
843-740-1334
doug.marcy@noaa.gov
coast.noaa.gov

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2234 S. Hobson Avenue
Charleston, SC 29405

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doug.marcy@noaa.gov
coast.noaa.gov

94 Re_ All revisions are done.pdf

From: Caffrey, Maria
To: Beavers, Rebecca
Subject: Re: All revisions are done
Date: Tuesday, March 07, 2017 3:12:32 PM
Attachments: Slides for RBs CCRP webinar.pptx

I have attached some slides. The first slide is a summary slide. I've also included a number of other slides that either just show maps or a summary of the methods. I wasn't sure which direction you would like to take the second slide in, so I've given you a bunch of options to choose from. Feel free to delete all the extra stuff. I think the first slide is fine by itself.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Tue, Mar 7, 2017 at 2:21 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Great! Thank you!.
>
> Can you send me 1 or more slides about this report for the CCRP webinar on Thursday? This may even be one slide from your CCRP webinar with a date, etc for people to go back to the webinar for more info.
>
> Rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> FIND YOUR PARK
>
> On Tue, Mar 7, 2017 at 11:29 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:
>
>> I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

You might want to give it another read before sending on. I changed the title to "Sea level rise and storm surge projections for the National Park Service." I'm open to other title suggestions for the title. I just shortened it a little more to get around Cat's suggestion that it be "Sea level rise and storm surge projections for 118 and 79 National Park Service units (respectively)."

Cheers,

Maria Caffrey, PhD

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Energy and Minerals * Active Processes and Hazards * Geologic Heritage

94 1 Attachment Slides for RBs CCRP webinar.pdf

Sea Level/Storm Surge Project

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/XXXX/NRDS—2017/XXX

- Project is lead by Dr. Maria Caffrey
- The project covers 118 coastal units
- The report will be released in the coming months

More information at:
https://www.nps.gov/subjects/climatechange/sealevelchange.htm

October 2016 Caffrey webinar [NPS internal site]:
https://tinyurl.com/caffreywebinar

Sea Level/Storm Surge Project

- Sea level projections use the source model for the latest (AR5) IPCC report
- We used projections directly from the report for 2050 and 2100
- We also downscaled sea level rise for 2030
- Used NOAA SLOSH model to estimate storm surge

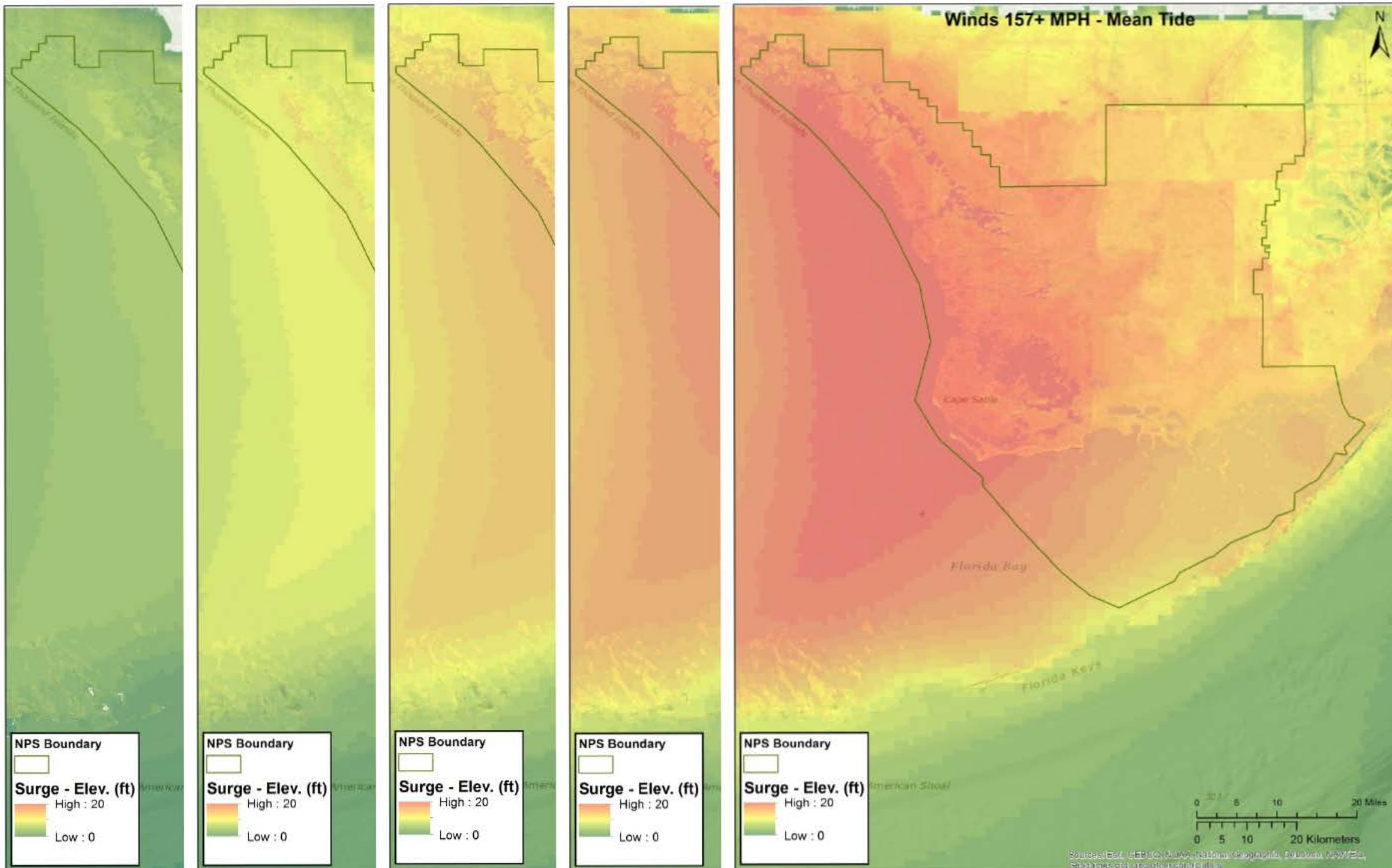
Key strengths of this approach:

- Uses the latest CMIP5 data (coupled models that use the new representative concentration pathways)
- Widely respected data sources
- Nationwide coverage for sea level rise
- Maximum coverage for storm surge

RCP8.5 2050

RCP8.5 2100

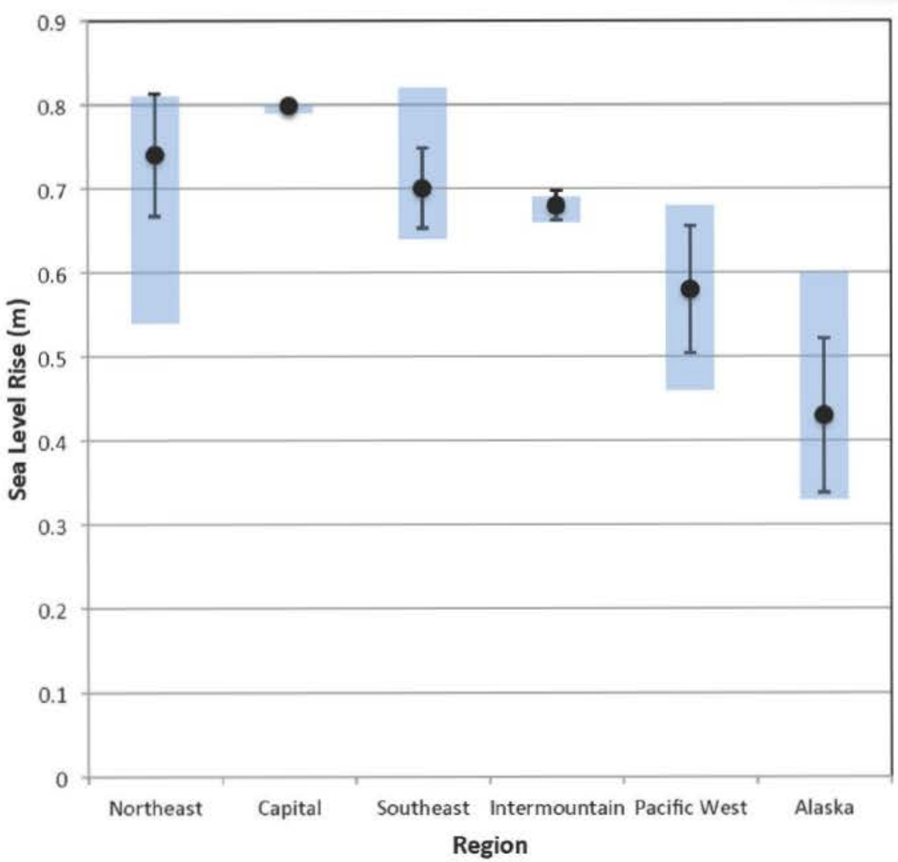
Storm Surge



Winds 157+ MPH - Mean Tide
N
NPS Boundary
Surge - Elev. (ft)
High : 20
Low : 0
Cape Sable
Florida Bay
Florida Keys
American Shoal
0 5 10 20 Miles
0 5 10 20 Kilometers

Sea Level Rise By Region

Projected future sea level by region for 2100 under RCP8.5.



Black dots indicate the average sea level rise (m) for all units within the respective regions.

Black bars represent the standard deviation of each average. Blue bars mark the full range of sea level estimates for each region.

These averages do not include the impact of land movement.

Comparing Parks

- Highest sea level rise by 2100 (RCP8.5) =

Wright Brothers National Memorial/Cape Hatteras National Seashore

- Lowest sea level rise by 2100 (RCP8.5) =

Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park

- Strongest (by pressure) historical storm =

Everglades National Park

RCP4.5 2100

RCP8.5 2100

95 Re_ All revisions are done(1).pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Re: All revisions are done
Date: Tuesday, March 07, 2017 3:27:50 PM

Thank you! Any news from greeley?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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FIND YOUR PARK

On Tue, Mar 7, 2017 at 11:29 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form
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> Energy and Minerals * Active Processes and Hazards * Geologic Heritage

96 Sea level_storm surge projections - Invitation ....pdf

From: Rebecca Beavers (via Google Drive)
To: amanda_babson@nps.gov
Cc: courtney_schupp@nps.gov; patrick_gonzalez@nps.gov
Subject: Sea level/storm surge projections - Invitation to collaborate
Date: Monday, March 13, 2017 2:25:38 PM

Rebecca Beavers has invited you to **contribute to** the following shared folder:

Sea level/storm surge projections

Open

99 Re_ final Caffrey SL_SS projections report(1).pdf

From: Babson, Amanda
To: Beavers, Rebecca
Subject: Re: final Caffrey SL/SS projections report
Date: Wednesday, March 15, 2017 11:03:02 AM

I am reviewing and will finish by Friday.
Amanda

On Mon, Mar 13, 2017 at 4:25 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Patrick, Amanda, & Courtney:
>
> Can you check this final manuscript for any glaring errors/major omissions? A reply by Fri 3/17 would be great. I would like to know if there are grammar mistakes, but we are past the point of preferred wording- though the title changed based on a request from Cat.
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> https://drive.google.com/open?id=0B2z-WBMLTvtHbGIxSHdFT0RKaW8
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> ---------- Forwarded message ----------
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> Date: Tue, Mar 7, 2017 at 11:29 AM
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> Maria Caffrey, PhD

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--
Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile

Northeast Region Climate Change Toolkit

Find Your Park: Women's Rights National Historical Park tells the story of the first Women's Rights Convention held in Seneca Falls, NY on July 19-20,1848. It is a story of struggles for civil rights, human rights, and equality, global struggles that continue today.

101 1 Attachment Review of Caffrey et al 2017 Sea level storm _1.pdf

Review of Caffrey et al. **Sea Level Rise and Storm Surge Projections for the National Park Service**

- p ix line 9 - delete "the" in the sentence "We would also like to thank the Susan..."
- p 1 introduction - "Melilo" should be "Melillo" ?
- p 1 introduction - it is not clear what 1/398, 1/1570, 1/100 means. I'd suggest writing it out in words at least in the first instance (1/398).
- p 2 first paragraph- add "regions" to end of sentence, to read "...Pacific West, and Alaska regions."
- p 2 first paragraph- add "to" so that it reads "...are vulnerable to the effects of..."
- p 2 second paragraph- when referring to a word as the word itself, put it in quotations marks:
    - 'we use the term "flooding" to describe...'
    - similarly, '..."Inundation" is used to refer to...'
    - similarly, for consistency in the last paragraph, put "sea level change" in quotation marks instead of italics in the sentence 'For this reason, we use the term "sea level change" as it...'
- p 4 methods – Suggest adding a comma to first sentence to read "…project, initiated in 2013,…"
- p4 methods item 3- change "impact" to "impacts"
- p 4 header "Sea level Rise Data" capitalize 'level'
- p 5 remove 'to' in the sentence "AOGCMs to simulate the processes…"
- p 6- Move the explanation of what a "simple bathtub model" is from p 9 to here.
- P 7 fig 2 caption- add "Island" to "Assateague National Seashore"
- P 7 revise the verb in the sentence "The NOAA SLOSH model is comprised of the…" to read either "model is composed of the following" or "model comprises the following"
- p 7- Is it safe to assume that readers will know what probabilistic, deterministic, and composite approaches are? If not consider adding a brief explanation of their differences.
- P 9 first paragraph – change "Alaskan" to "Alaska" for consistency with "Guam, and American Samoa park units"
- Ensure verb consistency with the plural "data" throughout document
    - P 10 first paragraph "… data that either meets or exceeds…"
    - P 10 first paragraph "This is discussed in more detail in the metadata that accompanies each map. "
    - P 10 first paragraph "USGS data was used for areas, such as Alaska…"
    - P 11 "All GIS data from this project is available…"
- P 11 missing the word "the" in the sentence "…given that many of park units are some distance from..."
- P 12 add a period to the end of the second sentence "…in Appendix D Following…"
- P 15 second paragraph capitalize "region" in "Alaska region"
- P 17 second paragraph: "the" should be lowercase in the sentence "For example, The Eugene Island…"

- P 17 second paragraph: revise “sea level” to “change in sea level” in both mentions here: “…we can see that relative sea level is more than double the projected sea level using the IPCC estimates alone.”
- P 24- “Glacier Bay Preserve” should be “Glacier Bay National Park and Preserve”
- P 27- first paragraph- add “Island” to “Assateague National Seashore”
- Appendix D – please repeat column headers on every page.

102 Re_ final Caffrey SL_SS projections report(3).pdf

From:	Beavers, Rebecca
To:	Schupp, Courtney
Subject:	Re: final Caffrey SL/SS projections report
Date:	Wednesday, March 15, 2017 11:55:23 AM

thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

On Wed, Mar 15, 2017 at 11:49 AM, Schupp, Courtney <courtney_schupp@nps.gov> wrote:

> Rebecca,
> My suggested edits (mostly typos and grammar flags) are attached.
> Glad to see this is coming out soon.
> Courtney
>
> On Wed, Mar 15, 2017 at 11:57 AM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:
>
>> Thanks, Rebecca. I will aim to send any final edits by the end of Friday.
>>
>> Patrick
>>
>> ....
>> Patrick Gonzalez, Ph.D.
>> Principal Climate Change Scientist
>> Natural Resource Stewardship and Science
>> U.S. National Park Service
>>
>> Department of Environmental Science, Policy, and Management
>> University of California, Berkeley
>> 131 Mulford Hall, Berkeley, CA 94720-3114 USA
>>
>> patrick_gonzalez@nps.gov
>> patrickgonzalez@berkeley.edu
>> (510) 643-9725
>> @pgonzaleztweet
>> http://www.patrickgonzalez.net
>> ....
>>
>> ---------- Forwarded message ----------

From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Mon, Mar 13, 2017 at 1:25 PM
Subject: final Caffrey SL/SS projections report
To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

Patrick, Amanda, & Courtney:

Can you check this final manuscript for any glaring errors/major omissions? A reply by Fri 3/17 would be great. I would like to know if there are grammar mistakes, but we are past the point of preferred wording- though the title changed based on a request from Cat.

https://drive.google.com/open?id=0B2z-WBMLTvtHbGIxSHdFT0RKaW8

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
Date: Tue, Mar 7, 2017 at 11:29 AM
Subject: All revisions are done
To: Rebecca Beavers <rebecca_beavers@nps.gov>

I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

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Cheers,

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Energy and Minerals * Active Processes and Hazards * Geologic Heritage

--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

104 Re_ final Caffrey SL_SS projections report(5).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Re: final Caffrey SL/SS projections report
Date:	Wednesday, March 15, 2017 12:14:03 PM

This is the google drive folder I am using to share the report/comment with Patrick and Amanda; it includes a google doc with Courtney's comments that Patrick, Amanda, & I will supplement.

https://drive.google.com/open?id=0B2z-WBMLTvtHbGIxSHdFT0RKaW8

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Mar 15, 2017 at 11:57 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Will do.
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
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> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Wed, Mar 15, 2017 at 11:55 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > I have some minor revisions coming your way. Amanda, Patrick & I will have final comments by Friday.
> >
> > 1st comments from Courtney are attached. Can you make these changes soon?
> >
> > Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> > National Park Service | Geologic Resources Division
> > 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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From: **Schupp, Courtney** <courtney_schupp@nps.gov>
Date: Wed, Mar 15, 2017 at 11:49 AM
Subject: Re: final Caffrey SL/SS projections report
To: Rebecca Beavers <rebecca_beavers@nps.gov>

Rebecca,
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> Date: Mon, Mar 13, 2017 at 1:25 PM
> Subject: final Caffrey SL/SS projections report
> To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda"

<amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

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Energy and Minerals * Active Processes and Hazards * Geologic Heritage

--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

105 Fwd_ final Caffrey SL_SS projections report(1).pdf

From: Beavers, Rebecca
To: Patrick Gonzalez; Babson, Amanda
Subject: Fwd: final Caffrey SL/SS projections report
Date: Wednesday, March 15, 2017 12:30:02 PM
Attachments: Review of Caffrey et al 2017 Sea level storm surge.docx

---

Courtney's comments are attached please insert your comments in this google doc if feasible.

Patrick: you can send me a separate word doc or email with any final changes if the google doc is not easy for you to access/use.

https://drive.google.com/open?id=1LG4oyWW5CU4PvtIo1EY1DPxeFLu6CqpmGKKCAEARyA0

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To: Rebecca Beavers <rebecca_beavers@nps.gov>

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You might want to give it another read before sending on. I changed the title to "Sea level rise and storm surge projections for the National Park Service." I'm open to other title suggestions for the title. I just shortened it a little more to get around Cat's suggestion that it be "Sea level rise and storm surge projections for 118 and 79 National Park Service units (respectively)."

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

105 1 Attachment Review of Caffrey et al 2017 Sea level storm _2.pdf

Review of Caffrey et al. **Sea Level Rise and Storm Surge Projections for the National Park Service**

- p ix line 9 - delete "the" in the sentence "We would also like to thank the Susan..."
- p 1 introduction - "Melilo" should be "Melillo" ?
- p 1 introduction - it is not clear what 1/398, 1/1570, 1/100 means. I'd suggest writing it out in words at least in the first instance (1/398).
- p 2 first paragraph- add "regions" to end of sentence, to read "...Pacific West, and Alaska regions."
- p 2 first paragraph- add "to" so that it reads "...are vulnerable to the effects of..."
- p 2 second paragraph- when referring to a word as the word itself, put it in quotations marks:
    - 'we use the term "flooding" to describe...'
    - similarly, '..."Inundation" is used to refer to...'
    - similarly, for consistency in the last paragraph, put "sea level change" in quotation marks instead of italics in the sentence 'For this reason, we use the term "sea level change" as it...'
- p 4 methods – Suggest adding a comma to first sentence to read "…project, initiated in 2013,…"
- p4 methods item 3- change "impact" to "impacts"
- p 4 header "Sea level Rise Data" capitalize 'level'
- p 5 remove 'to' in the sentence "AOGCMs to simulate the processes…"
- p 6- Move the explanation of what a "simple bathtub model" is from p 9 to here.
- P 7 fig 2 caption- add "Island" to "Assateague National Seashore"
- P 7 revise the verb in the sentence "The NOAA SLOSH model is comprised of the…" to read either "model is composed of the following" or "model comprises the following"
- p 7- Is it safe to assume that readers will know what probabilistic, deterministic, and composite approaches are? If not consider adding a brief explanation of their differences.
- P 9 first paragraph – change "Alaskan" to "Alaska" for consistency with "Guam, and American Samoa park units"
- Ensure verb consistency with the plural "data" throughout document
    - P 10 first paragraph "… data that either meets or exceeds…"
    - P 10 first paragraph "This is discussed in more detail in the metadata that accompanies each map. "
    - P 10 first paragraph "USGS data was used for areas, such as Alaska…"
    - P 11 "All GIS data from this project is available…"
- P 11 missing the word "the" in the sentence "…given that many of park units are some distance from..."
- P 12 add a period to the end of the second sentence "…in Appendix D Following…"
- P 15 second paragraph capitalize "region" in "Alaska region"
- P 17 second paragraph: "the" should be lowercase in the sentence "For example, The Eugene Island…"

- P 17 second paragraph: revise "sea level" to "change in sea level" in both mentions here: "…we can see that relative sea level is more than double the projected sea level using the IPCC estimates alone."
- P 24- "Glacier Bay Preserve" should be "Glacier Bay National Park and Preserve"
- P 27- first paragraph- add "Island" to "Assateague National Seashore"
- Appendix D – please repeat column headers on every page.

106 Re_ final Caffrey SL_SS projections report(6).pdf

From:	Gonzalez, Patrick
To:	Rebecca Beavers
Subject:	Re: final Caffrey SL/SS projections report
Date:	Wednesday, March 15, 2017 12:35:20 PM

Hi Rebecca,

I just downloaded the March 7 draft from Google Drive and can use that.

Thanks,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

---------- Forwarded message ----------
From: Beavers, Rebecca <rebecca_beavers@nps.gov>
Date: Wed, Mar 15, 2017 at 11:30 AM
Subject: Fwd: final Caffrey SL/SS projections report
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>

Courtney's comments are attached please insert your comments in this google doc if feasible.

Patrick: you can send me a separate word doc or email with any final changes if the google doc is not easy for you to access/use.

https://drive.google.com/open?id=1LG4oyWW5CU4PvtIo1EY1DPxeFLu6CqpmGKKCAEARyA0

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: Schupp, Courtney <courtney_schupp@nps.gov>
Date: Wed, Mar 15, 2017 at 11:49 AM
Subject: Re: final Caffrey SL/SS projections report
To: Rebecca Beavers <rebecca_beavers@nps.gov>

Rebecca,
My suggested edits (mostly typos and grammar flags) are attached.
Glad to see this is coming out soon.
Courtney

On Wed, Mar 15, 2017 at 11:57 AM, Gonzalez, Patrick
<patrick_gonzalez@nps.gov> wrote:
>
> Thanks, Rebecca. I will aim to send any final edits by the end of Friday.
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Department of Environmental Science, Policy, and Management
> University of California, Berkeley
> 131 Mulford Hall, Berkeley, CA 94720-3114 USA
>
> patrick_gonzalez@nps.gov
> patrickgonzalez@berkeley.edu
> (510) 643-9725
> @pgonzaleztweet
> http://www.patrickgonzalez net
> ....
>
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> ---------- Forwarded message ----------
> From: Beavers, Rebecca <rebecca_beavers@nps.gov>
> Date: Mon, Mar 13, 2017 at 1:25 PM
> Subject: final Caffrey SL/SS projections report
> To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
>
>
> Patrick, Amanda, & Courtney:
>
> Can you check this final manuscript for any glaring errors/major omissions? A reply by Fri 3/17 would be great. I would like to know if there are grammar mistakes, but we are past the point of preferred wording- though the title changed based on a request from Cat.
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> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division

> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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> ---------- Forwarded message ----------
> From: Caffrey, Maria <maria_a_caffrey@partner nps.gov>
> Date: Tue, Mar 7, 2017 at 11:29 AM
> Subject: All revisions are done
> To: Rebecca Beavers <rebecca_beavers@nps.gov>
>
>
> I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form
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>

--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

107 Re_ final Caffrey SL_SS projections report(7).pdf

From:	Babson, Amanda
To:	Beavers, Rebecca
Cc:	Patrick Gonzalez
Subject:	Re: final Caffrey SL/SS projections report
Date:	Wednesday, March 15, 2017 3:53:39 PM

My comments are in Courtney's document. While there are a few bigger ones that I may be too late to raise now, you can take a look and see if you agree and which are feasible now.
Glad this is getting so close.
Amanda

On Wed, Mar 15, 2017 at 2:30 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Courtney's comments are attached please insert your comments in this google doc if feasible.
>
> Patrick: you can send me a separate word doc or email with any final changes if the google doc is not easy for you to access/use.
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> https://drive.google.com/open?id=1LG4oyWW5CU4PvtIo1EY1DPxeFLu6CqpmGKKCAEARyA0
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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Patrick

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Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

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Date: Mon, Mar 13, 2017 at 1:25 PM
Subject: final Caffrey SL/SS projections report
To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

Patrick, Amanda, & Courtney:

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Subject: All revisions are done

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> Cheers,
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--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

--
Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile

Northeast Region Climate Change Toolkit

Find Your Park: Women's Rights National Historical Park tells the story of the first Women's Rights Convention held in Seneca Falls, NY on July 19-20,1848. It is a story of struggles for civil rights, human rights, and equality, global struggles that continue today.

108 comments on SLR_SS paper are attached.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Cc:	Courtney Schupp; Babson, Amanda
Subject:	comments on SLR/SS paper are attached
Date:	Friday, March 17, 2017 2:35:05 PM
Attachments:	ReviewofCaffreyetal2017Sealevelstormsurge_Schupp_Babson_Beavers_2017_03.docx

Amanda, Courtney & I flagged many typos in what is a copy edit phase. Some phrasing and content still stood out as needing revision, etc.

Document is attached and available as a Google Doc. https://drive.google.com/open?id=1LG4oyWW5CU4PvtIo1EY1DPxeFLu6CqpmGKKCAEARyA0

Let's discuss on Monday. Have a great weekend.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

108 1 Attachment ReviewofCaffreyetal2017Sealevelstormsurge_Sch.pdf

Review of Caffrey et al. **Sea Level Rise and Storm Surge Projections for the National Park Service**

- p ii change title in citation
- p iii remove additional space prior to Frequently Used Terms, p 2
- p iii Capitalize Level in Sea Level Rise Data, p 4
- p iv Figure 1. Change second “based on” to “for” or other similar term
- p iv Captions for Fig 4,5,6, 3rd or 4th line, delete one term in “of from”: should be worded similar to Figure 7.
- p iv fig 6. line 2, delete extra space before 1st period. “scenario).”
- p v. Table D3 replace was with “were”. Data are plural.
- p vi Photo 2. delete “th” after December 5.
- p viii line 17-18: delete “, and show how storm surge could propagate in the future” as you no longer do this.
- p. vii, line 20 delete comma after units.(unless you really want to keep it to make the reader pause.)
- p. ix, line 2, replace comma with and
- p ix, lines 5 and 6 add Rebecca Beavers as a member of both teams.
- p ix line 9 - delete "the" in the sentence "We would also like to thank the Susan..."
- p 1 introduction, para 1. - "Melilo" should be "Melillo" ?
- p 1 introduction, para 2, sentence 1 - Used revised sentence from abstract wiht subset (79).
- p 1 introduction, para 2, line 7 - After “this report is to” replace “;” with “:”
- p 1 introduction, para 3 - it is not clear what 1/398, 1/1570, 1/100 means. I'd suggest writing it out in words at least in the first instance (1/398).
- p 2 first paragraph- add "regions" to end of sentence, to read "...Pacific West, and Alaska regions."
- p 2 first paragraph- add "to" so that it reads "...are vulnerable to the effects of..."
- p 2 second paragraph- when referring to a word as the word itself, put it in quotations marks:
    - 'we use the term "flooding" to describe...'
    - similarly, '..."Inundation" is used to refer to...'
    - similarly, for consistency in the last paragraph, put "sea level change" in quotation marks instead of italics in the sentence 'For this reason, we use the term "sea level change" as it...'
- p 4 methods – Suggest adding a comma to first sentence to read “…project, initiated in 2013,…”
- p4 methods item 3- change “impact” to “impacts”
- p4 methods, last paragraph is awkward in its placement as a paragraph hanging out there. I would add a shorter version of the text under 3.
- p 4 header “Sea level Rise Data” capitalize ‘level’
- p4 Sea Level Rise data, sentence 1, replace :”results from” to “is caused by”
- p 4 delete s from Lakes (SLOSH is Lake singular)
- p 5 remove ‘to’ in the sentence “AOGCMs to simulate the processes…”
- p 6- Move the explanation of what a “simple bathtub model” is from p 9 to here.
- P 7 fig 2 caption- add “Island” to “Assateague National Seashore”

- P 7 revise the verb in the sentence "The NOAA SLOSH model is comprised of the…" to read either "model is composed of the following" or "model comprises the following"
- p 7- Is it safe to assume that readers will know what probabilistic, deterministic, and composite approaches are? If not consider adding a brief explanation of their differences.
- P 9 first paragraph – change "Alaskan" to "Alaska" for consistency with "Guam, and American Samoa park units"
- p 9 delete "to" in "near to a tide gauge"
- p 9 be consistent in "tidal gauge" vs "tide gauge". I suggest using using "tide gauge"
- p 9 2nd to last line, extra space between "in" and "methods"
- p 10 first line, extra space before "horizontal"
- Ensure verb consistency with the plural "data" throughout document
    - P 10 first paragraph "… data that either meets(meet) or exceeds(exceed)…"
    - P 10 first paragraph "This is discussed in more detail in the metadata that accompanies (y) each map. "
    - P 10 first paragraph "USGS data was(were) used for areas, such as Alaska…"
    - P 11 "All GIS data from this project is(are) available…"
- P 11 missing the word "the" in the sentence "…given that many of park units are some distance from..."
-
- p 12 1st link page does not exist, 2nd link, I got an error
- p 13 2nd line, extra space before "Appendix", missing period after "Appendix"
- p 13 last line, delete "above waterline", this is not a meaningful datum and is unnecessary
- p 13-14 figure caption revision. see comment on p iv
- P 15 second paragraph capitalize "region" in "Alaska region"
- p 15 last sentence in 2nd to last paragraph, I suggest adding the clarifying phrase in italics to "units *of this highest rise grouping* that contain coastline with their boundaries." or something to that effect. After Fort McHenry, add National Monument and Historic Shrine.
- p. 15, last sentence. add m in final numbers. -0.54 m)
- P 17 second paragraph: "the" should be lowercase in the sentence "For example, The Eugene Island…"
- P 17 second paragraph: revise "sea level" to "change in sea level" in both mentions here: "…we can see that relative sea level is more than double the projected sea level using the IPCC estimates alone."
- p. 17, para 3. I don't know that discussion of the highest rates of SLR at WRBR is worthwhile. We do not and will not manage that shoreline. I suggest eliminating this paragraph.
- p. 19-20 This is probably past the time for this suggestion, but the Harpers Ferry paragraph highlights that this park does not belong in the analysis. I suggest deleting or rewording to say that Harpers Ferry should not have been included in the study because it is not subject to sea level rise, it is way upstream on a non-tidal river. Or Rebecca Suggests eliminating this information from the paper. These types of topics really detract from the overall results. I suggesting cutting Harpers Ferry from the overall study, tables, etc.
- p 20 2nd paragraph, suggest changing "would" to "could have widespread impacts. "

- p 20 last sentence, I suggest deleting because outside of scope of study
- P 24- “Glacier Bay Preserve” should be “Glacier Bay National Park and Preserve”
- p 26, Sallenger et al paragraph, again this is probably past time for this suggestion, but it is logically flawed/inconsistent with what is in paper. At a minimum, delete “, combined with storm surges”. Issues: 1) Sallenger does not combine with storm surge, 2) Sallenger is observations, but “could create” makes it sound like projections, 3)you’re comparing to your flooded projections (so storm surge) not inundated
- P 27- first paragraph- add “Island” to “Assateague National Seashore”
- p 27 extra space between “in” and “coastal”
- p 27 Aerts reference. Replace comma after New York City with a period.
- p. 28 Duff reference. Replace comma after Record with a period.
- p. 28 Glahn. eliminate comma after *Digest*.
- p. 29 Lin Write out PNAS as “Proceedings….” see Lambeck.
- p. 30 Melillo reference. add period after C in T.C. Richmond.
- p. 30 Moss reference. Italicize Nature.
- p. 30 Rahmstorf, second ref. Eliminatecomma after Change and “no.”
- p. 31 Schmid. use quotes around paper title.
- p. 31 Storlazzi. Change report info to “Open-File Report 2013-1069.”
- p. 31 Tollefson. eliminate comma after Nature.
- p. B-1 4th question, Rephrase question to read “use data from Tebaldi” or other phraseing to eliminae 2nd “use/used”
- p. B-1 5th question. insert and before Wrangell
- p. B-2 Saffir-Simpson question: insert “into the northern latitudes of” after “sustain itslef into”
- p B-2 , Question *What are the effects of NAVD88 on projections for some parks?* is confusing and needs work. The sentence “It uses a fixed value for the height of the sea level.” is inconsistent with my understanding of NAVD88 and our uses of datums in general.
- p B-3 1st answer needs some work: “For example, El Niño and La Niña years will impact sea level. “ needs to connect the dots between impacts to sea level and differences in storm surge.
- p B-3, I suggest adding “storm surge barriers” to “such as levees and dams”
- p B-3 This is another one that it may be past time for suggestion, but I suggest moving the sentence “Permanent inundation will change the way waves propagate within a basin in the future. “ to the beginning of the answer and rewriting it to “Higher sea level and permanent inundation will change the way waves propagate within a basin in the future”. and I guess the following sentences should go forward with that one too.
- p. B-4 Why are only adverse impacts included in this answer?
- Appendix D – please repeat column headers on every page.

109 Edits for Caffrey et al. sea level report.pdf

From:	Patrick Gonzalez NPS
To:	Beavers, Rebecca; Maria Caffrey; Maria Caffrey
Cc:	Cat Hoffman
Subject:	Edits for Caffrey et al. sea level report
Date:	Monday, March 20, 2017 7:58:36 AM
Attachments:	Review of Caffrey et al 2017 Sea level storm surge.docx

---

Hi Rebecca and Maria,

Thank you for sending the final draft of the sea level rise report. I was grateful that Maria invited me to be a co-author. I had only seen the draft last year before it went out for review and before Maria's invitation.

I recognize that Rebecca wants to wrap up the process quickly now. Yet, since I'm listed as a co-author, I needed to go through the draft in detail. You will receive a second e-mail with a URL link to the document on the National Park Service ftp site with my recommended edits tracked in Word. I have sought to only make edits for scientific clarity and accuracy. You will find explanatory comments for many of the edits.

I hope that you recognize the value of the recommended edits and that any delay will make the report scientifically stronger. I can talk on the telephone if that would be helpful.

Thanks for all of your work.

Best regards,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

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From: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Subject: Fwd: final Caffrey SL/SS projections report
Date: March 15, 2017 at 11:30:02 AM PDT
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To: Rebecca Beavers <rebecca_beavers@nps.gov>

I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

You might want to give it another read before sending on. I changed the title to "Sea level rise and storm surge projections for the National Park Service." I'm open to other title suggestions for the title. I just shortened it a little more to get around Cat's suggestion that it be "Sea level rise and storm surge projections for 118 and 79 National Park Service units (respectively)."

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

109 1 Attachment Review of Caffrey et al 2017 Sea level storm _3.pdf

Review of Caffrey et al. **Sea Level Rise and Storm Surge Projections for the National Park Service**

- p ix line 9 - delete "the" in the sentence "We would also like to thank the Susan..."
- p 1 introduction - "Melilo" should be "Melillo" ?
- p 1 introduction - it is not clear what 1/398, 1/1570, 1/100 means. I'd suggest writing it out in words at least in the first instance (1/398).
- p 2 first paragraph- add "regions" to end of sentence, to read "...Pacific West, and Alaska regions."
- p 2 first paragraph- add "to" so that it reads "...are vulnerable to the effects of..."
- p 2 second paragraph- when referring to a word as the word itself, put it in quotations marks:
    - 'we use the term "flooding" to describe...'
    - similarly, '..."Inundation" is used to refer to...'
    - similarly, for consistency in the last paragraph, put "sea level change" in quotation marks instead of italics in the sentence 'For this reason, we use the term "sea level change" as it...'
- p 4 methods – Suggest adding a comma to first sentence to read "…project, initiated in 2013,…"
- p4 methods item 3- change "impact" to "impacts"
- p 4 header "Sea level Rise Data" capitalize 'level'
- p 5 remove 'to' in the sentence "AOGCMs to simulate the processes…"
- p 6- Move the explanation of what a "simple bathtub model" is from p 9 to here.
- P 7 fig 2 caption- add "Island" to "Assateague National Seashore"
- P 7 revise the verb in the sentence "The NOAA SLOSH model is comprised of the…" to read either "model is composed of the following" or "model comprises the following"
- p 7- Is it safe to assume that readers will know what probabilistic, deterministic, and composite approaches are? If not consider adding a brief explanation of their differences.
- P 9 first paragraph – change "Alaskan" to "Alaska" for consistency with "Guam, and American Samoa park units"
- Ensure verb consistency with the plural "data" throughout document
    - P 10 first paragraph "… data that either meets or exceeds…"
    - P 10 first paragraph "This is discussed in more detail in the metadata that accompanies each map. "
    - P 10 first paragraph "USGS data was used for areas, such as Alaska…"
    - P 11 "All GIS data from this project is available…"
- P 11 missing the word "the" in the sentence "…given that many of park units are some distance from..."
- P 12 add a period to the end of the second sentence "…in Appendix D Following…"
- P 15 second paragraph capitalize "region" in "Alaska region"
- P 17 second paragraph: "the" should be lowercase in the sentence "For example, The Eugene Island…"

- P 17 second paragraph: revise “sea level” to “change in sea level” in both mentions here: “…we can see that relative sea level is more than double the projected sea level using the IPCC estimates alone.”
- P 24- “Glacier Bay Preserve” should be “Glacier Bay National Park and Preserve”
- P 27- first paragraph- add “Island” to “Assateague National Seashore”
- Appendix D – please repeat column headers on every page.

110 Edits for Caffrey et al. sea level report on ftp.pdf

From:	<patrick_gonzalez@nps.gov> on behalf of patrick_gonzalez@nps.gov
To:	rebecca_beavers@nps.gov; maria.caffrey@colorado.edu; maria_a_caffrey@partner.nps.gov; patrickgonzalez@berkeley.edu
Cc:	cat_hawkins_hoffman@nps.gov
Subject:	Edits for Caffrey et al. sea level report on ftp
Date:	Monday, March 20, 2017 8:03:00 AM
Attachments:	Bitdefender.txt

You have received 1 secure file from patrick_gonzalez@nps.gov.
Use the secure link below to download.

From: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
Subject: Edits for Caffrey et al. sea level report
Date: March 20, 2017 at 6:59:29 AM PDT
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Maria Caffrey <maria_a_caffrey@partner.nps.gov>, Maria Caffrey <maria.caffrey@colorado.edu>
Cc: Cat Hoffman <cat_hawkins_hoffman@nps.gov>

Hi Rebecca and Maria,

Thank you for sending the final draft of the sea level rise report. I was grateful that Maria invited me to be a co-author. I had only seen the draft last year before it went out for review and before Maria's invitation.

I recognize that Rebecca wants to wrap up the process quickly now. Yet, since I'm listed as a co-author, I needed to go through the draft in detail. You will receive a second e-mail with a URL link to the document on the National Park Service ftp site with my recommended edits tracked in Word. I have sought to only make edits for scientific clarity and accuracy. You will find explanatory comments for many of the edits.

I hope that you recognize the value of the recommended edits and that any delay will make the report scientifically stronger. I can ta k on the telephone if that would be helpful.

Thanks for all of your work.

Best regards,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

From: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Subject: Fwd: final Caffrey SL/SS projections report
Date: March 15, 2017 at 11:30:02 AM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>

Courtney's comments are attached please insert your comments in this google doc if feasible.

Patrick: you can send me a separate word doc or email with any final changes if the google doc is not easy for you to access/use.

https://drive.google.com/open?id=1LG4oyWW5CU4PvtIo1EY1DPxeFLu6CqpmGKKCAEARyA0

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: Schupp, Courtney <courtney_schupp@nps.gov>
Date: Wed, Mar 15, 2017 at 11:49 AM
Subject: Re: final Caffrey SL/SS projections report
To: Rebecca Beavers <rebecca_beavers@nps.gov>

Rebecca,
My suggested edits (mostly typos and grammar flags) are attached.
Glad to see this is coming out soon.
Courtney

On Wed, Mar 15, 2017 at 11:57 AM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:
Thanks, Rebecca. I will aim to send any final edits by the end of Friday.

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

---------- Forwarded message ----------
From: Beavers, Rebecca <rebecca_beavers@nps.gov>
Date: Mon, Mar 13, 2017 at 1:25 PM
Subject: final Caffrey SL/SS projections report
To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

Patrick, Amanda, & Courtney:

Can you check this final manuscript for any glaring errors/major omissions? A reply by Fri 3/17 would be great. I would like to know if there are grammar mistakes, but we are past the point of preferred wording- though the title changed based on a request from Cat.

https://drive.google.com/open?id=0B2z-WBMLTvtHbGIxSHdFT0RKaW8

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division

303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: Caffrey, Maria <maria_a_caffrey@partner.nps.gov>
Date: Tue, Mar 7, 2017 at 11:29 AM
Subject: All revisions are done
To: Rebecca Beavers <rebecca_beavers@nps.gov>

I have added the report to this folder: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

You might want to give it another read before sending on. I changed the title to "Sea level rise and storm surge projections for the National Park Service." I'm open to other title suggestions for the title. I just shortened it a little more to get around Cat's suggestion that it be "Sea level rise and storm surge projections for 118 and 79 National Park Service units (respectively)."

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
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Click link to download:

Sea Level Change Report Draft March 7 2017 PG.docx
34.77 MB, Fingerprint: 796636f008309ad1c78e3d942e3a6b88 (What is this?)

112 Re_ Edits for Caffrey et al. sea level report.pdf

From:	Caffrey, Maria
To:	Patrick Gonzalez NPS
Cc:	Beavers, Rebecca; Cat Hoffman
Subject:	Re: Edits for Caffrey et al. sea level report
Date:	Monday, March 20, 2017 8:57:56 AM

Patrick,

Thanks for taking the time to look over this for us. I'm sure your edits are exactly what it needs. I really want this document to be as scientifically strong as possible, so it's great to get your input on this.

I'll be in touch if I have any questions.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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On Mon, Mar 20, 2017 at 7:59 AM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Rebecca and Maria,
>
> Thank you for sending the final draft of the sea level rise report. I was grateful that Maria invited me to be a co-author. I had only seen the draft last year before it went out for review and before Maria's invitation.
>
> I recognize that Rebecca wants to wrap up the process quickly now. Yet, since I'm listed as a co-author, I needed to go through the draft in detail. You will receive a second e-mail with a URL link to the document on the National Park Service ftp site with my recommended edits tracked in Word. I have sought to only make edits for scientific clarity and accuracy. You will find explanatory comments for many of the edits.
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> I hope that you recognize the value of the recommended edits and that any delay will make the report scientifically stronger. I can talk on the telephone if that would be helpful.
>
> Thanks for all of your work.
>
> Best regards,
>
> Patrick
>
> ....

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Principal Climate Change Scientist
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From: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Subject: Fwd: final Caffrey SL/SS projections report
Date: March 15, 2017 at 11:30:02 AM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>

Courtney's comments are attached please insert your comments in this google doc if feasible.

Patrick: you can send me a separate word doc or email with any final changes if the google doc is not easy for you to access/use.

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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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From: **Schupp, Courtney** <courtney_schupp@nps.gov>
Date: Wed, Mar 15, 2017 at 11:49 AM
Subject: Re: final Caffrey SL/SS projections report

To: Rebecca Beavers <rebecca_beavers@nps.gov>

Rebecca,
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Glad to see this is coming out soon.
Courtney

On Wed, Mar 15, 2017 at 11:57 AM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:

> Thanks, Rebecca. I will aim to send any final edits by the end of Friday.
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
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> Date: Mon, Mar 13, 2017 at 1:25 PM
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> To: Courtney Schupp <courtney_schupp@nps.gov>, "Babson, Amanda" <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
>
> Patrick, Amanda, & Courtney:
>
> Can you check this final manuscript for any glaring errors/major omissions? A reply by Fri 3/17 would be great. I would like to know if there are grammar mistakes, but we are past the point of preferred wording- though the title changed based on a request from Cat.
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> https://drive.google.com/open?id=0B2z-WBMLTvtHbGIxSHdFT0RKaW8
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator

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From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
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To: Rebecca Beavers <rebecca_beavers@nps.gov>

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--
Courtney Schupp
Coastal Geologist
National Park Service
(225) 726-0558
courtney_schupp@nps.gov

113 Re_ Advice on wording.pdf

From:	Caffrey, Maria
To:	Smith, Tim
Cc:	Curdts, Thom; Rebecca Beavers
Subject:	Re: Advice on wording
Date:	Tuesday, March 21, 2017 9:44:07 AM

Tim,

This is extremely useful. Thanks for making these edits.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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On Tue, Mar 21, 2017 at 8:03 AM, Smith, Tim <tim_smith@nps.gov> wrote:

> (b) (5) [redacted] I had a few edit myself. I hope you do not mind:
>
> A. The North American Vertical Datum of 1988 (NAVD88) is the most commonly used vertical datum for North America. It is what most people refer to as the "elevation" of a location. It uses a fixed value located at Rimouski, Canada for the height of North America's mean sea level (MSL). While this is a popular datum for mapping, it has the limitation of being based on the the observed mean sea level at a single location. As you move further away from this datum point you can expect the local observed mean sea level to differ from the MSL height at Rimouski. For locations such as California, this can result in a significant difference between observed local mean sea level and the local NAVD88 height. Your natural resource or GIS specialist may have further information about your specific location. Alternatively, you can look up the differences in your region by checking the datum information for your nearest tide gauge station at the NOAA website: https://tidesandcurrents.noaa.gov/stations.html?type=Datums . Keep in mind that MSL (Mean Sea Level) is not the same as the NAVD88 height. If the NAVD88 height has been produced for a local tide station then there will be a height that is stated as "NAVD88".
>
> Thanks for the opportunity to comment. Hope this helps.
>
> Best,
> Tim
>
> On Mon, Mar 20, 2017 at 5:56 PM, Curdts, Thom <thom_curdts@partner.nps.gov> wrote:
>
> > I guess I agree with you, Maria, but I'm including Tim Smith to see what he says.
> >
> > Hey Tim, do you want to chime in on Maria's original question? Go to the bottom of the thread. Thanks.
> >
> > ---
> >
> > From Wikipedia (my bolds):

NAVD 88 was established in 1991 by the minimum-constraint adjustment of geodetic leveling observations in Canada, the United States, and Mexico. **It held fixed the height of the primary tidal bench mark**, referenced to the International Great Lakes Datum of 1985 local mean sea level height value, at Rimouski, Quebec, Canada. Additional tidal bench mark elevations were not used due to the demonstrated variations in sea surface topography, i.e., that mean sea level is not the same equipotential surface at all tidal bench marks.

The definition of NAVD 88 uses the Helmert orthometric height, which calculates the location of the geoid (which approximates sea level) from modeled local gravity. **The NAVD 88 model is based on then-available measurements, and remains fixed despite later improved geoid models.**

~~~~~~~~~~~~~~~~~~~
Thom Curdts
GIS & Sea Level Specialist
NPS-CSU
303-969-2342 (w)
303-437-5042 (c)
thom_curdts@partner.nps.gov
~~~~~~~~~~~~~~~~~~~

On Mon, Mar 20, 2017 at 5:07 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

Thanks Thom! The reviewer (Amanda Babson) said that she (b) (5) [redacted] According to her comments that is (b) (5) [redacted]

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Mar 20, 2017 at 4:57 PM, Curdts, Thom <thom_curdts@partner.nps.gov> wrote:

Hi Maria,

I don't see anything really wrong with this. But I've suggested some changes below that might tighten it up a little. Would it be worth asking the reviewer for specifics?

A. The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America. It uses a fixed value for the height of North America's mean sea level. While this is a popular datum for mapping, it has the limitation of being based on the the observed mean sea level at a single location: Rimouski, Canada. In other areas you can expect the local observed mean sea level to differ from mean sea level at Rimouski. For locations such as California, this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location.

Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents noaa.gov/stations html?type=Datums "

hope that helps,
Thom

~~~~~~~~~~~~~~~~~~~
Thom Curdts
GIS & Sea Level Specialist
NPS-CSU
303-969-2342 (w)
303-437-5042 (c)
thom_curdts@partner.nps.gov
~~~~~~~~~~~~~~~~~~~

On Mon, Mar 20, 2017 at 4:15 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

Thom,

I'm going through some reviewer edits on my final report. One of my reviewers says that I've described how NAVD88 incorrectly. Could you look at the following text and let me know what I've got wrong or if there is a better way to word this?

"*Q. What are the effects of NAVD88 on projections for some parks?*

A. The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America. It uses a fixed value for the height of the sea level. While this is a popular datum for mapping, it has the limitation that it is based on the tidal benchmark for Rimouski, Canada. As you move further away from this benchmark you can expect actual sea level to differ from the reference benchmark. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums "

Thanks!

Maria Caffrey, PhD

Research Associate, University of Colorado
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Cell: (303) 518-3419

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--

Tim Smith, National GPS Program Coordinator
RISD, NISC, IRM
National Park Service
39.65152 N 105.07747 W (NAD83)
(303) 969-2086
(720) 443-2023
(303) 884-3692 cell
(303) 987-6736 fax
Send text message via email: 3038843692@txt.att.net

"Surveying with GPS can be extremely productive, but it has also been known to cause bouts of depression and loathing."

116 Re_ Copy edits for the SLR_SS(1).pdf

From:	Caffrey, Maria
To:	Port, Rebecca
Cc:	Rebecca Beavers
Subject:	Re: Copy edits for the SLR/SS
Date:	Tuesday, March 21, 2017 1:29:02 PM

Track changes would be great. Would you be able to get it back to me by the end of the week? Is that too soon?

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Tue, Mar 21, 2017 at 1:27 PM, Port, Rebecca <rebecca_port@nps.gov> wrote:

> No problem Maria, we can look it over. When do you need it back? And does track changes work for providing comments/suggestions?
>
> --
>
> **Rebecca Port**
> NPS Geologic Resources Inventory
> Office: (303) 969-2171   Mobile: (561) 350-5182   Email: Rebecca_Port@nps.gov
> **Program Website:** http://www.nature.nps.gov/geology/inventory/index.cfm
>
> ---
>
> **National Park Service Geologic Resources Division** http://go.nps.gov/geology
> *Energy and Minerals * Active Processes and Hazards * Geologic Heritage*
>
>
>
> On Tue, Mar 21, 2017 at 1:03 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:
>
>> Hi Rebecca,
>>
>> Rebecca (Beavers) told me that you offered to take a look at the sea level/storm surge report to see if it conforms to the report series standards. I've posted the latest copy of the report here:
>>
>> N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Copy edit comments
>>
>> Do you think you or Michael could take a look and let me know if I've got the

formatting right or if I'm missing anything? I really appreciate your help on this.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

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119 Re_ Questions on weekly.pdf

From:	Jennifer Wyse
To:	Beavers, Rebecca
Cc:	Hoffman Cat; Sauvajot Raymond; Brian Carlstrom; Adema Guy; Steensen Dave; Hal Pranger
Subject:	Re: Questions on weekly
Date:	Wednesday, March 22, 2017 9:59:03 AM

Thank you!

Sent from my iPhone

On Mar 22, 2017, at 11:32 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Good morning:

This report " Sea level rise and storm surge projections for the National Park Service" will not by ready for release in March 2017. We will submit it to the Natural Resource Report Series next week (3/ for formatting and to assign the report number. This process will include creating an IRMA (online) record, but *the report will not be public until all agree on a release process.*

Q. Is there a comms plan?
Q. Is there a briefing paper?

A. There will be a comms plan and a set of talking points. The Comms plan will be developed with Jeff Olson (WASO Comms). If needed, briefings about the report will be held in person or via webinar, etc.

There is a communication team with this project; members are Larry Perez, Ryan Stubblebine, and Matt Holly (All CCRP Comms); Shawn Norton (SOCC); Ann Gallagher (NCRO); Janet Cakir (SERO); Stanton Enomoto (PWRO, former member); Will Elder (GOGA, former member); and Lynda Bell (NRSS-OCRB, former member).

Q. Who did peer review?

A. Peer review was conducted with both internal and external reviewers. Reviewers were selected based on their expertise in one or more fields relating to coastal climate change, sea level change, or storm surge. The following people reviewed the document: Amanda Babson (NPS), Ann Gallagher (NPS), Larry Perez (NPS), Steve Nerem (University of Colorado-IPCC lead on sea level), Bob Glahn (emeritus, NOAA), Doug Marcy (NOAA), Chris Zarvas (NOAA), Rob Thieler (USGS), and Claudia Tebaldi

(Climate Central).

All peer review comments have been compiled in either spreadsheets as PDFs. Comments covered the entire report.

Q. Is it available to read before it is released?

A copy of the publication will be available to an internal audience prior to release.

Thank you for your interest in this report.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Mar 22, 2017 at 8:20 AM, Jennifer Wyse <jennifer_wyse@nps.gov> wrote:

> Hi Cat and Rebecca,
>
> Please see the questions from Maureen below. Will you please draft responses?
>
> If we have a briefing statement and comms plan, please send those along as well.
>
> Thank you very much!
>
> Have a great day, Jen
>
> Sent from my iPhone
>
> Begin forwarded message:

From: "Viets, Alexa" <alexa_viets@nps.gov>
Date: March 22, 2017 at 10:14:03 AM EDT
To: Jennifer Wyse <jennifer_wyse@nps.gov>
Cc: Justin Monetti <justin_monetti@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Raymond Sauvajot <ray_sauvajot@nps.gov>
Subject: Fwd: Questions on weekly

Jen,

Can you help us track down answers to Maureen's questions?

Tx,
Alexa

---------- Forwarded message ----------
From: **Foster, Maureen** <maureen_foster@ios.doi.gov>
Date: Wed, Mar 22, 2017 at 10:07 AM
Subject: Questions on weekly
To: Alexa Viets <alexa_viets@nps.gov>, Justin Monetti <justin_monetti@nps.gov>

There may be questions about the report.

Here is the first one:

In late March, the NPS will release a peer-reviewed report on projections of sea level rise and storm surge for 118 and 79 coastal parks (respectively). The results are intended to inform park planning, and adaptation and mitigation strategies for lands managed by the NPS. In recent years, the NPS has provided data to parks on a case-by-case basis for localized planning, but this report is a summary of the full analysis that is now complete.

- Is there a comms plan?
- Who did peer review?
- Is there a briefing paper?
- Is it available to read before it is released?

Maureen D. Foster
Chief of Staff
Office of the Assistant Secretary

for Fish and Wildlife and Parks
1849 C Street, NW, Room 3161
Washington, DC 20240

202.208.5970 (desk)
202.208.4416 (main)

Maureen_Foster@ios.doi.gov

--
Alexa Viets
Chief of Staff (Acting)
National Park Service
202-208-4530

120 Re_ Questions on weekly(1).pdf

From:	Beavers, Rebecca
To:	Perez, Larry
Subject:	Re: Questions on weekly
Date:	Wednesday, March 22, 2017 10:16:55 AM

will do.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Mar 22, 2017 at 10:15 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Sure thing, Rebecca.
>
> Friday would be best for me...have a look at my calendar and shoot me an invite. I would also recommend we pull Jeff into this call.
>
> In advance of that, could you please forward me the most recent version of the report?
>
> Thanks,
>
> L
>
> On Wed, Mar 22, 2017 at 9:34 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Hi Larry:
>>
>> Can we discuss a comms plan, etc for this report one day this week?
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Wed, Mar 22, 2017 at 9:32 AM
Subject: Re: Questions on weekly
To: Jennifer Wyse <jennifer_wyse@nps.gov>
Cc: Hoffman Cat <cat_hawkins_hoffman@nps.gov>, Sauvajot Raymond <ray_sauvajot@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Adema Guy <guy_adema@nps.gov>, Steensen Dave <Dave_Steensen@nps.gov>, Hal Pranger <harold_pranger@nps.gov>

Good morning:

This report " Sea level rise and storm surge projections for the National Park Service" will not by ready for release in March 2017. We will submit it to the Natural Resource Report Series next week (3/ for formatting and to assign the report number. This process will include creating an IRMA (online) record, but *the report will not be public until all agree on a release process.*

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A. There will be a comms plan and a set of talking points. The Comms plan will be developed with Jeff Olson (WASO Comms). If needed, briefings about the report will be held in person or via webinar, etc.

There is a communication team with this project; members are Larry Perez, Ryan Stubblebine, and Matt Holly (All CCRP Comms); Shawn Norton (SOCC); Ann Gallagher (NCRO); Janet Cakir (SERO); Stanton Enomoto (PWRO, former member); Will Elder (GOGA, former member); and Lynda Bell (NRSS-OCRB, former member).

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All peer review comments have been compiled in either spreadsheets as PDFs. Comments covered the entire report.

Q. Is it available to read before it is released?

A copy of the publication will be available to an internal audience prior to release.

Thank you for your interest in this report.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Sent from my iPhone

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Maureen D. Foster
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Maureen_Foster@ios.doi.gov

--

Alexa Viets
Chief of Staff (Acting)
National Park Service
202-208-4530

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Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

121 Fwd_ Questions on weekly(2).pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Questions on weekly
Date: Thursday, March 23, 2017 9:06:05 AM

FYI

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Date: Wed, Mar 22, 2017 at 9:32 AM
Subject: Re: Questions on weekly
To: Jennifer Wyse <jennifer_wyse@nps.gov>
Cc: Hoffman Cat <cat_hawkins_hoffman@nps.gov>, Sauvajot Raymond <ray_sauvajot@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Adema Guy <guy_adema@nps.gov>, Steensen Dave <Dave_Steensen@nps.gov>, Hal Pranger <harold_pranger@nps.gov>

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FIND YOUR PARK

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Subject: Fwd: Questions on weekly

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Alexa

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Maureen D. Foster
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202.208.4416 (main)

Maureen_Foster@ios.doi.gov

--
Alexa Viets
Chief of Staff (Acting)
National Park Service
202-208-4530

FIND YOUR PARK

122 File for google drive.pdf

From: Caffrey, Maria
To: Rebecca Beavers
Subject: File for google drive
Date: Thursday, March 23, 2017 11:13:42 AM

Rebecca,

I have checked the document and added the details we discussed. The file is here if you would like to upload it to a google share drive:

N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

123 Invitation_ Sea level rise_storm surge communic....pdf

From: Maria Caffrey
To: larry_perez@nps.gov; rebecca_beavers@nps.gov; janet_cakir@nps.gov; ann_gallagher@nps.gov; matt_holly@nps.gov; Maria Caffrey
Subject: Invitation: Sea level rise/storm surge communication team meeting @ Wed Apr 19, 2017 10am - 11am (larry_perez@nps.gov)
Date: Tuesday, March 28, 2017 9:11:15 AM
Attachments: invite.ics

Sea level rise/storm surge communication team meeting

more details »

Agenda:
1) Update on the status of the report
2) Give feedback and make edits on the attached talking points (please review the attached document BEFORE the meeting)

When	Wed Apr 19, 2017 10am – 11am Mountain Time
Where	1-(b) (5) (b) (5) (map)
Video call	https://plus.google.com/hangouts/_/doi.gov/maria-a-caffrey
Calendar	larry_perez@nps.gov
Who	• maria_a_caffrey@partner.nps.gov - organizer • larry_perez@nps.gov • rebecca_beavers@nps.gov • janet_cakir@nps.gov • ann_gallagher@nps.gov • matt_holly@nps.gov
Attachments	SLR and SS Report Key Messages.docx

Going? **Yes** - **Maybe** - **No** more options »

124 501 compliant report.pdf

From: Caffrey, Maria
To: Rebecca Beavers
Subject: 501 compliant report
Date: Thursday, April 06, 2017 4:34:39 PM

Rebecca,

The 501 compliant version of the report is in: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

It is the April 5 version.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

125 RE_ 501 compliant report.pdf

From: Rebecca Beavers
To: Caffrey, Maria
Subject: RE: 501 compliant report
Date: Thursday, April 06, 2017 6:05:43 PM

Excellent!Thank you. I will review and submit it tomorrow.

Sent from my Verizon Wireless 4G LTE smartphone

-------- Original message --------
From: "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>
Date: 04/06/2017 4:34 PM (GMT-07:00)
To: Rebecca Beavers <rebecca_beavers@nps.gov>
Subject: 501 compliant report

Rebecca,

The 501 compliant version of the report is in: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Manuscript submittal form

It is the April 5 version.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

126 Re_ NRSS Weekly Outlook Report - week of 04_10_....pdf

From:	Perez, Larry
To:	Amanda Carlson; Amanda Hardy; Amber Childress; Beavers, Rebecca; Cat Hoffman; David Lawrence; gregor_schuurman; Gross, John; Holly, Matt; Patrick Gonzalez; Rockman, Marcia (Marcy); Ryan Stubblebine; William Dozier; Wood, Melanie
Subject:	Re: NRSS Weekly Outlook Report - week of 04/10/2017
Date:	Monday, April 10, 2017 10:42:48 AM
Attachments:	04_10_2017_NRSS Weekly Outlook.docx

Team,

Just a reminder to please have any submissions for the next report to me by COB Thursday.

Thanks,

L

---------- Forwarded message ----------
From: **Commins, Bill** <bill_commins@nps.gov>
Date: Fri, Apr 7, 2017 at 5:27 PM
Subject: NRSS Weekly Outlook Report - week of 04/10/2017
To: NPS NRSS All Employees All Locations <nrss_all_employees_all_locations@nps.gov>
Cc: John Dennis <john_dennis@nps.gov>, Bill Commins <bill_commins@nps.gov>, Adam Beeco <adam_beeco@nps.gov>, "Crosson, Thomas" <thomas_crosson@nps.gov>, "Rohmer, Ashton" <ashton_rohmer@nps.gov>, Peter Budde <peter_budde@nps.gov>, Erik Stabenau <erik_stabenau@nps.gov>, Karel Morales <karel_morales@nps.gov>

All,

The NRSS Weekly Outlook Report for the week of 04/10/2017 is attached.

Regards,

--
Bill Commins
U.S. National Park Service
1201 I Street, N.W. Floor 8, Room 79
Washington, D.C. 20005 -5905
bill_commins@nps.gov
Phone: 202 513-7166, Fax 202-371-2131

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____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200

Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

126 1 Attachment 04_10_2017_NRSS Weekly Outlook.pdf

Weekly Outlook for
Natural Resource Stewardship and Science
April 10, 2017

NRSS Staff Schedule for the Week of April 10, 2017

ADNRSS
Ray Sauvajot AD: All week - AL
Guy Adema D-AD, Colorado:
Brian Carlstrom D-AD, Washington DC:

NRSS Immediate Office (in unless noted)
John Dennis:
Ann Hitchcock:
Karel Morales:
Claire Shields: All week - AL
Jennifer Wyse: Wednesday – out of office

Division Chiefs/Program Managers (in unless noted)
Kirsten Gallo (IMD):
Heather Eggleston (NNL): 303-969-2945
Elaine Leslie (BRD):
Ed Harvey (WRD):
Carol McCoy (ARD):
Cat Hawkins Hoffman (CCRP): 970-225-3567
(OEO):
Dave Steensen (GRD):
Karen Trevino (NSNSD):
Bruce Peacock (EQD):

Eye Street Staff
Bill Commins: Wednesday-TW
Patrick Gonzalez (duty station- UC Berkeley, CA): Monday thru Thursday: Travel Lassen, Friday – out (lieu)
Michelle McBryde:
Cliff McCreedy:
Vince Santucci: Tuesday, Thursday - Eye Street / Monday, Wednesday - TW
Tom Tansey:
Tim Watkins:

GENERAL UPDATES

(EQD; Duplicate of Park Entry) Morristown NHP Vegetation and Deer Management Plan EA: On April 5, we will be distributing, via US Mail, approximately 80 newsletters updating interested individuals and groups on the progress and next steps of the Morristown National Historical Park Vegetation and Deer Management Planning process. These individuals and groups have been involved with the project since its kick-off and have asked to stay informed of the plan's progress. Specifically, the newsletter will announce the change in the NEPA pathway from an Environmental Impact Statement (EIS) to an Environmental Assessment (EA) due to our finding, after careful study and analysis, that none of the alternatives considered have the potential to result in significant adverse environmental impacts. It will also be the first ungulate management plan to dismiss contraception as a possible alternative to be considered for analysis. See newsletter for more details. (EQD Contact: Dan Niosi, 303-969-2068)

(NSNSD) Girls in STEM Outreach Event: NSNSD will participate in the Girls in STEM Expanding Your Horizons event at Colorado State University on April 8th. Participation includes assisting in hands-on science workshops and staffing a NPS booth. (Katie Nuessly, 970-267-2114)

TECHNICAL ASSISTANCE AND TRAINING

(CCRP) Climate change assistance to Lassen Volcanic NP: Patrick Gonzalez will provide assistance on climate change science and resource management to staff of Lassen Volcanic NP, in collaboration with planners from Denver Service Center, at a Resource Stewardship Strategy workshop April 11-13, 2017 at park headquarters. (Contact patrick_gonzalez@nps.gov)

(GRD) Emergency Rockfall Assistance at Grand Canyon: Staff will be traveling Sunday, April 9, to Grand Canyon National Park on an emergency basis to help park staff determine how best to address rockfalls that have damaged the park's only waterline this past week. An ongoing rockfall hazard apparently exists that needs geologic consultation. (Contact Eric Bilderback @ 303-969-2154, or eric_bilderback@nps.gov)

(NSNSD) Attendance at NPS Fundamentals: Natural Sounds & Night Skies staff will attend NPS Fundamentals on March 20 - 31. Staff will be learning about the origin of NPS and how the different roles within NPS come together to support the NPS mission. NPS staff will have the opportunity to present an overview of the Natural Sounds & Night Skies Division, including the services and expertise available to parks and regions and how these programs help fulfill the NPS mission of protecting and preserving our natural resources and their enjoyment by visitors. This will be the third staff member attending NPS Fundamentals in the last year. (Contact: Bob Meadows, 970-267-2199)

(WRD) Wetland Restoration Design Charrette, DEWA: In an effort to create park staff buy-in and ownership of a 30-acre design project, WRD staff will generate grading plans that represent design alternatives and modify the alternatives with input from park staff. In addition, WRD staff will conduct a pre-application meeting with state and federal agencies to present the design of another wetland restoration project at DEWA. (Contact: Pete Sharpe, 267 858 1001 or Kevin Noon, 303 969 2815)

UPCOMING NRSS TRAINING AND EVENTS

[Save the Date (All NRSS staff)] Resource Stewardship Strategy (RSS) Presentations, Denver and Fort Collins: On May 3 from 1-2:30 in Denver rooms 435/440 and on May 15 from 10:00-11:30 in Fort Collins Yellowstone Rooms, Chris Church and Don Wojcik from Denver Service Center will give a presentation on the current status and evolution of the RSS process. The National Working Group's vision is to develop an integrated, strategic resource management tool to help parks achieve their stewardship goals over time. All staff is encouraged to attend the presentation because close collaboration, support and engagement from parks, regions and program offices are critical to the success of this program. Come learn who each division's representatives are and what their role has been in the process. Contact: Lori Makarick.

PAPERS, PRESENTATIONS AND MEETINGS

(ARD) Lassen Volcanic National Park Resource Stewardship Strategy (RSS) Workshop April 11-13 2017, Mineral, CA: NPS Denver Service Center (DSC) project managers will lead staff from LAVO, PWR, NRSS (BRD, ARD, CRPP, IMD, NSNSD) in the first of two workshops to develop the park's RSS as part of a second round of 15 DSC led pilot RSSs in FY2017. The first workshop will gather existing information on park resources, evaluate key issues, stressors, and threats, identified priority resources and components, and begin setting long-term goals. The second workshop, scheduled May 23-25 2017, will complete RSS development by setting short-term goals and identify and prioritize stewardship activities, including integrated activities that may benefit both natural and cultural resources. (Contact: Jim Cheatham 303-969-2703)

(ARD) Presentation at the Air & Waste Management Association's 2017 Air Quality Conference: Mike Barna will be presenting at the Air and Waste Management - Rocky Mountain States Section (AWMA-RMSS) annual meeting, which will be held in Denver on April 13th. The title of his talk is "Simulating the Contribution of Emissions from Oil and Gas Development to Regional Nitrogen Deposition at National Parks in the Intermountain West." This 1-day conference provides a forum to discuss current air pollution issues in the western US with regulators, consultants, and researchers. (contact: Mike Barna, 970-491-8692).

(ARD, GRD) NRSS participation at Denver Museum of Nature and Science Free Day Monday April 10: We are using the event to highlight science in the national parks as staff from both divisions will bring hands on activities, educational posters, and Junior Ranger activity books. We will promote Every Kid In a Park, National Park Week, and encourage visitors to find their park with Servicewide and Colorado park maps. We will also set up a "photo booth" featuring NPS landscapes from Colorado. The event runs from 10 am to 4 pm and the museum expects around 9,000 people to visit that day. (Contact Jason Kenworthy; 303-987-6923)

(BRD) Western Bat Working Group Biennial Meeting in Fort Collins, Colorado: BRD staff will be participating in the Western Bat Working Group meeting held April 11 - 14 in Fort Collins. The WBWG is a partner in the Coalition of North American Bat Working Groups and includes state and federal agencies, universities, and NGOs dedicated to bat research, management and conservation in western US states, Canadian provinces, and northern Mexico. The conference, sponsored in part by NPS, provides opportunities for sharing knowledge and technologies, discussing action plans, and building collaborations for coordinated management of bats. Presentations, panel discussions, break-out sessions and hands-on training for best practices in acoustics and surveillance for white-nose syndrome will be included. (Contact: Michelle Verant, 970-225-3541)

(BRD) Planning meeting for a Bats and Climber Engagement Film: BRD staff will be meeting with Ravenswood Media and other project collaborators on April 10th in Fort Collins to discuss plans for a film funded by a White-nose Syndrome Small Grant provided through the Wildlife Management Institute with funds from the US Fish and Wildlife Service. The film is intended to engage the climbing community in bat conservation and raise awareness of bats and the threats they face, including white-nose syndrome, proposed filming locations include Acadia NP, Devils Tower NM and Yosemite NP. Project collaborators include the parks listed, Idaho Department of Fish and Game, Colorado Natural Heritage Program and Bat Conservation International. (Contact: Michelle Verant, 970-225-3541)

(CCRP) Recently Published Articles of Note: CCRP staff contributed to recent articles featured in Slate and Vox. (Contact: Larry Perez at larry_perez@nps.gov or 970-267-2136.)

(IMD) USGS/BLM workshop: Joe DeVivo will present an overview of the Inventory and Monitoring Program at a jointly-hosted USGS/BLM workshop on April 11, designed to identify and evaluate potential broad-scale indicators to be included as a part of BLM's long-term monitoring program.

(NSNSD) IOA Modification Working Group Call with FAA: On Apr. 13, NSNSD will be talking with FAA policy staff to further work on establishing a process for modifying interim operating authority (IOA) at parks based on NPS request to FAA in order to address the protection of park resources and visitor experience. IOA has already been removed from operators who once had IOA but no longer have an active operating certificate. FAA and NPS are exploring methods to further remove IOA from operators at parks where they have IOA but are not conducting tours. (Vicki Ward 970-225-3563)

(NSNSD) Air Tour Planning: NSNSD will have a conference call with FAA and Department of Transportation Volpe Center on April 12th to discuss the status of ongoing air tour planning efforts, including development of air tour management agreements with commercial operators as authorized under the National Parks Air Tour Management Act of 2000, as amended. (Vicki Ward, 970-267-2117)

THREE WEEKS OUT

(CCRP) Sometime in April, University of Rhode Island collaborators will publish a new Natural Resource Report entitled Designing and scoping climate change vulnerability assessments for coastal national parks in the Northeast Region: guidance and lessons learned. (Contact: Amanda Babson, NPS)

(CCRP) Sometime in April, the National Park Service will release a peer reviewed report entitled Sea Level and Storm Surge Projections for 118 National Park Service Units. (Contact: Rebecca Beavers, NPS)

(CCRP) On April 22-24, the Climate Change Response Program and Indiana Dunes National Lakeshore will host elementary and secondary students for a multi-day Every Kid in a Park event. The immersive learning experience will involve students in citizen science efforts to identify the effects of climate change on park resources. (Contact: Larry Perez, NPS)

(CCRP) On May 11, CCRP Climate Change scientist Patrick Gonzalez will deliver the plenary session at the 2017 San Francisco Bay Area National Parks Science and Natural Resources Symposium to be held at Golden Gate National Recreation Area. (Contact: Patrick Gonzalez, NPS)

(CCRP) On May 24-26, the Climate Change Response Program and Cape Cod National Lakeshore will host elementary and secondary students for a multi-day Every Kid in a Park event. The immersive learning experience will involve students in citizen science efforts to identify the effects of climate change on park resources. (Contact Larry Perez, NPS)
Divisions using Google Drive for submissions: WRD (Frias), NSNSD, EQD (Fox)

129 Fwd_ Manuscript Submittal_ Sea Level and Storm ....pdf

From:	Beavers, Rebecca
To:	John Gross
Cc:	Caffrey, Maria
Subject:	Fwd: Manuscript Submittal: Sea Level and Storm Surge
Date:	Friday, April 14, 2017 4:45:29 PM

Peer review documents are uploaded to the google shared folder for the SL_SS report:

https://drive.google.com/open?id=0B2z-WBMLTvtHa0dsYTY0ZnA2NlU

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
Date: Fri, Apr 14, 2017 at 4:43 PM
Subject: Manuscript Submittal: Sea Level and Storm Surge
To: Chalmers-Fagan Johnson <fagan_johnson@nps.gov>
Cc: John Gross <John_Gross@nps.gov>, Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>, "Caffrey, Maria" <maria.caffrey@colorado.edu>, Larry Perez <larry_perez@nps.gov>

We submit the linked document "Sea level rise and storm surge projections for the National Park Service" for review and publication.

The MSF and report are available at:

https://drive.google.com/open?id=0B2z-WBMLTvtHemFmcDNSanNmZlU

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

130 [Update] Sea level rise_storm surge communicati....pdf

From: rebecca_beavers@nps.gov
To: ann_gallagher@nps.gov; maria_a_caffrey@partner.nps.gov; matt_holly@nps.gov; rebecca_beavers@nps.gov; janet_cakir@nps.gov; larry_perez@nps.gov; rebecca_beavers@nps.gov
Subject: [Update] Sea level rise/storm surge communication team meeting
Date: Friday, April 14, 2017 5:06:04 PM

Hi Team:

Updated media drafts and the version of the report submitted for publication are available in this folder:

https://drive.google.com/drive/folders/0B2z-WBMLTvtHemFmcDNSanNmZlU?usp=sharing

Sea level rise/storm surge communication team meeting

Agenda:
1) Update on the status of the report
2) Give feedback and make edits on the attached talking points (please review the attached document BEFORE the meeting)

When	Wed Apr 19, 2017 10am – 11am Mountain Time
Where	1-(b) (5) (b) (5) (map)
Video call	https://plus.google.com/hangouts/_/doi.gov/maria-a-caffrey
Who	• maria_a_caffrey@partner.nps.gov - organizer • ann_gallagher@nps.gov • rebecca_beavers@nps.gov • matt_holly@nps.gov • larry_perez@nps.gov • janet_cakir@nps.gov
Attachments	SLR and SS Report Key Messages.docx

131 DRAFT InsideNPS Post.pdf

From:	Perez, Larry
To:	Beavers, Rebecca; Maria Caffrey
Subject:	DRAFT InsideNPS Post
Date:	Monday, April 17, 2017 2:24:26 PM
Attachments:	2017-04-17 DRAFT InsideNPS Post.docx

Rebecca & Maria,

In preparation for our meeting on March, I wanted to make some headway on a draft InsideNPS post to accompany release.

Have a look below and feel free to edit/comment. I want to make sure this accurately represents your work & findings, and this was admittedly a hasty first stab.

Some of this could easily be worked into a press release, if WASO Comms decides to go that route.

-L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

131 1 Attachment 2017-04-17 DRAFT InsideNPS Post.pdf

Approximately one-fourth of all National Park Service (NPS) sites are situated on or near the coast. These parks protect a diverse array of ecosystems, historic sites, recreational areas, and infrastructure. From the submerged reefs of Biscayne National Park to the elevated span of the Golden Gate Bridge, coastal parks are experiencing quickening rates of sea level rise. A new report out today helps bring to light the possible extent and timing of sea level change projections for the future.

In *Sea Level Rise and Storm Surge Projections for the National Park Service*, report authors analyze existing datasets from NOAA and the IPCC relative to national park sites. The results illustrate the potential for permanent coastal inundation and flooding due to storm surge under varying greenhouse gas emissions scenarios. Results of the analysis were used to create a suite of storm surge maps for each site included in the study.

Comment [PL1]: This will be linked to the report on IRMA or our landing page.

Comment [PL2]: This could be linked either to IRMA or the Flickr site…your preference.

Results suggest the parks in the National Capital Region are poised to experience the greatest amount of sea level rise over the next century. Meanwhile, all parks will need to contend with both rising sea levels and the intensification of storms and associated storm surge. This is particularly true of parks along the southeast coast, which have historically taken the brunt of tropical storms and hurricanes.

It is important to note, however, that coastal areas will experience sea level change differently, owing to the variable nature of ocean currents, topography of the coast, and the influence of localized changes in land elevation. The coastline near Jean Lafitte National Park, for example, is likely to experience faster rates of relative sea level due to high rates soil subsidence. Conversely, most Alaskan parks are expected to see continued falling of sea level as the land mass rebounds from the loss of heavy, land-based ice.

The catastrophic damage wrought by Hurricane Sandy in 2012 underscores the need to understand the nature of changing conditions along the coast. Taking stock of trends in sea level change is a necessary precursor to identifying future vulnerabilities and managing risk responsibly. When coupled with earlier work examining infrastructure at risk along the coast, the results of this study can help identify vulnerabilities, prioritize management action, and guide public investments in sustainable projects.

132 Draft edits.pdf

From:	Caffrey, Maria
To:	Perez, Larry
Subject:	Draft edits
Date:	Monday, April 17, 2017 2:46:48 PM
Attachments:	2017-04-17 DRAFT InsideNPS Post_mc edits.docx

Here are my edits.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

132 1 Attachment 2017-04-17 DRAFT InsideNPS Post_mc edits.pdf

Approximately one-fourth of all National Park Service (NPS) sites are situated on or near the coast. These parks protect a diverse array of ecosystems, historic sites, recreational areas, and infrastructure. From the submerged reefs of Biscayne National Park to the elevated span of the Golden Gate Bridge, coastal parks are experiencing quickening rates of sea level rise. A new report out today helps bring to light the possible extent and timing of sea level change projections for the future.

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Due to the tight clustering of parks in the ~~Results suggest the parks in the~~ National Capital Region results suggest they are poised to experience the greatest amount of sea level rise over the next century. Meanwhile, all parks will need to contend with both rising sea levels and the intensification of storms and associated storm surge. This is particularly true of parks along the southeast coast, which have historically taken the brunt of tropical storms and hurricanes.

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Comment [PL2]: This could be linked either to IRMA or the Flickr site…your preference.

Comment [MAC3]: This is a really inelegant way of saying this. Feel free to change my corrections to make it sound better. I just think it's worth noting that part of the reason it is so high is because they isn't much standard deviation. The Wright Brothers/Cape Hatteras area has the highest numbers in the whole system.

Comment [MAC4]: It's not just the soil that is causing this subsidence. I think it is fine just to say "subsidence" rather than get into the complexities of building on fluvial sediment.

133 Draft 2.pdf

From:	Caffrey, Maria
To:	Rebecca Beavers
Subject:	Draft 2
Date:	Monday, April 17, 2017 2:50:36 PM
Attachments:	2017-04-17 DRAFT InsideNPS Post_mc edits.docx

Here is my second attempt. I just replaced capital with Outer Banks Area.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

133 1 Attachment 2017-04-17 DRAFT InsideNPS Post_mc edits_1.pdf

Approximately one-fourth of all National Park Service (NPS) sites are situated on or near the coast. These parks protect a diverse array of ecosystems, historic sites, recreational areas, and infrastructure. From the submerged reefs of Biscayne National Park to the elevated span of the Golden Gate Bridge, coastal parks are experiencing quickening rates of sea level rise. A new report out today helps bring to light the possible extent and timing of sea level change projections for the future.

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134 Re_ Draft 2.pdf

From:	Caffrey, Maria
To:	Rebecca Beavers
Subject:	Re: Draft 2
Date:	Monday, April 17, 2017 2:56:35 PM
Attachments:	2017-04-17 DRAFT InsideNPS Post_mc edits.docx

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Apr 17, 2017 at 2:50 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Here is my second attempt. I just replaced capital with Outer Banks Area.
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage

134 1 Attachment 2017-04-17 DRAFT InsideNPS Post_mc edits_2.pdf

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Comment [MAC3]: It's not just the soil that is causing this subsidence. I think it is fine just to say "subsidence" rather than get into the complexities of building on fluvial sediment.

135 Re_ DRAFT InsideNPS Post.pdf

From:	Caffrey, Maria
To:	Beavers, Rebecca
Cc:	Perez, Larry
Subject:	Re: DRAFT InsideNPS Post
Date:	Monday, April 17, 2017 3:00:36 PM
Attachments:	2017-04-17 DRAFT InsideNPS Post_mc edits.docx

Larry,

Here are the edits from me and Rebecca.

Thanks for getting ahead on this!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Apr 17, 2017 at 2:34 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Thank you, Larry. We will discuss and reply to you.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Mon, Apr 17, 2017 at 2:23 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Rebecca & Maria,
>>
>> In preparation for our meeting on March, I wanted to make some headway on a draft InsideNPS post to accompany release.
>>
>> Have a look below and feel free to edit/comment. I want to make sure this accurately represents your work & findings, and this was admittedly a hasty first stab.
>>
>> Some of this could easily be worked into a press release, if WASO Comms decides to go that route.

-L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

135 1 Attachment 2017-04-17 DRAFT InsideNPS Post_mc edits_3.pdf

Approximately one-fourth of all National Park Service (NPS) sites are situated on or near the coast. These parks protect a diverse array of ecosystems, historic sites, recreational areas, and infrastructure. From the submerged reefs of Biscayne National Park to the elevated span of the Golden Gate Bridge, coastal parks are experiencing quickening rates of sea level rise. A new report out today helps bring to light the possible extent and timing of sea level change projections for the future.

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Comment [MAC3]: It's not just the soil that is causing this subsidence. I think it is fine just to say "subsidence" rather than get into the complexities of building on fluvial sediment.

136 Updated Invitation_ Sea level rise_storm surge ....pdf

From: Maria Caffrey
To: larry_perez@nps.gov; matt_holly@nps.gov; ann_gallagher@nps.gov; janet_cakir@nps.gov; rebecca_beavers@nps.gov; Maria Caffrey
Subject: Updated Invitation: Sea level rise/storm surge communication team meeting @ Wed Apr 19, 2017 10am - 11am (larry_perez@nps.gov)
Date: Monday, April 17, 2017 3:05:37 PM
Attachments: invite.ics

This event has been changed.

Sea level rise/storm surge communication team meeting

more details »

Changed: Agenda:
1) Update on the status of the report
2) Give feedback and make edits on the attached talking points (please review the attached document BEFORE the meeting)

Use the following link for the latest versions of all files: https://drive.google.com/drive/folders/0B2z-WBMLTvtHemFmcDNSanNmZlU?usp=sharing

When Wed Apr 19, 2017 10am – 11am Mountain Time

Where 1-(b) (5) (b) (5) (map)

Video call https://plus.google.com/hangouts/_/doi.gov/maria-a-caffrey

Calendar larry_perez@nps.gov

Who
- maria_a_caffrey@partner.nps.gov - organizer
- matt_holly@nps.gov
- ann_gallagher@nps.gov
- larry_perez@nps.gov
- janet_cakir@nps.gov
- rebecca_beavers@nps.gov

Going? **Yes** - **Maybe** - **No** more options »

137 Re_ DRAFT InsideNPS Post(1).pdf

From:	Perez, Larry
To:	Caffrey, Maria
Cc:	Beavers, Rebecca
Subject:	Re: DRAFT InsideNPS Post
Date:	Monday, April 17, 2017 3:10:22 PM

Thank you...you guys are quick!

I think we need to clarify how we portray which area is projected to see the greatest rise, but we can discuss on Monday.

Best,

L

On Mon, Apr 17, 2017 at 3:00 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Larry,
>
> Here are the edits from me and Rebecca.
>
> Thanks for getting ahead on this!
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
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>
> On Mon, Apr 17, 2017 at 2:34 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
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>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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Rebecca & Maria,

In preparation for our meeting on March, I wanted to make some headway on a draft InsideNPS post to accompany release.

Have a look below and feel free to edit/comment. I want to make sure this accurately represents your work & findings, and this was admittedly a hasty first stab.

Some of this could easily be worked into a press release, if WASO Comms decides to go that route.

-L

Larry Perez, Communications Coordinator
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Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
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Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

138 Re_ Manuscript Submittal_ Sea Level and Storm S....pdf

From: Perez, Larry
To: Beavers, Rebecca
Cc: Caffrey, Maria; Holly, Matt
Subject: Re: Manuscript Submittal: Sea Level and Storm Surge
Date: Monday, April 17, 2017 3:17:14 PM

Please keep us posted on what you hear from Fagan.

Once he gives a green light on the final version, it will be important to get a copy to Matt to have him update the landing page in advance of release.

Thanks,

L

On Fri, Apr 14, 2017 at 4:43 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> We submit the linked document "Sea level rise and storm surge projections for the National Park Service" for review and publication.
>
> The MSF and report are available at:
>
> https://drive.google.com/open?id=0B2z-WBMLTvtHemFmcDNSanNmZlU
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
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____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
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Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

139 Re_ Updated Invitation_ Sea level rise_storm su....pdf

From: Caffrey, Maria
To: Perez, Larry
Subject: Re: Updated Invitation: Sea level rise/storm surge communication team meeting @ Wed Apr 19, 2017 10am - 11am (larry_perez@nps.gov)
Date: Monday, April 17, 2017 3:17:42 PM

I'm open to that, although I'll leave it to Rebecca to decide.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Apr 17, 2017 at 3:14 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Maria & Rebecca,
>
> Seeing as how we are getting pretty close to release, do we want to invite Jeff O to participate?
>
> -L
>
> On Mon, Apr 17, 2017 at 3:05 PM, Maria Caffrey <maria_a_caffrey@partner.nps.gov> wrote:
>
> > **This event has been changed.**
> >
> > **Sea level rise/storm surge communication team meeting** **more details »**
> >
> > **Changed:** Agenda:
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> >
> > When Wed Apr 19, 2017 10am – 11am Mountain Time
> >
> > Where 1-(b) (5) (b) (5) (map)
> >
> > Video call https://plus.google.com/hangouts/_/doi.gov/maria-a-caffrey
> >
> > Calendar larry_perez@nps.gov
> >
> > Who
> > - maria_a_caffrey@partner.nps.gov - organizer
> > - matt_holly@nps.gov
> > - ann_gallagher@nps.gov
> > - larry_perez@nps.gov
> > - janet_cakir@nps.gov

- rebecca_beavers@nps.gov

Going? **Yes** - **Maybe** - **No** more options »

Invitation from Google Calendar

You are receiving this email at the account larry_perez@nps.gov because you are subscribed for updated invitations on calendar larry_perez@nps.gov.

To stop receiving these emails, please log in to https://www.google.com/calendar/ and change your notification settings for this calendar.

Forwarding this invitation could allow any recipient to modify your RSVP response. Learn More.

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

140 Re_ Updated Invitation_ Sea level rise_storm su...(1).pdf

From:	Perez, Larry
To:	Beavers, Rebecca
Cc:	Maria Caffrey
Subject:	Re: Updated Invitation: Sea level rise/storm surge communication team meeting @ Wed Apr 19, 2017 10am - 11am (larry_perez@nps.gov)
Date:	Tuesday, April 18, 2017 9:32:40 AM

I'm good with that...we'll plan on a sidebar with Jeff...

-L

On Tue, Apr 18, 2017 at 9:15 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> I also thought this might be appropriate, but I also know Jeff has many other irons in the fire.
>
> This call is the time to get parks/ programs on track. I think Jeff would benefit most from the recap and even a direct call that is focused on the PIO element (not all the communication related tasks).
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> FIND YOUR PARK
>
> On Mon, Apr 17, 2017 at 3:14 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Maria & Rebecca,
>>
>> Seeing as how we are getting pretty close to release, do we want to invite Jeff O to participate?
>>
>> -L
>>
>> On Mon, Apr 17, 2017 at 3:05 PM, Maria Caffrey <maria_a_caffrey@partner.nps.gov> wrote:
>>
>>> **This event has been changed.**
>>>
>>> **Sea level rise/storm surge communication team meeting** **more details »**
>>>
>>> **Changed:** Agenda:
>>> 1) Update on the status of the report
>>> 2) Give feedback and make edits on the attached talking points (please review the attached document BEFORE the meeting)
>>>
>>> Use the following link for the latest versions of all files: https://drive.google.com/drive

/folders/0B2z-WBMLTvtHemFmcDNSanNmZlU?usp=sharing

When Wed Apr 19, 2017 10am – 11am Mountain Time

Where 1-(b) (5) (b) (5) (map)

Video call https://plus.google.com/hangouts/_/doi.gov/maria-a-caffrey

Calendar larry_perez@nps.gov

Who
- maria_a_caffrey@partner.nps.gov - organizer
- matt_holly@nps.gov
- ann_gallagher@nps.gov
- larry_perez@nps.gov
- janet_cakir@nps.gov
- rebecca_beavers@nps.gov

Going? **Yes** - **Maybe** - **No** more options »

--

____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

141 Re_ Manuscript Submittal_ Sea Level and Storm S...(1).pdf

From:	Johnson, Chalmers-Fagan
To:	Grace, Lise
Cc:	John Gross; Cat Hawkins Hoffman; Patrick Gonzalez; Caffrey, Maria; Caffrey, Maria; Larry Perez; Beavers, Rebecca
Subject:	Re: Manuscript Submittal: Sea Level and Storm Surge
Date:	Wednesday, April 19, 2017 8:37:38 AM

Rebecca: I'm way behind because of some recent computer problems, and am having Lise work with you really quickly before the report is sent to me.

Lise: Give this report a good once-over and talk and work with Rebecca if you need to reformat anything that does not meet NRR standards.

> I have not even opened this file and have no idea how much or little time this will take.

Let me know if you have any questions.

Thanks.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

> *"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."* Mark Twain

On Fri, Apr 14, 2017 at 4:43 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> We submit the linked document "Sea level rise and storm surge projections for the National Park Service" for review and publication.
>
> The MSF and report are available at:
>
> https://drive.google.com/open?id=0B2z-WBMLTvtHemFmcDNSanNmZlU
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

142 Fwd_ Manuscript Submittal_ Sea Level and Storm ...(1).pdf

From:	Perez, Larry
To:	Matt Holly
Subject:	Fwd: Manuscript Submittal: Sea Level and Storm Surge
Date:	Wednesday, April 19, 2017 8:43:50 AM

FYI

---------- Forwarded message ----------
From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
Date: Wed, Apr 19, 2017 at 8:37 AM
Subject: Re: Manuscript Submittal: Sea Level and Storm Surge
To: "Grace, Lise" <lise_grace@nps.gov>
Cc: John Gross <John_Gross@nps.gov>, Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>, "Caffrey, Maria" <maria.caffrey@colorado.edu>, Larry Perez <larry_perez@nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Rebecca: I'm way behind because of some recent computer problems, and am having Lise work with you really quickly before the report is sent to me.

Lise: Give this report a good once-over and talk and work with Rebecca if you need to reformat anything that does not meet NRR standards.

> I have not even opened this file and have no idea how much or little time this will take.

Let me know if you have any questions.

Thanks.

Fagan Johnson
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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

--

____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

143 Re_ Manuscript Submittal_ Sea Level and Storm S...(2).pdf

From:	Johnson, Chalmers-Fagan
To:	Grace, Lise
Cc:	John Gross; Cat Hawkins Hoffman; Patrick Gonzalez; Caffrey, Maria; Caffrey, Maria; Larry Perez; Beavers, Rebecca
Subject:	Re: Manuscript Submittal: Sea Level and Storm Surge
Date:	Wednesday, April 19, 2017 9:07:43 AM

Change of plans. Sorry!

I'll be working on this report instead of Lise.

I need Lise to work on a giant vegetation inventory map that was just sent to me instead.

Thanks.

Fagan Johnson
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Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

> *"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."* Mark Twain

On Wed, Apr 19, 2017 at 8:37 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> Rebecca: I'm way behind because of some recent computer problems, and am having Lise work with you really quickly before the report is sent to me.
>
> Lise: Give this report a good once-over and talk and work with Rebecca if you need to reformat anything that does not meet NRR standards.
>
> > I have not even opened this file and have no idea how much or little time this will take.
>
> Let me know if you have any questions.
>
> Thanks.
>
> Fagan Johnson
> Web and Report Specialist
> National Park Service
> Inventory & Monitoring Division

1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

> *"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."* Mark Twain

On Fri, Apr 14, 2017 at 4:43 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

We submit the linked document "Sea level rise and storm surge projections for the National Park Service" for review and publication.

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https://drive.google.com/open?id=0B2z-WBMLTvtHemFmcDNSanNmZlU

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

144 feedback.pdf

From: Gallagher, Ann
To: Caffrey, Maria; Beavers, Rebecca
Subject: feedback
Date: Thursday, April 20, 2017 3:10:52 PM
Attachments: Sea Level and Surge - comments agm 4-20-2017.docx

---

I have attached my questions and suggestions for consideration.

Depending on the responses and the desirability of sharing the answers, FAQ could include something about the decisions made for this national effort.

Yours,
Ann

Ann M. Gallagher, M.S.
Science Education Coordinator
ISA Certified Arborist® MA-5484A
Natural Resources & Science, National Capital Region
4598 MacArthur Blvd, NW
Washington, DC 20007
Phone: 202-339-8320
Cell: 202-322-9888
Fax: 202-282-1031

144 1 Attachment Sea Level and Surge - comments agm 4-20-2017.pdf

Sea Level and Surge

page	comment
6	Provide a short definition of the bathtub model – “a simplification of the sea as a tub of water removing confounding factors such as erosion or specifics of storm activities” than when the reader gets to the limitations of the model on page 9 they will already have had enough of a hint to make the pages in between have meaning.
iv	representative concentration pathways – write out for Figure 2.
1	Wish for a more dramatic word in the introductory sentence. Gradual vs. significantly do not capture the dramatic change in rate. Consider “… climate change has dramatically increased the rate of global…”
4	Is it easier to process percent than fractions? Try thermal expansion was responsible for 40% and melting ice 50%
5	The first paragraph could flow better. Give the reader more about the process-based model at the beginning of the paragraph and then contrast with the semi-empirical models.
5	GIS – write out
5	Give the reader a little more about the MHHW for brief context. It is high tide averaged over 19 years or it is the point beyond which inundation begins would help the reader.
6	Why was standard error considered beyond the scope of the project. How can we tell how believable the modeling is or any of the other important information gleaned from errors and deviation?
10	If surge estimates are only accurate 20% of the time then why bother?
11	Why has no one looked at the applicability of the gauges to the parks their data is being used? How will parks know that the gauge is reasonable? How will readers outside of NPS use the information if they gauge used did not provide any useful data?
12	What is the value of the national range of averages? I suggest it will confuse especially since there is no “rule of thumb” value to the statement. Consider saying something about how sea level rise and storm surge effect the whole county with a wide range of variation based on unique characteristics of each park unit.
14	Hurricanes within 10 miles is confusing to me. Rainfall and winds extend beyond the hurricane’s center by hundreds of miles, sometimes. So why limit to 10 miles?
19	No need to call out Harpers Ferry’s other cc impacts. This report is just about sea level and surge.
19	Are the Beaumont, Texas defenses natural or artificial? What are they?
22	Why use other storm types in the Pacific West but not use nor’easter data for Acadia?
24	Church et al. addressed the criticisms but I would love a hint at what they outlined. Could there be a sentence here to let the reader know enough to know if they need to find the reference.
24	Audience question: If the audience is NPS internal they a definition of radiative forcing is likely to be helpful.
26	In conclusions section the general statements are certainly true. Could they have a bit more detail? What research could be prioritized, for example? A statement with the kinds of details that would yield more accurate predictions for each unit could be included. Such a statement might suggest that park specifics such as elevation, substrate, coastal geometry, water temperature, relative land change… would allow for greater resolution for the modeling. I’d hope such a statement might encourage parks to look of an expert with the ability to find those details to be engaged in refining the modeling.

145 Re_ feedback.pdf

From:	Gallagher, Ann
To:	Caffrey, Maria
Cc:	Beavers, Rebecca
Subject:	Re: feedback
Date:	Thursday, April 20, 2017 3:14:03 PM

Hope it helps!

Yours,
Ann

Ann M. Gallagher, M.S.
Science Education Coordinator
ISA Certified Arborist® MA-5484A
Natural Resources & Science, National Capital Region
4598 MacArthur Blvd, NW
Washington, DC 20007
Phone: 202-339-8320
Cell: 202-322-9888
Fax: 202-282-1031

On Thu, Apr 20, 2017 at 5:12 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Hi Ann,
>
> Thanks for this!
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Thu, Apr 20, 2017 at 3:10 PM, Gallagher, Ann <ann_gallagher@nps.gov> wrote:
>
>> I have attached my questions and suggestions for consideration.
>>
>> Depending on the responses and the desirability of sharing the answers, FAQ could include something about the decisions made for this national effort.
>>
>> Yours,
>> Ann
>>
>> Ann M. Gallagher, M.S.
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>> Washington, DC 20007
>> Phone: 202-339-8320
>> Cell: 202-322-9888

Fax: 202-282-1031

147 Re_ Sea Level Rise Report Final Layout Policy R....pdf

From:	Beavers, Rebecca
To:	Johnson, Chalmers-Fagan
Cc:	John Gross; Cat Hoffman; Patrick Gonzalez; Tani Hubbard; Margaret Beer
Subject:	Re: Sea Level Rise Report Final Layout Policy Review
Date:	Monday, April 24, 2017 11:25:17 AM

Thank you, Fagan.

We are making some minor text revisions to fix some misspellings, etc.. I will send you the Final version after the co-authors have an opportunity to review this version.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, Apr 21, 2017 at 4:23 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.
>
> The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).
>
> **Three Remaining Steps**
> (Download detailed instructions for all three steps)
>
> **Step 1. Download the updated MS Word file and final and updated MSF at:**
>
> https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ?usp=sharing
>
> **Maintaining your own copy of the final MSF is optional. We maintain multiple archived versions.
>
> **Step 2. Double-check and approve my updates and have Fagan export the final to PDF (Rebecca and Fagan).**

a) **Make your absolute final edits (if any)**, and send the **VERY FINAL** version of the .docx file back to **Fagan**.

If you want to know exactly what we updated in your report (optional), proceed to the ***Report Updates and Changes** section below.

Make sure that there are no more changes when you send the report to Fagan. The sub-step below takes about 2-3 minutes per page. Changes after that point usually require starting over with the entire process (re-tagging all pages and not just the ones with changes).

b) **When all edits are final, Fagan will** export the final to PDF format and manually check fix the HTML-type tags on each page to meet current Section 508 of the Rehabilitation Act standards, such that the final document to be read aloud correctly by special screen readers for the visually and cognitively impaired.

Step 3. Activate the draft IRMA record that I created for you, and upload the final PDF (Fagan).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2239974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

Note: The Data Store search engine only searches on the bibliographic information you enter here. It does not search anything located inside any uploaded digital files.

c) When you are finished updating the Data Store bibliographic information, click the *Activate* button at the bottom-right of the page to save your changes and make the record visible to the public.

d) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF and *Activate* it (the PDF Holding also has to be *Active* to be downloadable).

(Download detailed instructions for all three steps)

*****Everything below this point is just for people that really want to know EXACTLY what we edited and updated in their report.**

*** * *New Report Numbers and Citation (new/important information below highlighted in yellow):**

Series Name Number:

Natural Resource Report NPS/NRSS/NRR—2017/1425

Citation (on shown on page ii):

- we use sentence case here (only first letters, proper names, and acronyms capitalized).

A good rule-of-thumb for proper names that we use, is whether or not you can send a physical letter through the mail to that entity.

You **cannot** send a letter to: Sea Level Rise

But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

TIC Number: 999/137852

*** * * Report Updates and Changes : here is what I updated and changed in your report.**

How closely the rest of the report adheres to the "best practices" format and layout standards presented in our document templates, is up to the official Peer Review Manager for that report (Cat or John).

Front Cover and Title Pages (we are only this picky about the front and back cover pages):

- set your page margins to 0.75-inch on the left, top, and right; and 1-inch on the bottom (yours were 1-inch on all sides).
- updated the series name/number with the one that I gave you above.
- made sure that your cover image had alternate text (Section 508 - matches the caption on the following page).
- set the publication month and year to now.

Page ii:
- updated the sixth paragraph to the newer 2017 template standards (DOI/NPS prefers that we just add the hyperlink to the name of the webpage or website, and not spell-out the URL separately).
- updated the official report citation with the information that I gave you above.
- incorporated your new TIC number and the current month and year into the last line on the page.

Page Numbers: Were showing up in different locations on different pages, so I deleted and re-added them to all pages.

> This is a common MS Word bug that occurs whenever multiple versions of MS Word edit or create pages inside the same document (especially when more than two major versions were used).

First Order Headings: Set them all to begin at the top of a new page.

> All first order headings must begin at the top of a new page.
>
> The only exception to this rule is if you already have a first order heading at the top of a new page, then you may also place additional first order headings lower on the very same page.

Lists of Contents, Figures, Tables, Photos, and Appendices:
- checked for common software bugs. These were fine.
- updated the page numbers in the tables when I was finished with everything else.

Figures - Made sure that figures:
- stayed inside the page margins (Section 508 and document stability). They were fine.
- were in-line with text (no text wrapping—avoids export to PDF issues and prevents document crashes while editing).
- used consistent and predictable page placement in general (center-justified, same vertical distance from captions, etc.).

Tables - Made sure that:
- the table caption was located on the text line immediately above the table (and not in a table cell—avoids export to PDF issues).
- tables stayed inside the page margins (avoids export to PDF issues and prevents document crashes while editing). For tables that were larger than the page, I either:

> a) Shrank the size of the table to fit inside the page margins.
>
> b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

- replaced mid-table multiple column header rows with additional left-hand columns.

- made sure that all captions and table notes were repeated above and below all sub-tables for tables that spanned multiple pages.

- split and merged cells as needed such that all table cells would be read aloud correctly by screen readers for the visually and cognitively impaired (that software was designed to read tables aloud that are set up more like a spreadsheet).

- used a consistent and predictable layout scheme (left-justified, same border and background treatments, etc.) .

Inside Back and Outside Back Cover Page s:

- made sure that the inside back cover occurred on an odd-numbered page.

This insures that the outside back cover is the absolute final printed page (no extra blank page).

- incorporated your new TIC number and the current month and year into the last line on the inside cover page.

That's it!

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

148 Fwd_ Sea Level Rise Report Final Layout Policy ....pdf

From:	Beavers, Rebecca
To:	Larry Perez; Cat Hawkins Hoffman; Patrick Gonzalez
Cc:	Hal Pranger
Subject:	Fwd: Sea Level Rise Report Final Layout Policy Review
Date:	Monday, April 24, 2017 11:39:13 AM

HI Larry, Patrick & Cat:

We received the next version of the report from Fagan. I'll send you our revised version of the document soon (later today or Tuesday). Do we want the full science & communication teams to get an "absolute final review opportunity" or just a courtesy "heads up"?

Larry: When should we give Jeff Olson a "Heads Up"?

Status: While the report is ready (and may be considered ready for publication in April), we should make the data available to readers along with the report release **in an ideal world**. That is a separate process & will require some funding to get the web interface "back" online. At one point the interface was online in a beta version, and more work is needed to keep pace with our great web updates. The work is helping to integrate these data with a variety of park planning tools, etc. It is not a mere data repository/query platform.

Have a great day.

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
Date: Fri, Apr 21, 2017 at 4:23 PM
Subject: Sea Level Rise Report Final Layout Policy Review
To: Rebecca Beavers <rebecca_beavers@nps.gov>, John Gross <john_gross@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Tani Hubbard <tani_hubbard@nps.gov>, Margaret Beer <margaret_beer@nps.gov>

Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.

The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).

Three Remaining Steps

(Download detailed instructions for all three steps)

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Series Name Number:

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Citation (on shown on page ii):

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You **cannot** send a letter to: Sea Level Rise

But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

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TIC Number: 999/137852

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Page ii:

- updated the sixth paragraph to the newer 2017 template standards (DOI/NPS prefers that we just add the hyperlink to the name of the webpage or website, and not spell-out the URL separately).
- updated the official report citation with the information that I gave you above.
- incorporated your new TIC number and the current month and year into the last line on the page.

Page Numbers: Were showing up in different locations on different pages, so I deleted and re-added them to all pages.

> This is a common MS Word bug that occurs whenever multiple versions of MS Word edit or create pages inside the same document (especially when more than two major versions were used).

First Order Headings: Set them all to begin at the top of a new page.

> All first order headings must begin at the top of a new page.
>
> The only exception to this rule is if you already have a first order heading at the top of a new page, then you may also place additional first order headings lower on the very same page.

Lists of Contents, Figures, Tables, Photos, and Appendices:

- checked for common software bugs. These were fine.
- updated the page numbers in the tables when I was finished with everything else.

Figures - Made sure that figures:

- stayed inside the page margins (Section 508 and document stability).

They were fine.
- were in-line with text (no text wrapping—avoids export to PDF issues and prevents document crashes while editing).
- used consistent and predictable page placement in general (center-justified, same vertical distance from captions, etc.).

Tables - Made sure that:
- the table caption was located on the text line immediately above the table (and not in a table cell—avoids export to PDF issues).
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a) Shrank the size of the table to fit inside the page margins.

b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

- replaced mid-table multiple column header rows with additional left-hand columns.

- made sure that all captions and table notes were repeated above and below all sub-tables for tables that spanned multiple pages.

- split and merged cells as needed such that all table cells would be read aloud correctly by screen readers for the visually and cognitively impaired (that software was designed to read tables aloud that are set up more like a spreadsheet).

- used a consistent and predictable layout scheme (left-justified, same border and background treatments, etc.) .

Inside Back and Outside Back Cover Page s:
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This insures that the outside back cover is the absolute final printed page (no extra blank page).

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That's it!

Fagan Johnson

Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

149 Re_ Sea Level Rise Report Final Layout Policy R...(1).pdf

From: Beavers, Rebecca
To: Gonzalez, Patrick
Subject: Re: Sea Level Rise Report Final Layout Policy Review
Date: Monday, April 24, 2017 11:51:50 AM

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, Apr 24, 2017 at 11:43 AM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:

> Hi Rebecca,
>
> I look forward to seeing the most recent version of the Word file for a final read. Whatever you decide on further internal review will be OK with me.
>
> Thanks,
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Department of Environmental Science, Policy, and Management
> University of California, Berkeley
> 131 Mulford Hall, Berkeley, CA 94720-3114 USA
>
> patrick_gonzalez@nps.gov
> patrickgonzalez@berkeley.edu
> (510) 643-9725
> @pgonzaleztweet
> http://www.patrickgonzalez.net
> ....
>
> ---------- Forwarded message ----------
> From: **Beavers, Rebecca** <rebecca_beavers@nps.gov>
> Date: Mon, Apr 24, 2017 at 10:39 AM

Subject: Fwd: Sea Level Rise Report Final Layout Policy Review
To: Larry Perez <larry_perez@nps.gov>, Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Hal Pranger <harold_pranger@nps.gov>

HI Larry, Patrick & Cat:

We received the next version of the report from Fagan. I'll send you our revised version of the document soon (later today or Tuesday). Do we want the full science & communication teams to get an "absolute final review opportunity" or just a courtesy "heads up"?

Larry: When should we give Jeff Olson a "Heads Up"?

Status: While the report is ready (and may be considered ready for publication in April), we should make the data available to readers along with the report release **in an ideal world**. That is a separate process & will require some funding to get the web interface "back" online. At one point the interface was online in a beta version, and more work is needed to keep pace with our great web updates. The work is helping to integrate these data with a variety of park planning tools, etc. It is not a mere data repository/query platform.

Have a great day.

-rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

---------- Forwarded message ----------
From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
Date: Fri, Apr 21, 2017 at 4:23 PM
Subject: Sea Level Rise Report Final Layout Policy Review
To: Rebecca Beavers <rebecca_beavers@nps.gov>, John Gross <john_gross@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Tani Hubbard <tani_hubbard@nps.gov>, Margaret Beer <margaret_beer@nps.gov>

Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.

The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).

Three Remaining Steps

(Download detailed instructions for all three steps)

Step 1. Download the updated MS Word file and final and updated MSF at:

https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ?usp=sharing

**Maintaining your own copy of the final MSF is optional. We maintain multiple archived versions.

Step 2. Double-check and approve my updates and have Fagan export the final to PDF (Rebecca and Fagan).

a) **Make your absolute final edits (if any)**, and send the **VERY FINAL** version of the .docx file back to **Fagan**.

If you want to know exactly what we updated in your report (optional), proceed to the *****Report Updates and Changes** section below.

Make sure that there are no more changes when you send the report to Fagan. The sub-step below takes about 2-3 minutes per page. Changes after that point usually require starting over with the entire process (re-tagging all pages and not just the ones with changes).

b) **When all edits are final, Fagan will** export the final to PDF format and manually check fix the HTML-type tags on each page to meet current Section 508 of the Rehabilitation Act standards, such that the final document to be read aloud correctly by special screen readers for the visually and cognitively impaired.

Step 3. Activate the draft IRMA record that I created for you, and upload the final PDF (Fagan).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2239974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

> **Note:** The Data Store search engine only searches on the bibliographic information you enter here. It does not search anything located inside any uploaded digital files.

c) When you are finished updating the Data Store bibliographic information, click the *Activate* button at the bottom-right of the page to save your changes and make the record visible to the public.

d) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF and *Activate* it (the PDF Holding also has to be *Active* to be downloadable).

(Download detailed instructions for all three steps)

*****Everything below this point is just for people that really want to know EXACTLY what we edited and updated in their report.**

*** * *New Report Numbers and Citation (new/important information below highlighted in yellow):**

Series Name Number:

Natural Resource Report NPS/NRSS/NRR—2017/1425

Citation (on shown on page ii):

- we use sentence case here (only first letters, proper names, and acronyms capitalized).

> A good rule-of-thumb for proper names that we use, is whether or not you can send a physical letter through the mail to that entity.
>
> You **cannot** send a letter to: Sea Level Rise
>
> But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425.

National Park Service, Fort Collins, Colorado.

TIC Number: 999/137852

***** Report Updates and Changes : here is what I updated and changed in your report.**

How closely the rest of the report adheres to the "best practices" format and layout standards presented in our document templates, is up to the official Peer Review Manager for that report (Cat or John).

Front Cover and Title Pages (we are only this picky about the front and back cover pages):

- set your page margins to 0.75-inch on the left, top, and right; and 1-inch on the bottom (yours were 1-inch on all sides).
- updated the series name/number with the one that I gave you above.
- made sure that your cover image had alternate text (Section 508 - matches the caption on the following page).
- set the publication month and year to now.

Page ii:

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- stayed inside the page margins (Section 508 and document stability). They were fine.
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>
> b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

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That's it!

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

152 Re_ Response Needed_ Final Proofing_ Sea Level_...(1).pdf

From:	Pranger, Harold
To:	Beavers, Rebecca
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Wednesday, April 26, 2017 9:28:29 AM

Thanks.

Yes, right after I sent you that note I saw that you BCC:d me and weren't asking for a review anyhow.

Thanks for the heads up.

Looking forward to see the SLR on Web/ GIS!

-Hal

"We conserve only what we love, we love only what we understand, and we understand only what we are taught.

Hal (Harold) Pranger | Chief, Geologic Systems Branch, Geologic Resources Division
Natural Resource Stewardship and Science | U.S. National Park Service
Office: 303 969-2018 | Mobile: 303 963-6538 | E-Mail: harold_pranger@nps.gov

NPS Geologic Resources Division **http://go.nps.gov/geology**
*Energy and Minerals * Active Processes and Hazards * Geologic Heritage*

On Wed, Apr 26, 2017 at 9:26 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Thank you for your response. I am sending you these documents as a "heads up."
>
> Cat also approved funds $8K for the associated enterprise GIS website work we are doing with the park atlas team.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Wed, Apr 26, 2017 at 8:14 AM, Pranger, Harold <harold_pranger@nps.gov> wrote:
>
>> Thank you, Rebecca:

I will not be reviewing this document. It appears you have plenty of good eyes on this document.

Very exciting!

Take care.

-Hal

"We conserve only what we love, we love only what we understand, and we understand only what we are taught.

Hal (Harold) Pranger | Chief, Geologic Systems Branch, Geologic Resources Division
Natural Resource Stewardship and Science | U.S. National Park Service
Office: 303 969-2018 | Mobile: 303 963-6538 | E-Mail: harold_pranger@nps.gov

NPS Geologic Resources Division **http://go.nps.gov/geology**
*Energy and Minerals * Active Processes and Hazards * Geologic Heritage*

On Tue, Apr 25, 2017 at 12:15 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

It's that time for a final check prior to publication of:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

https://drive.google.com/drive/folders/0B2z-WBMLTvtHTFFpOVJjY3U0Snc?usp=sharing

The NPS Sea Level and Storm Surge Projections Report report is available in the google drive folder and ready for the following Next Steps:

- **Final check by co-authors Patrick Gonzalez and Cat Hawkins Hoffman.**
- **Final check by Science and Communication Team Members. (Babson, Cakir, Gallagher, Holly, Norton, Perez, Thieler (USGS))**
- **If you have edits or will not comment please notify Rebecca.**
- Once complete, we will publish and post on IRMA with internal NPS access(initially & by 4/28 if we want to keep April 2017 text in report)

Plan for Release

- Website updates (Matt Holly)
- Rebecca Beavers and Larry Perez will coordinate release plans through Jeff Olson. Two paths forward are 1) internal release and 2) external release.

Co-authors/Communication team members: please review/edit these documents that will be used to guide the release process.
https://drive.google.com/open?id=0B2z-WBMLTvtHMXhvZjFaRVZxYXM

Status: the provided manuscript represents:

- Fagan's NRR series review that includes some reformatting of margins and some tables. (completed 4/21)
- Final edits to address comments from Ann Gallagher as presented on 4/19 communication team call. (completed 4/24)
- Content check by Maria Caffrey and Rebecca Beavers. (completed 4/25)

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

153 Re_ Response Needed_ Final Proofing_ Sea Level_...(2).pdf

From:	Beavers, Rebecca
To:	Patrick Gonzalez NPS
Cc:	Maria Caffrey
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Thursday, April 27, 2017 9:46:44 AM

Thank you, Patrick!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Wed, Apr 26, 2017 at 3:24 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria, Rebecca,
>
> Thanks for accepting the changes that I had recommended for the final draft. I went through this last version and it looks OK. Congratulations on getting the report close to publication.
>
> Thanks,
>
> Patrick
>
> ---
>
> **From:** "Beavers, Rebecca" <rebecca_beavers@nps.gov>
> **Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report**
> **Date:** April 25, 2017 at 1:34:47 PM PDT
> **To:** Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
> **Cc:** Maria Caffrey <maria_a_caffrey@partner.nps.gov>
>
> Thank you!
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Apr 25, 2017 at 2:27 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

Hi Rebecca, Maria,

I've downloaded this near-final draft and am reading it now.

Patrick

——

From: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Subject: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: April 25, 2017 at 11:15:01 AM PDT
To: Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Larry Perez <larry_perez@nps.gov>, Janet Cakir <janet_cakir@nps.gov>, Shawn Norton <Shawn_Norton@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Amanda Babson <amanda_babson@nps.gov>, "E. Thieler" <rthieler@usgs.gov>, Ann Gallagher <ann_gallagher@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>, "Caffrey, Maria" <maria.caffrey@colorado.edu>

It's that time for a final check prior to publication of:

> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

https://drive.google.com/drive/folders/0B2z-WBMLTvtHTFFpOVJjY3U0Snc?usp=sharing

The NPS Sea Level and Storm Surge Projections Report report is available in the google drive folder and ready for the following Next Steps:

- **Final check by co-authors Patrick Gonzalez and Cat Hawkins Hoffman.**
- **Final check by Science and Communication Team Members. (Babson, Cakir, Gallagher, Holly, Norton, Perez, Thieler (USGS))**

If you have edits or will not comment please notify Rebecca.

- Once complete, we will publish and post on IRMA with internal NPS access(initially & by 4/28 if we want to keep April 2017 text in report)

Plan for Release

- Website updates (Matt Holly)
- Rebecca Beavers and Larry Perez will coordinate release plans through Jeff Olson. Two paths forward are 1) internal release and 2) external release.
- **Co-authors/Communication team members: please review/edit these documents** that will be used to guide the release process. https://drive.google.com/open?id=0B2z-WBMLTvtHMXhvZjFaRVZxYXM

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Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

154 Fwd_ Response Needed_ Final Proofing_ Sea Level....pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Monday, May 01, 2017 9:00:49 AM

FYI- another science team review

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Rob Thieler** <rthieler@usgs.gov>
Date: Mon, May 1, 2017 at 7:46 AM
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

RB,
Have not had much time to look at this. Gave it a quick scan. Looks ok for what it does — i.e., bathtub model with lower-than-generally-accepted-and-non-probabilistic SLR scenarios. What is the expected lifetime of this document? What's next? There are bodies of literature and newer data and models that could begin to get at this more realistically.

Nice work getting this incremental step done.

From: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Date: Tuesday, April 25, 2017 at 2:15 PM
To: Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Larry Perez <larry_perez@nps.gov>, Janet Cakir <janet_cakir@nps.gov>, Shawn Norton <Shawn_Norton@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Amanda Babson <amanda_babson@nps.gov>, Rob Thieler <rthieler@usgs.gov>, Ann Gallagher <ann_gallagher@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>, "Caffrey, Maria" <maria.caffrey@colorado.edu>
Subject: Response Needed: Final Proofing: Sea Level/Strom Surge Report

It's that time for a final check prior to publication of:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

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Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

155 Re_ Response Needed_ Final Proofing_ Sea Level_...(3).pdf

From:	Beavers, Rebecca
To:	Babson, Amanda
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Monday, May 01, 2017 2:42:33 PM

Great! Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, May 1, 2017 at 1:52 PM, Babson, Amanda <amanda_babson@nps.gov> wrote:

> Hi Rebecca, I didn't have time for a full check, but I did a check of the three Appendix D table and the NER parks numbers are consistent with the earlier format tables. I did a spot check on other regions and they look good too.
> Amanda
>
> On Tue, Apr 25, 2017 at 2:15 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > It's that time for a final check prior to publication of:
> >
> > Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.
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> >
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Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
(401) 932-9812 (mobile)

Northeast Region Climate Change Toolkit

Find Your Park: César E. Chávez National Monument tells the story of the farm worker movement that established the country's first permanent agricultural union and greatly improved working and living conditions and wages for farm workers.

156 Fwd_ Response Needed_ Final Proofing_ Sea Level...(1).pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Fwd: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Monday, May 01, 2017 2:42:59 PM

Good news from amanda.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Babson, Amanda** <amanda_babson@nps.gov>
Date: Mon, May 1, 2017 at 1:52 PM
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>

Hi Rebecca, I didn't have time for a full check, but I did a check of the three Appendix D table and the NER parks numbers are consistent with the earlier format tables. I did a spot check on other regions and they look good too.
Amanda

On Tue, Apr 25, 2017 at 2:15 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> It's that time for a final check prior to publication of:
>
> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.
>
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>
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>
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> - **Final check by Science and Communication Team Members. (Babson, Cakir, Gallagher, Holly, Norton, Perez, Thieler (USGS))**
> - **If you have edits or will not comment please notify Rebecca.**

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Plan for Release

- Website updates (Matt Holly)
- Rebecca Beavers and Larry Perez will coordinate release plans through Jeff Olson. Two paths forward are 1) internal release and 2) external release.
- **Co-authors/Communication team members: please review/edit these documents** that will be used to guide the release process. https://drive.google.com/open?id=0B2z-WBMLTvtHMXhvZjFaRVZxYXM

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- Final edits to address comments from Ann Gallagher as presented on 4/19 communication team call. (completed 4/24)
- Content check by Maria Caffrey and Rebecca Beavers. (completed 4/25)

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

--
Amanda L. Babson, PhD
Coastal Landscape Adaptation Coordinator
Northeast Region
National Park Service
University of Rhode Island Bay Campus
215 South Ferry Rd.
Narragansett, RI 02882
(401) 874-6015
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157 Re_ Response Needed_ Final Proofing_ Sea Level_...(4).pdf

From: Beavers, Rebecca
To: Rob Thieler
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Thursday, May 04, 2017 1:30:47 PM

Hi RT:

This document is a first opportunity to get a consistent SLR dataset across all coastal parks. The next step is uncertain; largely due to budget uncertainties. Of primary importance is improving on relative land movements

For specific locations (FL, NY, CA, WA, OR, and more) more detailed information has been and will be available into the future. For places such as NW Alaska, there is no major push for more detailed info so next steps are uncertain.

I'm all ears on future opportunities to improve on this work on a park/ region, or other basis.

Thank you for your effort and time to serve on the science team for this project.

-rb

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, May 1, 2017 at 7:46 AM, Rob Thieler <rthieler@usgs.gov> wrote:

> RB,
> Have not had much time to look at this. Gave it a quick scan. Looks ok for what it does — i.e., bathtub model with lower-than-generally-accepted-and-non-probabilistic SLR scenarios. What is the expected lifetime of this document? What's next? There are bodies of literature and newer data and models that could begin to get at this more realistically.
>
> Nice work getting this incremental step done.
>
> ---
>
> **From:** "Beavers, Rebecca" <rebecca_beavers@nps.gov>
> **Date:** Tuesday, April 25, 2017 at 2:15 PM
> **To:** Cat Hawkins Hoffman <Cat_Hawkins_Hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

Cc: Larry Perez <larry_perez@nps.gov>, Janet Cakir <janet_cakir@nps.gov>, Shawn Norton <Shawn_Norton@nps.gov>, "Holly, Matt" <matt_holly@nps.gov>, Amanda Babson <amanda_babson@nps.gov>, Rob Thieler <rthieler@usgs.gov>, Ann Gallagher <ann_gallagher@nps.gov>, "Caffrey, Maria" <maria_a_caffrey@partner.nps.gov>, "Caffrey, Maria" <maria.caffrey@colorado.edu>
Subject: Response Needed: Final Proofing: Sea Level/Strom Surge Report

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> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

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Plan for Release

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- Content check by Maria Caffrey and Rebecca Beavers. (completed 4/25)

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

158 Re_ Response Needed_ Final Proofing_ Sea Level_...(5).pdf

From:	Perez, Larry
To:	Beavers, Rebecca
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Thursday, May 04, 2017 2:36:21 PM

No need for my review at this juncture, Rebecca, but thanks for keeping me in the loop.

-L

On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
>
> Cheers,
> rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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Thank you.

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FIND YOUR PARK

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

159 Re_ Response Needed_ Final Proofing_ Sea Level_...(6).pdf

From:	Hoffman, Cat
To:	Beavers, Rebecca
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Thursday, May 04, 2017 4:57:30 PM

I'll do a last quick review tomorrow/Friday or this weekend.

On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
>
> Cheers,
> rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
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> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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Thank you.

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FIND YOUR PARK

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

161 Re_ Response Needed_ Final Proofing_ Sea Level_...(8).pdf

From: Hoffman, Cat
To: Beavers, Rebecca
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Sunday, May 07, 2017 9:16:01 PM

forgot...

I haven't read the media information, but if you and Larry are compiling this in conjunction with Jeff, I'm sure it's fine.

On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
>
> Cheers,
> rebecca
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
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Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

--

Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

162 Re_ Response Needed_ Final Proofing_ Sea Level_...(9).pdf

From:	Gallagher, Ann
To:	Caffrey, Maria
Cc:	Rebecca Beavers
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Monday, May 08, 2017 9:01:57 AM

I would be delighted to make myself useful to you!

Yours,
Ann

Ann M. Gallagher, M.S.
Science Education Coordinator
ISA Certified Arborist® MA-5484A
Natural Resources & Science, National Capital Region
4598 MacArthur Blvd, NW
Washington, DC 20007
Phone: 202-339-8320
Cell: 202-322-9888
Fax: 202-282-1031

On Mon, May 8, 2017 at 11:00 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> You were a tremendous help to the project!
>
> We will likely roll this out with some regional webinars where we introduce the report and answer any questions folks have. I hope you don't mind if we continue to call on you for help/advice when we get to that stage? You really have a good handle on how people are likely to respond. Your advice has been especially helpful in delivering a product that everyone can understand.
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Mon, May 8, 2017 at 8:49 AM, Gallagher, Ann <ann_gallagher@nps.gov> wrote:
>
>> I hope I was a help to the project!
>>
>> Yours,
>> Ann
>>
>> Ann M. Gallagher, M.S.
>> Science Education Coordinator
>> ISA Certified Arborist® MA-5484A
>> Natural Resources & Science, National Capital Region
>> 4598 MacArthur Blvd, NW
>> Washington, DC 20007
>> Phone: 202-339-8320

Cell: 202-322-9888
Fax: 202-282-1031

On Mon, May 8, 2017 at 10:24 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

Hi Ann,

Thanks for looking this over again. I will make the change you suggested.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Thu, May 4, 2017 at 3:29 PM, Gallagher, Ann <ann_gallagher@nps.gov> wrote:

My only comment this time around applies to this question and answer.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Higher sea level and permanent inundation will change the way waves propagate within a basin in the future. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.

I suggest an example of what is meant by fluid dynamics – wave size, tidal distance…

Yours,
Ann

Ann M. Gallagher, M.S.
Science Education Coordinator
ISA Certified Arborist® MA-5484A
Natural Resources & Science, National Capital Region

4598 MacArthur Blvd, NW
Washington, DC 20007
Phone: 202-339-8320
Cell: 202-322-9888
Fax: 202-282-1031

On Thu, May 4, 2017 at 3:31 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Thank you!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Thu, May 4, 2017 at 1:25 PM, Gallagher, Ann <ann_gallagher@nps.gov> wrote:

Thanks for the reminder. I am looking at the FAQs right now.

Yours,
Ann

Ann M. Gallagher, M.S.
Science Education Coordinator
ISA Certified Arborist® MA-5484A
Natural Resources & Science, National Capital Region
4598 MacArthur Blvd, NW
Washington, DC 20007
Phone: 202-339-8320
Cell: 202-322-9888
Fax: 202-282-1031

On Thu, May 4, 2017 at 3:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

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Cheers,
rebecca

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

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163 RE_ Response Needed_ Final Proofing_ Sea Level_..._1.pdf

From: Rebecca Beavers
To: Hoffman, Cat; Maria Caffrey
Subject: RE: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Monday, May 08, 2017 10:30:53 AM

Cat:

Thank you. See you soon in MN.

Sent from my Verizon Wireless 4G LTE smartphone

-------- Original message --------
From: "Hoffman, Cat" <cat_hawkins_hoffman@nps.gov>
Date: 05/07/2017 9:15 PM (GMT-07:00)
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Maria Caffrey <maria_a_caffrey@partner.nps.gov>
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report

I gave the report a very quick speed-read (sorry I just didn't have time to review in much detail)....it looks good to me. thanks for all the work on this!

On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
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> Cheers,
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FIND YOUR PARK

--

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Adaptation websites: public, NPS managers
Climate Change Response Resources

164 Report is done.pdf

From: Caffrey, Maria
To: Rebecca Beavers
Subject: Report is done
Date: Thursday, May 11, 2017 11:05:00 AM

Rebecca,

I have made the change that Ann suggested. I think that's all of the revisions done. The final document can be found here: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\2017_04 NRSS Layout Reviewed

It is called "Sea Level Change Report_final_fagan_final_May 11.docx"

Cheers,

Maria Caffrey, PhD

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NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

165 Consolidated reviewer comments.pdf

From:	Caffrey, Maria
To:	Rebecca Beavers
Subject:	Consolidated reviewer comments
Date:	Tuesday, May 16, 2017 10:11:55 AM
Attachments:	Consolidated reviewer comments.xlsx

Here are the consolidated comments. A conope of this is also on the n drive under: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\Reviewer edits and comments

Maria Caffrey, PhD

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165 1 Attachment Consolidated reviewer comments.pdf

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
Overall			See word doc	Each con	8/23/16	Beavers
Overall			See PDF	I have ad	9/12/16	Thieler
Overall			See PDF	Each con	10/4/16	Gonzalez
Overall			See PDF	1) This is	11/17/16	Nerem
Overall			See PDF	Each con	11/30/16	Glahn
no page number	2	17	First paragraph of Introduction needs to have at least one sentence introducing this is a report about parks. Maybe mov	Inserted	11/9/16	Babson
4	19	19	Suggest adding "potentially" before "vulnerable".	Done	11/9/16	Babson
4	21	21	Is this rates of sea level change or is it sea level change projections?	Reworde	11/9/16	Babson
5	5	7	Suggest revising to: While the melting of sea ice is problematic from an oceanographic and heat budget perspective (pri	Done	11/9/16	Babson
5	11	12	Suggest moving first sentence of paragraph into previous paragraph. 2nd sentence: not sure if getting into density chang	Done	11/9/16	Babson
7	5	5	Missing word "in" or "for" between "inundation" and "all"	Done	11/9/16	Babson
7	5	5	Suggest adding a a sentence explaining choice of RCPs (e.g. These two represent a plausible range of scenarios between	Done	11/9/16	Babson
7	18	18	Need to make it clear that SLOSH is at current sea level. I would suggest adding to end of first sentence, but you may ha	Done	11/9/16	Babson
9	11	38	Need to add limitations on vertical accuracy of DEMs.	Inserted	11/9/16	Babson
11	Fig. 4		Personal pet peeve - this pie chart conveys remarkably little information. The same point could more effectively be conv	Removed	11/9/16	Babson
11	14	19	Can you give a range of the land level change values you got from the available tide gauges so for places where one is n	Inserted	11/9/16	Babson
12	3	3	Word choice: "per" doesn't totally fit, I guess it's definitionally correct, but would "by" work better? See also subsequen	Changed	11/9/16	Babson
12	Fig. 5		Change to "National Capital" region	Done	11/9/16	Babson
12	27	29	Suggest adding a clause that indicates that it will likely be more than that because of what is known about direction (and	Inserted	11/9/16	Babson
12	37	37	The "above waterline" made me realize that the question of which datums the rise is relative to had not been discussed	Inserted	11/9/16	Babson
14	22	22	grammar - is how an extra word?	Changed	11/9/16	Babson
General grammar			I would suggest a re-write of how you use average as a verb in a lot of places. If I was doing it in track changes, I suggest	No time	11/9/16	Babson
12	Fig. 5 caption		Need to clarify the difference between the standard deviation and the range, you explain it but I didn't have quite enoug	Changed	11/9/16	Babson
14	1	2	Methodologically, this is unsound. I raised this early on, and I thought you were not doing this. Since this has been done	I agree, b	11/9/16	Babson
14	3		Good idea	Ok.	11/9/16	Babson
14	8	9	It's not just classified differently, it that the storm surge behaves highly differently and SLOSH is only designed to model	Changed	11/9/16	Babson
14	10	10	I suggest using "hurricanes" instead of "storms" unless the database captures extratropical storms, then it's ok.	Changed	11/9/16	Babson
14	29	29	Delete "so". Good explanation in following sentence.	Done.	11/9/16	Babson
9	9	9	Suggest adding a sentence (could be here or it could be the first time you should one of the maps) explaining that the SL	Added a	11/9/16	Babson
16	3	3	Word choice: although, suggest deleting	Done	11/9/16	Babson
16	10	20	I'm confused about whether/how you combined SLR and storm surge (maybe my comment on line 20 isn't about you ha	Reworde	11/9/16	Babson
17	3	5	Need a sentence with the explanation that these things aren't additive because storm surge will propagate differently at higher se		11/9/16	Babson
16	3	3	storms should be plural	Done.	11/9/16	Babson
16	2	2	Capitalize Southeast Region	Done.	11/9/16	Babson
16	16	20	This is a great example, would be even better if it included the numbers you estimate that do not include land level char	Inserted	11/9/16	Babson
Big picture			In Introduction, it would be helpful to explain types of planning sea level rise info and storm surge info can inform, sepa	Come ba	11/9/16	Babson
17	9	9	I have trouble with talking about "ranking". I think your point here is a good one, but by raising that term it makes me th	reworde	11/9/16	Babson
16	10	11	Here I am confused again. The way this is written I expect the figure (or something) to show combined SLR & storm surg	removed	11/9/16	Babson
17	23	23	Because it's now so developed? And/or because sea level is higher?	inserted	11/9/16	Babson
17	25	25	I suggest adding a sentence that states what the SLR projections are for NCR parks.	Added "T	11/9/16	Babson
18	6	10	This seems like an awful lot of text to devote to a park that shouldn't have been included as coastal in the first place. Su	This was	11/9/16	Babson
18	17	17	Suggest changing from "could be nominated for a study of this nature" to are subject to sea level change.	Changed	11/9/16	Babson

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
19	16	17	Really interesting point - it may be worth mentioning that in the front section, that SLOSH does not look at impacts due	No time	11/9/16	Babson
19	20	20	Figure 12 caption: should this be Intermountain Region?	Yes, char	11/9/16	Babson
20	15	15	I'm confused about standard deviation again (could be fixed by clarification of my comment on row 19	Changed	11/9/16	Babson
20	17	17	See my earlier comment about "tied"	Changed	11/9/16	Babson
21	5	15	Can you say something in the first sentence that's less about modeling and more about whether parks in the Pacific Nor	Inserted	11/9/16	Babson
22	2	2	Change do to does	Done	11/9/16	Babson
23	19	19	word choice: results section does not back up "catastrophic"	Changed	11/9/16	Babson
23	23	23	Instead of "if combined with a storm surge", I suggest "if the dynamic landforms are not able to keep pace with such hig	Changed	11/9/16	Babson
23	25	26	Also p. 13 line 1: What are the sea level rise maps? Is Fig. 2 an example of these and the whole slate of them is linked to	Pointed t	11/9/16	Babson
23	14	16	Really key sentence - I'd suggest bringing that up to the start of the discussion. Word choice on regions - it may be confu	Changed	11/9/16	Babson
3	Fig. 1		One summary figure that would be amazing and important to have is your own equivalent of Fig. 1, make a dot for each	No time	11/9/16	Babson
23	34	36	I read the Sallenger paper differently than you are describing it here. The storm surge is not what's causing the hotspot.	Reworde	11/9/16	Babson
23	36	40	Here's my confusion again - if you've mapped these things, why aren't you including the figure? If I knew what you were	Removed	11/9/16	Babson
24	25	25	Re-write to clarify so that storm surge is not before due to anthropogenic climate change. Do the same p.25, line 1	Removed	11/9/16	Babson
24	26	31	To follow up on my previous comment about "ranking", I think you want to highlight conclusions about how most (exclu	Deleted	11/9/16	Babson
24	32	32	Word choice: instead of "unique" I suggest "locally-specific"	Done	11/9/16	Babson
25	2	3	This may be incorrect due to confusion on this issue, but is it possible what you mean to say is "by providing both sea le	Done	11/9/16	Babson
A-1	8		Need to include an explanation of the the various layers and key meta-data here.	This has	11/9/16	Babson
B-1	9		Need to include an explanation of the categories of hurricane, methods on mean and high tide and key meta-data here.	This has	11/9/16	Babson
C-1	7		Suggest adding a sentence about guidance provided to include parks that have a shoreline as well as within a non-specif	Not sure	11/9/16	Babson
C-2	2		See earlier comment about datums, at that point and here needs an explantation of what NAVD88 is. Here (and potentia	Done	11/9/16	Babson
C-2	15		after factors, I suggest adding: including risk tolerance and expected time horizon of the project	Done	11/9/16	Babson
C-2	20	24	Need to add a discussion on the accuracy of the vertical data that is the base of the maps (here as well as where I indica	Done.	11/9/16	Babson
C-2	26	32	I thought MOMs are maximums, not average. Isn't it a worst case scenario? Or is it an average of worst case scenarios?	Clarified.	11/9/16	Babson
C-3	7	11	This is so important, but it was not clear in body of report that you do not recommend adding them together, since you	Discusse	11/9/16	Babson
C-4	1		word choice: change destroyed to damaged	Done	11/9/16	Babson
C-4	1	5	Suggest adding: increased erosion	Done	11/9/16	Babson
C-4	2		did you mean "buried"?	Changed	11/9/16	Babson
D-1			General thought on the waysides: I expected to have the waysides include the SLR projections and storm surge maps. I t	It would	11/9/16	Babson
E-1			Great to see that you have rates of subsidence for all parks but two. Text in the Methods needs to be clear that subsider	This got	11/9/16	Babson
Overall			This is a very well-written report: your methods and results are easy to follow, and appropriate "side boards" are placed	on releva	12/13/16	Perez
1	22	24	It should be noted that estimates from Aerts et al. are specific to NYC. Also, this sentence is a bit wonky: t sets up an imp	Inserted	12/13/16	Perez
1	31	31	Reword 2 to read something like "show how storm surge generated by hurricanes…"	Inserted	12/13/16	Perez
2	4	4	Change page number to "ix"	Done	12/13/16	Perez
2	Figure 1		Recommend increasing the size of the figure enough to make the credit line in the lower left corner legible	Moved to	12/13/16	Perez
3	23	23	From "...find out more information..." to "learn"	Done	12/13/16	Perez
4	3	4	To keep the subject of both paragraphs cosistent and clear, consider swapping the final phrase of line 3 with the openin	Done	12/13/16	Perez
4	1	7	Consider shortening statements regarding the implication of sea-ice into a single, succinct paragraph, and move mentior	Consolid	12/13/16	Perez
4	Table 1		Unless this table is reference elsewhere (perhaps to demonstrate the increasing rate of rise) it is a poor tool for illustrati	It is cited	12/13/16	Perez
8	7	15	The question could be asked (and probably should be addressed): why did we filter historic storm intensity using only a	This is so	12/13/16	Perez
8	25		inputted or "imported", perhaps?	Changed	12/13/16	Perez
9	32	33	Recommend rewording to: "Changes in various land-based loadings on the continents—such as ice sheets during the las	Changed	12/13/16	Perez

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
9	34	35	This line is also a bit confusing: post-glacial isostatic rebound is the result of pressure being removed from the earth's cr	Reworde	12/13/16	Perez
12	2		Currently, it looks like this is being made available only in Appendix A.	Changed	12/13/16	Perez
12	3		Appendix D?	Changed	12/13/16	Perez
13-Dec			Currently, the sea level change data for regions is rolled out/discussed in this order: 2100, 2030, 2050. For reader clarity, I recomm		12/13/16	Perez
15	13	14	recommend: "...path passed present-day Boston National..."	Done	12/13/16	Perez
16	5		recommend: "...indicate the potential height and extend of storm surge generated by..."	Did not c	12/13/16	Perez
16	6	7	In reading this, it occurs to me that additional caveats might be necessary (i.e. a nod to the influence of storm direction.)	Given SL	12/13/16	Perez
23	17		Change "then" to "the"	Done	12/13/16	Perez
23	35		I defer to better knowledge, but would suspect that it is more accurate to say: "...discussed how changes in ocean circula	Amanda	12/13/16	Perez
24	3		change "regions" to "region"	Done	12/13/16	Perez
24	7		change "as energy" to "energy"	Done	12/13/16	Perez
viii	3	3	and the potential for	Done	12/14/16	Gallagher
viii	5	5	present ~~many~~ challenges	Done	12/14/16	Gallagher
viii	19	19	bathtub - should be defined in the abstract for readers who never go further	Changed	12/14/16	Gallagher
viii	24	24	Region is ~~also~~ projected	Done	12/14/16	Gallagher
ix	24	25	The North American land surface is still returning to equilibrium after the melting of this continental ice.	Done	12/14/16	Gallagher
1	5		"If human" - even if we don't stop we will continue to warm but if we do stop then the warming will not be as extreme	Reworde	12/14/16	Gallagher
1	8	8	sea levels to continue to rise	Done	12/14/16	Gallagher
1	22	22	amount change to cost and end the sentence with "be extreme; extreme storms have extreme costs.	Done	12/14/16	Gallagher
1	23	23	Concern: Will the general reader know that 1/100 is rare while 1/500 is even more rare? Maybe a modifier here would h	I think th	12/14/16	Gallagher
1	38	1	Funding change to "The scope of this project was limited to sea levels. Even though interior waterways and lakes, espec	Done	12/14/16	Gallagher
2	11	12	Furthermore, sea-level rise refers only to rising water levels resulting..."	Done	12/14/16	Gallagher
3	3	3	Alaska is ~~also very~~ tectonically...	Done	12/14/16	Gallagher
4	3	3	I'm not sure the general reader is familiar with albedo - please define	Changed	12/14/16	Gallagher
4	4	5	If you write: Melting sea ice is not a cause of sea-level rise. The volume of water in the sea remains the same whether th	I think I c	12/14/16	Gallagher
4	8	8	As ocean waters warm, the density of these waters - clarify density here. The warmer waters have a lower density than	I think th	12/14/16	Gallagher
Overall			See PDF	This was	12/15/16	Tebaldi
3	18	20	Mentions the SLOSH modeling used but not the Tebaldi et al, 2012 data that is mentioned later for West Coast.	Tebaldi h	1/11/17	Marcy
5	23	24	Is this the NOAA method used for their SLR viewer? Potenially site the mapping method used. Marcy, D., Brooks, W., Draganov, K., Hadley, B., Haynes, C., Herold, N., McCombs, J., Pendleton, M., Ryan, S., Schmid, K., Sutherland, M., and Waters, K. (2011) New Mapping Tool and Techniques for Visualizing Sea Level Rise and Coastal Flooding Impacts. Solutions to Coastal Disasters 2011: pp. 474-490. doi: 10.1061/41185(417)42	This is ju	1/11/17	Marcy
3	33	whole section	Im sure you may get this question from other reviewers. Why use the lower IPCC estimates of SLR that really don't take into account more aggressive ice melt scenarios. Most Federal Agencies are/or have agreed to use the Parris et al, 2012 (input to the 3rd National Climate Assessment) scenarios or at least other similar scenarios such as the NRC west coast scenarios or the USACE scenarios. Also these have been used by DOD more recently and updated in their Coastal Assessment Regional Scenario Working Group (CARSWG). https://www.serdp-estcp.org/content/download/38961/375873/version/3/file/CARSWG+SLR+FINAL+April+2016.pdf The FEMA TMAC future conditions mapping report points to these scnenarios as does the E.O. 13690 - Federal Flood Risk Management Standard (FFRMS) - Climate Informed Science Approach.	This has	1/11/17	Marcy

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
3	33	whole section	It is not very clear if local subsidence was taken into account for all of these sites? The SLR scenarios should be based on locals relative sea level rise. At the very least, choosing closest tide gauge and using the USACE SLR Calculator would result in more accurate local scenarios if you were to use the NCA scenarios, or just use the subsidence values in the equations to extrapolate future sea level rise. I fear not taking into account local subsidence will result in number too low for the future scenarios.	This is di	1/11/17	Marcy
3	33	whole section	The highest SLR scenario used is the RCP 8.5 by 2100 which only estimates ~0.8m of Sea Level Rise. The upper end of the NCA3 scenarios was 2.0m and the NCA4 range is likley to go up to 2.5m for the 2100 worse case RCP 8.5 scenario. I think your SLR estimates are too low for future planning.	Ok. This	1/11/17	Marcy
6	15	whole section	Please check the descriptions of the P-Surge, MEOWS, and MOMs. P-Surge is used for probabalistic real-time runs during landfalling storms and produces an exceedence probablilty. The MEOWS and MOMS in the SLOSH display program were not derived from P-Surge and have no probability associated with them. The MEOWS are a worst case basin snapshot for a particular storm category, forward speed, trajectory, and initial tide level, incorporating uncertainty in forecast landfall location. These products are compiled when a SLOSH basin is developed or updated. MEOWs are not storm specific and are available to view in the SLOSH display program for all operational basins. No single hurricane will produce the regional flooding depicted in the MEOWs. Instead, the product is intended to capture the worst case high water value at a particular location for hurricane evacuation planning. MOMS provide a worst case snapshot for a particular storm category under "perfect" storm conditions. Each MOM considers combinations of forward speed, trajectory, and initial tide level. These products are compiled when a SLOSH basin is developed or updated. As with MEOWs, MOMs are not storm specific and are available to view in the SLOSH display program for all operational basins. No single hurricane will produce the regional flooding depicted in the MOMs. Instead, the product is intended to capture the worst case high water value at a particular location for hurricane evacuation planning. The MOMs are also used to develop the nation's evauation zones. Long story short is that MOMS are used for worse case evacuation planning and are not in any way related to the 100 year or 1% chance storm and thus should not be compared to the Tebaldi et al, 2012 numbers.	This has	1/11/17	Marcy
6	15	whole section	Using MOMs can be problematic because in the SLOSH display program there are often mean tide and high tide runs, but the various basins ran different amounts of tide and different tide scenarios, based on what the State Partners wanted modeled for their state Hurricane Evacuation Study. Also where basins overlap there will be non-matching values. Choosing the correct basin value is often a judgement call. NHC has recently put out a National MOM product and they are working on a version 2 and they plan to make the GIS data available. I suggest you contact NHC and try to access this data to improve your study results. http://noaa.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=b1a20ab5eec149058bafc059635a82ee http://www.nhc.noaa.gov/news/20141106_pa_natlSurgeMap.pdf	This goes	1/11/17	Marcy
9	9	10	Tebaldi uses MHW to reference the extreme surge values…and the mapping for the SLR projections was relateive to MHHW. Make sure datums are consistent.	Ok	1/11/17	Marcy
9	16	16	SLOSH uses a multiple scenario approach…not probabalistic.	Changed	1/11/17	Marcy
10	31	36	The Storm surge layers were not in the map viewer. I could not find where to download the GIS data. Also I noticed the maps for the high SLR scenario for RCP 8.5 are comparible to the NOAA SLR viewer maps for around 2FT above MHHW. I think this is too low of a scenario for 2100 planning. We have reached 2FT above MHHW during high frequency king tide / perigean tide events in Charleston, SC.	See prev	1/11/17	Marcy
12	11	27	Figure 4. Does this include the Gulf Coast? Seems like the number should be much higher in the Gulf based on the very high SLR trends in Louisiana vs. the East Coast.	The Gulf	1/11/17	Marcy

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
22	12	whole section	Discussion: need to add a description of the difference between using SLOSH MOMs worse case scenarios and Tebaldi numbers for West Coast. These really are not comparible. The Tebaldi numbers are based on the work of NOAA (Zervis) which are based on 1% water levels at the tide gauges. These numbers will also not match FEMA coastal flood studies because wave effects are not included. The SLOSH MOMs are often way higher than the 1% flood. For example, in Charleston, SC the 1% chance water level at the Charleston tide gauge is ~7.5FT. The category 1 MOM is that high. Going out to Cat 2-5 will produce surge value way above the 1% chance. So comparing SLOSH vs. Tebaldi numbers isn't really valid. One is based on probalistic analysis of historical data and the other is on 4500 or so scenario runs and having a cumlative peek value. In many cases in the east and gulf coast the 1% chance FEMA BFE is only a Cat 1 to Cat 2 MOM value.	Inserted	1/11/17	Marcy
6	15	mapping	How were the SLOSH results mapped? There are methods out there from the USACE for doing this for HES studies. http://www.northerngulfinstitute.org/impact/resources/inundationWorkshop/scott.pdf	This will	1/11/17	Marcy
Datums			SLR mapping was done using MHHW but was that converted to NAVD88 to match the DEMs? Just wanting to make sure all the map legend values are showing correct height relative to the same datum for both sets of maps.	Yes.	1/11/17	Marcy
Overall			See PDF	Each con	1/26/17	Hoffman
viii	3	3	and the potential for	Done	1/4/17	Gallagher
viii	5	5	present many challenges	Done	1/4/17	Gallagher
viii	19	19	bathtub - should be defined in the abstract for readers who never go further	Changed	1/4/17	Gallagher
viii	24	24	Region is also projected	Done	1/4/17	Gallagher
ix	24	25	The North American land surface is still returning to equilibrium after the melting of this continental ice.	Done	1/4/17	Gallagher
1	5		If human - even if we don't stop we will continue to warm but if we do stop then the warming will not be as extreme		1/4/17	Gallagher
1	8	8	sea levels to continue to rise		1/4/17	Gallagher
1	22	22	amount change to cost and end the sentence with "be extreme; extreme storms have extreme costs.		1/4/17	Gallagher
1	23	23	Concern: Will the general reader know that 1/100 is rare while 1/500 is even more rare? Maybe a modifier here would help.		1/4/17	Gallagher
1	38	1	Funding change to "The scope of this project was limited to sea levels. Even though interior waterways and lakes, especially the G		1/4/17	Gallagher
2	11	12	Furthermore, sea-level rise refers only to rising water levels resulting..."		1/4/17	Gallagher
3	3	3	Alaska is also very tectonically...		1/4/17	Gallagher
4	3	3	I'm not sure the general reader is familiar with albedo - please define		1/4/17	Gallagher
4	4	5	If you write: Melting sea ice is not a cause of sea-level rise. The volume of water in the sea remains the same whether the water is		1/4/17	Gallagher
4	8	8	As ocean waters warm, the density of these waters - clarify density here. The warmer waters have a lower density than cold wate		1/4/17	Gallagher
1 (Introduction)	1		Since you have chosen the IPCC projections over the semi-empirical approach, you should probably briefly mention that	Inserted	1/4/17	Zervas
2	18 (Figure caption)	18	Substitute 'for 2015' with 'using all available data including 2015'	Done	1/4/17	Zervas
2	19 (Figure caption)	19	Cross out 'relative to global mean sea level'. A trend is not relative to any level.	Done	1/4/17	Zervas
4	6	6	Substitute 'ice wholly contained within water and not supported by land' with 'ice wholly supported by water'	Done	1/4/17	Zervas
4	19	28	This paragraph is another place to note that the semi-empirical approach can result in projected levels over twice as hig	Inserted	1/4/17	Zervas
21	37	40	This is an important point. Most of southern Alaska is rising rapidly with spatially and temporally variable rates. Therefo	Thanks	1/4/17	Zervas
Overall			See PDF	Each con	Not sure	Beavers, Schupp, Babson combined.
Overall			See word doc	Each con	3/17/17	Schupp
Overall			Multiple edits suggested over google drive	Accepted	3/20/17	Gonzalez
Overall			Hi Rebecca, I know you love 12th hour typo edits, but I was just looking at the report and noticed that Stanton's name is	Done	4/21/17	Babson
Overall			See PDF	Every cha	4/24/17	Johnson

Page Number(s)	Line Number Beginning	Line Number Ending	Reviewer Comment	Commen	Date Edit	Reviewer
Appendix B			My only comment this time around applies to this question and answer. Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers? A. Higher sea level and permanent inundation will change the way waves propagate within a basin in the future. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.	Done	5/4/17	Gallagher

167 Fwd_ Sea Level Storm Surge Report.pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Sea Level Storm Surge Report
Date:	Friday, May 19, 2017 10:34:41 AM

Can you check the report citations (again?)

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
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---------- Forwarded message ----------
From: **Cakir, Janet** <janet_cakir@nps.gov>
Date: Fri, May 19, 2017 at 10:13 AM
Subject: Sea Level Storm Surge Report
To: Rebecca Beavers <rebecca_beavers@nps.gov>

Hi Rebecca,
FYI - this report is great, I wanted to let you know I just noticed a couple of missing citations (Nerem was one), so you might want to see if someone can comb through the report if it isn't finalized.

Janet

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~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Janet Cakir Ph.D.
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South Atlantic Landscape Conservation Cooperative
1751 Varsity Dr.
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office: (919) 707-0288
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www.southatlanticlcc.org
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

168 Re_ Sea Level Storm Surge Report.pdf

From:	Beavers, Rebecca
To:	Cakir, Janet
Subject:	Re: Sea Level Storm Surge Report
Date:	Friday, May 19, 2017 10:35:08 AM

We'll check them!

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, May 19, 2017 at 10:13 AM, Cakir, Janet <janet_cakir@nps.gov> wrote:

> Hi Rebecca,
> FYI - this report is great, I wanted to let you know I just noticed a couple of missing citations (Nerem was one), so you might want to see if someone can comb through the report if it isn't finalized.
>
> Janet
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> --
> ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

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www.southatlanticlcc.org

169 Answers about climate projections and flooding,....pdf

From:	Patrick Gonzalez NPS
To:	Marcy Rockman
Subject:	Answers about climate projections and flooding, for upcoming Preservation Brief workshops
Date:	Friday, May 19, 2017 11:50:40 PM
Attachments:	NPS sea level draft.pdf

Hi Marcy,

Maria Caffrey and colleagues have conducted spatial analyses of sea level rise and storm surge for coastal national parks. I've attached for you a draft of the report. She provides quantitative results by individual park. The method is the same for all the parks.

NOAA has conducted spatial analyses of sea level rise for the entire U.S.:

NOAA Sea level rise viewer
https://coast.noaa.gov/slr

and coastal flood exposure for the east coast:

Coastal Flood Exposure Mapper
https://coast.noaa.gov/floodexposure/#/map

The NPS and NOAA results certainly go beyond the old FEMA flood maps. Maria's spatial outputs are broadly similar to the NOAA outputs, but Maria used the IPCC scenarios, while NOAA used non-standard U.S. scenarios.

I hope that your presentations go well for you!

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
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....

....

From: "Rockman, Marcia (Marcy)" <marcy_rockman@nps.gov>
Subject: question about climate projections and flooding, for upcoming Preservation Brief workshops
Date: May 18, 2017 at 10:28:38 AM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hi Patrick,

This is probably an enormous question - are there models or sources of data or approaches you would recommend for a state agency wanting to get a better understanding of future flood risks?

Perhaps in other words - sources of data or analysis beyond the FEMA flood risk maps?

Reason for asking - Cultural Resources Technical Preservation Services/State Tribal Local Planning and Grants programs are in the process of developing a new Preservation Brief that will provide guidance and standards for historic property owners who are planning or required to elevate those historic buildings. We're now preparing to do a series of three workshops in different parts of the country to listen to and work with State Historic Preservation Offices, as part of testing and collecting info that will go into the Brief.

I've been asked to give a climate change introduction for each workshop - with the general theme of how climate change is contributing to flood risk and sea level rise, and making the point that these risks are not going away, and that threats that pose these risks are likely to become more unpredictable.

I have some understanding of how NPS has been trying to track and model sea level rise (Maria Caffrey's work, Rob Young's team, for example). But as the nature of flooding risk can be highly specific to individual locations, I don't really have sense of what NPS is doing overall to capture it. So -- I guess that's my real question - do we have a method overall? Or have we been assessing it on a park-by-park basis?

I'd be grateful for thoughts or suggestions you might have. I need to send a set of slides off to the rest of the team by end of next week (26th), so if you're able to send on thoughts before then, that would be great.

Thank you so much,
Marcy

Marcy Rockman, PhD, RPA
Climate Change Adaptation Coordinator for Cultural Resources
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169 1 Attachment NPS sea level draft.pdf

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

ON THIS PAGE
Driftwood washed up on the shoreline of Redwood National Park, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

ON THE COVER
Fort Point National Historic Site and the Golden Gate Bridge, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

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April 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available in digital format from the Climate Change Response Program website and the Natural Resource Publications Management website. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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NPS 999/137852, April 2017

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Photo 1. Looking out towards the Gulf of Mexico from Fort Jefferson, Dry Tortugas National Park. Photo credit: Used with permission from Rachel Sullivan Photography.

Executive Summary

Changing relative sea levels and the potential for increasing storm surges due to anthropogenic climate change present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Within the National Park Service, the National Capital Region is projected to experience the highest average rate of sea level change by 2100. The coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is projected to experience the highest storm surges based on historical data and NOAA storm surge models.

These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

Photo 2. Basement flooding in the visitor center at Rosie the Riveter WWII Home Front National Historical Park. This photograph was taken on December 5, 2012 —12 years after the establishment of the park. Photo credit: Maria Caffrey.

Acknowledgments

This project was awarded funds through the NPS Servicewide Comprehensive Call (FY2013–2015) and augmented by funds from the Natural Resource Stewardship and Science Directorate's Geologic Resources Division and Climate Change Response Program. We would like to thank the members of the communication advisory team (Rebecca Beavers, Lynda Bell, Maria Caffrey, Janet Cakir, Will Elder, Stanton Enomoto, Ann Gallagher, Matt Holly, Shawn Norton, Larry Perez, and Ryan Stubblebine) and science advisory team (Amanda Babson, Rebecca Beavers, Maria Caffrey, Patrick Gonzalez, Steve Nerem, and Rob Thieler) for their time and input into this project.

We would also like to thank Susan Teel and Caroline Rohe at Gulf Islands National Seashore for assistance in designing two wayside exhibits. Likewise, we thank Julie Whitbeck, Aleutia Scott, Kristy Wallisch, and Stacy Meyers for helping design, review, and install a wayside at Jean Lafitte National Historical Park and Preserve. Elizabeth Rogers and Kathy Krause helped design a wayside for Fire Island National Seashore. Doug Wilder, Dorothy Friday, and Neal Jander designed the online map viewer. We would also like to thank Jason Kenworthy, Rebecca Port, Michael Barthelmes, Bob Glahn, Doug Marcy, Chris Zervas, and Claudia Tebaldi for their assistance in editing and reviewing this document. Finally, we thank the National Oceanic and Atmospheric Administration for and the Intergovernmental Panel on Climate Change for providing the respective storm surge and sea level rise data cited throughout this document.

List of Terms

The following list of terms are defined here as they will be used in this report.

Bathtub model: A simplification of the sea as bathtub of water to simulate a change in water level relative to the land. This model does not include other factors such changes in erosion or accretion that change alter the geometry of the coastline.

Flooding: The temporary occurrence of water on the land.

Inundation: The permanent impoundment of water on what had previously been dry land.

Isostatic rebound: A change in land level caused by a change in loadings on the Earth's crust. The most common cause of isostatic rebound is the loading of continental ice during the Last Glacial Maximum in North America. The North American land surface is still returning to equilibrium after the melting of this continental ice in an effort to return to equilibrium with its original pre-loading state.

National Park Service unit: Property owned or managed by the National Park Service.

Relative sea level: Where the water level can be found compared to some reference point on land. This term is most frequently used in discussion of *changes* in relative sea level. A change in relative sea level could be caused by a change in water volume or a change in land level (or some combination of these two factors).

Sea level: The average level of the seawater surface.

Sea level change: This term is frequently used in reference to *relative* sea level change. This is the product of two main factors, 1) an increase in the volume of ocean water, and 2) a change in land level. These two factors can be broken down further into other drivers that will be discussed in greater detail in other sections. This term is sometimes mistakenly confused with the term *sea level rise*.

Sea level rise: An increase in sea level. This is the result of an increase in ocean water volume caused principally by melting continental ice and thermal expansion. This term is not to be confused with increasing *relative* sea level, which can also be caused by decreasing land levels.

Introduction

Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2009, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Human activities continue to release carbon dioxide (CO_2) into the atmosphere, causing the Earth's atmosphere to warm (IPCC 2013, Mearns et al. 2013, Melillo et al. 2014). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

This report provides estimates of sea level change due to climate change for 118 National Park Service units and estimates of storm surge for 79 of those units. As temperature increases, sea levels rise due to a number of factors that will be discussed in greater detail. As sea levels incrementally rise, periods of flooding caused by storms and hurricanes exacerbate the growing problem of coastal inundation (see list of terms). Peek et al. (2015) estimated that the cost of sea level rise in 40 National Park Service units could exceed $40 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks.

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to anthropogenic climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2−5 billion and a 500 year storm surge could cost $5−11 billion (Aerts et al. 2013). Under future scenarios of increasing anthropogenic greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline. Increasing sea levels increase the likelihood of another Hurricane Sandy-sized storm surge striking New York City. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

Format of This Report

This report contains five sections (introduction, methods, results, discussion, and conclusion), and presents results per park alphabetically by region. The 118 park units studied for this project cover six administrative regions: the Northeast, Southeast, National Capital, Intermountain, Pacific West, and Alaska. The scope of this project focuses on sea levels. The scope of this project did not include projected changes in lake levels, although interior waterways and lakes, especially the Great Lakes, are vulnerable to the effects of climate change. Further explanation on how to access the data from this project is available in the methods sections and accompanying appendices.

Frequently Used Terms

Definitions of the most basic terms used in this report occur on page ix. However, some terms require greater explanation for their use. For example, we follow the advice of Flick et al. (2012) in differentiating between the terms *flooding* and *inundation*. While many choose to use these terms interchangeably, we use the term "flooding" to describe the temporary impoundment of water on land. This usually results from storm activity and other short-lived events, such as periodic tidal action, and will therefore be used here in reference to the effects of a storm surge on land. "Inundation" is used to refer to the gradual permanent submergence of land that will occur due to sea level rise.

The terms sea level rise and sea level change are also used differently. Sea level rise refers only to rising water levels resulting from an increase in global ocean volumes. In most parts of the United States this increase in water volume will lead to increasing relative sea levels. However, in some parts of the country relative sea level is *decreasing* due to isostatic rebound. Figure 1 shows current sea level trends based on tide gauge records for United States that span at least 30-years of data.

For example, the Southeast Region of Alaska is experiencing a decrease in relative sea level. Alaska's crust continues to rebound following the melting of large volumes of ice that occurred for centuries to millennia on land in the form of glaciers and ice fields. Alaska is tectonically complex with extensive faults that contribute to this crustal motion. Although the volume of ocean water in this region is increasing, the rate of sea level rise is less than the rate of isostatic rebound, resulting in a decrease in relative sea level. For this reason, we use the term "sea level change" as it includes regions that will experience a decrease in relative sea level (at least in the early part of this century) as well as those that will see increasing relative sea levels.

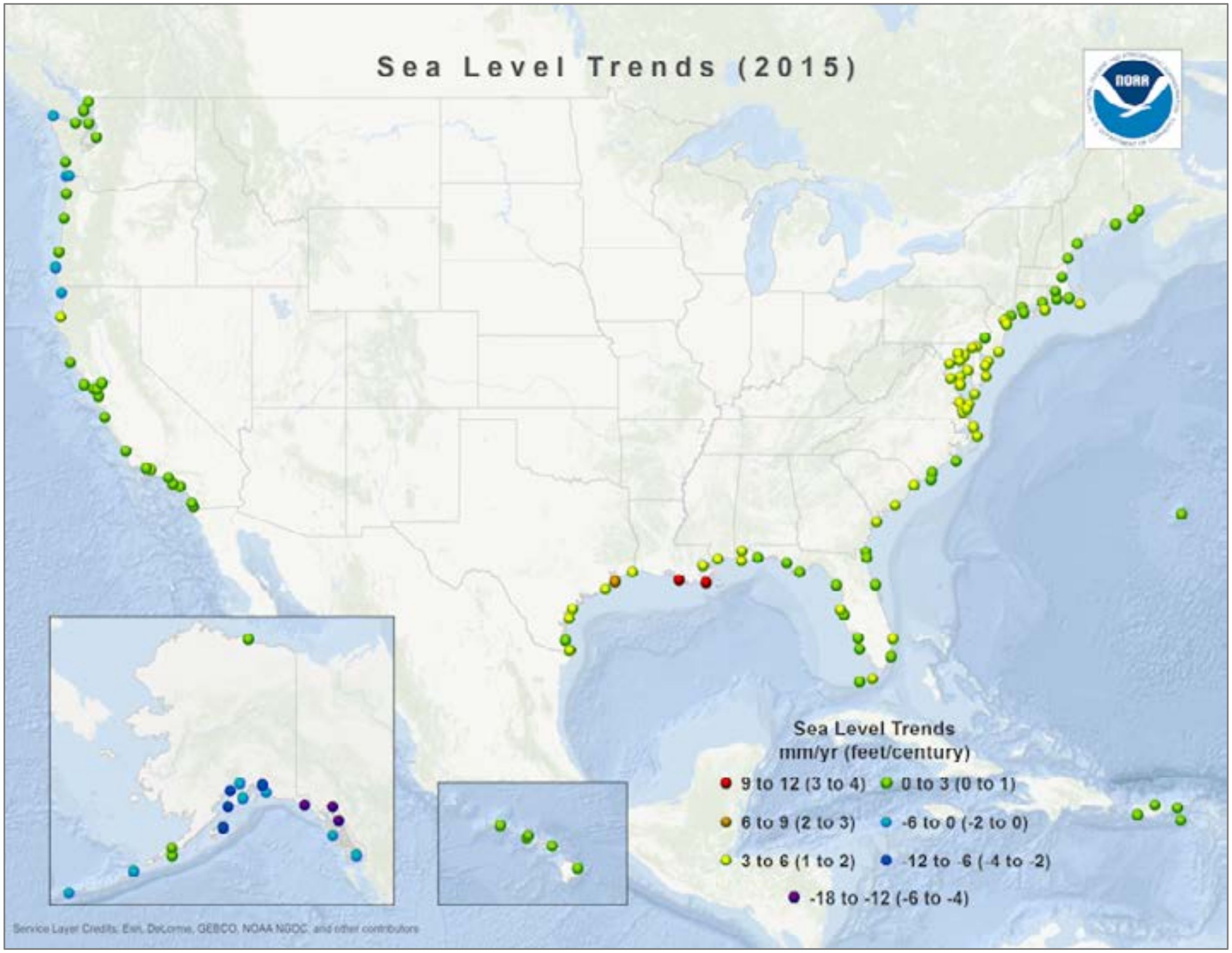

Figure 1. Sea level trends for the United States based on Zervas (2009), for all available data through 2015. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change. Stations depicted by yellow to red dots are experiencing greater than the global average (primarily driven by regional subsidence) and blue to purple dots are stations experiencing less than the global average (due to isostatic rebound or other tectonically-driven factors). Source: https://tidesandcurrents.noaa.gov/sltrends/slrmap.htm

Methods

This report summarizes work of a three-year project initiated in 2013, analyzing sea level change in 118 National Park Service units. Consultation with regional managers regarding units they considered to be potentially vulnerable to sea level change and/or storm surge resulted in selection of these 118 coastal park units (Appendix B). Project activities included the following:

1) Prepare sea level projections over multiple time horizons for each park unit.
2) Estimate potential exposure to storm surge using the National Oceanographic and Atmospheric Administration (NOAA) Sea, Lake, and Overland Surge from Hurricanes (SLOSH) Model and Tebaldi et al. (2012).
3) Create wayside exhibits[1] with information about the impacts of climate change in the coastal zone for three National Park Service units.

Based on recommendations from regional personnel, three National Park Service units were selected as sites for wayside exhibits: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore. The finished wayside designs are in Appendix C. Each design is different, customized to reflect the messaging and/or themes of each unit.

Sea Level Rise Data

Sea level rise is caused by numerous factors. As human activities release CO_2 and other greenhouse gases into the atmosphere, mean global temperatures increase (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). Rising global temperatures cause ice located on land and in the sea to melt. The melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise.

While the melting of sea ice is problematic from an oceanographic and heat budget perspective (primarily because it alters water temperatures and salinity and also because it changes the reflectance of solar energy from the surface), melting sea ice does not cause sea level rise. It is the melting of ice that is currently stored on land that raises global sea levels. Water level does not change when sea ice (ice wholly supported by water) melts. The volume of water in the sea remains the same whether it is frozen or liquid. The phase shift of water from solid to liquid does not displace an additional volume of water.

As ocean waters warm, the density of these waters also changes, causing thermal expansion. Thermal expansion was responsible for two-fifths of sea level rise from 1993 to 2010, while melting ice accounted for half (IPCC 2013). Table 1 lists the contribution to sea level rise from several key sources.

---

[1] A wayside is an exhibit designed to be installed outside for visitors to learn about a particular subject (https://www nps.gov/hfc/products/waysides/).

Table 1. Observed global mean sea level budget (mm/y) for multiple time periods (IPCC 2013).

Source	1901–1990	1971–2010	1993–2010
Therma expans on	n/a	0.08	1.1
G ac ers except n Green and and Antarct ca[a]	0.54	0.62	0.76
G ac ers n Green and	0.15	0.06	0.10[b]
Green and ce sheet	n/a	n/a	0.33
Antarct c ce sheet	n/a	n/a	0.27
Land water storage	-0.11	0.12	0.38
Total of contributions	**n/a**	**n/a**	**2.80**
Observed	**1.50**	**2.00**	**3.20**
Residual[c]	**0.50**	**0.20**	**0.40**

[a]Data unt 2009, not 2010.

[b]Th s s not nc uded n the tota because these numbers have a ready been nc uded n the Green and ce sheet.

[c]Th s s ca cu ated as observed g oba mean sea eve r se – mode ed g ac ers – observed and water storage. See tab e 13.1 n IPCC (2013) for more deta s.

The IPCC sea level rise projections used in this analysis follow a *process-based model* approach, which estimates sea level based on the underlying physical processes. This contrasts with *semi-empirical* models that combine past sea level observations with other variables or theoretical considerations, including, in some cases, expert opinion (surveys or interviews of professionals) (Rahmstorf 2010, Orlic and Pasaric 2013). Often the semi-empirical approach yields higher sea level estimates. IPCC (2013) uses coupled atmosphere-ocean general circulation models (AOGCMs) to simulate the processes of change rather than the statistical inferences of the semi-empirical approach. AOGCMs are considered a process-based technique, although some variables derive from semi-empirical methods (IPCC 2013).

Sea level rise estimates for 2050 and 2100 were taken directly from the IPCC (2013) regional climate models (RCMs) downscaled to a spatial grid resolution of 1˚ x 1˚ from AOGCMs. Because many park units require estimates for shorter time horizons that fit more closely with the expected lifetime of various projects, sea level rise projections for 2030 were calculated using IPCC RCM data for each sea level rise driver shown in Table 2, interpolated to 2030 for each RCP. All projections are reported relative to the period 1986–2005 (see Appendix B for further discussion). All geographic information systems (GIS) maps display the projected sea level on top of mean higher-high water (MHHW) using the most recent tidal datum epoch (1983–2001). MHHW is calculated by averaging the highest daily water level over a 19-year tidal datum epoch.

Table 2. Median values for projections of global mean sea level rise and contributions of individual sources, for 2100, relative to 1986-2005, in meters (IPCC 2013).

Source	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Therma expans on	0.15	0.20	0.22	0.32
G ac ers	0.11	0.13	0.14	0.18
Green and ce sheet surface mass ba ance[a]	0.03	0.05	0.05	0.10
Antarct c ce sheet surface mass ba ance	-0.02	-0.03	-0.03	-0.05
Green and ce sheet rap d dynam cs	0.04	0.04	0.04	0.05
Antarct c ce sheet rap d dynam cs	0.08	0.08	0.08	0.08
Land water storage	0.05	0.05	0.05	0.05
Sea level rise	**0.44**	**0.53**	**0.55**	**0.74**

[a]Changes n ce mass der ved through d rect observat on and sate   te data.

The standard error (σ) for each site estimate was not calculated because it was beyond the scope of this project. However, it can be calculated using the following equation and data available from the IPCC (2013, supplementary material):

Eq 1. $$\sigma_{tot}^2 \quad \left(\sigma_{steric/dyn} + \sigma_{smb\_a} + \sigma_{smb\_g}\right)^2 + \sigma_{glac}^2 + \sigma_{IBE}^2 + \sigma_{GIA}^2 + \sigma_{LW}^2 + \sigma_{dyn\_a}^2 + \sigma_{dyn\_g}^2$$

Where: *steric/dyn* = the global thermal expansion uncertainty plus dynamic sea surface height; *smb_a* = the Antarctic ice sheet surface mass balance uncertainty; *smb_g* = the Greenland ice sheet surface mass balance uncertainty; glac = glacier uncertainty; *IBE* = the inverse barometer effect uncertainty; *GIA* = global isostatic adjustment; *LW* = the land water uncertainty; *dyn_a* = Antarctica ice sheet rapid dynamics uncertainty; and, *dyn_g* = Greenland ice sheet rapid dynamics uncertainty.

Initial data were exported as GeoTIFF files for use in ArcGIS. For parks that crossed more than one pixel, an average sea level rise was calculated by weighting pixel values by the length of park shoreline in each pixel. A standard bathtub model approach was used to identify areas of projected inundation and flooding. In this method, projected sea level under climate change was determined by adding the IPCC RCM value to the current mean higher high water level. The land that would be at or below a projected sea level was then determined by analyzing digital elevation models (DEMs) of land elevation at spatial resolutions of 500 to 7000 m, depending on data availability for the areas of each park. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast). Areas of inundation and flooding are denoted in the maps (Appendix A) in blue. Additional low-lying areas that could be potentially inundated or flooded are shown in green (Figure 2). These low-lying areas do not appear to have any inlet or other pathway for water (based on our elevation datasets), although they should still be considered vulnerable to exposure to either groundwater seepage or potential flooding via breaching. The lack of high-resolution DEMs and time constraints prevented us from attempting a dynamic modeling approach (see limitations below). Maps were created to illustrate inundation for all park units for 2050 and

2100 under RCP4.5 and RCP8.5. These two represent a plausible range of scenarios between significant policy response (RCP4.5) and business as usual (RCP8.5).

Figure 2. An example of how areas of inundation appear in ArcGIS. In this example for the Toms Cove area of Assateague Island National Seashore, areas of inundation (RCP4.5 2050) appear in blue. Green shading indicates other low lying areas that are blocked from inundation by some impediment, but nonetheless could experience flooding should the physical barrier be removed or breached.

Storm Surge Data

NOAA SLOSH data estimate potential storm surge height at current (most recent tidal datum) sea level (NOAA 2016). The NOAA SLOSH model comprises the following three products (P-Surge, MEOW, and MOMs) that utilize three different modeling approaches (probabilistic, deterministic, and composite) to estimate storm surge.

P-Surge (also known as the tropical cyclone storm surge probabilities product) uses a probabilistic approach by examining past events to estimate the storm surge generated by a cyclone that is present and within 72-hours of landfall. It statistically evaluates National Hurricane Center data (calculated in part using a deterministic approach) including the official projected cyclone track and historical forecasting errors. It also incorporates astronomical tide calculations and variations in the radius of

maximum wind into this estimate. These rates of motion variables are then fit to a Cartesian or polar (depending on the location) grid (Jalesnianski et al. 1992).

The Maximum Envelope Of Water (MEOW) calculates flooding using past SLOSH output to create a composite estimate of the potential storm surge generated by a hypothetical storm. This product generates a worst-case scenario based on a hypothetical storm category that includes forward speed, trajectory of the storm when it strikes the coastline, and initial (mean vs. high) tide level that will also incorporate any historical uncertainty from previous landfall forecasts.

The final SLOSH product is the MOM (Maximum of MEOWs) model. MOM is a further composite approach that uses the forward speed, trajectory, and initial tide level data that is also used by MEOW to create a worst-of-the-worst scenario (or "perfect storm"). Storms are simulated for 32 regions (also known as operational basins, Figure 3) defined by NOAA. Data was imported into ArcGIS using the SLOSH display program. Maps were generated showing storm surge for all possible Saffir-Simpson hurricane categories for each site. While most sites had data for Saffir-Simpson hurricane categories 1–5 (Table 3), a few sites, such as Acadia National Park, were missing the highest category. NOAA did not model this scenario because it is considered extremely unlikely at a location that far north in the Atlantic Ocean.

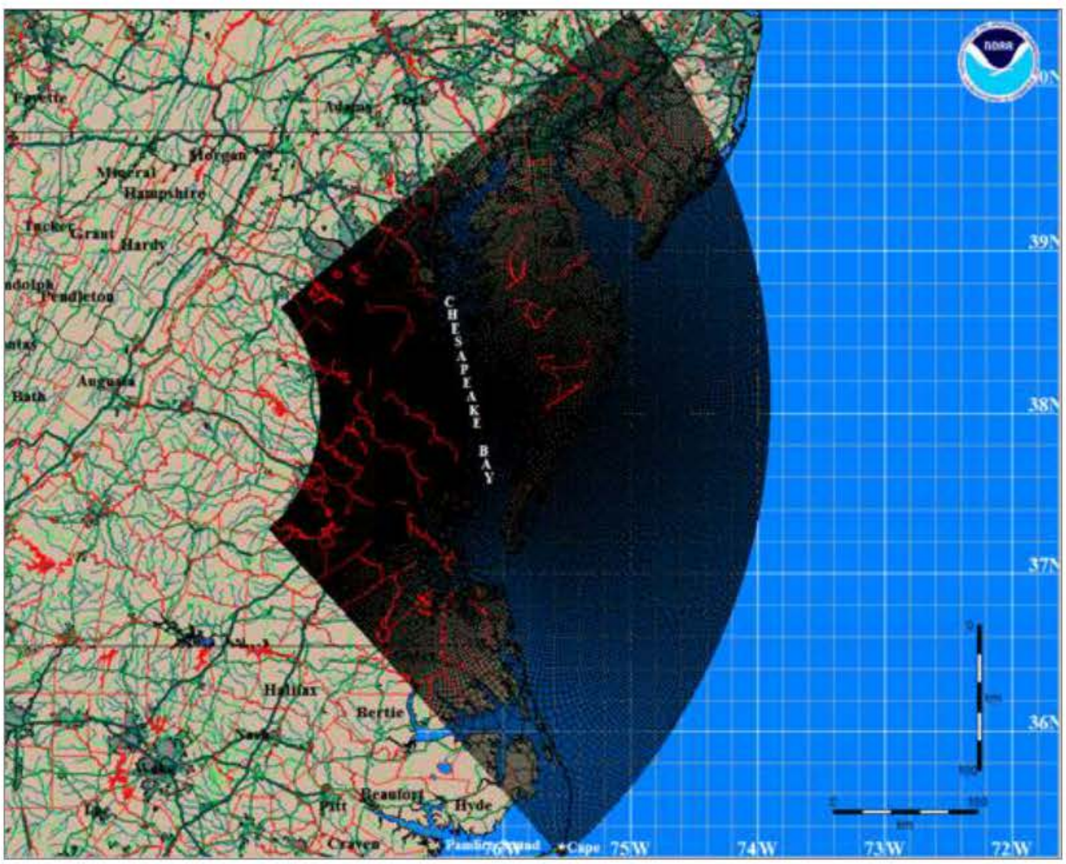

Figure 3. An example of the extent of an operational basin shown in NOAA's SLOSH display program (http://www.nhc.noaa.gov/surge/slosh.php). The black area is the full extent of the operational basin for Chesapeake Bay.

Table 3. Saffir-Simpson hurricane categories.

Saffir-Simpson Hurricane Category	Sustained Wind Speed (miles per hour, mph; knots, kt; kilometers per hour, km/h)
1	74–95 mph; 64–82 kt; 118–153 km/h
2	96–110 mph; 83–95 kt; 154–177 km/h
3	111–129 mph; 96–112 kt; 178–208 km/h
4	130–165 mph; 113–136 kt; 209–251 km/h
5	More than 157 mph; 137 kt; 252 km/h

SLOSH MOM was used to estimate potential storm surge in 79 coastal park units. Unfortunately, MOM data do not exist for the remaining 39 units, so we supplemented this with data from Tebaldi et al. (2012) wherever possible. Tebaldi et al. (2012) used 55 long-term tide gauge records to calculate potential sea level and storm surge estimates above mean high water levels. We used the current 50-year and 100-yr return level data from their paper for any parks near a tide gauge. Unfortunately, due to insufficient coverage by tide gauges in this area, we were unable to use either Tebaldi et al. (2012) or SLOSH MOM data for the Alaska, Guam, and American Samoa park units. It is important to note that the Tebaldi (2012) and SLOSH MOM data differ in their methods of calculation making it inadvisable to compare storm surge values from the Pacific West Region to other regions. However, this method had to be used due to the lack of SLOSH MOM data for the Pacific West Region.

We recommend that parks planning for future hurricanes use information from one hurricane category higher than any previous storm experienced. Historical hurricane data from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010) is listed in Appendix D (Table D3) to allow staff to determine the highest Saffir-Simpson category hurricane to strike within 10 miles of each park unit. Applying information from one storm category higher than historical data may more closely approximate what could happen in the future, as storms are projected to be more intense under continued climate change (Emanuel 2005, Webster et al. 2005, Mendelsohn et al. 2012). However, we recommend caution in using this approach for any detailed (site-level) planning due to limitations discussed in the following section of this report.

Limitations

All projects of this nature have limitations that should be clearly described to ensure appropriate use and interpretation of these data.

Every effort has been made to incorporate any parks established after this project began (e.g. Harriet Tubman Underground Railroad National Monument); however, some maps might be missing due to lack of available boundary data in new units.

Sea level and storm surge estimates were derived using separate programs from the IPCC and NOAA, respectively. These numbers were then imported into GIS maps using the program ArcGIS. We used a bathtub modeling approach to map the extent of sea level rise and storm surge over every unit. Bathtub modeling simply simulates how high or how far inland water will go under different

climate change scenarios. It does not recognize changes in topography or other environmental or artificial systems that may exist or occur in response to encroaching water. Although the bathtub model is the most widely used technique for modeling inundation, it is also a simplistic approach to simulating how sea level rise will affect a landscape (Storlazzi et al. 2013). Dynamic models could simulate changes in flow around buildings or estimate how topographic features such as dune systems may migrate in response to inundation and flooding, but dynamic models also vary, which can be a severe limitation in trying to standardize data for summary analysis and comparison.

The maps provided through this analysis vary in horizontal and vertical accuracy depending on which digital elevation model (DEM) data were available at the time of mapping. This is discussed in more detail in the metadata that accompany each map. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast/) which uses source elevation data that either meet or exceed current Federal Emergency Management mapping specifications. These NOAA digital coast data were required to have a minimum root mean square error of 18.5 cm for low lying areas that were then corrected for MHHW using the NOAA VDatum model (Parker et al. 2003). USGS data were used for areas, such as Alaska, where digital coastal data were not available. We recommend referring to Schmid et al. (2014) for further discussion on potential uncertainty of this technique.

Although SLOSH MOM has the widest geographic storm surge coverage of any model in the US, storm surge data were not available for every part of the coastline. Every effort has been made by this project to bridge any gaps where SLOSH MOM does not exist. While the Tebaldi et al. (2012) data cover the California, Oregon, Washington, and southern Alaskan coastlines, they do not cover northern Alaskan, American Samoan, or Guam coastlines. These coastlines are vulnerable to storm surge but we could not find data that satisfied our standards of accuracy sufficiently to be included in our mapping efforts.

Furthermore, storm surge maps are only intended as a rough guide of how flooding caused by storm surge will look today. As more of the coastline becomes inundated we can expect coastal flooding patterns to also change accordingly. The SLOSH model is a multiple scenario approach that uses previous storms to estimate future storm surge. It cannot take into account changes in future basin morphology that could affect the fluid dynamics and propagation of coastal flooding.

SLOSH MOM is modeled using mean sea level (0 m NAVD88) and what NOAA terms "high tide" (which is not tied to the local tidal datum, but is actually a round number based on the modeled average high tide for the region). Jalesnianski et al. (1992) estimate surge estimates to be accurate +/-20%, although Glahn et al. (2009) discuss how others have found the P-Surge model to be more accurate than originally estimated. Such factors must be kept in mind when using these numbers for mapping.

Land Level Change

It is important to include changes in land level while interpreting changes in sea level. The IPCC (2013) includes a limited amount of data regarding changes in relative sea level in their calculations of sea level change. Our sea level rise results include the IPCC estimates of how changes in land

level will change over time based on estimates of glacial isostatic adjustment. Land level change is an important variable when calculating relative sea level. Land levels have changed over time in response to numerous factors. Changes in various land-based loadings—such as ice sheets during the last glacial maximum—has been a significant cause of land level change in the U.S. Post-glacial isostatic rebound is the result of this pressure being released after the removal of ice sheets on the Earth's crust. Land level can also be altered by other factors such as tectonic shifts, particularly along the Alaska and continental U.S. Pacific coastlines. These drivers can often prompt a relative increase or decrease in land level depending on location. Other factors such as aquifer drawdown and the draining of coastal swamps can create decreases in relative land level.

Quantifying how land levels are changing is difficult given the paucity of data available prior to modern satellite data. An upcoming NASA publication on land-based movement (Nerem pers. comm.) will help to address this data need, providing numbers for land-based movement across the country. Data from the NASA report can then be incorporated with sea level rise numbers from this analysis using the following equation (after Lentz et al. 2016):

Eq. 2 $$\mathrm{a}e = \mathrm{E}_0 - e_\mathrm{i} + \mathrm{R}$$

Where; ae is the adjusted elevation, E_0 is the initial land elevation, e_i is the future sea level for either 2030, 2050, or 2100, and R is the current rate of land movement over time due to isostatic adjustments.

In the interim, tide gauges can provide further data regarding changes in land level, but should be used cautiously. We have listed tide gauge data for the rate of change in land level for tide gauges nearest to all units for this study in Appendix D; however, only Fort Pulaski National Monument and Golden Gate National Recreation Area have a long-term tide gauge on site. This lack of nearby long-term data can limit the accuracy of these numbers if they are applied to sea level change projections for almost all other parks units. We indicate in Table D1 which of the nearest tides gauges we do not recommend using to estimate land movement. This is because in many case the boundary of the park unit is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. Land level changes were only reported for long-term tide gauges that had at least thirty years of data in order to ensure a statistically robust dataset. Based on these limited records, we estimate that seven park units are currently experiencing decreasing relative sea levels (Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park), although we cannot be certain of this number given that many of the park units are some distance from a tide gauge. We expect the release of the NASA data (Nerem pers. comm.) to help refine these estimates.

A discussion of the applicability of these land level numbers (with a natural resources manager or similar expert) should accompany use of individual park maps from this analysis to ensure that the nearest tide gauge to any particular project site is appropriate. Current rates of subsidence at these tide gauges range between +7.6 mm/y (Grand Isle, Louisiana) and -19 mm/y (Skagway, Alaska; Table D1). In selecting an appropriate tide gauge to use, variables including oceanographic setting, length of the record, completeness of data, and geography of the coastline must be considered. The

science team for this project decided against setting a threshold for how close a park unit should be to a long-term tide gauge based on considerations discussed above.

Where to Access the Data

All GIS data from this project are available at https://irma.nps.gov/Portal for archiving by park.

A website discussing this project is available at the following address: https://www.nps.gov/subjects/climatechange/sealevelchange.htm

The raw IPCC (2013) data can be downloaded using the following link: http://www.ipcc.ch/report/ar5/wg1/docs/ar5_wg1_ch13sm_datafiles.zip

Results

Sea level and storm surge maps are in Appendix A. A full list of the 118 park units and a table listing sea level projections by park are available in Appendix D. Following the methods outlined above, we found that sea level rise projections across the 118 park units average between 0.45 m (RCP2.6) and 0.67 m (RCP8.5) by 2100. However, this number masks how these projections will vary geographically. Figure 4 shows these projections in more detail and provides sea level estimates by region. Error bars in Figure 4 denote the standard deviation for each average per region, further revealing how these numbers can vary. A high standard deviation and range signals that sea level estimates vary between units within regions, whereas a low standard deviation and small range are to be expected in smaller regions where sea level rise estimates do not cover such a large geographic area.

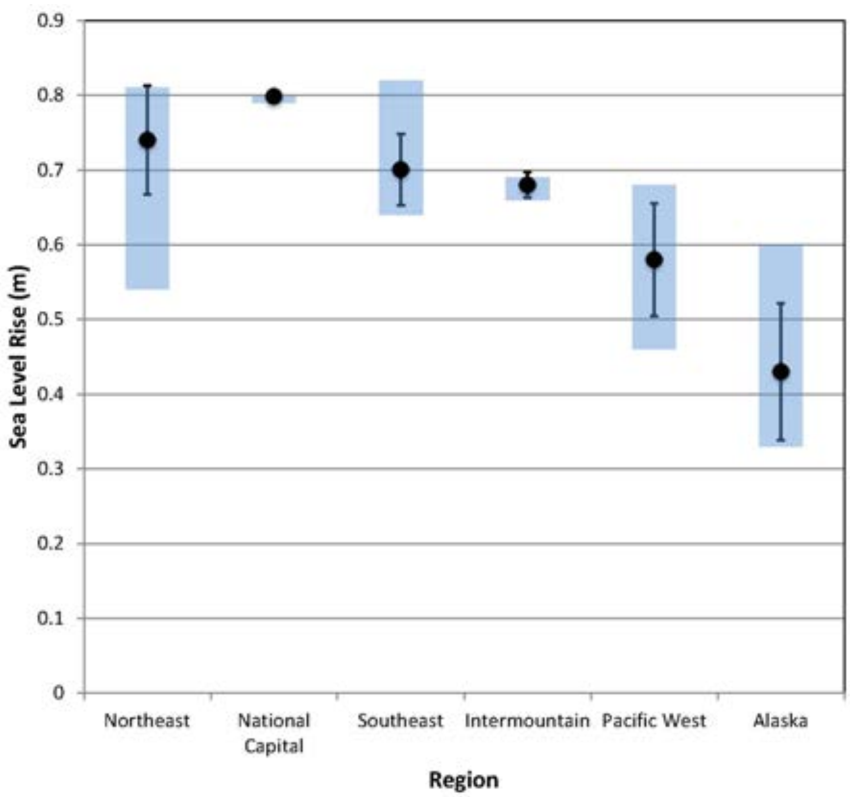

Figure 4. Projected future sea level by NPS region for 2100 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Based on the averages per region, we found that the shoreline within the National Capital Region is projected to experience the highest sea level rise by 2100 (0.80 m RCP8.5), although this number does not include the full extent of changes in land level over the same time interval. The shoreline near Wright Brothers National Memorial in the Southeast Region has the highest overall projected sea level rise (0.82 m, RCP8.5, 2100). Glacier Bay Preserve and Klondike Gold Rush National

Historical Park are tied for lowest projected sea level rise at 0.33 m using RCP8.5 for 2100. The Alaska Region also has the highest standard deviation among park units. The National Capital Region conversely has very little standard deviation due to the compact nature of the region (meaning that all of the parks units fell within the same raster cell). This is not to say that all of the parks will experience exactly the same rate of sea level rise, but that the IPCC model projected that sea levels could rise up to an average 0.80 m (RCP8.5) for that region by 2100. The sea level rise maps (discussed in the National Capital section below) illustrate differences among the National Capital parks in more detail.

Comparing RCP8.5 data for 2030 and 2050 (Figures 5 and 6, respectively) shows the Northeast Region almost tied with the National Capital Region in 2030 based on average projected sea level rise, with the National Capital Region ranked highest. The Alaska Region ranks lowest for all three time intervals followed by the Pacific Northwest region, Intermountain Region, and Southeast Region. The Northeast Region ranks second highest for 2050 and 2100.

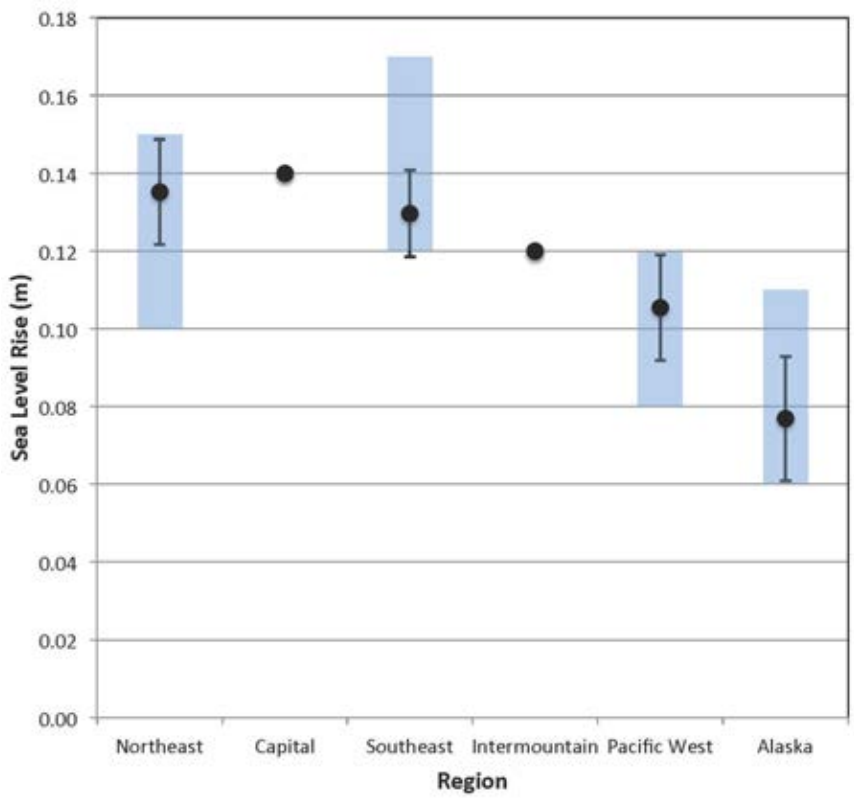

Figure 5. Projected future sea level rise by NPS region for 2030 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

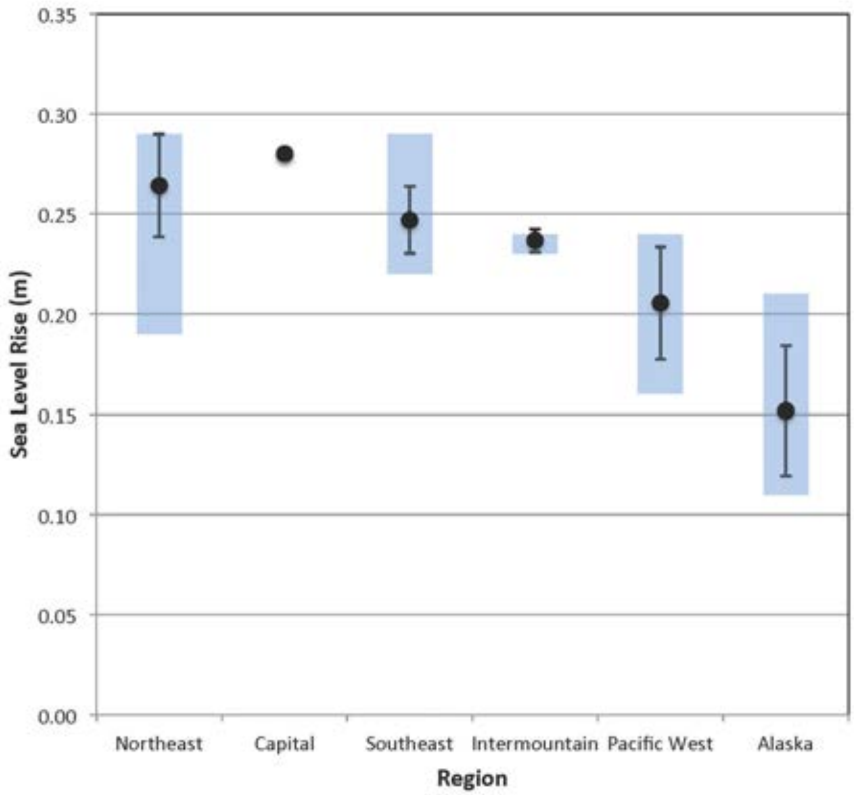

Figure 6. Projected future sea level rise by NPS region for 2050 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Storm surge was mapped for 79 park units. We list data for one storm category higher than the highest historical storm in Table D3 in Appendix D. Some (31) park units did not have a historical storm path occurrence within 10 miles of their boundaries, so a Saffir-Simpson hurricane 1 was simulated for these locations. The lack of a historical storm does not mean that these parks are not subject to strong storms. It may merely be that these parks are in regions that either do not have extensive historical records or they experience strong storms, such as nor'easters, that behave differently and are not part of the NOAA database.

The Southeast Region has the strongest historical hurricanes (average of highest recorded storm categories = 2.79), followed by the Intermountain Region (average = 2.33), National Capital Region (average = 1.90), and the Northeast (average = 1.03). None of the historical data intersected with the 10-mile (16.1 km) buffers around the Alaska Region parks. The Pacific West Region has experienced some tropical depressions, particularly in Hawaii, but most of their storm surges are driven by other phenomena, such as mid-latitude cyclones or extreme tides (sometimes colloquially referred to as king tides). The strongest (highest winds) and most intense (lowest pressure at landfall) recorded historical storm to have impacted a park unit was the "Labor Day Hurricane" that passed within 10 miles of Everglades National Park in 1935. While this storm may have been the highest intensity storm, it is certainly not the most damaging or costly storm in National Park Service history.

Northeast Region

Colonial National Historical Park, Fort Monroe National Monument, and Petersburg National Battlefield have the highest projected sea level rise in 2050 and 2100, and, together with Edgar Allen Poe National Historic Site, Fort McHenry National Monument and Historic Shrine, Independence National Historical Park, and Thaddeus Kosciusko National Memorial (parks near coastlines) they also have the highest projected sea level rise for 2030. However, while these parks may have ranked highly, caution should be used in applying these results. Many of these parks do not have coastline and so these projections are based on sea level rise for the coastline adjacent to these parks. The maps in Appendix A show how the projected sea level rise may affect each of these parks. Colonial National Historical Park, Fort McHenry, and Fort Monroe National Monument are the only park units of this highest rise grouping that contain coastline with their boundaries.

Figure 7 shows the range of sea level projections for the Northeast Region for 2100, averaging between 0.49 m (RCP2.6) and 0.74 m (RCP8.5) of sea level rise by the end of the century. Acadia National Park had the lowest projected rates of sea level rise for 2030 (0.08–0.10 m), 2050 (0.14–0.19 m), and 2100 (0.28–0.54 m).

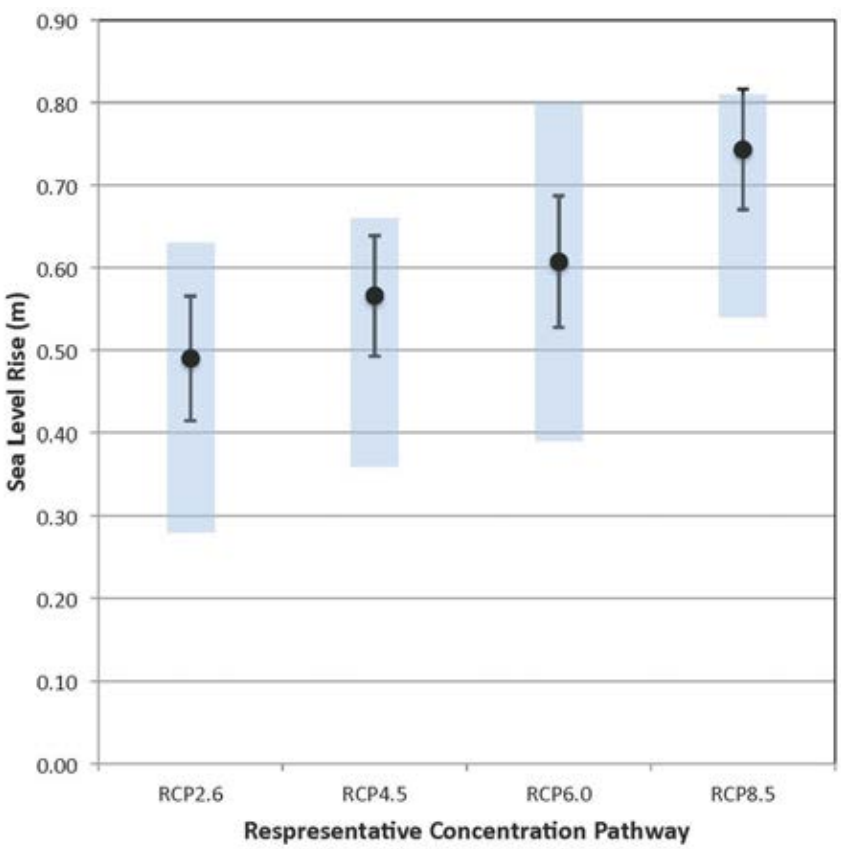

Figure 7. Projected future sea level rise by 2100 for the NPS Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each category.

Regarding storm surge, the highest recorded storm to have travelled within 10 miles of any of the 29 parks units identified for study was an officially unnamed hurricane in 1869 known colloquially as Saxby's Gale, which was classified as a Saffir-Simpson 3 hurricane. The storm path passed present-day Boston National Historical Park and Roger Williams National Memorial. Figure 8 shows the estimated extent and height of a storm surge from category 3 hurricane striking Boston Harbor Islands National Recreation Area at mean tide.

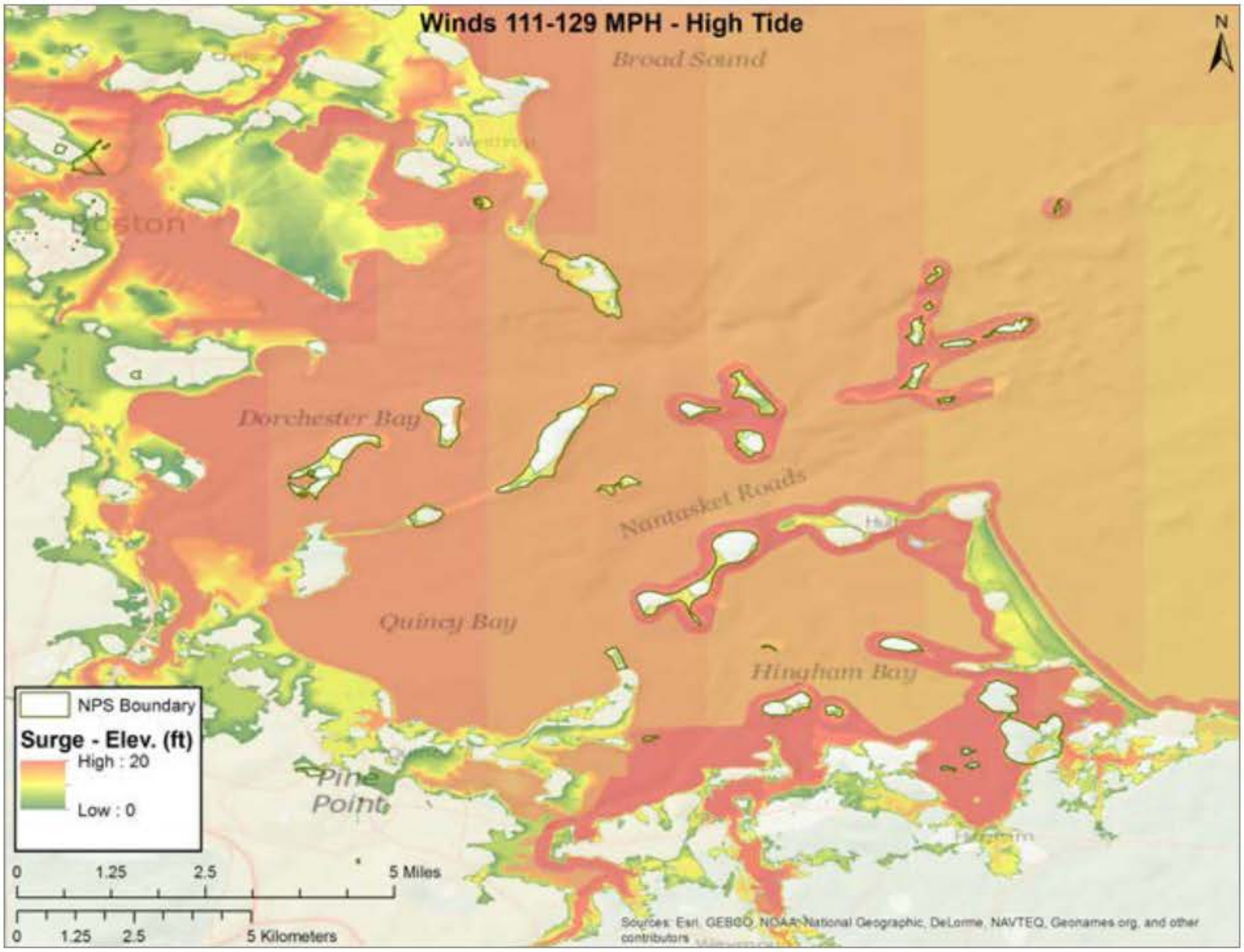

Figure 8. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at high tide near Boston Harbor Islands National Recreation Area. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Southeast Region

Historically, the Southeast Region has the highest intensity storms (highest Saffir-Simpson storm category); Everglades National Park has recorded a category 5 hurricane within 10 miles of its boundary, the colored areas in Figure 9 indicate the potential height and extent of a storm generated by two different categories of hurricane. A category 2 hurricane could completely flood the park.

Future storm surges will be exacerbated by future sea level rise nationwide; this could be especially dangerous for the Southeast Region where they already experience hurricane-strength storms.

Moreover, sea level rise projections only include changes in land movement due to glacial isostatic adjustment and do not include the full range of drivers of potential changes in land level. Using Table D1 from Appendix D as a rough guide, changing land level for parks near tide gauges can be evaluated. For example, the Eugene Island, Louisiana tide gauge's current rate of sea level rise is the highest in the country at 9.65 mm/y, owing in part to the large rate of subsidence in the region (Figure 1). Using the nearest tide gauge to Jean Lafitte National Historical Park and Preserve (Grand Isle, Louisiana, gauge 8761724) we can estimate that land will subside by 7.60 mm/y. Applying this estimate of subsidence (using a baseline of 1992) to our RCP8.5 projections, the park could experience approximately 0.41 m of *relative* sea level rise by 2030 followed by 0.69 m by 2050 and 1.50 m by 2100. This is an inexact estimate of the land movement for the park given that Jean Lafitte National Historical Park and Preserve is approximately 60 miles (97 km) from the tide gauge; still, factoring in changes in land level, we can see that relative change in sea level is more than double the projected change in sea level using the IPCC estimates alone.

This analysis projects that, by 2100, the shoreline adjacent to Wright Brothers National Memorial may have the greatest sea level rise among the Southeast Region's parks (0.82 m RCP8.5). Given elevations within the park, this may not inundate a large area of the memorial, unless combined with other factors such as a storm surge. For example, the park may be almost completely flooded if a category 2 or higher hurricane strikes on top of inundation from sea level rise.

Nearby Cape Hatteras and Cape Lookout National Seashores are projected to experience sea level rise of up to 0.79 m and 0.76 m, respectively (RCP8.5) by 2100, resulting in large areas of inundation. While sea level rise around these national seashores may not be as high as what has been projected for Wright Brothers National Memorial, they serve as examples of how caution must be used when using these numbers to assess which park units are most vulnerable to sea level rise. Other factors, such as percent of exposed land, changes in land movement, and adaptive capacity must also be taken into account for vulnerability analyses (Peek et al. 2015).

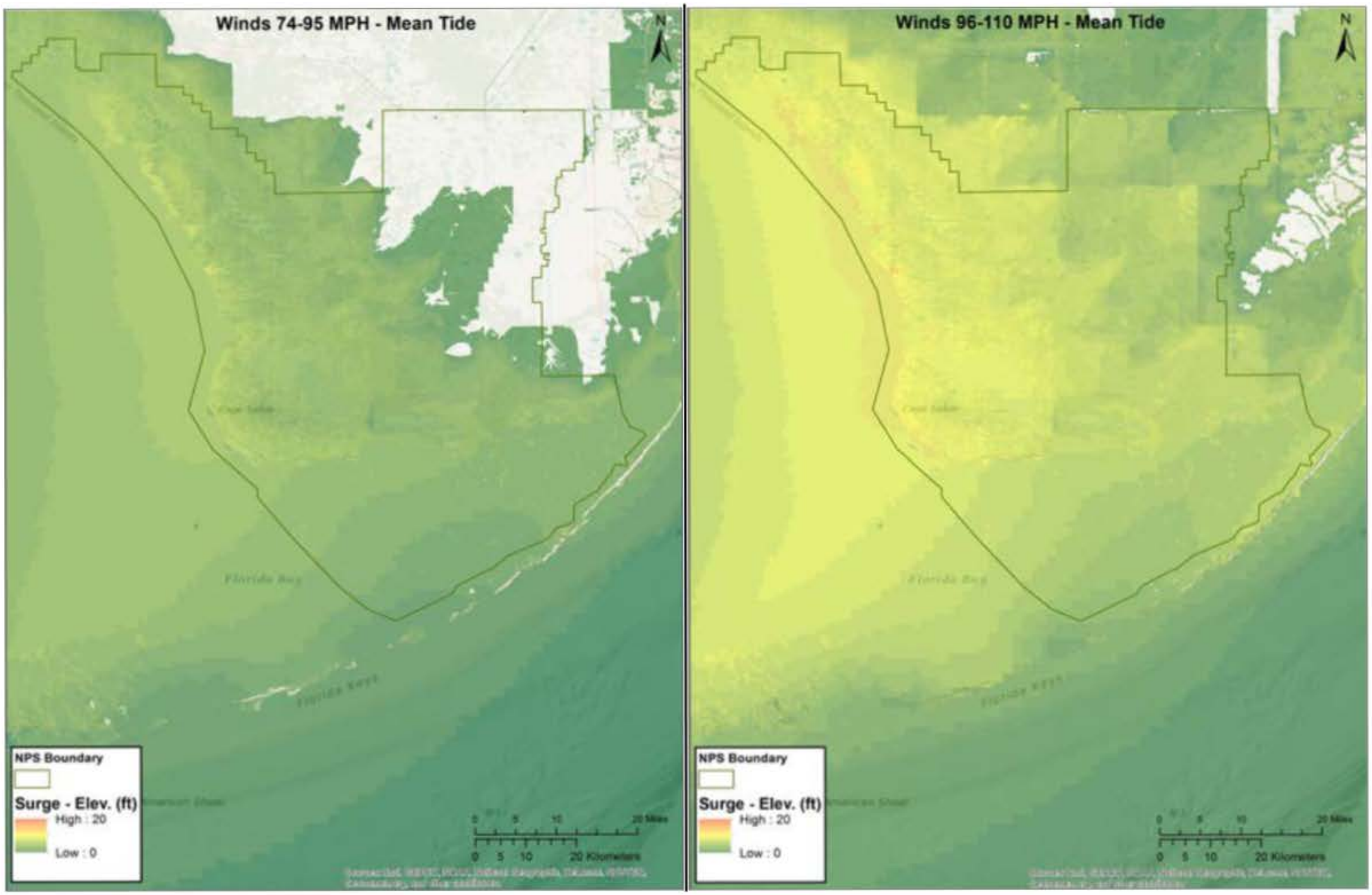

Figure 9. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide (right). Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

National Capital

National Capital Region has minimal variability in projected sea level rise because all park units selected for study are adjacent to the same section of coastline that was modeled. Their proximity also explains why they share the same storm history. Despite these similarities, projected sea level rise may affect each individual park unit differently based on local topography. The strongest storm recorded within 10 miles (10.1 km) of the National Capital Region parks was a Saffir-Simpson category 2 hurricane that struck the city in 1878. While the 1878 storm caused relatively little damage, we can expect a significantly larger amount of damage if a similar storm struck the city again given considerable development now existing in the area. Figure 10 shows the extent of flooding caused by a Saffir-Simpson category 2 hurricane. A storm surge measuring more than 3 m could travel up the Potomac River causing large amounts of flooding. Such a storm surge could be worse by the end of this century given projected sea level rise around the Capital Region of up to 0.8 m.

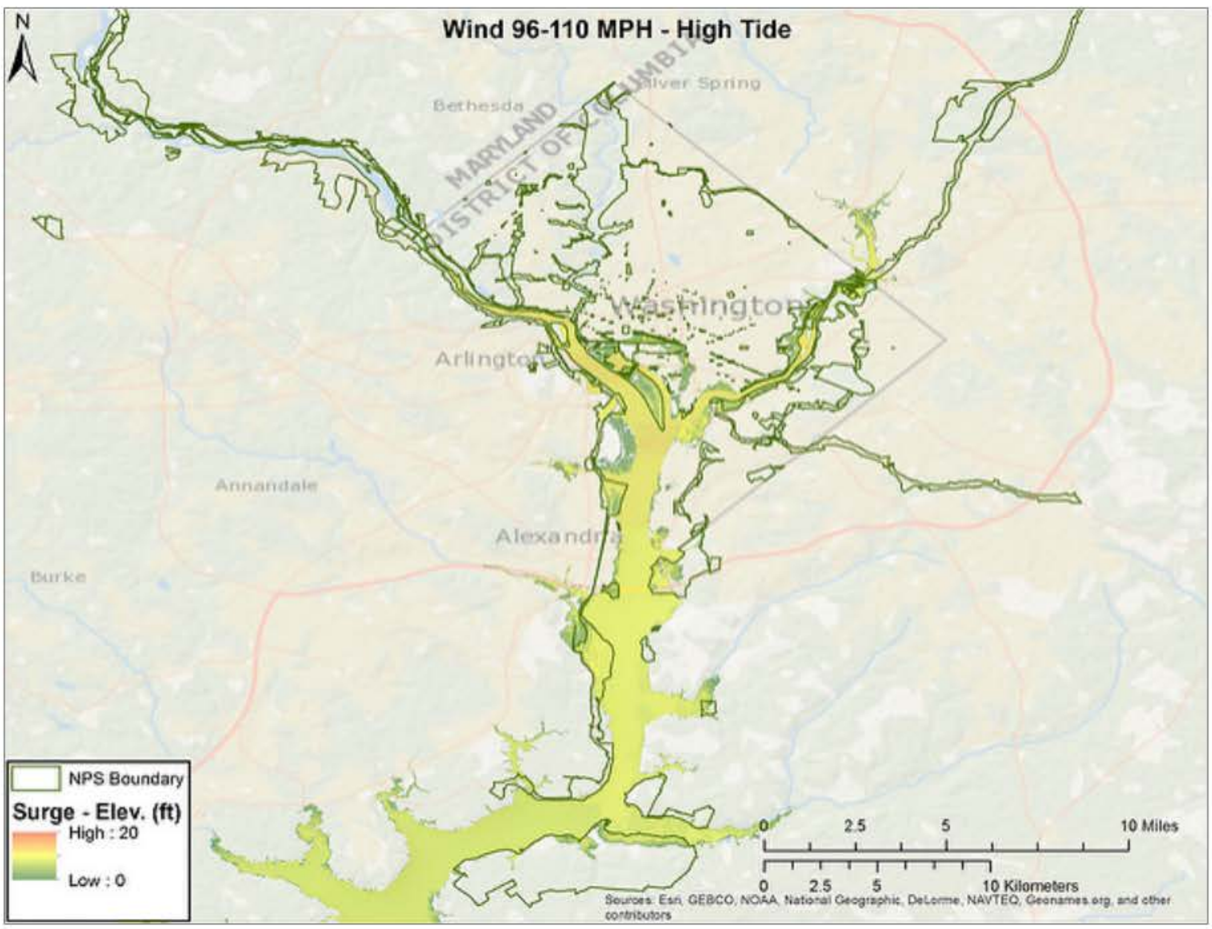

Figure 10. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

IPCC/SLOSH models showed either storm surge or sea level rise (or some combination of the two) affecting every National Capital Region park included in this analysis, with the exception of Harpers Ferry National Historical Park. Our mapping efforts revealed that Harpers Ferry National Historical Park (located approximately 149 m above sea level) is unlikely to experience any impacts of sea level rise due to its elevation and is unlikely to be damaged by storm surge from a hurricane, given its relatively protected location behind several dams along the Potomac and Shenandoah Rivers.

Sea level rise alone is not expected to spread very far into Washington D.C., although a large section on the east side of Theodore Roosevelt Island could be inundated. However, storm surge flooding on top of this sea level rise would have widespread impacts.

Intermountain Region

The Intermountain Region covers mostly inland park units stretching from Texas to Montana. Within the region, only three park units in Texas are subject to sea level change: Big Thicket National Preserve, Palo Alto Battlefield National Historical Park, and Padre Island National Seashore. Of these, Padre Island National Seashore may experience the greatest effects of sea level and storm surge; sea level is projected to rise 0.46–0.69 m (RCP2.6–8.5, Figure 11) by 2100. The same amount of sea level rise is projected for the shoreline near Palo Alto Battlefield National Historical Park, but inundation is not projected to extend far enough to reach the park. Palo Alto Battlefield National Historical Park has no history of being within 10 miles of any hurricane, making the site unlikely to be flooded by storm surge. SLOSH MOM models for the park unit show that that the region would have to have either a Saffir-Simpson category 4 hurricane striking at high tide or a category 5 hurricane striking at any tide in order for the park to experience any storm surge. On the other hand, Figure 12 shows that Padre Island National Seashore, located to the east of Palo Alto Battlefield National Historical Park, historically was within 10 miles of a category 4 hurricane. SLOSH MOM data show that should a category 4 hurricane occur here again, it would likely flood almost the entire island.

Storm surge could potentially travel up the Neches River and flood the southernmost part of Big Thicket National Preserve, although both artificial and natural storm surge defenses in Beaumont, Texas, to the south of the preserve, may buffer it from any surge.

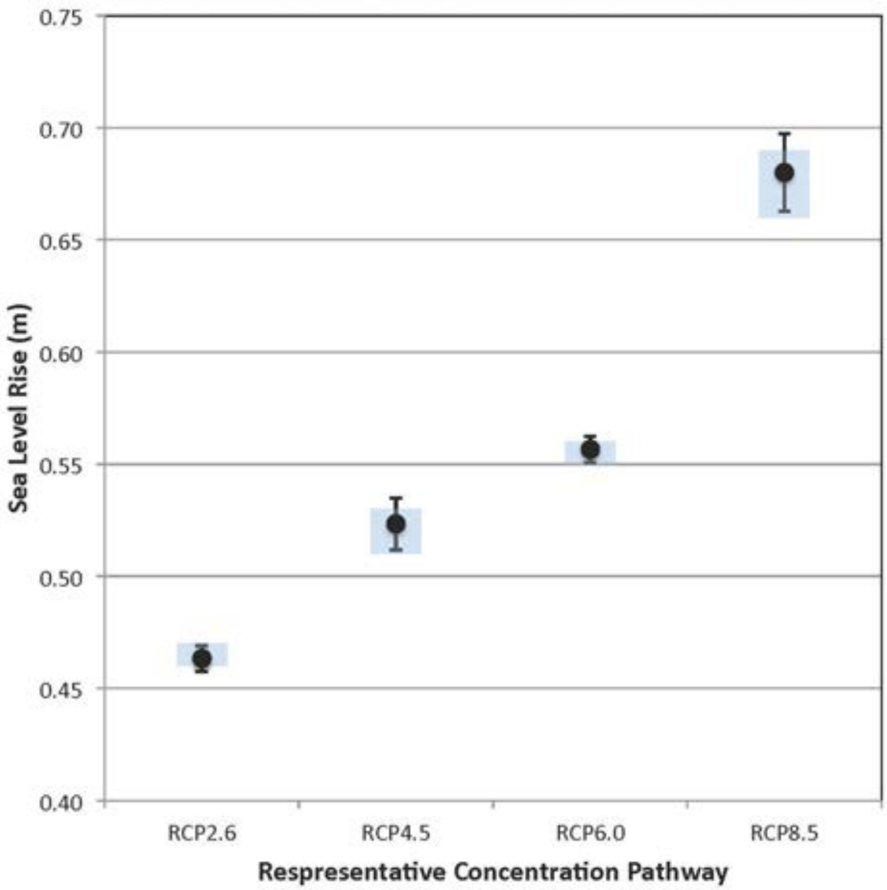

Figure 11. Projected future sea level rise by 2100 for the NPS Intermountain Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation from each mean. Blue bars mark the full range of sea level estimates for each category.

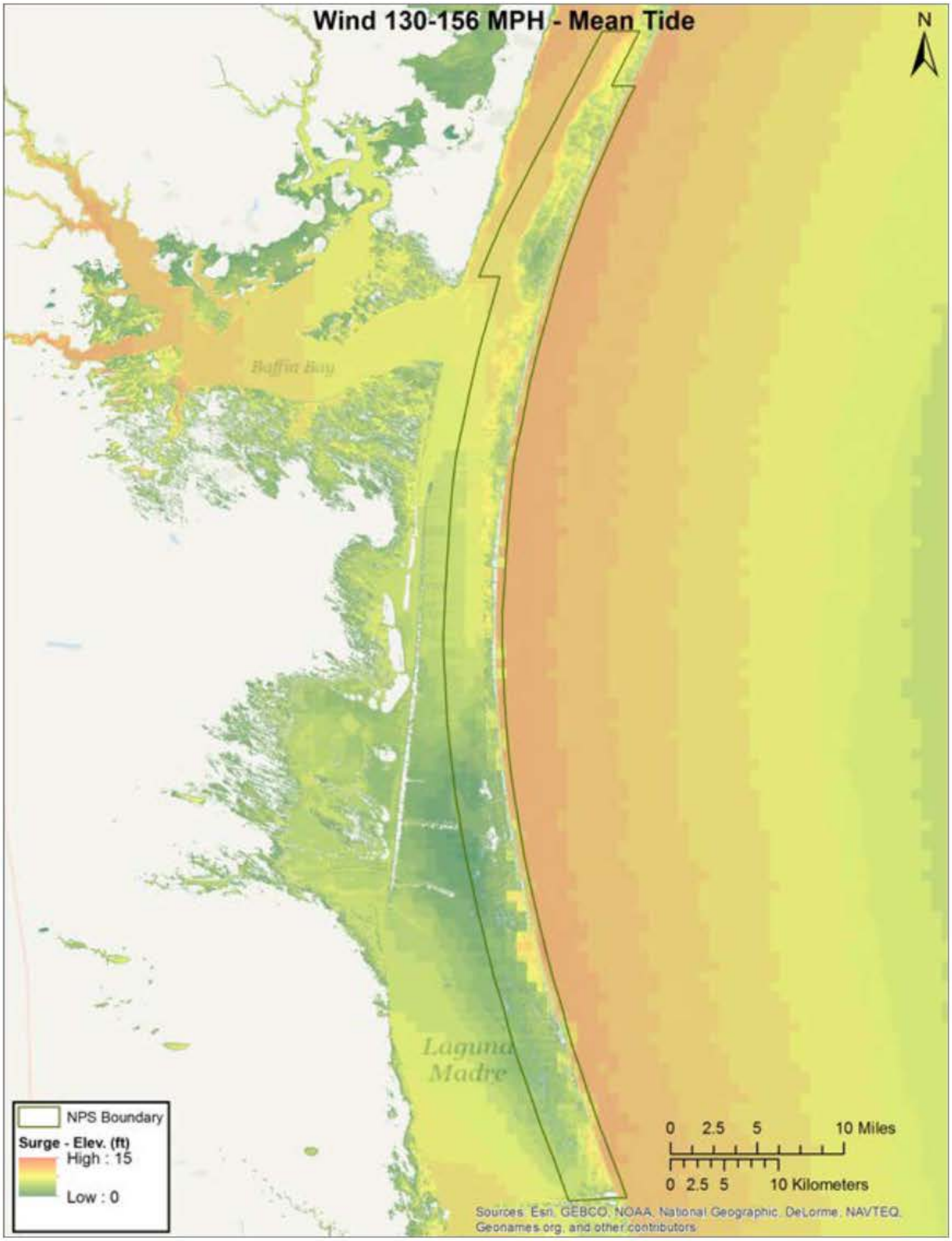

Figure 12. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Pacific West Region

The Pacific West Region identified 24 park units for analysis in this study that could be vulnerable to sea level rise and/or storm surge. These units occur over a large area that includes California, Oregon, Washington, Hawaii, American Samoa, and Guam. War in the Pacific National Historical Park in Guam has the highest projected sea level rise at 0.68 m (RCP8.5) by 2100, and shares the highest projected sea level rise with almost all of the Hawaiian park units in 2030 and 2050. The average projected sea level rise range is 0.40–0.58 m (RCP2.6–8.5) by 2100 for the whole region; high standard deviations (0.04 m and 0.08 m for RCP2.6 and RCP8.5, respectively) indicate that park-specific projections vary widely across the region.

At the other end of the spectrum, projected sea level rise around Washington's Olympic Peninsula and in the San Juan Islands, affecting Ebey's Landing National Historical Reserve, Olympic National Park, and San Juan Island Historical Park, is expected to occur more slowly, reaching a maximum 0.46 m (RCP8.5) by 2100. This region is subject to tectonic shifts and continuing land movement due to isostatic rebound, further complicating sea level projections. Long-term tide gauge records at Neah Bay, Washington (gauge 9443090), and Tofino, British Columbia, Canada (gauge 822-116), show relative sea levels currently decreasing while tide gauges in Port Angeles, Washington (gauge 9444090), Victoria, Canada (gauge 822-101), and Seattle, Washington (gauge 9447130), show it to be increasing (Zervas 2009). Our projections indicate rising sea level in this region throughout this century, although further investigation of localized changes in land movement could shed more light on this matter.

Park units in the Pacific West Region need to be concerned about potential future storms that could travel along the eastern Pacific Ocean's increasingly warmer waters. Because of the relative lack of hurricanes in this region historically, we used data from Tebaldi et al. (2012), which includes anomalous surges that could be created by storms, and other factors (very high tides sometimes referred to as king tides). Based on the Tebaldi et al. (2012) data, La Jolla, California (gauge 9410230), has the lowest 100-year storm surge (0.95 m) and Toke Point, Washington (gauge 9440910), has the highest 100-year storm surge (1.96 m) in the Pacific West Region. Tebaldi et al. (2012) did not analyze storm data for Hawaii, Guam, or American Samoa, although IBTrACS (Knapp et al. 2010) does have hurricane records for these areas. Only tropical depressions have been recorded within 10 miles of almost all of the Hawaiian park units we analyzed (Haleakala National Park, Hawaii Volcanoes National Park, Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puukohola Heiau National Historic Site, and World War II Valor in the Pacific National Monument).

Alaska Region

The Alaska Region has the lowest average projected sea level rise (0.28–0.43 m by 2100) compared to the five regions described above. Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park in southeastern Alaska share the lowest projected sea level rise (0.33 m, RCP8.5, 2100) while Bering Land Bridge National Preserve on the west coast of the state has the highest projected sea level rise (0.60 m, RCP8.5, 2100).

Figure 1 shows how current relative sea levels vary across the state. Land levels are rapidly rising in the southeast of the region due to isostatic rebound and other tectonic shifts. The net result of these increasing land levels is decreasing relative sea levels for at least the early part of this century. Relative sea level in Skagway, Alaska is decreasing at an average rate of 17.6 mm/y (Zervas 2009). Despite melting ice and other factors outlined in Table 1 that increase ocean water volume, the amount of rising water is insufficient to keep up with land level changes. Seven park units (Glacier Bay National Park, Glacier Bay National Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park) are identified as potentially having decreasing relative sea levels based on the nearest tide gauge data to each of these parks. None of these parks have long-term tide gauges with data spanning at least thirty years. A great strength of using the IPCC (2013) process-based model approach is that, unlike many other semi-empirical models, it does not rely on long-term tide gauge records to statistically project future sea levels. However, sea level projections in this analysis do not include changes in land level. The estimates that we report here represent the expected rise due to water volume expansion alone near to each of these park units. Table D1 shows how land levels are changing at long-term tide gauges across the country. However, given that all of these park units are located far from a tide gauge and that the region is relatively geologically complex, we do not recommend using the land movement numbers from the nearest tide gauge for any of the Alaskan parks.

Storm surge is also very difficult to model for this region. Historically, many of the parks had sea ice along the coastline that helped protect these parks from storm surge. Consequently, NOAA does not have SLOSH MOM models for this region. IBTrACS data (Knapp et al. 2010) show a few storm paths that have moved towards the region, but these types of storms typically do not make landfall once they move over colder waters. Alaska does hold the record for the highest intensity (lowest central pressure) storm (Duff 2015). A downgraded super typhoon, Nuri, struck Adak Island, Alaska, in 2014 with recorded winds gusting up to 122 mph. It is impossible to determine an average or peak historical storm surge without adequate tide gauge data.

Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/y, although this rate accelerated over the latter part of the century. Slangan et al. (2016) found that emissions of greenhouse gases from human activities have been the primary driver of global sea level change since 1970 and that the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/y (Cazenave et al. 2014, Fasullo et al. 2016).

The IPCC (2013) projects that, without greenhouse gas emissions reductions, this rate will increase, and that global average sea levels could rise by 0.40–0.63 m (RCP2.6–8.5) by 2100. We used regional sea level projections from the IPCC (2013) generated for 2050 and 2100 in combination with our interpolated projections for 2030 to estimate the amount of sea level rise 118 coastal national park units could experience in the future. Our projections are based on the new representative concentration pathways (Moss et al. 2010, Figure 13), using a process-based model approach.

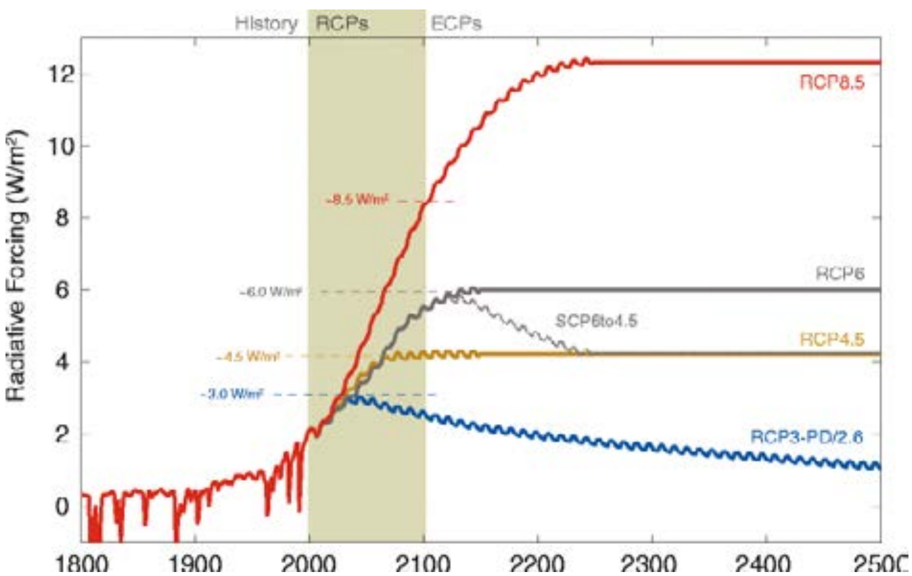

Figure 13. Radiative forcing for each of the Representative Concentration Pathways (RCPs). An increase in radiative forcing (due to the loading of anthropogenic gases into the atmosphere) will result in higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are slightly higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011.

Numerous academic articles use mostly semi-empirical models (Rahmstorf 2007) to estimate sea level rise regions across the U.S. The IPCC (2013) lists several semi-empirical sea level rise estimates, all of which result in projections of future sea level that are higher than the IPCC (2013) approach. The differences in these approaches can be attributed to many factors. For example, some of the older papers may have higher sea level estimates because they are based on the older IPCC SRES scenarios (e.g. Vermeer and Rahmstorf 2009, Grinsted et al. 2010, Jevrejeva et al. 2010). Other papers may include input from "expert elicitations" in their sea level projections, in which experts provide their opinion on how much sea level (or a related factor) could rise in the future (e.g. Bamber and Aspinall 2013, Jevrejeva et al. 2014, Horton et al. 2014). Some published articles criticize the IPCC sea level estimates as being too conservative or underestimating rates of future sea level change (e.g. Kerr 2013, Horton et al. 2014). Church et al. (2013) addresses these criticisms by explaining how the IPCC define the probability and likelihood of their estimates, and so they are not discussed in detail here. Recent analyses by Clark et al. (2015) further support the findings of the IPCC.

A key strength of the methods used in this analysis lies in providing a unified approach to identify how sea level change may affect all coastal park units across the National Park System, rather than relying on sea level data generated for specific areas. Our analyses revealed that the National Capital Region is projected to experience the greatest increase in sea level (not taking into account changes in land level). This rise will affect each of the region's units in different ways depending on the elevation of the individual unit, but it could be significant if combined with a storm surge from a storm such as the Saffir-Simpson category 2 hurricane in 1878.

At the individual park level, IPCC projections reveal the sea level along the coastline adjacent to Wright Brothers National Memorial could rise up 0.82 m (RCP8.5) by 2100, which could lead to significant flooding if the dynamic landforms are not able to keep pace with such high rates of sea level rise. In addition, storm surge impacts at this higher sea level would be significant. The Southeast Region as a whole is generally susceptible to inundation and flooding due to its low-lying nature in many places, particularly in Cape Hatteras and Cape Lookout National Seashores. Our sea level rise maps (Appendix A) highlight how much all of these park units may be affected.

These estimates do not include the latest data on changing land levels. The IPCC included estimates of global isostatic adjustment (Equation 1) in their predictions, but those do not include changes in land level due to other factors, such as earthquakes and groundwater extraction. We expect the latest, state-of-the-art land level estimates to be released by NASA in 2017. In the meantime, we can roughly estimate relative sea level change for a small number of parks based on current rates of subsidence gathered from nearby long-term tide gauge data. We project Jean Lafitte National Historical Park and Preserve to have the greatest relative sea level increase based on the current rate of land movement. Our sea level projections agree with current sea level trends in showing that the southeast Alaska region is experiencing the least amount of sea level rise of anywhere in the National Park System.

Sallenger et al. (2012) discussed how changes in Atlantic Ocean temperatures and salinity (resulting from changes in circulation) could lead to changes in sea level that could create a 1000-km long "hotspot" along the North Atlantic coast from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. We estimate that almost all of the coastal park units in this area would be flooded under these conditions.

It is unknown exactly to what degree future storm surge will affect the Alaskan park units. Accurate long-term (>30 years) storm surge data do not exist for the Alaska region. Even if such data did exist, it would be not be analogous to future conditions in the region because sea ice that had previously protected the shores for many of the western Alaska park units melts to reveal an easily erodible coastline (Frey et al. 2015). The warming of ocean waters in the Gulf of Alaska and Pacific Ocean could also make it more conducive for more storms like Typhoon Nuri to travel north without losing energy as under historic conditions.

The Pacific West Region shows high variability among parks. War in The Pacific National Historical Park in Guam ranks highest in projected sea level rise among units in the Pacific West Region. The large area of the region partly explains the relatively high standard deviation in results for the region. The tectonically complex setting of many of the region's parks also complicates future sea level estimates. Changes in land movement are somewhat gradual nationwide in comparison to Alaska and the Pacific West Region, especially where earthquakes can rapidly change the position of the land relative to the sea.

Island park units in general are particularly exposed to the impacts of sea level change and storm surge. Many of the barrier island parks, such as Fire Island National Seashore, Assateague Island National Seashore, Palo Alto Battlefield National Historical Park, Gulf Islands National Seashore, and Cape Hatteras National Seashore, are all projected to experience sea level rise of over 0.69 m by 2100 (RCP8.5). This sea level rise, combined with storm surge, could be especially difficult for isolated island park units, such as the Caribbean park units, the National Park of American Samoa, and War in the Pacific National Historical Park, where access to aid in the event of a natural disaster may not be immediately available.

Conclusions

This report presents projections of sea level change (118 parks) and storm surge (79 parks) in coastal park units administered by the National Park Service. Sea level change and storm surge vary geographically, resulting in locally-specific challenges for adaptation and management. It is important to acknowledge that sea level change will affect some parts of Alaska differently than coastal parks in the rest of the country. Northwest Alaska can expect relative sea levels to increase over time; while in southeast Alaska, relative sea levels may continue to decrease over the first part of this century, followed by an increase in relative sea level towards the end of the century.

This project is an important first step in assessing how changes in sea level and storm surge may affect national park units. Using sea level rise and storm surge information, parks can begin to plan for effects on resources, facilities, access, and other areas of management. While methods used here are not appropriate for combining the separate sea level rise and storm surge results, parks should be aware of the potential for synergistic effects of sea level rise and storm surge causing impacts larger than either may cause individually. It is clear that more research can be done on these complex issues to assess how these changes may affect parks and regions. These data can inform future projects related to both natural and cultural resources as well as the planning and management of infrastructure.

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Appendix A

Links to Data Sources

Maps were created for this project using NOAA DEM data. For further information regarding our methods refer to methods section on page 3.

Digital versions of our sea level rise maps will be available at www.irma.gov

Storm surge maps are also available on www.irma.gov and
www.flickr.com/photos/125040673@N03/albums/with/72157645643578558

Appendix B

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with regional managers. Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.

Q. Who originally identified which park units should be used in this study?

A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific West Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. In what instance did you use data from Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to provide data for park units in California, Oregon, Washington, and southern Alaska. The following parks used Tebaldi et al. (2012) data: Cabrillo National Monument, Channel Islands National Park, Ebey's Landing National Historical Reserve, Fort Point National Historic Site, Fort Vancouver National Historic Site, Golden Gate National Recreation Area, Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, Rosie the Riveter WWII Home Front National Historical Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012). These parks are: Aniakchak Preserve, Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Glacier Bay National Park and Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park, War in the Pacific National Historical Park, and Wrangell – St. Elias National Park and Preserve.

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into the northern latitudes of that region.

Q. Why are the storm surge maps in NAVD88?

A. That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on sea level and storm surge projections for some parks?

A. The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America to refer to the "elevation" of a location. It uses a fixed value for the height of North America's mean sea level. While this is a popular datum for mapping, it has the limitation that it is based on the observed mean sea level for a single location: Rimouski, Canada. As you move further away from this location you can expect actual sea level to differ from the mean sea level at Rimouski. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

A. All parks are different, as are all projects. Your choice of scenario may depend on many different factors including risk tolerance and expected time horizon of the project. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. (2009). Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). IPCC global sea level rise projections range between 0.26 m (RCP2.6 minimum likely range) and 0.82 m (RCP8.5 maximum likely range) by 2100. The standard error of the IPCC is explained in greater detail in the Chapter 13 supplementary material in AR5 (IPCC 2013). An explanation on the horizontal and vertical accuracy of the digital elevation models used for mapping can be found in the metadata that accompanies the map data on www.irma.gov. DEM data were required to have a ≤18.5 cm root mean square error vertical accuracy before they were converted to MHHW. An exception to this was in Alaska where these data were not available.

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent a maximum based on a typical storm surge category. As described above, there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, periodic changes in regional water temperatures (caused by phenomena such as El Niño and La Niña) will impact water levels that will add to any storm surge. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of all man-made structures, such as flood barriers, levees, and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Higher sea level and permanent inundation will change the way waves propagate within a basin. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. As sea level changes, the fluid dynamics of a particular region will also change. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www.nhc.noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bathtub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact park, region, or Climate Change Response Program staff for assistance. It may be possible to interpolate projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing sources.

Q. What are other impacts from sea level rise that parks should consider?

A. Impacts from sea level rise could include, but are not limited to, increased erosion, damaged cultural resources, damage to above and below ground infrastructure, difficulty accessing inundated infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems. For more information on the topic, please see the Coastal Adaptation Strategies Handbook at: http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

Appendix C

Waysides

The following pages show the final designs for waysides that were installed in parks as part of the funding for this project. Gulf Islands National Seashore received two waysides that were received in 2015. Jean Lafitte National Historical Park and Preserve and Fire Island National Seashores waysides were installed in 2016.

See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the snow white beaches, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Each year, erosion, storms, coastal development, and rising sea level shrink the nesting beach habitat of sea turtles. When a female sea turtle is ready to lay her eggs, she will try to return to the same sandy beach every two to three years. Will her nesting home still be here?

Please join the National Park Service in protecting these beaches, so that you and your children may watch her hatchlings return to lay their eggs.

The road at Fort Pickens gets overwashed with storm waves. As the sea level rises, these events are becoming more common

C-3

Gulf Islands National Seashore

National Park Service
U.S. Department of the Interior

See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the historic forts, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Fighting the Rising Sea

Each year, erosion, storms, shipping channels, and rising sea level are changing the shoreline of the barrier islands. The National Park Service and Corp of Engineers work together on renourishment projects to rebuild the coastline around historic Fort Massachusetts. The fort is often battered by waves, putting the structure in jeopardy.

Please join the National Park Service in protecting our seashore, so that you and your children may continue to enjoy these historic places.

C-4

Jean Lafitte National Historical Park and Preserve

National Park Service
U.S. Department of the Interior

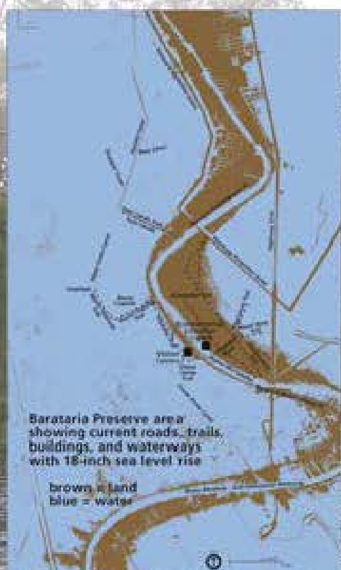
Sinking Land, Rising Water

This is the Barataria Basin, built of soil washed to this area by the Mississippi River. This soil is still compacting and sinking, a process called subsidence. Most of the Barataria Preserve is less than two feet above sea level, and its subsidence rate is nearly half an inch a year.

Meanwhile, glaciers and polar ice sheets are melting and our warming climate is heating oceans everywhere, making their waters expand just like water does when you heat it on the stove. Everywhere on the planet, the oceans are a little higher every day.

The combination of the Barataria Basin's sinking land and global sea level rise means that the ocean is creeping in faster here than almost anywhere else in North America.

- Floods are becoming more frequent and lasting longer
- Coastal wetlands are disappearing as land sinks and water rises
- Less land is available to buffer Gulf of Mexico storms
- Storm and flooding threats to homes, communities, and infrastructure like highways, ports, and energy facilities are increasing
- Salt water from the Gulf is moving into freshwater wetlands, killing the plants that hold the land together
- Death of plants, animals, and microbes that cannot tolerate increased flooding or salt water



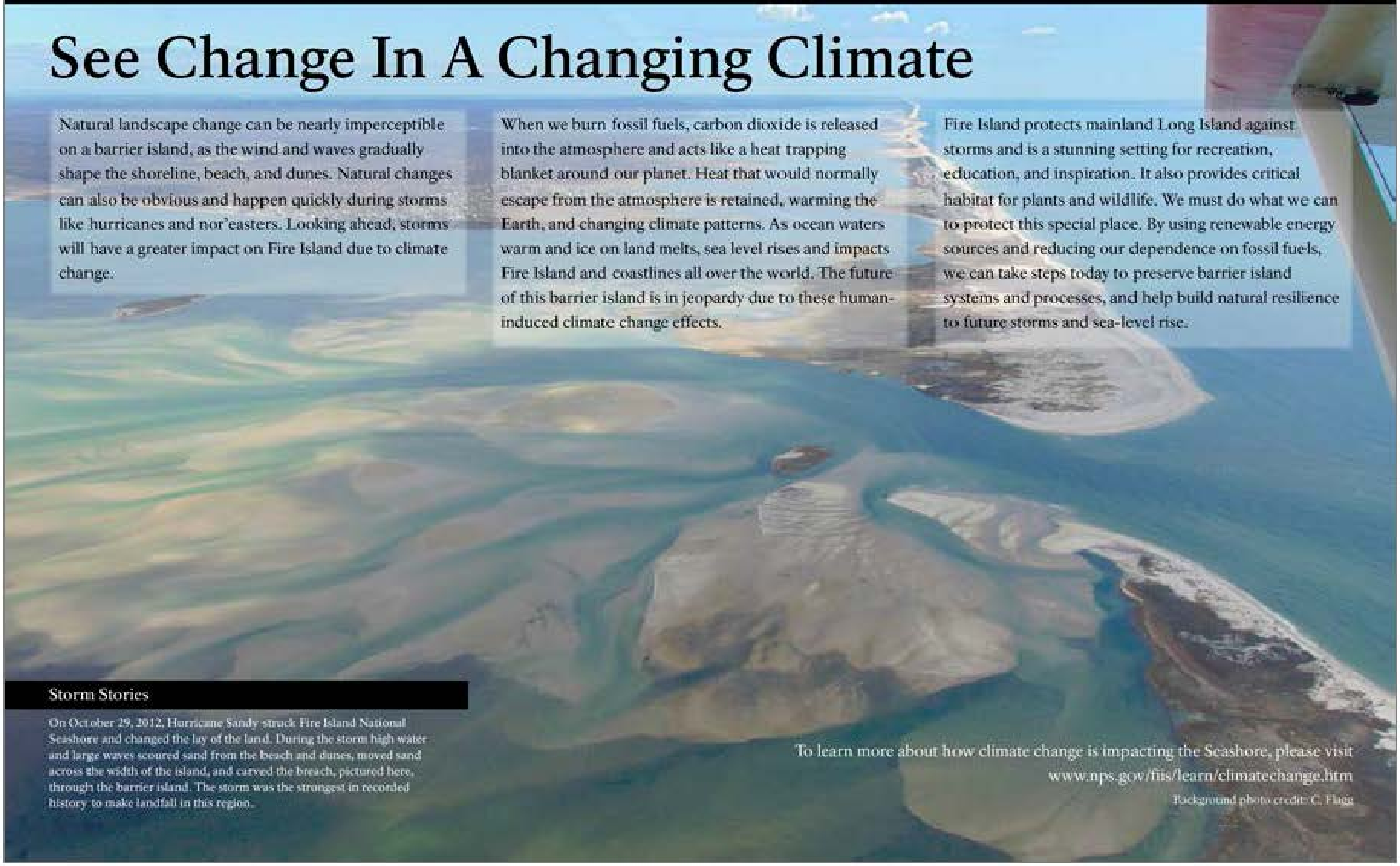
The photo shows two feet of flooding on Barataria Boulevard after Hurricane Isaac in August 2012. The map shows predicted consequences of 18 inches of sea level rise in the preserve; blue areas would be flooded and brown areas would remain land.

See Change In A Changing Climate

Natural landscape change can be nearly imperceptible on a barrier island, as the wind and waves gradually shape the shoreline, beach, and dunes. Natural changes can also be obvious and happen quickly during storms like hurricanes and nor'easters. Looking ahead, storms will have a greater impact on Fire Island due to climate change.

When we burn fossil fuels, carbon dioxide is released into the atmosphere and acts like a heat trapping blanket around our planet. Heat that would normally escape from the atmosphere is retained, warming the Earth, and changing climate patterns. As ocean waters warm and ice on land melts, sea level rises and impacts Fire Island and coastlines all over the world. The future of this barrier island is in jeopardy due to these human-induced climate change effects.

Fire Island protects mainland Long Island against storms and is a stunning setting for recreation, education, and inspiration. It also provides critical habitat for plants and wildlife. We must do what we can to protect this special place. By using renewable energy sources and reducing our dependence on fossil fuels, we can take steps today to preserve barrier island systems and processes, and help build natural resilience to future storms and sea-level rise.



Storm Stories

On October 29, 2012, Hurricane Sandy struck Fire Island National Seashore and changed the lay of the land. During the storm high water and large waves scoured sand from the beach and dunes, moved sand across the width of the island, and carved the breach, pictured here, through the barrier island. The storm was the strongest in recorded history to make landfall in this region.

To learn more about how climate change is impacting the Seashore, please visit www.nps.gov/fiis/learn/climatechange.htm

Background photo credit: C. Flagg

Appendix D

Data Tables

Table D1. The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)[†]	Rate of Subsidence (mm/y)
Northeast Region	Acad a Nat ona Park	Bar Harbor, ME (8413320)	N	60	0.750
	Assateague Is and Nat ona Seashore[‡]	Lewes, DE (8557380)	N	88	1.660
	Boston Harbor Is ands Nat ona Recreat on Area	Boston, MA (8443970)	N	86	0.840
	Boston Nat ona H stor ca Park	Boston, MA (8443970)	N	86	0.840
	Cape Cod Nat ona Seashore	Woods Ho e, MA (8447930)	N	75	0.970
	Cast e C nton Nat ona Monument	New York, The Battery, NY (8518750)	N	151	1.220
	Co on a Nat ona H stor ca Park	Sewe s Po nt, VA (8638610)	N	80	2.610
	Edgar A en Poe Nat ona H stor c S te	Ph ade ph a, PA (8545240)	N	107	1.060
	Federa Ha Nat ona Memor a	New York, The Battery, NY (8518750)	N	151	1.220
	F re Is and Nat ona Seashore	Montauk, NY (8510560)	N	60	1.230
	Fort McHenry Nat ona Monument and H stor c Shr ne	Ba t more, MD (8574680)	N	105	1.330

[†]Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

[‡]It s not recommended that you use th s t de gauge data to determ ne and eve for th s park. The boundary s ocated e ther too far away or on a d fferent and mass to where the nearest t de gauge s, wh ch ncreases the naccuracy of th s data. It s strong y recommended that you wa t for the forthcom ng NASA report on and eve (Nerem n prep).

*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region (continued)	Fort Monroe Nat ona Monument‡	Sewe s Po nt, VA (8638610)	N	80	2.610
	Gateway Nat ona Recreat on Area*‡	Sandy Hook, NJ (8531680)	N	75	2.270
	Genera Grant Nat ona Memor a	New York, The Battery, NY (8518750)	N	151	1.220
	George Wash ngton B rthp ace Nat ona Monument‡	So omons Is and, MD (8577330)	N	70	1.830
	Governors Is and Nat ona Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
	Ham ton Grange Nat ona Memor a	New York, The Battery, NY (8518750)	N	151	1.220
	Harr et Tubman Underground Ra road Nat ona Monument	Cambr dge, MD (8571892)	N	64	1.900
	Independence Nat ona H stor ca Park	Ph ade ph a, PA (8545240)	N	107	1.060
	New Bedford Wha ng Nat ona H stor ca Park	Woods Ho e, MA (8447930)	N	75	0.970
	Petersburg Nat ona Batt ef e d‡	Sewe s Po nt, VA (8638610)	N	80	2.610
	Roger W ams Nat ona Memor a	Prov dence, RI (8454000)	N	69	0.300

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region (continued)	Sagamore H Nat ona H stor c S te	K ngs Po nt, NY (8516945)	N	76	0.670
	Sa nt Cro x Is and Internat ona H stor c S te‡	Eastport, ME (8410140)	N	78	0.350
	Sa em Mar t me Nat ona H stor c S te	Boston, MA (8443970)	N	86	0.840
	Saugus Iron Works Nat ona H stor c S te	Boston, MA (8443970)	N	86	0.840
	Statue of L berty Nat ona Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
	Thaddeus Kosc uszko Nat ona Memor a	Ph ade ph a, PA (8545240)	N	107	1.060
	Theodore Rooseve t B rthp ace Nat ona H stor c S te	New York, The Battery, NY (8518750)	N	151	1.220
Southeast Reg on	B g Cypress Nat ona Preserve	Nap es, FL (8725110)	N	42	0.270
	B scayne Nat ona Park‡	M am Beach, FL (Inact ve – 8723170)	N	51	0.690
	Buck Is and Reef Nat ona Monument‡	San Juan, Puerto R co (9755371)	N	45	-0.020
	Canavera Nat ona Seashore	Daytona Beach Shores, FL (Inact ve – 8721120)	N	59	0.620

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

‡It s not recommended that you use th s t de gauge data to determ ne and eve for th s park. The boundary s ocated e ther too far away or on a d fferent and mass to where the nearest t de gauge s, wh ch ncreases the naccuracy of th s data. It s strong y recommended that you wa t for the forthcom ng NASA report on and eve (Nerem n prep).

*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)[†]	Rate of Subsidence (mm/y)
Southeast Region (continued)	Cape Hatteras National Seashore*[‡]	Beaufort, NC (8656483)	N	54	0.790
	Cape Lookout National Seashore	Beaufort, NC (8656483)	N	54	0.790
	Castillo De San Marcos National Monument[‡]	Mayport, FL (8720218)	N	79	0.590
	Charles Pinckney National Historic Site	Charleston, SC (8665530)	N	86	1.240
	Christiansted National Historic Site[‡]	San Juan, Puerto Rico (9755371)	N	45	-0.202
	Cumberland Island National Seashore[‡]	Fernandina Beach, FL (8720030)	N	110	0.600
	De Soto National Memorial	St. Petersburg, FL (8726520)	N	60	0.920
	Dry Tortugas National Park[‡]	Key West, FL (8724580)	N	94	0.500
	Everglades National Park*[‡]	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
	Fort Caroline National Memorial[‡]	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Frederica National Monument[‡]	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Matanzas National Monument[‡]	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620

[†]Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaces curves(superseded).cfm)

[‡]It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Reg on (cont nued)	Fort Pu ask Nat ona Monument	Fort Pu ask , GA (8670870)	Y	72	1.360
	Fort Ra e gh Nat ona H stor c S te‡	Beaufort, NC (8656483)	N	54	0.790
	Fort Sumter Nat ona Monument‡	Char eston, SC (8665530)	N	86	1.240
	Gu f Is ands Nat ona Seashore (A abama sect on)*‡	Dauph n Is and, AL (8735180)	N	41	1.220
	Gu f Is ands Nat ona Seashore (F or da sect on)*‡	Pensaco a, FL (8729840)	N	84	0.330
	Jean Laf tte Nat ona H stor ca Park and Preserve‡	Grand Is e, LA (8761724)	N	60	7.600
	Moores Creek Nat ona Batt ef e d‡	W m ngton, NC (8658120)	N	72	0.430
	New Or eans Jazz Nat ona H stor ca Park‡	Grand Is e, LA (8761724)	N	60	7.600
	Sa t R ver Bay Nat ona H stor ca Park and Eco og ca Preserve‡	San Juan, Puerto R co (9755371)	N	45	-0.020
	San Juan Nat ona H stor c S te	San Juan, Puerto R co (9755371)	N	45	-0.020
	T mucuan Eco og ca and H stor c Preserve‡	Fernand na Beach, FL (8720030)	N	110	0.600

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

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*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Reg on (cont nued)	V rg n Is ands Cora reef Nat ona Monument‡	San Juan, Puerto R co (9755371)	N	45	-0.020
	V rg n Is ands Nat ona Park‡	San Juan, Puerto R co (9755371)	N	45	-0.020
	Wr ght Brothers Nat ona Memor a ‡	Sewe s Po nt, VA (8638610)	N	80	2.610
Nat ona Cap ta Reg on	Anacost a Park	Wash ngton, DC (8594900)	N	83	1.340
	Chesapeake and Oh o Cana Nat ona H stor ca Park	Wash ngton, DC (8594900)	N	83	1.340
	Const tut on Gardens	Wash ngton, DC (8594900)	N	83	1.340
	Fort Wash ngton Park	Wash ngton, DC (8594900)	N	83	1.340
	George Wash ngton Memor a Parkway	Wash ngton, DC (8594900)	N	83	1.340
	Harpers Ferry Nat ona H stor ca Park	Wash ngton, DC (8594900)	N	83	1.340
	Korean War Veterans Memor a	Wash ngton, DC (8594900)	N	83	1.340
	L nco n Memor a	Wash ngton, DC (8594900)	N	83	1.340
	Lyndon Ba nes Johnson Memor a Grove on the Potomac Nat ona Memor a	Wash ngton, DC (8594900)	N	83	1.340
	Mart n Luther K ng Jr. Memor a	Wash ngton, DC (8594900)	N	83	1.340

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

‡It s not recommended that you use th s t de gauge data to determ ne and eve for th s park. The boundary s ocated e ther too far away or on a d fferent and mass to where the nearest t de gauge s, wh ch ncreases the naccuracy of th s data. It s strong y recommended that you wa t for the forthcom ng NASA report on and eve (Nerem n prep).

*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Nat ona Cap ta Reg on (cont nued)	Nat ona Ma	Wash ngton, DC (8594900)	N	83	1.340
	Nat ona Ma and Memor a Parks	Wash ngton, DC (8594900)	N	83	1.340
	Nat ona Wor d War II Memor a	Wash ngton, DC (8594900)	N	83	1.340
	P scataway Park	Wash ngton, DC (8594900)	N	83	1.340
	Potomac Her tage Nat ona Scen c Tra	Wash ngton, DC (8594900)	N	83	1.340
	Pres dent s Park (Wh te House)	Wash ngton, DC (8594900)	N	83	1.340
	Rock Creek Park	Wash ngton, DC (8594900)	N	83	1.340
	Theodore Rooseve t Is and Park	Wash ngton, DC (8594900)	N	83	1.340
	Thomas Jefferson Memor a	Wash ngton, DC (8594900)	N	83	1.340
	V etnam Veterans Memor a	Wash ngton, DC (8594900)	N	83	1.340
	Wash ngton Monument	Wash ngton, DC (8594900)	N	83	1.340
Intermounta n Reg on	B g Th cket Nat ona Preserve‡	Sab ne Pass, TX (8770570)	N	49	3.850
	Pa o A to Batt ef e d Nat ona H stor ca Park‡	Port Isabe , TX (8779770)	N	63	2.160
	Padre Is and Nat ona Seashore*	Padre Is and, TX (8779750)	N	49	1.780

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)[†]	Rate of Subsidence (mm/y)
Pac f c West Reg on	Amer can Memor a Park[‡]	Mar anas Is ands, Guam (Inact ve – 1630000)	N	46	-2.750
	Cabr o Nat ona Monument	San D ego, CA (9410170)	N	101	0.370
	Channe Is ands Nat ona Park[‡]	Santa Mon ca, CA (9410840)	N	74	-0.280
	Ebey s Land ng Nat ona H stor ca Reserve[‡]	Fr day Harbor, WA (9449880)	N	73	-0.580
	Fort Po nt Nat ona H stor c S te	San Franc sco, CA (9414290)	Y	110	0.360
	Fort Vancouver Nat ona H stor c S te[‡]	Astor a, OR (9439040)	N	82	-2.100
	Go den Gate Nat ona Recreat on Area	San Franc sco, CA (9414290)	N	110	0.360
	Ha eaka a Nat ona Park*[‡]	Kahu u , HI (1615680)	N	60	0.510
	Hawa Vo canoes Nat ona Park*[‡]	H o, HI (1617760)	N	80	1.470
	Ka oko-Honokohau Nat ona H stor ca Park[‡]	H o, HI (1617760)	N	80	1.470
	Lew s and C ark Nat ona H stor ca Park	Astor a, OR (9439040)	N	82	-2.100
	Nat ona Park of Amer can Samoa	Pago Pago, Amer can Samoa (1770000)	N	59	0.370
	O ymp c Nat ona Park*[‡]	Seatt e, WA (9447130)	N	109	0.540

[†]Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

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*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Pac f c West Reg on (cont nued)	Po nt Reyes Nat ona Seashore‡	San Franc sco, CA (9414290)	N	110	0.360
	Port Ch cago Nava Magaz ne Nat ona Memor a ‡	A ameda, CA (9414750)	N	68	-0.780
	Pu uhonua O Honaunau Nat ona H stor ca Park*‡	H o, HI (1617760)	N	80	1.470
	Puukoho a He au Nat ona H stor c S te*‡	H o, HI (1617760)	N	80	1.470
	Redwood Nat ona and State Parks	Crescent C ty, CA (9419750)	N	74	-2.380
	Ros e the R veter WWII Home Front Nat ona H stor ca Park*	A ameda, CA (9414750)	N	68	-0.780
	San Franc sco Mar t me Nat ona H stor ca Park	San Franc sco, CA (9414290)	N	110	0.360
	Santa Mon ca Mounta ns Nat ona Recreat on Area	Santa Mon ca, CA (9410840)	N	74	-0.280
	War n the Pac f c Nat ona H stor ca Park‡	Mar anas Is ands, Guam (Inact ve – 1630000)	N	46	-2.750
	Wor d War II Va or n the Pac f c Nat ona Monument‡	Hono u u, HI (1612340)	N	102	-0.180
A aska Reg on	An akchak Preserve*‡	Una aska, AK (9462620)	N	50	-7.250
	Ber ng Land Br dge Nat ona Preserve‡	No data	No data	No data	No data

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

‡It s not recommended that you use th s t de gauge data to determ ne and eve for th s park. The boundary s ocated e ther too far away or on a d fferent and mass to where the nearest t de gauge s, wh ch ncreases the naccuracy of th s data. It s strong y recommended that you wa t for the forthcom ng NASA report on and eve (Nerem n prep).

*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
A aska Reg on (cont nued)	Cape Krusenstern Nat ona Monument‡	No data	No data	No data	No data
	G ac er Bay Nat ona Park*‡	Juneau, AK (9452210)	N	71	-14.620
	G ac er Bay Preserve*‡	Juneau, AK (9452210)	N	71	-14.620
	Katma Nat ona Park‡	Se dov a, AK (9455500)	N	43	-11.420
	Kena Fjords Nat ona Park‡	Seward, AK (9455090)	N	43	-3.820
	K ond ke Go d Rush Nat ona H stor ca Park‡	Skagway, AK (9452400)	N	63	-18.960
	Lake C ark Nat ona Park‡	Se dov a, AK (9455500)	N	43	-11.420
	S tka Nat ona H stor ca Park‡	S tka, AK (9451600)	N	83	-3.710
	Wrange – St. E as Nat ona Park‡	Cordova, AK (9454050)	N	43	3.450
	Wrange – St. E as Nat ona Preserve‡	Cordova, AK (9454050)	N	43	3.450

†Number of years used by the USACE to ca cu ate sea eve change (source: http://www.corpsc mate.us/ccaces curves(superseded).cfm)

‡It s not recommended that you use th s t de gauge data to determ ne and eve for th s park. The boundary s ocated e ther too far away or on a d fferent and mass to where the nearest t de gauge s, wh ch ncreases the naccuracy of th s data. It s strong y recommended that you wa t for the forthcom ng NASA report on and eve (Nerem n prep).

*The park boundary stretches over e ther arge or mu t p e areas. More than one t de gauge record s appropr ate for th s park.

Table D2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Reg on	Acad a Nat ona Park	2030	0.08	0.09	0.09	0.1
		2050	0.14	0.16	0.16	0.19
		2100	0.28	0.36	0.39	0.54
	Assateague Is and Nat ona Seashore[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Boston Harbor Is ands Nat ona Recreat on Area	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Boston Nat ona H stor ca Park	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Cape Cod Nat ona Seashore[§]	2030	0.13	0.15	0.13	0.15
		2050	0.23	0.27	0.23	0.29
		2100	0.45	0.51	0.57	0.69
	Cast e C nton Nat ona Monument*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†]Parks that are   ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve   n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡]No data was ava ab e for th s scenar o. Data from an adjacent ce   was used n   eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu   data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Reg on (cont nued)	Co on a Nat ona H stor ca Park	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Edgar A en Poe Nat ona H stor c S te*	2030	0.16‡	0.15	0.15‡	0.14
		2050	0.27‡	0.27	0.27‡	0.28
		2100	0.54‡	0.62	0.68‡	0.79
	Federa Ha Nat ona Memor a *	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	F re Is and Nat ona Seashore§	2030	0.14	0.14	0.14	0.14
		2050	0.25	0.26	0.25	0.27
		2100	0.5	0.58	0.62	0.76
	Fort McHenry Nat ona Monument and H stor c Shr ne	2030	0.16‡	0.15	0.15‡	0.14
		2050	0.27‡	0.27	0.27‡	0.28
		2100	0.54‡	0.62	0.68‡	0.79
	Fort Monroe Nat ona Monument	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Reg on (cont nued)	Gateway Nat ona Recreat on Area	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Genera Grant Nat ona Memor a *	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	George Wash ngton B rthp ace Nat ona Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Governors Is and Nat ona Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Ham ton Grange Nat ona Memor a *	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Harr et Tubman Underground Ra road Nat ona Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

[*] Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†] Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡] No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Reg on (cont nued)	Independence Nat ona H stor ca Park*	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	New Bedford Wha ng Nat ona H stor ca Park*	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Petersburg Nat ona Batt ef e d*	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Roger W ams Nat ona Memor a *	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Sagamore H Nat ona H stor c S te	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Sa nt Cro x Is and Internat ona H stor c S te	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.26	0.26	0.27
		2100	0.52	0.59	0.64	0.76

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†]Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡]No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Reg on (cont nued)	Sa em Mar t me Nat ona H stor c S te	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Saugus Iron Works Nat ona H stor c S te	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Statue of L berty Nat ona Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Thaddeus Kosc uszko Nat ona Memor a *	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Theodore Rooseve t B rthp ace Nat ona H stor c S te*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
Southeast Reg on	B g Cypress Nat ona Preserve[§]	2030	0.13	0.13	0.12	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.46	0.54	0.55	0.69

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†]Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡]No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Reg on (cont nued)	B scayne Nat ona Park	2030	0.14‡	0.13	0.12	0.12
		2050	0.24‡	0.23	0.21	0.24
		2100	0.47‡	0.53	0.53	0.68
	Buck Is and Reef Nat ona Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Canavera Nat ona Seashore	2030	0.14‡	0.13	0.13‡	0.12
		2050	0.25‡	0.24	0.24‡	0.24
		2100	0.50‡	0.54	0.59‡	0.68
	Cape Hatteras Nat ona Seashore	2030	0.15‡	0.15	0.15	0.14
		2050	0.26‡	0.28	0.28	0.28
		2100	0.53‡	0.63	0.68	0.79
	Cape Lookout Nat ona Seashore§	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	Cast o De San Marcos Nat ona Monument	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Reg on (cont nued)	Char es P nckney Nat ona H stor c S te*	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Chr st ansted Nat ona H stor c S te	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Cumber and Is and Nat ona Seashore	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	De Soto Nat ona Memor a	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.56	0.57	0.72
	Dry Tortugas Nat ona Park§	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.24
		2100	0.47	0.54	0.56	0.69
	Everg ades Nat ona Park§	2030	0.13	0.13	0.12	0.17
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.54	0.68

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Fort Caroline National Memorial	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Frederica National Monument	2030	0.14	0.13	0.12	0.12
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.54	0.54	0.69
	Fort Matanzas National Monument	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Pulaski National Monument§	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Fort Raleigh National Historic Site	2030	0.15‡	0.15	0.15	0.14
		2050	0.27‡	0.28	0.28	0.28
		2100	0.53‡	0.63	0.68	0.79
	Fort Sumter National Monument	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Reg on (cont nued)	Gu f Is ands Nat ona Seashore[§]	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.55	0.57	0.7
	Jean Laf tte Nat ona H stor ca Park and Preserve[†§]	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Moores Creek Nat ona Batt ef e d*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	New Or eans Jazz Nat ona H stor ca Park*	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Sa t R ver Bay Nat ona H stor c Park and Eco og ca Preserve	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	San Juan Nat ona H stor c S te	2030	0.12	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.22
		2100	0.43	0.49	0.5	0.64

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Reg on (cont nued)	T mucuan Eco og ca and H stor c Preserve	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	V rg n Is ands Cora Reef Nat ona Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	V rg n Is ands Nat ona Park[§]	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	Wr ght Brothers Nat ona Memor a *	2030	0.15[‡]	0.16	0.16	0.15
		2050	0.27[‡]	0.29	0.28	0.29
		2100	0.53[‡]	0.65	0.7	0.82
Nat ona Cap ta Reg on	Anacost a Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Chesapeake & Oh o Cana Nat ona H stor ca Park[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†]Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡]No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Nat ona Cap ta Reg on (cont nued)	Const tut on Gardens*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Fort Wash ngton Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	George Wash ngton Memor a Parkway§	2030	0.15‡	0.15	0.15‡	0.14
		2050	0.26‡	0.27	0.26‡	0.28
		2100	0.53‡	0.62	0.66‡	0.79
	Harpers Ferry Nat ona H stor ca Park*§	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79
	Korean War Veterans Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	L nco n Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are   ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve   n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce   was used n   eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu   data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Nat ona Cap ta Reg on (cont nued)	Lyndon Ba nes Johnson Memor a Grove on the Potomac Nat ona Memor a	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Mart n Luther K ng Jr. Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Nat ona Ma *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Nat ona Ma & Memor a Parks*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Nat ona Wor d War II Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	P scataway Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Nat ona Cap ta Reg on (cont nued)	Potomac Her tage Nat ona Scen c Tra	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Pres dent s Park (Wh te House)*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Rock Creek Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Theodore Rooseve t Is and Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Thomas Jefferson Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	V etnam Veterans Memor a *	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

[†]Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

[‡]No data was ava ab e for th s scenar o. Data from an adjacent ce was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Nat ona Cap ta Reg on (cont nued)	Wash ngton Monument*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
Intermounta n Reg on	B g Th cket Nat ona Preserve*	2030	0.14‡	0.12	0.12‡	0.12
		2050	0.23‡	0.23	0.22‡	0.23
		2100	0.47‡	0.51	0.55‡	0.66
	Pa o A to Batt ef e d Nat ona H stor ca Park*§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
	Padre Is and Nat ona Seashore§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
Pac f c West Reg on	Amer can Memor a Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	Cabr o Nat ona Monument	2030	0.1	0.1	0.09	0.1
		2050	0.17	0.17	0.17	0.19
		2100	0.35	0.4	0.41	0.53

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve   n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

‡No data was ava ab e for th s scenar o. Data from an adjacent ce   was used n eu.

§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu   data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pac f c West Reg on (cont nued)	Channe Is ands Nat ona Park§	2030	0.11	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.39	0.44	0.46	0.57
	Ebey s Land ng Nat ona H stor ca Reserve	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Fort Po nt Nat ona H stor c S te	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Fort Vancouver Nat ona H stor c S te*	2030	0.12	0.11	0.11	0.1
		2050	0.21	0.2	0.19	0.19
		2100	0.42	0.45	0.47	0.55
	Go den Gate Nat ona Recreat on Area§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.18	0.17	0.19
		2100	0.37	0.42	0.43	0.54
	Ha eaka a Nat ona Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are   ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve   n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

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§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu   data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pac f c West Reg on (cont nued)	Hawa Vo canoes Nat ona Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Ka aupapa Nat ona H stor ca Park§	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.66
	Ka oko-Honokohau Nat ona H stor ca Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Lew s and C ark Nat ona H stor ca Park§	2030	0.12	0.1	0.1	0.1
		2050	0.2	0.19	0.18	0.19
		2100	0.4	0.44	0.46	0.53
	Nat ona Park of Amer can Samoa	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.65
	O ymp c Nat ona Park§	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve   n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

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§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu   data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pac f c West Reg on (cont nued)	Po nt Reyes Nat ona Seashore§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.19	0.18	0.19
		2100	0.38	0.43	0.45	0.55
	Port Ch cago Nava Magaz ne Nat ona Memor a	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Pu uhonua O Honaunau Nat ona H stor ca Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Puukoho a He au Nat ona H stor c S te	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.51	0.52	0.67
	Redwood Nat ona and State Parks	2030	0.12	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.4	0.44	0.46	0.56
	Ros e the R veter WWII Home Front Nat ona H stor ca Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pac f c West Reg on (cont nued)	San Franc sco Mar t me Nat ona H stor ca Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	San Juan Is and Nat ona H stor ca Park	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Santa Mon ca Mounta ns Nat ona Recreat on Area§	2030	0.12	0.11	0.1	0.11
		2050	0.2	0.2	0.19	0.2
		2100	0.4	0.45	0.46	0.58
	War n the Pac f c Nat ona H stor ca Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	Wor d War II Va or n the Pac f c Nat ona Monument§	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.67
A aska Reg on	An akchak Preserve§	2030	0.09‡	0.09	0.09	0.09
		2050	0.15‡	0.17	0.16	0.18
		2100	0.31‡	0.38	0.4	0.51

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

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§Parks that cover two or more ce s. Data were averaged between these parks based on percentage of shore ne n each ce . Adjacent ce s were used n cases where boundar es crossed nto nu data ce s.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
A aska Reg on (cont nued)	Ber ng Land Br dge Nat ona Preserve[§]	2030	0.11	0.11	0.1	0.11
		2050	0.18	0.19	0.18	0.21
		2100	0.37	0.44	0.45	0.6
	Cape Krusenstern Nat ona Monument[§]	2030	0.1	0.1	0.1	0.1
		2050	0.17	0.18	0.17	0.2
		2100	0.35	0.42	0.43	0.58
	G ac er Bay Nat ona Park[†§]	2030	0.07	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.12
		2100	0.23	0.25	0.28	0.34
	G ac er Bay Preserve[†]	2030	0.06	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.11
		2100	0.22	0.24	0.27	0.33
	Katma Nat ona Park[§]	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.15	0.16
		2100	0.31	0.34	0.37	0.47
	Katma Nat ona Preserve[†§]	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.14	0.16
		2100	0.3	0.33	0.34	0.45

[*]Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
A aska Reg on (cont nued)	Kena Fjords Nat ona Park[†§]	2030	0.09[‡]	0.08	0.08[‡]	0.08
		2050	0.15[‡]	0.14	0.14[‡]	0.15
		2100	0.30[‡]	0.33	0.34[‡]	0.44
	K ond ke Go d Rush Nat ona H stor ca Park*[†§]	2030	0.06[‡]	0.06	0.06[‡]	0.06
		2050	0.11	0.11	0.11[‡]	0.11
		2100	0.22	0.24	0.27	0.33
	Lake C ark Nat ona Park*[†]	2030	0.08	0.08	0.07	0.08
		2050	0.14	0.14	0.13	0.15
		2100	0.29	0.32	0.33	0.43
	S tka Nat ona H stor ca Park[†]	2030	0.08	0.07	0.07	0.07
		2050	0.14	0.14	0.13	0.14
		2100	0.28	0.31	0.33	0.41
	Wrange - St. E as Nat ona Park[§]	2030	0.07	0.06	0.06	0.07
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.8	0.35
	Wrange – St. E as Nat ona Preserve*[§]	2030	0.07	0.06	0.06	0.06
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.29	0.35

*Parks that do not have shore ne. These numbers are for the nearest shore ne to the park.

†Parks that are ke y to be s gn f cant y mpacted by changes n and eve that cou d resu t *decreasing* re at ve sea eve n the short term fo owed by *increased* re at ve sea eve by the end of the century. Refer to sect on methods for more nformat on.

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Table D3. IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	**Park Unit**	**Highest Recorded Hurricane Within 10 mi (16.1 km)**
Northeast Reg on	Acad a Nat ona Park	Hurr cane, Saff r-S mpson category 1
	Assateague Is and Nat ona Seashore	Hurr cane, Saff r-S mpson category 1
	Boston Harbor Is ands Nat ona Recreat on Area	Hurr cane, Saff r-S mpson category 2
	Boston Nat ona H stor ca Park	Hurr cane, Saff r-S mpson category 3
	Cape Cod Nat ona Seashore	Hurr cane, Saff r-S mpson category 2
	Cast e C nton Nat ona Monument	Hurr cane, Saff r-S mpson category 1
	Co on a Nat ona H stor ca Park	Trop ca storm
	Edgar A en Poe Nat ona H stor c S te	Extratrop ca storm
	Federa Ha Nat ona Memor a	Hurr cane, Saff r-S mpson category 1
	F re Is and Nat ona Seashore	Hurr cane, Saff r-S mpson category 2
	Fort McHenry Nat ona Monument and H stor c Shr ne	Trop ca storm
	Fort Monroe Nat ona Monument	Trop ca storm
	Gateway Nat ona Recreat on Area	Hurr cane, Saff r-S mpson category 1
	Genera Grant Nat ona Memor a	Hurr cane, Saff r-S mpson category 1
	George Wash ngton B rthp ace Nat ona Monument	Extratrop ca storm
	Governors Is and Nat ona Monument	Hurr cane, Saff r-S mpson category 1
	Ham ton Grange Nat ona Memor a	Hurr cane, Saff r-S mpson category 1
	Harr et Tubman Underground Ra road Nat ona Monument	Trop ca storm
	Independence Nat ona H stor ca Park	Extratrop ca storm
	New Bedford Wha ng Nat ona H stor ca Park	Extratrop ca storm
	Petersburg Nat ona Batt ef e d	Hurr cane, Saff r-S mpson category 2
	Roger W ams Nat ona Memor a	Hurr cane, Saff r-S mpson category 3
	Sagamore H Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 2
	Sa nt Cro x Is and Internat ona H stor c S te	Hurr cane, Saff r-S mpson category 2
	Sa em Mar t me Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Northeast Reg on (cont nued)	Saugus Iron Works Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 1
	Statue of L berty Nat ona Monument	Hurr cane, Saff r-S mpson category 1
	Thaddeus Kosc uszko Nat ona Memor a	Extratrop ca storm
	Theodore Rooseve t B rthp ace Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 1
Southeast Reg on	B g Cypress Nat ona Preserve	Hurr cane, Saff r-S mpson category 4
	B scayne Nat ona Park	Hurr cane, Saff r-S mpson category 4
	Buck Is and Reef Nat ona Monument	Hurr cane, Saff r-S mpson category 2
	Canavera Nat ona Seashore	Hurr cane, Saff r-S mpson category 2
	Cape Hatteras Nat ona Seashore	Hurr cane, Saff r-S mpson category 3
	Cape Lookout Nat ona Seashore	Hurr cane, Saff r-S mpson category 3
	Cast o De San Marcos Nat ona Monument	Hurr cane, Saff r-S mpson category 3
	Char es P nckney Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 4
	Chr st ansted Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 4
	Cumber and Is and Nat ona Seashore	Hurr cane, Saff r-S mpson category 4
	De Soto Nat ona Memor a	Hurr cane, Saff r-S mpson category 1
	Dry Tortugas Nat ona Park	Hurr cane, Saff r-S mpson category 4
	Everg ades Nat ona Park	Hurr cane, Saff r-S mpson category 5
	Fort Caro ne Nat ona Memor a	Hurr cane, Saff r-S mpson category 2
	Fort Freder ca Nat ona Monument	Hurr cane, Saff r-S mpson category 1
	Fort Matanzas Nat ona Monument	Hurr cane, Saff r-S mpson category 1
	Fort Pu ask Nat ona Monument	Hurr cane, Saff r-S mpson category 2
	Fort Ra e gh Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 2
	Fort Sumter Nat ona Monument	Hurr cane, Saff r-S mpson category 4
	Gu f Is ands Nat ona Seashore	Hurr cane, Saff r-S mpson category 4
	Jean Laf tte Nat ona H stor ca Park and Preserve	Hurr cane, Saff r-S mpson category 2
	Moores Creek Nat ona Batt ef e d	Hurr cane, Saff r-S mpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Southeast Reg on (cont nued)	New Or eans Jazz Nat ona H stor ca Park	Hurr cane, Saff r-S mpson category 2
	Sa t R ver Bay Nat ona H stor c Park and Eco og ca Preserve	Hurr cane, Saff r-S mpson category 4
	San Juan Nat ona H stor c S te	Hurr cane, Saff r-S mpson category 3
	T mucuan Eco og ca and H stor c Preserve	Hurr cane, Saff r-S mpson category 2
	V rg n Is ands Cora Reef Nat ona Monument	Hurr cane, Saff r-S mpson category 3
	V rg n Is ands Nat ona Park	Hurr cane, Saff r-S mpson category 3
	Wr ght Brothers Nat ona Memor a	Hurr cane, Saff r-S mpson category 2
Nat ona Cap ta Reg on	Anacost a Park	Hurr cane, Saff r-S mpson category 2
	Chesapeake & Oh o Cana Nat ona H stor ca Park	Hurr cane, Saff r-S mpson category 2
	Const tut on Gardens	Hurr cane, Saff r-S mpson category 2
	Fort Wash ngton Park	Hurr cane, Saff r-S mpson category 2
	George Wash ngton Memor a Parkway	Hurr cane, Saff r-S mpson category 2
	Harpers Ferry Nat ona H stor ca Park	Extratrop ca storm
	Korean War Veterans Memor a	Hurr cane, Saff r-S mpson category 2
	L nco n Memor a	Hurr cane, Saff r-S mpson category 2
	Lyndon Ba nes Johnson Memor a Grove on the Potomac Nat ona Memor a	Hurr cane, Saff r-S mpson category 2
	Mart n Luther K ng Jr. Memor a	Hurr cane, Saff r-S mpson category 2
	Nat ona Ma	Hurr cane, Saff r-S mpson category 2
	Nat ona Ma & Memor a Parks	Hurr cane, Saff r-S mpson category 2
	Nat ona Wor d War II Memor a	Hurr cane, Saff r-S mpson category 2
	P scataway Park	Hurr cane, Saff r-S mpson category 2
	Potomac Her tage Nat ona Scen c Tra	Hurr cane, Saff r-S mpson category 2
	Pres dent s Park (Wh te House)	Hurr cane, Saff r-S mpson category 2
	Rock Creek Park	Hurr cane, Saff r-S mpson category 2
	Theodore Rooseve t Is and Park	Hurr cane, Saff r-S mpson category 2
	Thomas Jefferson Memor a	Hurr cane, Saff r-S mpson category 2

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Nat ona Cap ta Reg on (cont nued)	V etnam Veterans Memor a	Hurr cane, Saff r-S mpson category 2
	Wash ngton Monument	Hurr cane, Saff r-S mpson category 2
Intermounta n Reg on	B g Th cket Nat ona Preserve	Hurr cane, Saff r-S mpson category 3
	Pa o A to Batt ef e d Nat ona H stor ca Park	No recorded h stor ca storm
	Padre Is and Nat ona Seashore	Hurr cane, Saff r-S mpson category 4
Pac f c West Reg on	Amer can Memor a Park	Trop ca storm
	Cabr o Nat ona Monument	Trop ca depress on
	Channe Is ands Nat ona Park	No recorded h stor ca storm
	Ebey s Land ng Nat ona H stor ca Reserve	No recorded h stor ca storm
	Fort Po nt Nat ona H stor c S te	No recorded h stor ca storm
	Fort Vancouver Nat ona H stor c S te	No recorded h stor ca storm
	Go den Gate Nat ona Recreat on Area	No recorded h stor ca storm
	Ha eaka a Nat ona Park	Trop ca depress on
	Hawa Vo canoes Nat ona Park	Trop ca depress on
	Ka aupapa Nat ona H stor ca Park	Trop ca depress on
	Ka oko-Honokohau Nat ona H stor ca Park	Trop ca depress on
	Lew s and C ark Nat ona H stor ca Park	No recorded h stor ca storm
	Nat ona Park of Amer can Samoa	No recorded h stor ca storm
	O ymp c Nat ona Park	No recorded h stor ca storm
	Po nt Reyes Nat ona Seashore	No recorded h stor ca storm
	Port Ch cago Nava Magaz ne Nat ona Memor a	No recorded h stor ca storm
	Pu uhonua O Honaunau Nat ona H stor ca Park	No recorded h stor ca storm
	Puukoho a He au Nat ona H stor c S te	Trop ca depress on
	Redwood Nat ona and State Parks	No recorded h stor ca storm

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Pac f c West Reg on (cont nued)	Ros e the R veter WWII Home Front Nat ona H stor ca Park	No recorded h stor ca storm
	San Franc sco Mar t me Nat ona H stor ca Park	No recorded h stor ca storm
	San Juan Is and Nat ona H stor ca Park	No recorded h stor ca storm
	Santa Mon ca Mounta ns Nat ona Recreat on Area	No recorded h stor ca storm
	War n the Pac f c Nat ona H stor ca Park	No recorded h stor ca storm
	Wor d War II Va or n the Pac f c Nat ona Monument	Trop ca depress on
A aska Reg on	An akchak Preserve	No recorded h stor ca storm
	Ber ng Land Br dge Nat ona Preserve	No recorded h stor ca storm
	Cape Krusenstern Nat ona Monument	No recorded h stor ca storm
	G ac er Bay Nat ona Park	No recorded h stor ca storm
	G ac er Bay Preserve	No recorded h stor ca storm
	Katma Nat ona Park	No recorded h stor ca storm
	Katma Nat ona Preserve	No recorded h stor ca storm
	Kena Fjords Nat ona Park	No recorded h stor ca storm
	K ond ke Go d Rush Nat ona H stor ca Park	No recorded h stor ca storm
	Lake C ark Nat ona Park	No recorded h stor ca storm
	S tka Nat ona H stor ca Park	No recorded h stor ca storm
	Wrange - St. E as Nat ona Park	No recorded h stor ca storm
	Wrange – St. E as Nat ona Preserve	No recorded h stor ca storm

NPS 999/137852, April 2017

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakr dge Dr ve, Su te 150
Fort Co ns, CO 80525

www.nature.nps.gov

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170 RE_ Sea Level Rise Report Final Layout Policy R..._1.pdf

From:	Rebecca Beavers
To:	Gross, John
Subject:	RE: Sea Level Rise Report Final Layout Policy Review
Date:	Tuesday, May 23, 2017 4:23:31 PM

I can do this when I am online tomorrow. Thank you for the offer of assistance!

Sent from my Verizon Wireless 4G LTE smartphone

-------- Original message --------
From: "Gross, John" <john_gross@nps.gov>
Date: 05/23/2017 2:16 PM (GMT-07:00)
To: Rebecca Beavers <rebecca_beavers@nps.gov>
Subject: Re: Sea Level Rise Report Final Layout Policy Review

Rebecca,

Do you want me to go ahead and activate the record, but set it for NPS-only access? The would restrict access to the pdf, but I think anyone would be able to see the abstract and associated metadata.

johng

On Mon, May 22, 2017 at 4:28 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> For future reference, obtaining a report number should be one of the very last things that you do.
>
> With our database, we have no way to get "early" report numbers.
>
> The official publication date for that report number is tied to the exact time and date that we give the report a new report number.
>
> Thanks.
>
> Fagan Johnson
> Web and Report Specialist
> National Park Service
> Inventory & Monitoring Division
> 1201 Oakridge Drive, Suite 150
> Fort Collins, Colorado 80525
>
> Email: fagan_johnson@nps.gov
> Phone: 970-267-2190
>
> *"What's another word for Thesaurus?"* Steven Wright

On Mon, May 22, 2017 at 4:21 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Fagan:

1) We do not have DOI approval to make the report public at this point. It will be internal only access for a while.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, May 22, 2017 at 4:00 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

This is concerning your report that we approved for final publication on April 24, 2017.

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

We need someone to do the following over the next 3-5 work days:

1) Activate (make public) the Data Store record (https://irma.nps.gov/DataStore/Reference/Profile/2239974).

2) Upload the final PDF to the activated Data Store record.

Please let me know if you cannot do this yourself, and we will export the last copy that we sent back to you to create an absolute final PDF on this end.

Edits are locked once the final PDF has been made public.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150

Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

On Fri, Apr 21, 2017 at 4:23 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.
>
> The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).
>
> **Three Remaining Steps**
> (Download detailed instructions for all three steps)
>
> **Step 1. Download the updated MS Word file and final and updated MSF at:**
>
> https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ?usp=sharing
>
> **Maintaining your own copy of the final MSF is optional. We maintain multiple archived versions.
>
> **Step 2. Double-check and approve my updates and have Fagan export the final to PDF (Rebecca and Fagan).**
>
> a) **Make your absolute final edits (if any)**, and send the **VERY FINAL** version of the .docx file back to **Fagan**.
>
> If you want to know exactly what we updated in your report (optional), proceed to the *****Report Updates and Changes** section below.
>
> **Make sure that there are no more changes when you send the report to Fagan. The sub-step below takes about 2-3 minutes per page. Changes after that point usually require starting over with the entire process (re-tagging all pages and not just the ones with changes).**
>
> b) **When all edits are final, Fagan will** export the final to

PDF format and manually check fix the HTML-type tags on each page to meet current Section 508 of the Rehabilitation Act standards, such that the final document to be read aloud correctly by special screen readers for the visually and cognitively impaired.

Step 3. Activate the draft IRMA record that I created for you, and upload the final PDF (Fagan).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2239974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

Note: The Data Store search engine only searches on the bibliographic information you enter here. It does not search anything located inside any uploaded digital files.

c) When you are finished updating the Data Store bibliographic information, click the *Activate* button at the bottom-right of the page to save your changes and make the record visible to the public.

d) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF and *Activate* it (the PDF Holding also has to be *Active* to be downloadable).

(Download detailed instructions for all three steps)

*****Everything below this point is just for people that really want to know EXACTLY what we edited and updated in their report.**

*** * *New Report Numbers and Citation (new/important information below highlighted in yellow):**

Series Name Number:

Natural Resource Report NPS/NRSS/NRR—2017/1425

Citation (on shown on page ii):
- we use sentence case here (only first letters, proper names, and acronyms capitalized).

> A good rule-of-thumb for proper names that we use, is whether or not you can send a physical letter through the mail to that entity.
>
> > You **cannot** send a letter to: Sea Level Rise
> >
> > But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

TIC Number: 999/137852

***** Report Updates and Changes : here is what I updated and changed in your report.**

How closely the rest of the report adheres to the "best practices" format and layout standards presented in our document templates, is up to the official Peer Review Manager for that report (Cat or John).

Front Cover and Title Pages (we are only this picky about the front and back cover pages):
- set your page margins to 0.75-inch on the left, top, and right; and 1-inch on the bottom (yours were 1-inch on all sides).
- updated the series name/number with the one that I gave you above.
- made sure that your cover image had alternate text (Section 508 - matches the caption on the following page).
- set the publication month and year to now.

Page ii:
- updated the sixth paragraph to the newer 2017 template standards (DOI/NPS prefers that we just add the hyperlink to the name of the webpage or website, and not spell-out the URL separately).
- updated the official report citation with the information that I gave you above.
- incorporated your new TIC number and the current month and

year into the last line on the page.

Page Numbers: Were showing up in different locations on different pages, so I deleted and re-added them to all pages.

This is a common MS Word bug that occurs whenever multiple versions of MS Word edit or create pages inside the same document (especially when more than two major versions were used).

First Order Headings: Set them all to begin at the top of a new page.

All first order headings must begin at the top of a new page.

The only exception to this rule is if you already have a first order heading at the top of a new page, then you may also place additional first order headings lower on the very same page.

Lists of Contents, Figures, Tables, Photos, and Appendices:
- checked for common software bugs. These were fine.
- updated the page numbers in the tables when I was finished with everything else.

Figures - Made sure that figures:
- stayed inside the page margins (Section 508 and document stability). They were fine.
- were in-line with text (no text wrapping—avoids export to PDF issues and prevents document crashes while editing).
- used consistent and predictable page placement in general (center-justified, same vertical distance from captions, etc.).

Tables - Made sure that:
- the table caption was located on the text line immediately above the table (and not in a table cell—avoids export to PDF issues).
- tables stayed inside the page margins (avoids export to PDF issues and prevents document crashes while editing). For tables that were larger than the page, I either:

a) Shrank the size of the table to fit inside the page margins.

b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

- replaced mid-table multiple column header rows with additional left-hand columns.

- made sure that all captions and table notes were repeated above and below all sub-tables for tables that spanned multiple pages.

- split and merged cells as needed such that all table cells would be read aloud correctly by screen readers for the visually and cognitively impaired (that software was designed to read tables aloud that are set up more like a spreadsheet).

- used a consistent and predictable layout scheme (left-justified, same border and background treatments, etc.) .

Inside Back and Outside Back Cover Page s:
- made sure that the inside back cover occurred on an odd-numbered page.

This insures that the outside back cover is the absolute final printed page (no extra blank page).

- incorporated your new TIC number and the current month and year into the last line on the inside cover page.

That's it!

Fagan Johnson
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"What's another word for Thesaurus?" Steven Wright

--
John Gross, PhD
Climate Change Ecologist, NPS

171 Answers from Lassen.pdf

From:	Patrick Gonzalez
To:	Marcy Rockman
Cc:	Patrick Gonzalez
Subject:	Answers from Lassen
Date:	Wednesday, May 24, 2017 10:12:48 AM

Hi Marcy -

My first destination on Monday was a hike in the snow below Lassen Peak. This is a beautifully scenic park.

We are currently in the meeting planning management of the numerous cultural landscapes here.

Patrick

From: "Rockman, Marcia (Marcy)" <marcy_rockman@nps.gov>
Subject: Re: Answers about climate projections and flooding, for upcoming Preservation Brief workshops
Date: May 24, 2017 at 8:29:06 AM PDT
To: Patrick Gonzalez <patrickgonzalez@berkeley.edu>
Cc: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Thanks so much Patrick. That helps a great deal.

I know FEMA hasn't incorporated climate change, but was not sure about other sources. Now that you mention it, I remember a discussion on a call a while back talking about David's research.

Hope work at Lassen is going well and you get out to see some of the park. Am headed to Shenandoah this weekend - can hardly wait.

Marcy

Marcy Rockman, PhD, RPA
Climate Change Adaptation Coordinator for Cultural Resources
National Park Service
1849 C St. NW
Washington, DC 20240
office: 202.354.2105
cell: 202.360.2752
marcy_rockman@nps.gov

On Wed, May 24, 2017 at 9:45 AM, Patrick Gonzalez <patrickgonzalez@berkeley.edu> wrote:

Hi Marcy,

FEMA does not include projections of climate change in any of its flood risk maps, coastal or non-coastal. To my knowledge, USGS has not made publicly available a national flood and inundation data set for non-coastal areas that integrates projected climate change.

Dave Lawrence is looking into this, so you can ask him more.

Thanks,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
+1 (510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

From: "Rockman, Marcia (Marcy)" <marcy_rockman@nps.gov>
Date: May 22, 2017 at 8:22:35 AM PDT
To: Patrick Gonzalez <patrickgonzalez@berkeley.edu>
Subject: Fwd: Answers about climate projections and flooding, for upcoming Preservation Brief workshops

Hi Patrick,

Just got your out of office, noting that you're at Lassen.

Am sure you're busy there - if you have a chance to look at the follow up question below when you can, greatly appreciate it.

thanks again,
Marcy

Marcy Rockman, PhD, RPA
Climate Change Adaptation Coordinator for Cultural Resources
National Park Service

1849 C St. NW
Washington, DC 20240
office: 202.354.2105
cell: 202.360.2752
marcy_rockman@nps.gov

---------- Forwarded message ----------
From: **Rockman, Marcia (Marcy)** <marcy_rockman@nps.gov>
Date: Mon, May 22, 2017 at 11:19 AM
Subject: Re: Answers about climate projections and flooding, for upcoming Preservation Brief workshops
To: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>

Thanks so much for this Patrick. I just rewatched Maria's CCRP webinar presentation as well and have good notes down from that. Will work with her report for my presentation.

One more question to clarify - is there NPS consensus on how to look at or assess change in risk of inland/non-coastal flooding?

One of the presentations I'll be doing is in Milwaukee, which will have representatives from across the western states. Sea level rise and storm surge aren't their major concerns. So - looking to confirm if we have a set of methods to do this yet, or if this is still more on our list of things to do.

Does that make sense?

Thanks again,
Marcy

Marcy Rockman, PhD, RPA
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office: 202.354.2105
cell: 202.360.2752
marcy_rockman@nps.gov

On Sat, May 20, 2017 at 1:51 AM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Marcy,
>
> Maria Caffrey and colleagues have conducted spatial analyses of sea level rise and storm surge for coastal national parks. I’ve attached for you a draft of the report. She provides

quantitative results by individual park. The method is the same for all the parks.

NOAA has conducted spatial analyses of sea level rise for the entire U.S.:

NOAA Sea level rise viewer
https://coast.noaa.gov/slr

and coastal flood exposure for the east coast:

Coastal Flood Exposure Mapper
https://coast.noaa.gov/floodexposure/#/map

The NPS and NOAA results certainly go beyond the old FEMA flood maps. Maria's spatial outputs are broadly similar to the NOAA outputs, but Maria used the IPCC scenarios, while NOAA used non-standard U.S. scenarios.

I hope that your presentations go well for you!

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
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(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

....

From: "Rockman, Marcia (Marcy)" <marcy_rockman@nps.gov>
Subject: question about climate projections and flooding, for upcoming Preservation Brief workshops
Date: May 18, 2017 at 10:28:38 AM PDT
To: Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hi Patrick,

This is probably an enormous question - are there models or sources of data or approaches you would recommend for a state agency wanting to get a better understanding of future flood risks?

Perhaps in other words - sources of data or analysis beyond the FEMA flood risk maps?

Reason for asking - Cultural Resources Technical Preservation Services/State Tribal Local Planning and Grants programs are in the process of developing a new Preservation Brief that will provide guidance and standards for historic property owners who are planning or required to elevate those historic buildings. We're now preparing to do a series of three workshops in different parts of the country to listen to and work with State Historic Preservation Offices, as part of testing and collecting info that will go into the Brief.

I've been asked to give a climate change introduction for each workshop - with the general theme of how climate change is contributing to flood risk and sea level rise, and making the point that these risks are not going away, and that threats that pose these risks are likely to become more unpredictable.

I have some understanding of how NPS has been trying to track and model sea level rise (Maria Caffrey's work, Rob Young's team, for example). But as the nature of flooding risk can be highly specific to individual locations, I don't really have sense of what NPS is doing overall to capture it. So -- I guess that's my real question - do we have a method overall? Or have we been assessing it on a park-by-park basis?

I'd be grateful for thoughts or suggestions you might have. I need to send a set of slides off to the rest of the team by end of next week (26th), so if you're able to send on thoughts before then, that would be great.

Thank you so much,
Marcy

Marcy Rockman, PhD, RPA
Climate Change Adaptation Coordinator for Cultural Resources
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1849 C St. NW
Washington, DC 20240
office: 202.354.2105
cell: 202.360.2752
marcy_rockman@nps.gov

172 Re_ Response Needed_ Final Proofing_ Sea Level_...(10).pdf

From: Caffrey, Maria
To: Holly, Matt
Cc: Beavers, Rebecca; Larry Perez
Subject: Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date: Wednesday, May 24, 2017 2:02:30 PM

Matt,

It should be ready by the end of the week. Here is a link to the project page on irma: https://irma.nps.gov/DataStore/Reference/Profile/2240004

Could you include a link to the data or the project page on the website?

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Wed, May 24, 2017 at 1:59 PM, Holly, Matt <matt_holly@nps.gov> wrote:

> Just wanted to follow-up with this - I've had on my to-do list to get a webpage created for this report, and wasn't sure what the current status is. Is there a final document yet ready for me to post? I suppose I could always get a draft page up for now if not.
>
> Matt Holly
> National Park Service
> Climate Change Response Program
> (970) 225-3588
>
> **NPS Climate Change** on Facebook | Twitter | Youtube | Flickr
>
> On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
>>
>> Cheers,
>> rebecca
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> FIND YOUR PARK

On Tue, Apr 25, 2017 at 12:15 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

It's that time for a final check prior to publication of:

> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

https://drive.google.com/drive/folders/0B2z-WBMLTvtHTFFpOVJjY3U0Snc?usp=sharing

The NPS Sea Level and Storm Surge Projections Report report is available in the google drive folder and ready for the following Next Steps:

- **Final check by co-authors Patrick Gonzalez and Cat Hawkins Hoffman.**
- **Final check by Science and Communication Team Members. (Babson, Cakir, Gallagher, Holly, Norton, Perez, Thieler (USGS))**
- **If you have edits or will not comment please notify Rebecca.**
- Once complete, we will publish and post on IRMA with internal NPS access(initially & by 4/28 if we want to keep April 2017 text in report)

Plan for Release

- Website updates (Matt Holly)
- Rebecca Beavers and Larry Perez will coordinate release plans through Jeff Olson. Two paths forward are 1) internal release and 2) external release.
- **Co-authors/Communication team members: please review/edit these documents** that will be used to guide the release process. https://drive.google.com/open?id=0B2z-WBMLTvtHMXhvZjFaRVZxYXM

Status: the provided manuscript represents:

- Fagan's NRR series review that includes some reformatting of margins and some tables. (completed 4/21)
- Final edits to address comments from Ann Gallagher as presented on 4/19 communication team call. (completed 4/24)
- Content check by Maria Caffrey and Rebecca Beavers. (completed 4/25)

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

173 References checked on the final report.pdf

From: Caffrey, Maria
To: Rebecca Beavers
Subject: References checked on the final report
Date: Thursday, May 25, 2017 12:02:56 PM

Rebecca,

I've checked the references and have a final version of the document here: N:\GRD\Programs\Climate Change - Beavers & Brunner\Caffrey Sea Level Projections\Final report\2017_04 NRSS Layout Reviewed

It's called "Sea Level Change Report_final_for Fagan_May 25.docx"

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
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Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

174 Re_ Response Needed_ Final Proofing_ Sea Level_...(11).pdf

From:	Perez, Larry
To:	Caffrey, Maria
Cc:	Holly, Matt; Beavers, Rebecca; Jeremy Barnum
Subject:	Re: Response Needed: Final Proofing: Sea Level/Strom Surge Report
Date:	Thursday, May 25, 2017 2:48:30 PM

This is great...thanks for forwarding, Maria.

Just a quick update: Jeff Olson is now on a detail to GRCA for the next four months. Jeremy Barnum (also with WASO COMMS) will be filling in behind Jeff.

I forwarded Jeremy a copy of this report today, and provided him access to our media planning folder. We'll work through Jeremy and Tom Crosson to get this released internally when we're ready to do so.

-L

On Thu, May 25, 2017 at 12:07 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Matt,
>
> Here is a copy of the final version of the report: https://drive.google.com/a/doi.gov/file/d/0BxhhWNH7lJJwYWc4TVBQUkY0RHc/view?usp=sharing
>
> Fagan Johnson still needs to sign off on this and possibly reassign a new number to it, so don't post it to the website yet. I'm sharing this copy with you so you can see the layout and pull any figures you would like to use off of it. It's a rather large document that can take a couple minutes to download, so we should also make it so people have the option to download individual chapters to save time.
>
> Thanks for your help on this!
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage
>
> On Wed, May 24, 2017 at 2:02 PM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:
>
> > Matt,
> >
> > It should be ready by the end of the week. Here is a link to the project page on irma: https://irma.nps.gov/DataStore/Reference/Profile/2240004

Could you include a link to the data or the project page on the website?

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Wed, May 24, 2017 at 1:59 PM, Holly, Matt <matt_holly@nps.gov> wrote:

> Just wanted to follow-up with this - I've had on my to-do list to get a webpage created for this report, and wasn't sure what the current status is. Is there a final document yet ready for me to post? I suppose I could always get a draft page up for now if not.
>
> Matt Holly
> National Park Service
> Climate Change Response Program
> (970) 225-3588
>
> NPS Climate Change on Facebook | Twitter | Youtube | Flickr
>
> On Thu, May 4, 2017 at 1:24 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Please let me know if there are any more final reviews of this report headed our way. We have gotten the all clear from Amanda B, Patrick, and Rob Thieler.
>>
>> Cheers,
>> rebecca
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> On Tue, Apr 25, 2017 at 12:15 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>>
>>> It's that time for a final check prior to publication of:
>>>
>>> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for

the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

https://drive.google.com/drive/folders/0B2z-WBMLTvtHTFFpOVJjY3U0Snc?usp=sharing

The NPS Sea Level and Storm Surge Projections Report report is available in the google drive folder and ready for the following Next Steps:

- **Final check by co-authors Patrick Gonzalez and Cat Hawkins Hoffman.**
- **Final check by Science and Communication Team Members. (Babson, Cakir, Gallagher, Holly, Norton, Perez, Thieler (USGS))**
- **If you have edits or will not comment please notify Rebecca.**
- Once complete, we will publish and post on IRMA with internal NPS access(initially & by 4/28 if we want to keep April 2017 text in report)

Plan for Release

- Website updates (Matt Holly)
- Rebecca Beavers and Larry Perez will coordinate release plans through Jeff Olson. Two paths forward are 1) internal release and 2) external release.
- **Co-authors/Communication team members: please review/edit these documents** that will be used to guide the release process. https://drive.google.com/open?id=0B2z-WBMLTvtHMXhvZjFaRVZxYXM

Status: the provided manuscript represents:

- Fagan's NRR series review that includes some reformatting of margins and some tables. (completed 4/21)
- Final edits to address comments from Ann Gallagher as presented on 4/19 communication team call. (completed 4/24)
- Content check by Maria Caffrey and Rebecca Beavers. (completed 4/25)

Thank you.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FIND YOUR PARK

--

____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

175 NPS.pdf

From:	Patrick Gonzalez NPS
To:	Patrick Gonzalez
Subject:	NPS
Date:	Friday, July 14, 2017 12:48:57 PM

NPS

p. 6 Muir Woods National Monument and line pointing to it
p. 6. Fort Point National Historic Site and line pointing to it
p. 32 Sequoia sempervirens in italics
p. 33 caption Sea level rise

176 Meeting on Tuesday.pdf

From: Perez, Larry
To: Maria Caffrey
Subject: Meeting on Tuesday
Date: Friday, August 11, 2017 9:07:41 AM

Maria,

Just an FYI--

Cat and I will be meeting with Rebecca on Tuesday to discuss how to move the SLR report forward.

More to come...

-L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK | NATIONAL PARK SERVICE

177 Re_ Meeting on Tuesday.pdf

From: Caffrey, Maria
To: Perez, Larry
Subject: Re: Meeting on Tuesday
Date: Tuesday, August 15, 2017 8:45:46 AM

Excellent!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Fri, Aug 11, 2017 at 9:07 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Maria,
>
> Just an FYI--
>
> Cat and I will be meeting with Rebecca on Tuesday to discuss how to move the SLR report forward.
>
> More to come...
>
> -L
>
> ____
>
> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov

179 Re_ SLR Report & 508 Accessibility.pdf

From:	Perez, Larry
To:	Beavers, Rebecca
Cc:	Maria Caffrey; Holly, Matt
Subject:	Re: SLR Report & 508 Accessibility
Date:	Friday, August 18, 2017 1:53:06 PM

Please let me know when upload is complete so I can have a peek.

The briefing looks really good. When possible, could you just take a look at the very first bullet under background? I think I may have inadvertently deleted some text :(

Thanks,

L

On Fri, Aug 18, 2017 at 1:04 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> It is uploading to the shared google folder, but it is moving s l o w l y....
>
> The version I am uploading went through a fair amount of 508 compliance/formatting. Please check and turn into a pdf if feasible.
>
> https://drive.google.com/open?id=0B2z-WBMLTvtHTFFpOVJjY3U0Snc
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Fri, Aug 18, 2017 at 11:44 AM, Perez, Larry <larry_perez@nps.gov> wrote:
>
> > Probably best to hold off posting to IRMA--even internally--for just a little while longer.
> >
> > The latest version I have is from May 2017, and it appears to be final. If you have this final as a PDF (or any more recent version I'm unaware of) please forward it my way when possible.
> >
> > Thanks!
> >
> > -L
> >
> > On Fri, Aug 18, 2017 at 11:26 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
> >
> > > Larry:
> > >
> > > We held off on posting to IRMA (with much frustration on Fagan's behalf). Would you prefer I send you the 508 compliant draft via google drive or go ahead and post to IRMA with internal only access?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, Aug 18, 2017 at 11:23 AM, Perez, Larry <larry_perez@nps.gov> wrote:

Maria & Rebecca,

This far--to my recollection--I've only received the final version of the SLR report in Word format.

Has this report been exported as a 508 accessible PDF? This is really important, as this is the only accessible format we'll be able to post on our website.

I also recall vaguely that this report might already be hosted as an unpublished report on IRMA. If so, do you have a direct link?

-L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science

> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov

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____

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

180 ACTION REQUESTED_ Sea Level Rise and Storm Surg....pdf

From:	Perez, Larry
To:	Maria Caffrey; Beavers, Rebecca; Patrick Gonzalez; Cat Hoffman
Cc:	Holly, Matt
Subject:	ACTION REQUESTED: Sea Level Rise and Storm Surge Projections Report
Date:	Friday, August 18, 2017 2:00:57 PM

Report Authors,

As you are aware, (b) (5) (b) (5) [redacted] As such, Maria, Rebecca and I are recommending we move forward on coordinating a soft, internal release through WASO Comms.

At the moment, we are planning to have Maria & Rebecca provide an internal webinar briefing (if necessary) to relevant personnel at 1:00 MT on Thursday, September 7. We then plan to release the report on Friday, September 15. On that date, the report will be made available on both IRMA and our Coastal Adaptation web page, likely with a supporting post to InsideNPS. We will not pursue a media release.

To support this release, we have compiled several materials in this share folder, to which all of you have edit access. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report

Please take a moment to review these materials and make comments/edits as necessary by COB Tuesday, August 22. The following day, I will notify WASO Comms of our intended release to begin coordination.

Thanks,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

181 Sea Level Change Report_final_for Fagan_May 25.....pdf

From: Rebecca Beavers (via Google Drive)
To: larry_perez@nps.gov; Rebecca Beavers
Subject: Sea Level Change Report_final_for Fagan_May 25.docx
Date: Friday, August 18, 2017 2:04:41 PM

Rebecca Beavers has shared the following document:

W Sea Level Change Report_final_for Fagan_May 25.docx

Open

182 Fwd_ ACTION REQUESTED_ Sea Level Rise and Storm....pdf

From:	Beavers, Rebecca
To:	Dave Steensen; Hal Pranger
Subject:	Fwd: ACTION REQUESTED: Sea Level Rise and Storm Surge Projections Report
Date:	Friday, August 18, 2017 2:28:40 PM

FYI

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Perez, Larry** <larry_perez@nps.gov>
Date: Fri, Aug 18, 2017 at 2:00 PM
Subject: ACTION REQUESTED: Sea Level Rise and Storm Surge Projections Report
To: Maria Caffrey <maria_a_caffrey@partner.nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>
Cc: "Holly, Matt" <matt_holly@nps.gov>

Report Authors,

As you are aware, (b) (5) [redacted] As such, Maria, Rebecca and I are recommending we move forward on coordinating a soft, internal release through WASO Comms.

At the moment, we are planning to have Maria & Rebecca provide an internal webinar briefing (if necessary) to relevant personnel at 1:00 MT on Thursday, September 7. We then plan to release the report on Friday, September 15. On that date, the report will be made available on both IRMA and our Coastal Adaptation web page, likely with a supporting post to InsideNPS. We will not pursue a media release.

To support this release, we have compiled several materials in this share folder, to which all of you have edit access. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report

Please take a moment to review these materials and make comments/edits as necessary by COB Tuesday, August 22. The following day, I will notify WASO Comms of our intended release to begin coordination.

Thanks,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

183 Forthcoming Sea Level Rise and Storm Surge Proj....pdf

From: Perez, Larry
To: Chalmers-Fagan Johnson; Holly, Matt
Cc: Beavers, Rebecca; Maria Caffrey
Subject: Forthcoming Sea Level Rise and Storm Surge Projections Report
Date: Friday, August 18, 2017 3:27:07 PM

Gents,

We are preparing for a soft, internal release of the Sea Level Rise and Storm Surge Projections report on September 15.

I just got the final version of the report from Rebecca, which you can find here on our share drive (document #5):

Z:\CCRP\Communication\105 - Media Requests\FY 17\03 - SLR Report

Unfortunately, its still in Word. According to Rebecca, "The version I am uploading went through a fair amount of 508 compliance/formatting. Please check and turn into a pdf if feasible."

Our intent is to make this report live on both IRMA and our Sea Level Change page on the release date. Fagan, will you be converting this final version to an accessible PDF before uploading to IRMA?

Thanks,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

184 Fwd_ Sea Level Rise Report Final Layout Policy ...(1).pdf

From: Beavers, Rebecca
To: Larry Perez
Subject: Fwd: Sea Level Rise Report Final Layout Policy Review
Date: Friday, August 18, 2017 3:32:51 PM

Larry:

This is the communication chain I had with Fagan re: SL report. If this report comes up in a discussion with Fagan, you might relay the different "strings" that have tied up this report much longer than we could have anticipated.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
Date: Mon, May 22, 2017 at 4:28 PM
Subject: Re: Sea Level Rise Report Final Layout Policy Review
To: "Beavers, Rebecca" <rebecca_beavers@nps.gov>
Cc: John Gross <john_gross@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, Tani Hubbard <tani_hubbard@nps.gov>, Margaret Beer <margaret_beer@nps.gov>

For future reference, obtaining a report number should be one of the very last things that you do.

With our database, we have no way to get "early" report numbers.

The official publication date for that report number is tied to the exact time and date that we give the report a new report number.

Thanks.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

On Mon, May 22, 2017 at 4:21 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Fagan:
>
> 1) We do not have DOI approval to make the report public at this point. It will be internal only access for a while.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Mon, May 22, 2017 at 4:00 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
>> This is concerning your report that we approved for final publication on April 24, 2017.
>>
>> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.
>>
>> **We need someone to do the following over the next 3-5 work days:**
>>
>> 1) Activate (make public) the Data Store record (https://irma.nps.gov/DataStore/Reference/Profile/2239974).
>>
>> 2) Upload the final PDF to the activated Data Store record.
>>
>> Please let me know if you cannot do this yourself, and we will export the last copy that we sent back to you to create an absolute final PDF on this end.
>>
>> Edits are locked once the final PDF has been made public.
>>
>> Fagan Johnson
>> Web and Report Specialist
>> National Park Service

Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

On Fri, Apr 21, 2017 at 4:23 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.

The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).

Three Remaining Steps
(Download detailed instructions for all three steps)

Step 1. Download the updated MS Word file and final and updated MSF at:

https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ?usp=sharing

**Maintaining your own copy of the final MSF is optional. We maintain multiple archived versions.

Step 2. Double-check and approve my updates and have Fagan export the final to PDF (Rebecca and Fagan).

a) **Make your absolute final edits (if any)**, and send the **VERY FINAL** version of the .docx file back to **Fagan**.

If you want to know exactly what we updated in your report (optional), proceed to the *****Report Updates and Changes** section below.

Make sure that there are no more changes when you send the report to Fagan. The sub-step below takes about 2-3 minutes per page. Changes after that point usually require starting over with the entire process (re-tagging all pages and not just the ones with changes).

b) **When all edits are final, Fagan will** export the final to PDF format and manually check fix the HTML-type tags on each page to meet current Section 508 of the Rehabilitation Act standards, such that the final document to be read aloud correctly by special screen readers for the visually and cognitively impaired.

Step 3. Activate the draft IRMA record that I created for you, and upload the final PDF (Fagan).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2239974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

Note: The Data Store search engine only searches on the bibliographic information you enter here. It does not search anything located inside any uploaded digital files.

c) When you are finished updating the Data Store bibliographic information, click the *Activate* button at the bottom-right of the page to save your changes and make the record visible to the public.

d) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF and *Activate* it (the PDF Holding also has to be *Active* to be downloadable).

(Download detailed instructions for all three steps)

*****Everything below this point is just for people that really want to know EXACTLY what we edited and updated in their report.**

*** * *New Report Numbers and Citation (new/important information below highlighted in yellow):**

Series Name Number:

Natural Resource Report NPS/NRSS/NRR—2017/1425

Citation (on shown on page ii):
- we use sentence case here (only first letters, proper names, and acronyms capitalized).

> A good rule-of-thumb for proper names that we use, is whether or not you can send a physical letter through the mail to that entity.
>
> > You **cannot** send a letter to: Sea Level Rise
> >
> > But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

TIC Number: 999/137852

*** Report Updates and Changes : here is what I updated and changed in your report.

How closely the rest of the report adheres to the "best practices" format and layout standards presented in our document templates, is up to the official Peer Review Manager for that report (Cat or John).

Front Cover and Title Pages (we are only this picky about the front and back cover pages):
- set your page margins to 0.75-inch on the left, top, and right; and 1-inch on the bottom (yours were 1-inch on all sides).
- updated the series name/number with the one that I gave you above.
- made sure that your cover image had alternate text (Section 508 - matches the caption on the following page).
- set the publication month and year to now.

Page ii:
- updated the sixth paragraph to the newer 2017 template standards (DOI/NPS prefers that we just add the hyperlink to the name of the webpage or website, and not spell-out the URL separately).
- updated the official report citation with the information that I gave you above.
- incorporated your new TIC number and the current month and year into the last line on the page.

Page Numbers: Were showing up in different locations on different pages, so I deleted and re-added them to all pages.

This is a common MS Word bug that occurs whenever multiple versions of MS Word edit or create pages inside the same document (especially when more than two major versions were used).

First Order Headings: Set them all to begin at the top of a new page.

All first order headings must begin at the top of a new page.

The only exception to this rule is if you already have a first order heading at the top of a new page, then you may also place additional first order headings lower on the very same page.

Lists of Contents, Figures, Tables, Photos, and Appendices:
- checked for common software bugs. These were fine.
- updated the page numbers in the tables when I was finished with everything else.

Figures - Made sure that figures:
- stayed inside the page margins (Section 508 and document stability). They were fine.
- were in-line with text (no text wrapping—avoids export to PDF issues and prevents document crashes while editing).
- used consistent and predictable page placement in general (center-justified, same vertical distance from captions, etc.).

Tables - Made sure that:
- the table caption was located on the text line immediately above the table (and not in a table cell—avoids export to PDF issues).
- tables stayed inside the page margins (avoids export to PDF issues and prevents document crashes while editing). For tables that were larger than the page, I either:

a) Shrank the size of the table to fit inside the page margins.

b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

- replaced mid-table multiple column header rows with additional left-hand columns.

- made sure that all captions and table notes were repeated above and below all sub-tables for tables that spanned multiple pages.

- split and merged cells as needed such that all table cells would be read aloud correctly by screen readers for the visually and cognitively impaired (that software was designed to read tables aloud that are set up more like a spreadsheet).

- used a consistent and predictable layout scheme (left-justified, same border and background treatments, etc.) .

Inside Back and Outside Back Cover Page s:

- made sure that the inside back cover occurred on an odd-numbered page.

This insures that the outside back cover is the absolute final printed page (no extra blank page).

- incorporated your new TIC number and the current month and year into the last line on the inside cover page.

That's it!

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

186 Re_ Sea Level Rise Report Final Layout Policy R...(2).pdf

From:	Perez, Larry
To:	Beavers, Rebecca
Subject:	Re: Sea Level Rise Report Final Layout Policy Review
Date:	Friday, August 18, 2017 3:40:56 PM

Really appreciate your help with all this today, Rebecca, and I'm REALLY glad it was quiet around here today so I could focus!!

Have a great weekend,

L

On Fri, Aug 18, 2017 at 3:39 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Not too sure about that...I typically don't dabble in the IRMA process. That might be a Fagan question.
>
> Let's wait to see if he responds to my earlier email...he may make mention of this.
>
> -L
>
> On Fri, Aug 18, 2017 at 3:37 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> I gave you access to edit the IRMA record. How do we address the published in April, released in September element?
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> ---------- Forwarded message ----------
>> From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
>> Date: Mon, May 22, 2017 at 4:00 PM
>> Subject: Re: Sea Level Rise Report Final Layout Policy Review
>> To: Rebecca Beavers <rebecca_beavers@nps.gov>, John Gross <john_gross@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
>> Cc: Tani Hubbard <tani_hubbard@nps.gov>, Margaret Beer <margaret_beer@nps.gov>
>>
>> This is concerning your report that we approved for final publication on April 24, 2017.
>>
>> Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

We need someone to do the following over the next 3-5 work days:

1) Activate (make public) the Data Store record (https://irma.nps.gov/DataStore/Reference/Profile/2239974).

2) Upload the final PDF to the activated Data Store record.

Please let me know if you cannot do this yourself, and we will export the last copy that we sent back to you to create an absolute final PDF on this end.

Edits are locked once the final PDF has been made public.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

On Fri, Apr 21, 2017 at 4:23 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

Hello Rebecca, everyone. Hopefully this will only require a few more minutes of your time.

The only reason that this email is long, is to provide additional guidance for what you still need to do (the three steps below), and details about exactly what I changed in your document (optional reading below the three steps).

Three Remaining Steps

(Download detailed instructions for all three steps)

Step 1. Download the updated MS Word file and final and updated MSF at:

https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ?usp=sharing

**Maintaining your own copy of the final MSF is optional. We maintain multiple archived versions.

Step 2. Double-check and approve my updates and have Fagan export the final to PDF (Rebecca and Fagan).

a) **Make your absolute final edits (if any)**, and send the **VERY FINAL** version of the .docx file back to **Fagan**.

If you want to know exactly what we updated in your report (optional), proceed to the *****Report Updates and Changes** section below.

Make sure that there are no more changes when you send the report to Fagan. The sub-step below takes about 2-3 minutes per page. Changes after that point usually require starting over with the entire process (re-tagging all pages and not just the ones with changes).

b) **When all edits are final, Fagan will** export the final to PDF format and manually check fix the HTML-type tags on each page to meet current Section 508 of the Rehabilitation Act standards, such that the final document to be read aloud correctly by special screen readers for the visually and cognitively impaired.

Step 3. Activate the draft IRMA record that I created for you, and upload the final PDF (Fagan).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2239974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

Note: The Data Store search engine only searches on the bibliographic information you enter here. It does not search anything located inside any uploaded digital files.

c) When you are finished updating the Data Store bibliographic information, click the *Activate* button at the bottom-right of the page to save your changes and make the record visible to the public.

d) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF and *Activate* it (the PDF Holding also has to be *Active* to be downloadable).

(Download detailed instructions for all three steps)

*****Everything below this point is just for people that really want to know EXACTLY what we edited and updated in their report.**

*** * *New Report Numbers and Citation (new/important information below highlighted in yellow):**

Series Name Number:

Natural Resource Report NPS/NRSS/NRR—2017/1425

Citation (on shown on page ii):

- we use sentence case here (only first letters, proper names, and acronyms capitalized).

A good rule-of-thumb for proper names that we use, is whether or not you can send a physical letter through the mail to that entity.

You **cannot** send a letter to: Sea Level Rise

But, you **can** send a letter to the Sea Level Rise Program, or Office, or Committee.

- if you update the series name/number with the one that I gave you above, your citation becomes:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

TIC Number: 999/137852

***** Report Updates and Changes : here is what I updated and changed in your report.**

How closely the rest of the report adheres to the "best practices" format and layout standards presented in our document templates, is up to the official Peer Review Manager for that report (Cat or John).

Front Cover and Title Pages (we are only this picky about the

front and back cover pages):
- set your page margins to 0.75-inch on the left, top, and right; and 1-inch on the bottom (yours were 1-inch on all sides).
- updated the series name/number with the one that I gave you above.
- made sure that your cover image had alternate text (Section 508 - matches the caption on the following page).
- set the publication month and year to now.

Page ii:
- updated the sixth paragraph to the newer 2017 template standards (DOI/NPS prefers that we just add the hyperlink to the name of the webpage or website, and not spell-out the URL separately).
- updated the official report citation with the information that I gave you above.
- incorporated your new TIC number and the current month and year into the last line on the page.

Page Numbers: Were showing up in different locations on different pages, so I deleted and re-added them to all pages.

> This is a common MS Word bug that occurs whenever multiple versions of MS Word edit or create pages inside the same document (especially when more than two major versions were used).

First Order Headings: Set them all to begin at the top of a new page.

> All first order headings must begin at the top of a new page.
>
> The only exception to this rule is if you already have a first order heading at the top of a new page, then you may also place additional first order headings lower on the very same page.

Lists of Contents, Figures, Tables, Photos, and Appendices:
- checked for common software bugs. These were fine.
- updated the page numbers in the tables when I was finished with everything else.

Figures - Made sure that figures:
- stayed inside the page margins (Section 508 and document stability). They were fine.
- were in-line with text (no text wrapping—avoids export to PDF issues and prevents document crashes while editing).
- used consistent and predictable page placement in general (center-justified, same vertical distance from captions, etc.).

Tables - Made sure that:
- the table caption was located on the text line immediately above the table (and not in a table cell—avoids export to PDF issues).
- tables stayed inside the page margins (avoids export to PDF issues

and prevents document crashes while editing). For tables that were larger than the page, I either:

a) Shrank the size of the table to fit inside the page margins.

b) Changed the page orientation to landscape orientation.

- since this was an NRSS report, reorganized tables to make them more Section 508 compliant.

- replaced mid-table multiple column header rows with additional left-hand columns.

- made sure that all captions and table notes were repeated above and below all sub-tables for tables that spanned multiple pages.

- split and merged cells as needed such that all table cells would be read aloud correctly by screen readers for the visually and cognitively impaired (that software was designed to read tables aloud that are set up more like a spreadsheet).

- used a consistent and predictable layout scheme (left-justified, same border and background treatments, etc.) .

Inside Back and Outside Back Cover Page s:
- made sure that the inside back cover occurred on an odd-numbered page.

This insures that the outside back cover is the absolute final printed page (no extra blank page).

- incorporated your new TIC number and the current month and year into the last line on the inside cover page.

That's it!

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1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

> *"What's another word for Thesaurus?"* Steven Wright

--

____

Larry Perez, Communications Coordinator
Climate Change Response Program
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Office: 970-267-2136
Email: larry_perez@nps.gov

--

____

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Email: larry_perez@nps.gov

187 Accepted_ Potential Briefing for SLR & SS Repor....pdf

From: Maria Caffrey
To: larry_perez@nps.gov; Maria Caffrey
Subject: Accepted: Potential Briefing for SLR & SS Report @ Thu Sep 7, 2017 1pm - 2pm (larry_perez@nps.gov)
Date: Tuesday, August 22, 2017 9:31:59 AM
Attachments: invite.ics

Maria Caffrey has accepted this invitation.

Potential Briefing for SLR & SS Report

Details TBD

When Thu Sep 7, 2017 1pm – 2pm Mountain Time

Video call https://plus.google.com/hangouts/_/doi.gov/larry-perez

Calendar larry_perez@nps.gov

Who
- larry_perez@nps.gov - organizer
- rebecca_beavers@nps.gov
- matt_holly@nps.gov
- cat_hawkins_hoffman@nps.gov
- patrick_gonzalez@nps.gov
- maria_a_caffrey@partner.nps.gov

188 Re_ SLR Report & 508 Accessibility(1).pdf

From: Caffrey, Maria
To: Perez, Larry; Rebecca Beavers
Subject: Re: SLR Report & 508 Accessibility
Date: Tuesday, August 22, 2017 9:36:33 AM

Larry,

Just for reference, here's a link to the project page on irma: https://irma.nps.gov/DataStore/Reference/Profile/2240004

It only has links to the data (and the data are authorized for internal use only). I'll link the report to this page once we go live with it.

Cheers,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Fri, Aug 18, 2017 at 11:23 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Maria & Rebecca,
>
> This far--to my recollection--I've only received the final version of the SLR report in Word format.
>
> Has this report been exported as a 508 accessible PDF? This is really important, as this is the only accessible format we'll be able to post on our website.
>
> I also recall vaguely that this report might already be hosted as an unpublished report on IRMA. If so, do you have a direct link?
>
> -L
>
> ____
>

> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

189 Re_ ACTION REQUESTED_ Sea Level Rise and Storm ....pdf

From: Perez, Larry
To: Maria Caffrey; Beavers, Rebecca; Patrick Gonzalez; Cat Hoffman
Cc: Holly, Matt
Subject: Re: ACTION REQUESTED: Sea Level Rise and Storm Surge Projections Report
Date: Tuesday, August 22, 2017 2:00:25 PM

Team,

Just a quick reminder about this earlier request.

I'll be forwarding these materials and our intent to release this report on September 15 to WASO Comms late tomorrow.

Best,

L

On Fri, Aug 18, 2017 at 2:00 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Report Authors,
>
> As you are aware, (b) (5) [redacted] (b) (5) [redacted] As such, Maria, Rebecca and I are recommending we move forward on coordinating a soft, internal release through WASO Comms.
>
> At the moment, we are planning to have Maria & Rebecca provide an internal webinar briefing (if necessary) to relevant personnel at 1:00 MT on Thursday, September 7. We then plan to release the report on Friday, September 15. On that date, the report will be made available on both IRMA and our Coastal Adaptation web page, likely with a supporting post to InsideNPS. We will not pursue a media release.
>
> To support this release, we have compiled several materials in this share folder, to which all of you have edit access. In this folder you will find:
>
> - a communications plan for the soft release
> - a series of key messages
> - a briefing statement
> - a draft post to be published on InsideNPS
> - a copy of the final report
>
> Please take a moment to review these materials and make comments/edits as necessary by COB Tuesday, August 22. The following day, I will notify WASO Comms of our intended release to begin coordination.
>
> Thanks,
>
> L
>
> ---

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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

190 Re_ Forthcoming Sea Level Rise and Storm Surge ....pdf

From:	Perez, Larry
To:	Chalmers-Fagan Johnson; Holly, Matt
Cc:	Beavers, Rebecca; Maria Caffrey
Subject:	Re: Forthcoming Sea Level Rise and Storm Surge Projections Report
Date:	Tuesday, August 22, 2017 3:53:13 PM

Fagan,

Just bringing this to the top of your inbox again. We'll need to resolve this soon to meet our anticipated September 15 release.

Thanks,

L

On Fri, Aug 18, 2017 at 3:27 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Gents,
>
> We are preparing for a soft, internal release of the Sea Level Rise and Storm Surge Projections report on September 15.
>
> I just got the final version of the report from Rebecca, which you can find here on our share drive (document #5):
>
> Z:\CCRP\Communication\105 - Media Requests\FY 17\03 - SLR Report
>
> Unfortunately, its still in Word. According to Rebecca, "The version I am uploading went through a fair amount of 508 compliance/formatting. Please check and turn into a pdf if feasible."
>
> Our intent is to make this report live on both IRMA and our Sea Level Change page on the release date. Fagan, will you be converting this final version to an accessible PDF before uploading to IRMA?
>
> Thanks,
>
> L
>
> ____
>
> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov

--

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191 Re_ SLR Report & 508 Accessibility(2).pdf

From:	Caffrey, Maria
To:	Beavers, Rebecca
Cc:	Perez, Larry
Subject:	Re: SLR Report & 508 Accessibility
Date:	Wednesday, August 23, 2017 10:56:00 AM

Just checked it. It all looks good.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Fri, Aug 18, 2017 at 2:08 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

> Report upload is complete. I think the briefing statement typo was mine.
>
> Maria: Please check Larry's and my revisions to the briefing statement.
>
> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> National Park Service | Geologic Resources Division
> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>
> On Fri, Aug 18, 2017 at 1:52 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Please let me know when upload is complete so I can have a peek.
>>
>> The briefing looks really good. When possible, could you just take a look at the very first bullet under background? I think I may have inadvertently deleted some text :(
>>
>> Thanks,
>>
>> L
>>
>> On Fri, Aug 18, 2017 at 1:04 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>>
>>> It is uploading to the shared google folder, but it is moving s l o w l y....
>>>
>>> The version I am uploading went through a fair amount of 508 compliance/formatting. Please check and turn into a pdf if feasible.
>>>
>>> https://drive.google.com/open?id=0B2z-WBMLTvtHTFFpOVJjY3U0Snc
>>>
>>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator

National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Fri, Aug 18, 2017 at 11:44 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Probably best to hold off posting to IRMA--even internally--for just a little while longer.
>
> The latest version I have is from May 2017, and it appears to be final. If you have this final as a PDF (or any more recent version I'm unaware of) please forward it my way when possible.
>
> Thanks!
>
> -L
>
> On Fri, Aug 18, 2017 at 11:26 AM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
>> Larry:
>>
>> We held off on posting to IRMA (with much frustration on Fagan's behalf). Would you prefer I send you the 508 compliant draft via google drive or go ahead and post to IRMA with internal only access?
>>
>> Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
>> National Park Service | Geologic Resources Division
>> 303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov
>>
>> On Fri, Aug 18, 2017 at 11:23 AM, Perez, Larry <larry_perez@nps.gov> wrote:
>>
>>> Maria & Rebecca,
>>>
>>> This far--to my recollection--I've only received the final version of the SLR report in Word format.
>>>
>>> Has this report been exported as a 508 accessible PDF? This is really important, as this is the only accessible format we'll be able to post on our website.
>>>
>>> I also recall vaguely that this report might already be hosted as an unpublished report on IRMA. If so, do you have a direct link?
>>>
>>> -L

___

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___

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___

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Fort Collins, CO 80525
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Email: larry_perez@nps.gov

192 Forthcoming Publication_ Sea Level Rise and Sto....pdf

From:	Perez, Larry
To:	Jeremy Barnum
Cc:	Beavers, Rebecca; Maria Caffrey; Patrick Gonzalez; Cat Hoffman; Holly, Matt
Subject:	Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date:	Wednesday, August 23, 2017 4:28:17 PM

Jeremy,

As I mentioned briefly last week, NRSS has a forthcoming report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are planning for a soft, internal release on Friday, September 15. On that date, the report will be made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.

The primary audience for the report is park planners and managers. Additionally, it should be noted that this project did not generate any new data. Rather, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.

To support this internal release, we have compiled several materials in this share folder, to which you and Jeff have edit access. Feel free to share access with additional members on your team as appropriate. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report

Please review these materials at your earliest convenience. Please take note that--per the communication plan--we will rely on WASO Comms to provide notice to DOI, if necessary.

Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We are happy to coordinate this webinar through our office.

Thanks,

L

Larry Perez, Communications Coordinator
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Email: larry_perez@nps.gov

FIND YOUR PARK

194 Fwd_ Sea Level Change Report_final_for Fagan_Ma....pdf

From:	Perez, Larry
To:	Chalmers-Fagan Johnson
Cc:	Holly, Matt; Beavers, Rebecca; Maria Caffrey
Subject:	Fwd: Sea Level Change Report_final_for Fagan_May 25.docx
Date:	Friday, August 25, 2017 5:20:30 PM

Fagan,

Per our convo today, here's the final version of the SLR & SS report. No further changes are anticipated, so we can move forward with final formatting and compliance.

As I mentioned we're shooting to have this posted to both IRMA and our Sea Level Change page on September 15. Please have a look when you can, and let's touch base early next week on what we think might be needed to turn this into a fully compliant PDF.

Thanks,

L

---------- Forwarded message ----------
From: **Rebecca Beavers (via Google Drive)** <drive-shares-noreply@google.com>
Date: Fri, Aug 18, 2017 at 2:04 PM
Subject: Sea Level Change Report_final_for Fagan_May 25.docx
To: larry_perez@nps.gov

Rebecca Beavers has shared the following document:

W Sea Level Change Report_final_for Fagan_May 25.docx

Open

--

Larry Perez, Communications Coordinator

Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

195 Re_ Providing notification up the line....pdf

From: Rebecca Beavers
To: Perez, Larry; Dave Steensen; Hal Pranger
Cc: Maria Caffrey
Subject: Re: Providing notification up the line...
Date: Saturday, August 26, 2017 8:07:56 AM

Hal, Dave:

Bringing you into the recent communication we have with Larry Perez re: plans for release of SL/SS report.

Sent from my iPhone

On Aug 25, 2017, at 4:48 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Rebecca & Maria,
>
> I'm preparing to send notice up the line to Guy, Brian, & Ray first thing Monday regarding our expected release of the SLR report. Before I do, I just wanted to know: has Dave Steensen been made aware of our plan to release yet?
>
> -L
>
> ____
>
> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov
>
> FIND YOUR PARK

196 Hurricane Harvey.pdf

From: Perez, Larry
To: Beavers, Rebecca; Maria Caffrey; Cat Hoffman; Patrick Gonzalez
Subject: Hurricane Harvey
Date: Monday, August 28, 2017 8:23:53 AM

Report Authors,

I had a call first thing this morning with WASO comms, and the SLR/SS report was a topic of discussion. There is some hesitation on their part to broach DOI with our intended report release, given what is playing out in Texas right now. That said, they are open to trying.

My inclination is to proceed with our intended release predicated on these four points:

- We fully intend a soft, internal release with no public communications
- The intended release date of September 15 is still well over two weeks away
- The aftermath of Harvey provides a topical note of relevance for the importance of this work
- We have good records to defend the intended release date against any charges that it is reactionary

Before I push forward, however, I want to get a pulse from each of you regarding your thoughts.

-L

____

Larry Perez, Communications Coordinator
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Email: larry_perez@nps.gov

197 Fwd_ Sea Level Change Report_final_for Fagan_Ma...(1).pdf

From:	Beavers, Rebecca
To:	Caffrey, Maria
Subject:	Fwd: Sea Level Change Report_final_for Fagan_May 25.docx
Date:	Monday, August 28, 2017 2:20:13 PM

Do you have any requested changes?

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

---------- Forwarded message ----------
From: **Johnson, Chalmers-Fagan** <fagan_johnson@nps.gov>
Date: Mon, Aug 28, 2017 at 2:17 PM
Subject: Re: Sea Level Change Report_final_for Fagan_May 25.docx
To: "Perez, Larry" <larry_perez@nps.gov>
Cc: "Holly, Matt" <matt_holly@nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Maria Caffrey <maria_a_caffrey@partner.nps.gov>

This looks great, and won't take much work on my end to do the final review.

Depending on my work-load doing other reports, my final review should be sent back to you within 3-5 work days of when you send me the final copy.

Take care.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
Fort Collins, Colorado 80525

Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

On Fri, Aug 25, 2017 at 5:19 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Fagan,
>
> Per our convo today, here's the final version of the SLR & SS report. No further changes are anticipated, so we can move forward with final formatting and compliance.

As I mentioned we're shooting to have this posted to both IRMA and our Sea Level Change page on September 15. Please have a look when you can, and let's touch base early next week on what we think might be needed to turn this into a fully compliant PDF.

Thanks,

L

---------- Forwarded message ----------
From: **Rebecca Beavers (via Google Drive)** <drive-shares-noreply@google.com>
Date: Fri, Aug 18, 2017 at 2:04 PM
Subject: Sea Level Change Report_final_for Fagan_May 25.docx
To: larry_perez@nps.gov

Rebecca Beavers has shared the following document:

Sea Level Change Report_final_for Fagan_May 25.docx

Open

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

198 Re_ Sea Level Change Report_final_for Fagan_May....pdf

From:	Perez, Larry
To:	Johnson, Chalmers-Fagan
Cc:	Beavers, Rebecca; Holly, Matt; Maria Caffrey
Subject:	Re: Sea Level Change Report_final_for Fagan_May 25.docx
Date:	Monday, August 28, 2017 3:14:09 PM

Fagan,

Following up on our conversation:

- Sounds like you're good to go to get the report finalized and 508 compliant
- Let's plan to keep the report dated May 2017, as that was the date of report completion
- It does appear the report was already issued an NRR number: 2017/1425

Thank you so much for your help...please let me know if you need anything else.

I'll touch base with you again on this in a few days.

-L

On Mon, Aug 28, 2017 at 2:28 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Rebecca, let's talk about this before we change the date of the report, per my earlier email.
>
> Can you please call me when you can?
>
> -L
>
> On Mon, Aug 28, 2017 at 2:24 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
> > The final date will be the month and year when I do the final review.
> >
> > The new report number is tied directly to the date that I assign that number to an individual report.
> >
> > Fagan Johnson
> > Web and Report Specialist
> > National Park Service
> > Inventory & Monitoring Division
> > 1201 Oakridge Drive, Suite 150
> > Fort Collins, Colorado 80525
> >
> > Email: fagan_johnson@nps.gov
> > Phone: 970-267-2190
> >
> > *"What's another word for Thesaurus?"* Steven Wright
> >
> > On Mon, Aug 28, 2017 at 2:22 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:

Fagan:

Can the April Date in the Report be updated to September? (Thank you for your patience on this one; there has been so much outside our control on this one...)

Maria/Larry:

If the date is not updated, we need to be prepared with a good rationale for the delay in the release.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Mon, Aug 28, 2017 at 2:17 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> This looks great, and won't take much work on my end to do the final review.
>
> Depending on my work-load doing other reports, my final review should be sent back to you within 3-5 work days of when you send me the final copy.
>
> Take care.
>
> Fagan Johnson
> Web and Report Specialist
> National Park Service
> Inventory & Monitoring Division
> 1201 Oakridge Drive, Suite 150
> Fort Collins, Colorado 80525
>
> Email: fagan_johnson@nps.gov
> Phone: 970-267-2190
>
> *"What's another word for Thesaurus?"* Steven Wright
>
> On Fri, Aug 25, 2017 at 5:19 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Fagan,
>>
>> Per our convo today, here's the final version of the SLR & SS report. No further changes are anticipated, so we can move forward with final formatting and compliance.
>>
>> As I mentioned we're shooting to have this posted to both IRMA and our Sea Level

Change page on September 15. Please have a look when you can, and let's touch base early next week on what we think might be needed to turn this into a fully compliant PDF.

Thanks,

L

---------- Forwarded message ----------
From: **Rebecca Beavers (via Google Drive)** <drive-shares-noreply@google.com>
Date: Fri, Aug 18, 2017 at 2:04 PM
Subject: Sea Level Change Report_final_for Fagan_May 25.docx
To: larry_perez@nps.gov

Rebecca Beavers has shared the following document:

W Sea Level Change Report_final_for Fagan_May 25.docx

Open

--

___

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

199 Re_ Hurricane Harvey.pdf

From: Perez, Larry
To: Gonzalez, Patrick
Cc: Maria Caffrey; Rebecca Beavers; Cat Hawkins Hoffman
Subject: Re: Hurricane Harvey
Date: Tuesday, August 29, 2017 10:31:07 AM

Thanks, Patrick.

Rebecca and I spoke on the phone yesterday and she concurs on sticking with our intended release date.

I will advance that recommendation to WASO Comms and provide notice up the line to NRSS.

-L

On Tue, Aug 29, 2017 at 9:23 AM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:

> Larry, I agree with you that the report should be released as previously planned.
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Associate Adjunct Professor
> Department of Environmental Science, Policy, and Management
> University of California, Berkeley
> 131 Mulford Hall, Berkeley, CA 94720-3114 USA
>
> patrick_gonzalez@nps.gov
> patrickgonzalez@berkeley.edu
> (510) 643-9725
> @pgonzaleztweet
> http://www.patrickgonzalez.net
> ....
>
> ---------- Forwarded message ----------
> From: **Caffrey, Maria** <maria_a_caffrey@partner.nps.gov>
> Date: Mon, Aug 28, 2017 at 8:09 AM
> Subject: Re: Hurricane Harvey
> To: "Perez, Larry" <larry_perez@nps.gov>
> Cc: "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
>
> Larry,

This sounds fine to me. I don't think any of the projections significantly cross over into the area that is impacted by Harvey, so I really see this storm as outside the scope of anything this report will discuss.

Thanks for pushing this through. I really appreciate it.

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Mon, Aug 28, 2017 at 8:23 AM, Perez, Larry <larry_perez@nps.gov> wrote:

Report Authors,

I had a call first thing this morning with WASO comms, and the SLR/SS report was a topic of discussion. There is some hesitation on their part to broach DOI with our intended report release, given what is playing out in Texas right now. That said, they are open to trying.

My inclination is to proceed with our intended release predicated on these four points:

- We fully intend a soft, internal release with no public communications
- The intended release date of September 15 is still well over two weeks away
- The aftermath of Harvey provides a topical note of relevance for the importance of this work
- We have good records to defend the intended release date against any charges that it is reactionary

Before I push forward, however, I want to get a pulse from each of you regarding your thoughts.

-L

____

Larry Perez, Communications Coordinator
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Email: larry_perez@nps.gov

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____

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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

200 Following Up on Yesterday’s Call.pdf

From: Perez, Larry
To: Jeremy Barnum
Cc: Beavers, Rebecca; Maria Caffrey; Patrick Gonzalez; Cat Hoffman
Subject: Following Up on Yesterday"s Call
Date: Tuesday, August 29, 2017 11:43:40 AM

Jeremy,

Following our discussion yesterday morning, I consulted with the SLR/SS report authors. The consensus is that we would like to move forward on our intended September 15 release, predicated on these four points:

- We fully intend a soft, internal release with no public release
- The intended release date of September 15 is still well over two weeks away
- We feel the aftermath of Harvey provides a topical note of relevance for the importance of this work
- We have good records to defend the intended release date

Furthermore, Maria Caffrey--the lead author of the report--will end her term of service with the NPS in late October. Any delay in release could compromise our ability to have her provide briefings on the project and/or provide clarification on report results.

I will be providing notice up the line to NRSS that we will be moving forward on our intended release, and would appreciate your help in providing notice to DOI as appropriate.

I'll be in the office all day today if you'd like to touch base.

Thanks,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

201 Forthcoming Publication_ Sea Level Rise and Sto...(1).pdf

From: Perez, Larry
To: Guy Adema; Brian Carlstrom; Raymond Sauvajot
Cc: Dave Steensen; Cat Hoffman; Beavers, Rebecca; Maria Caffrey; Forrest Harvey; DiDonato, Eva; Jeremy Barnum
Subject: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date: Tuesday, August 29, 2017 3:27:35 PM

Guy, Brian & Ray,

As you are probably aware, several members of our team have collaborated on a completed report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are coordinating with WASO Comms for a soft, internal release on Friday, September 15. On that date, the report will be made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.

The primary audience for the report is park planners and managers. Additionally, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.

To support this soft release, we have compiled several materials in this share folder, to which you all have access. Feel free to share this folder with additional relevant personnel as appropriate. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report (not for distribution)

Please review these materials at your earliest convenience. Please take note that--per the communication plan--we are relying on WASO Comms to provide notice to DOI, as appropriate.

Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We can coordinate this webinar through our office.

Thanks,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
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Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

202 Re_ Forthcoming Publication_ Sea Level Rise and....pdf

From:	Perez, Larry
To:	DiDonato, Eva
Subject:	Re: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date:	Wednesday, August 30, 2017 7:05:44 AM

Sure thing...think that makes perfect sense.

-L

On Wed, Aug 30, 2017 at 6:50 AM, DiDonato, Eva <eva_didonato@nps.gov> wrote:

> Thanks Larry!
>
> I didn't know you have a Sea Level Rise Subject Site.
> We should link to that from our Oceans Subject Site.
> If it's OK with you, I'll work on getting that link made on this end.
>
> Eva
>
> On Tue, Aug 29, 2017 at 3:26 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Guy, Brian & Ray,
>>
>> As you are probably aware, several members of our team have collaborated on a completed report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are coordinating with WASO Comms for a soft, internal release on Friday, September 15. On that date, the report will be made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.
>>
>> The primary audience for the report is park planners and managers. Additionally, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.
>>
>> To support this soft release, we have compiled several materials in this share folder, to which you all have access. Feel free to share this folder with additional relevant personnel as appropriate. In this folder you will find:
>>
>> - a communications plan for the soft release
>> - a series of key messages
>> - a briefing statement
>> - a draft post to be published on InsideNPS
>> - a copy of the final report (not for distribution)
>>
>> Please review these materials at your earliest convenience. Please take note that--per the communication plan--we are relying on WASO Comms to provide notice to DOI, as appropriate.
>>
>> Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We can coordinate this webinar through our office.
>>
>> Thanks,
>>
>> L
>>
>> ---
>>
>> Larry Perez, Communications Coordinator
>> Climate Change Response Program
>> Natural Resource Stewardship and Science

1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

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\~~~~~~
Eva DiDonato
Chief, Ocean and Coastal Resources Branch
Water Resource Division
Natural Resource Stewardship and Science Directorate
National Park Service

1201 Oakridge Drive, Suite 250
Fort Collins, CO 80525
Office: 970-267-7291
Cell: 970-672-7626
Fax: 970-267-2186
eva_didonato@nps.gov
\~~~~~~
There are a whole lot of things in this world of ours you haven't even started wondering about yet.
– James and the Giant Peach

--

Larry Perez, Communications Coordinator
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Email: larry_perez@nps.gov

FIND YOUR PARK

NATIONAL PARK SERVICE

204 Accepted_ Potential Briefing for SLR & SS Repor...(1).pdf

From: Maria Caffrey
To: larry_perez@nps.gov; Maria Caffrey
Subject: Accepted: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 1pm - 2pm (larry_perez@nps.gov)
Date: Tuesday, September 05, 2017 9:46:44 AM
Attachments: invite.ics

Maria Caffrey has accepted this invitation.

Potential Briefing for SLR & SS Report

Details TBD

When Thu Sep 21, 2017 1pm – 2pm Mountain Time

Video call https://plus.google.com/hangouts/_/doi.gov/larry-perez

Calendar larry_perez@nps.gov

Who
- larry_perez@nps.gov - organizer
- rebecca_beavers@nps.gov
- matt_holly@nps.gov
- cat_hawkins_hoffman@nps.gov
- patrick_gonzalez@nps.gov
- maria_a_caffrey@partner.nps.gov

206 Re_ Update_ Release of SLR & SS Report.pdf

From:	Hoffman, Cat
To:	Perez, Larry
Subject:	Re: Update: Release of SLR & SS Report
Date:	Tuesday, September 05, 2017 10:32:41 AM

Hi Larry -- note that if Brian or Ray are interested in the webinar briefing, this time (1 pm Thursday 9/21) conflicts with the SLT meeting.

On Tue, Sep 5, 2017 at 10:21 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Report Authors,
>
> Just want to keep you in the loop on a couple of things:
>
> - Following conversations between WASO Comms and NRSS leadership, we are electing to push back release of this report by a couple of weeks. The target date for release is now September 29.
>
> - To accommodate this new timeline, we will also be rescheduling the webinar briefing (if requested/required) for Thursday, September 21 at 1:00 PM MT.
>
> - Fagan Johnson is formatting the final report for 508 accessibility. We still expect this work to be complete by September 15.
>
> At this time, Irma is churning as a major hurricane and Tropical Storm Jose has just formed in the Atlantic. We will, however, try to keep to this new release timeline, recognizing both the growing demand for the report data and the limited availability of the lead author.
>
> Best,
>
> L
>
> ____
>
> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
> 1201 Oakridge Drive. Suite 200
> Fort Collins, CO 80525
> Office: 970-267-2136
> Email: larry_perez@nps.gov

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

207 Fwd_ Update_ Release of SLR & SS Report.pdf

From:	Perez, Larry
To:	Holly, Matt
Subject:	Fwd: Update: Release of SLR & SS Report
Date:	Tuesday, September 05, 2017 11:19:06 AM

Sorry, dude...meant to cc: you...

-L

---------- Forwarded message ----------
From: **Perez, Larry** <larry_perez@nps.gov>
Date: Tue, Sep 5, 2017 at 10:21 AM
Subject: Update: Release of SLR & SS Report
To: Maria Caffrey <maria_a_caffrey@partner.nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>
Cc: Jeremy Barnum <jeremy_barnum@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Raymond Sauvajot <ray_sauvajot@nps.gov>

Report Authors,

Just want to keep you in the loop on a couple of things:

- Following conversations between WASO Comms and NRSS leadership, we are electing to push back release of this report by a couple of weeks. The target date for release is now September 29.

- To accommodate this new timeline, we will also be rescheduling the webinar briefing (if requested/required) for Thursday, September 21 at 1:00 PM MT.

- Fagan Johnson is formatting the final report for 508 accessibility. We still expect this work to be complete by September 15.

At this time, Irma is churning as a major hurricane and Tropical Storm Jose has just formed in the Atlantic. We will, however, try to keep to this new release timeline, recognizing both the growing demand for the report data and the limited availability of the lead author.

Best,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525

Office: 970-267-2136
Email: larry_perez@nps.gov

--

Larry Perez, Communications Coordinator
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Office: 970-267-2136
Email: larry_perez@nps.gov

208 Re_ Forthcoming Publication_ Sea Level Rise and...(1).pdf

From: Bryan Faehner
To: Perez, Larry
Cc: Wyse, Jennifer; brian_carlstrom@nps.gov
Subject: Re: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date: Friday, September 08, 2017 7:26:39 AM

Larry - Thanks for the update and heads up.

Sent from my iPhone

On Sep 8, 2017, at 8:40 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> Jen & Bryan,
>
> A quick update on this:
>
> In consultation with WASO Comms, we are electing to delay the release of our Sea Level Rise and Storm Surge report until September 29.
>
> We have also rescheduled our intended briefing for leadership (if requested/required) for Thursday, September 21 @ 3:00 PM ET.
>
> Please feel free to contact me should you have any questions.
>
> Best,
>
> L
>
> On Wed, Aug 30, 2017 at 10:11 AM, Perez, Larry <larry_perez@nps.gov> wrote:
>
> > Jen & Bryan,
> >
> > Bringing you both into the loop on this as well.
> >
> > Per the last line below, report authors are prepared to deliver an internal briefing on September 7 should one be requested through our office.
> >
> > Word of this will be included in our next NRSS Outlook Report.
> >
> > Best,
> >
> > L
> >
> > ---------- Forwarded message ----------
> > From: **Perez, Larry** <larry_perez@nps.gov>
> > Date: Tue, Aug 29, 2017 at 3:26 PM
> > Subject: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
> > To: Guy Adema <guy_adema@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Raymond Sauvajot <ray_sauvajot@nps.gov>
> > Cc: Dave Steensen <dave_steensen@nps.gov>, Cat Hoffman

<cat_hawkins_hoffman@nps.gov>, "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Maria Caffrey <maria_a_caffrey@partner.nps.gov>, Forrest Harvey <Forrest_Harvey@nps.gov>, "DiDonato, Eva" <eva_didonato@nps.gov>, Jeremy Barnum <jeremy_barnum@nps.gov>

Guy, Brian & Ray,

As you are probably aware, several members of our team have collaborated on a completed report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are coordinating with WASO Comms for a soft, internal release on Friday, September 15. On that date, the report will be made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.

The primary audience for the report is park planners and managers. Additionally, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.

To support this soft release, we have compiled several materials in this share folder, to which you all have access. Feel free to share this folder with additional relevant personnel as appropriate. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report (not for distribution)

Please review these materials at your earliest convenience. Please take note that--per the communication plan--we are relying on WASO Comms to provide notice to DOI, as appropriate.

Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We can coordinate this webinar through our office.

Thanks,

L

____

Larry Perez, Communications Coordinator
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Office: 970-267-2136
Email: larry_perez@nps.gov

FIND YOUR PARK

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Office: 970-267-2136
Email: larry_perez@nps.gov

209 Update_ Sea Level Rise & Storm Surge Report.pdf

From: Perez, Larry
To: Chalmers-Fagan Johnson
Cc: Holly, Matt
Subject: Update: Sea Level Rise & Storm Surge Report
Date: Friday, September 08, 2017 10:46:18 AM

Fagan,

Not sure where you are in getting the compliance work done on this report, but a couple of things to be aware of:

- Following conversation with WASO Comms, we are electing to push back the date for the internal release to September 29. That gives us a bit more time.
- There may (or may not) be a need to change some text in the introduction. If so, the necessary changes should all be confined to one page of the report. More to come on that soon.

If you haven't yet completed the work, I'd recommend holding off until I forward clarification. If you have, its hopefully not difficult to make changes to one page, tag accordingly, and bring into the existing document.

Thanks and have a great weekend,

L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

210 Draft final report.pdf

From: Caffrey, Maria
To: Rebecca Beavers
Subject: Draft final report
Date: Thursday, September 14, 2017 11:07:54 AM
Attachments: 2017 Final Report_192415.docx

Rebecca,

See attached.

Thanks,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

210 1 Attachment 2017 Final Report_192415.pdf

Cooperative Agreement No. H2370094000
Task Agreement No. P13AC01178

Final Report: Providing Sea Level Change and Storm Surge Projections for Coastal Parks

Dr. Maria Caffrey, PI, University of Colorado Boulder
September 14, 2017

Maria Caffrey will be ending her role as project PI as the project closes effective September 29, 2017. Dr. Caffrey has worked with the project communication and science groups to deliver a final report that is expected to be internally released. The report has undergone peer review and is currently being edited for 508 compliance with an expected release data of September 29, 2017. Sea level and storm surge results have been uploaded to the Integrated Resource Management Applications (IRMA) portal and linked to a project page on the same portal (https://irma.nps.gov/DataStore/Reference/Profile/2240004).

Results from this project were presented at during a webinar hosted by the Climate Change Response Program on October 13, 2016 and at the George Melendez Wright Meeting in April 2017. Dr. Caffrey has offered her services to help brief staff and answer inquiries after the project terminates. She will also be working with NPS Denver Service Center GIS Program Lead Doug Wilder to make the sea level rise results from this project available in a web mapping format.

211 Re_ Draft final report.pdf

From: Beavers, Rebecca
To: Caffrey, Maria
Subject: Re: Draft final report
Date: Thursday, September 14, 2017 11:12:36 AM

Looks good. Please send to Patrick and ask him to get it loaded in the PMIS statement.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Thu, Sep 14, 2017 at 11:07 AM, Caffrey, Maria <maria_a_caffrey@partner.nps.gov> wrote:

> Rebecca,
>
> See attached.
>
> Thanks,
>
> Maria Caffrey, PhD
>
> Research Associate, University of Colorado
> NPS Partner, Geologic Resources Division
> Office: (303) 969-2097
> Cell: (303) 518-3419
>
> NPS Geologic Resources Division http://nature.nps.gov/geology
> Energy and Minerals * Active Processes and Hazards * Geologic Heritage

213 REVIEW REQUESTED_ SLR &SS Report Final Text.pdf

From:	Perez, Larry
To:	Cat Hoffman; Patrick Gonzalez
Cc:	Beavers, Rebecca; Maria Caffrey
Subject:	REVIEW REQUESTED: SLR &SS Report Final Text
Date:	Monday, September 18, 2017 2:36:39 PM

Cat & Patrick,

I met with Rebecca and Maria this afternoon. Here's the final text of the Executive Summary and Introduction that we will include in the report.

Please call me ASAP if you have any questions or concerns: 970-267-2136.

Thanks,

L

Executive Summary

Changing relative sea levels and the potential for increasing storm surges present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Within the National Park Service, the National Capital Region is projected to experience the highest average rate of sea level change by 2100. The coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is projected to experience the highest storm surges based on historical data and NOAA storm surge models.

Sea level change and storm surge pose considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures located along the coast. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety. These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

Introduction

Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Earth continues to warm as human activities release carbon dioxide (CO_2) into the atmosphere (IPCC 2013, Mearns et al. 2013, Melillo et al. 2014). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

This report provides estimates of sea level change due to climate change for 118 National Park Service units and estimates of storm surge for 79 of those units. As temperature increases, sea levels rise due to a number of factors that will be discussed in greater detail. As sea levels incrementally rise, periods of flooding caused by storms and hurricanes exacerbate the growing problem of coastal inundation (see list of terms). This can present considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures located within coastal park units. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety.

Peek et al. (2015) estimated that the cost of sea level rise in 40 National Park Service units could exceed $40 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks.

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to anthropogenic climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2-5 billion and a 500 year storm surge could cost $5-11 billion (Aerts et al. 2013). Under future scenarios of increasing anthropogenic greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline. Increasing sea levels increase the likelihood of another Hurricane Sandy-sized storm surge striking New York City. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

Larry Perez, Communications Coordinator
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1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

214 Re_ REVIEW REQUESTED_ SLR &SS Report Final Text.pdf

From:	Perez, Larry
To:	Patrick Gonzalez NPS
Cc:	Maria Caffrey; Beavers, Rebecca; Cat Hoffman
Subject:	Re: REVIEW REQUESTED: SLR &SS Report Final Text
Date:	Monday, September 18, 2017 3:10:13 PM

Thanks, Patrick...appreciate the quick reply.

Best,

L

On Mon, Sep 18, 2017 at 3:03 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Larry,
>
> Thanks for the message. These passages include edits that I previously recommended to Maria and are fine.
>
> Thanks,
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Associate Adjunct Professor
> Department of Environmental Science, Policy, and Management
> University of California, Berkeley
> 131 Mulford Hall, Berkeley, CA 94720-3114 USA
>
> patrick_gonzalez@nps.gov
> patrickgonzalez@berkeley.edu
> (510) 643-9725
> @pgonzaleztweet
> http://www.patrickgonzalez.net
> ....
>
> **From:** "Perez, Larry" <larry_perez@nps.gov>
> **Subject: REVIEW REQUESTED: SLR &SS Report Final Text**
> **Date:** September 18, 2017 at 1:35:56 PM PDT
> **To:** Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
> **Cc:** "Beavers, Rebecca" <rebecca_beavers@nps.gov>, Maria Caffrey

<maria_a_caffrey@partner.nps.gov>

Cat & Patrick,

I met with Rebecca and Maria this afternoon. Here's the final text of the Executive Summary and Introduction that we will include in the report.

Please call me ASAP if you have any questions or concerns: 970-267-2136.

Thanks,

L

Executive Summary

Changing relative sea levels and the potential for increasing storm surges present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Within the National Park Service, the National Capital Region is projected to experience the highest average rate of sea level change by 2100. The coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is projected to experience the highest storm surges based on historical data and NOAA storm surge models.

Sea level change and storm surge pose considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures located along the coast. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety. These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

Introduction

Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016).

Earth continues to warm as human activities release carbon dioxide (CO_2) into the atmosphere (IPCC 2013, Mearns et al. 2013, Melillo et al. 2014). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

This report provides estimates of sea level change due to climate change for 118 National Park Service units and estimates of storm surge for 79 of those units. As temperature increases, sea levels rise due to a number of factors that will be discussed in greater detail. As sea levels incrementally rise, periods of flooding caused by storms and hurricanes exacerbate the growing problem of coastal inundation (see list of terms). This can present considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures located within coastal park units. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety.

Peek et al. (2015) estimated that the cost of sea level rise in 40 National Park Service units could exceed $40 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks.

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to anthropogenic climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2-5 billion and a 500 year storm surge could cost $5-11 billion (Aerts et al. 2013). Under future scenarios of increasing anthropogenic greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline. Increasing sea levels increase the likelihood of another Hurricane Sandy-sized storm surge striking New York City. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

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--

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Email: larry_perez@nps.gov

216 Re_ Forthcoming Publication_ Sea Level Rise and...(3).pdf

From:	Faehner, Bryan
To:	Adema, Guy
Cc:	Brian Carlstrom; Raymond Sauvajot; Cat Hoffman; Jeremy Barnum; Wyse, Jennifer; Perez, Larry
Subject:	Re: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date:	Tuesday, September 19, 2017 10:08:01 AM

Guy - Yesterday's NRSS Weekly Report included a reference (below) to the report in the Three Weeks Out section. I did not include it as one of the items I sent Justin Monetti for the report leadership shares with DOI.

(CCRP, GRD) Forthcoming Release of Sea Level Rise and Storm Surge Projections Report: A report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service* will be made available through IRMA in the weeks ahead. The report provides estimates of sea level change for 118 coastal units of the National Park System. The date of anticipated release will be updated in subsequent submissions.

On Tue, Sep 19, 2017 at 11:06 AM, Adema, Guy <guy_adema@nps.gov> wrote:

> Brian/Bryan,
> I haven't tracked how this has been included in the 3 week out recently. Has it been posted consistently for the past few weeks?
> Guy
>
> On Tue, Sep 19, 2017 at 8:29 AM, Perez, Larry <larry_perez@nps.gov> wrote:
>
> > Team,
> >
> > A quick followup on this earlier notice: A final version of the Sea Level Rise & Storm Surge report is now available for your review in this shared folder (please do not distribute.)
> >
> > It is our intent to make the report available through both IRMA and our public-facing Sea Level Change web page in late September, early October.
> >
> > Please reach out to me by COB today if you have any concerns with proceeding. Otherwise, we will request WASO Comms provide notice to the Department at their discretion.
> >
> > Best,
> >
> > L
> >
> > On Tue, Aug 29, 2017 at 3:26 PM, Perez, Larry <larry_perez@nps.gov> wrote:
> >
> > > Guy, Brian & Ray,
> > >
> > > As you are probably aware, several members of our team have collaborated on a completed report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are coordinating with WASO Comms for a soft, internal release on Friday, September 15. On that date, the report will be

made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.

The primary audience for the report is park planners and managers. Additionally, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.

To support this soft release, we have compiled several materials in this share folder, to which you all have access. Feel free to share this folder with additional relevant personnel as appropriate. In this folder you will find:

- a communications plan for the soft release
- a series of key messages
- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report (not for distribution)

Please review these materials at your earliest convenience. Please take note that--per the communication plan--we are relying on WASO Comms to provide notice to DOI, as appropriate.

Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We can coordinate this webinar through our office.

Thanks,

L

____

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____

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Email: larry_perez@nps.gov

--
Guy Adema
Deputy Associate Director
Natural Resource Stewardship and Science
303-987-6697

--
Bryan Faehner
National Park Service
Natural Resource Stewardship and Science
MIB Room 2642
202-513-7256 (office)
202-604-5076 (cell)

217 Re_ Updated Invitation_ Potential Briefing for ....pdf

From: Gonzalez, Patrick
To: Larry Perez
Subject: Re: Updated Invitation: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 12pm - 1pm (patrick_gonzalez@nps.gov)
Date: Tuesday, September 19, 2017 1:58:24 PM

OK - Thanks.

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Associate Adjunct Professor
Department of Environmental Science, Policy, and Management
University of California, Berkeley
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@pgonzaleztweet
http://www.patrickgonzalez.net
....

---------- Forwarded message ----------
From: **Perez, Larry** <larry_perez@nps.gov>
Date: Tue, Sep 19, 2017 at 12:39 PM
Subject: Re: Updated Invitation: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 12pm - 1pm (patrick_gonzalez@nps.gov)
To: "Gonzalez, Patrick" <patrick_gonzalez@nps.gov>

Patrick,

This calendar entry was only a placeholder in the event that NPS/DOI leadership required a pre-release briefing. That request may still come, so we'll need to stay light on our feet to be responsive. The date may change depending on their needs.

Looking forward to seeing you next month,

L :)

On Tue, Sep 19, 2017 at 1:31 PM, Gonzalez, Patrick <patrick_gonzalez@nps.gov> wrote:

> Hi Larry,
>
> Your Google invitation for a telephone call on Thursday says "potential." Are you planning to have the call?
>
> Thanks,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Associate Adjunct Professor
Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

---------- Forwarded message ----------
From: **Larry Perez** <larry_perez@nps.gov>
Date: Tue, Sep 5, 2017 at 8:28 AM
Subject: Updated Invitation: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 12pm - 1pm (patrick_gonzalez@nps.gov)
To: patrick_gonzalez@nps.gov, matt_holly@nps.gov, cat_hawkins_hoffman@nps.gov, maria_a_caffrey@partner.nps.gov, rebecca_beavers@nps.gov

This event has been changed.

Potential Briefing for SLR & SS Report **more details »**

Details TBD

When **Changed:** Thu Sep 21, 2017 12pm – 1pm Pacific Time

Video call https://plus.google.com/hangouts/_/doi.gov/larry-perez

Calendar patrick_gonzalez@nps.gov

Who
- larry_perez@nps.gov - organizer
- patrick_gonzalez@nps.gov
- matt_holly@nps.gov
- cat_hawkins_hoffman@nps.gov
- maria_a_caffrey@partner.nps.gov
- rebecca_beavers@nps.gov

Going? **Yes** - **Maybe** - **No** more options »

You are receiving this email at the account patrick_gonzalez@nps.gov because you are subscribed for updated invitations on calendar patrick_gonzalez@nps.gov.

To stop receiving these emails, please log in to https://www.google.com/calendar/ and change your notification settings for this calendar.

Forwarding this invitation could allow any recipient to modify your RSVP response. Learn More.

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Email: larry_perez@nps.gov

218 Re_ Updated Invitation_ Potential Briefing for ...(1).pdf

From:	Gonzalez, Patrick
To:	Larry Perez
Subject:	Re: Updated Invitation: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 12pm - 1pm (patrick_gonzalez@nps.gov)
Date:	Tuesday, September 19, 2017 1:59:50 PM
Attachments:	invite.ics

Hi Larry,

Your Google invitation for a telephone call on Thursday says "potential." Are you planning to have the call?

Thanks,

Patrick

....
Patrick Gonzalez, Ph.D.
Principal Climate Change Scientist
Natural Resource Stewardship and Science
U.S. National Park Service

Associate Adjunct Professor
Department of Environmental Science, Policy, and Management
University of California, Berkeley
131 Mulford Hall, Berkeley, CA 94720-3114 USA

patrick_gonzalez@nps.gov
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....

---------- Forwarded message ----------
From: **Larry Perez** <larry_perez@nps.gov>
Date: Tue, Sep 5, 2017 at 8:28 AM
Subject: Updated Invitation: Potential Briefing for SLR & SS Report @ Thu Sep 21, 2017 12pm - 1pm (patrick_gonzalez@nps.gov)
To: patrick_gonzalez@nps.gov, matt_holly@nps.gov, cat_hawkins_hoffman@nps.gov, maria_a_caffrey@partner.nps.gov, rebecca_beavers@nps.gov

This event has been changed.

Potential Briefing for SLR & SS Report more details »

Details TBD

When **Changed:** Thu Sep 21, 2017 12pm – 1pm Pacific Time

Video call https://plus.google.com/hangouts/_/doi.gov/larry-perez

Calendar patrick_gonzalez@nps.gov

Who

- larry_perez@nps.gov - organizer
- patrick_gonzalez@nps.gov
- matt_holly@nps.gov
- cat_hawkins_hoffman@nps.gov
- maria_a_caffrey@partner.nps.gov
- rebecca_beavers@nps.gov

Going? **Yes** - **Maybe** - **No** more options »

219 Re_ Sea level mapping website not working.pdf

From:	Caffrey, Maria
To:	Patrick Gonzalez NPS
Cc:	Babson, Amanda; Patrick Gonzalez UC; Steve Nerem; E. Robert Thieler
Subject:	Re: Sea level mapping website not working
Date:	Monday, September 25, 2017 11:35:02 AM

Hi Patrick,

Sorry about that. I will follow up with the team regarding support for macs. We have been experiencing some issues with it not loading the first time for people, but it never occurred to me to check how it loads on a mac.

I was told it was on a public facing server, but that seems to not be the case so Steve (and maybe Rob) won't be able to review it. It will eventually be public facing once we have worked the bugs out.

Thanks for letting me know about these issues!

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

On Fri, Sep 22, 2017 at 12:13 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Maria,
>
> I just looked at the site and the main page does not work in either Safari or Firefox for MacOS. Only the “About” and “Contact” links work.
>
> Also, the beta only seems to be open on government network, so Steve might not be able to see it.
>
> Thanks,
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science
> U.S. National Park Service
>
> Associate Adjunct Professor
> Department of Environmental Science, Policy, and Management

University of California, Berkeley
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patrick_gonzalez@nps.gov
patrickgonzalez@berkeley.edu
(510) 643-9725
@pgonzaleztweet
http://www.patrickgonzalez.net
....

---------- Forwarded message ----------
From: Caffrey, Maria <maria_a_caffrey@partner.nps.gov>
Date: Thu, Sep 14, 2017 at 1:09 PM
Subject: Science team review of sea level mapping website
To: Steve Nerem <nerem@colorado.edu>, "E. Robert Thieler" <rthieler@usgs.gov>, Amanda Babson <amanda_babson@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>

Hello everyone,

I am emailing because of your experience serving on the science team for the sea level and storm surge project. I have recently been working with some GIS experts at the National Park Service to create a sea level rise mapping website for NPS staff and members of the public to explore the data from my project without needing access to ArcGIS. Would it be possible for you to take a look at a beta version of the website and fill out a brief survey regarding your experience?

The beta version of the website can be accessed at:
(b) (5) [redacted]

Please provide feedback using our survey: https://www.surveymonkey.com/r/ZH7GRRC

We would appreciate it if reviewers could provide feedback by COB Monday September 25th. I apologize for the short turn around time. I know some of you are dealing with the current storm season. Feel free to forward this to anyone you think might be an appropriate reviewer if you don't have the time to take a look.

Many thanks,

Maria Caffrey, PhD

Research Associate, University of Colorado
NPS Partner, Geologic Resources Division
Office: (303) 969-2097
Cell: (303) 518-3419

NPS Geologic Resources Division http://nature.nps.gov/geology
Energy and Minerals * Active Processes and Hazards * Geologic Heritage

220 Re_ Forthcoming Publication_ Sea Level Rise and...(4).pdf

From:	Perez, Larry
To:	Faehner, Bryan
Cc:	Cat Hoffman
Subject:	Re: Forthcoming Publication: Sea Level Rise and Storm Surge Projections Report
Date:	Tuesday, September 26, 2017 9:05:44 AM

Cat,

Bryan and I connected this morning.

-L

On Tue, Sep 26, 2017 at 8:39 AM, Faehner, Bryan <bryan_faehner@nps.gov> wrote:

> Cat and Larry - Can one of you remind me if there has been a formal briefing for the NPS leadership on the report. I don't believe there was, but wanted to make sure. Also, have there been any further discussions regarding a potential release date? Thanks.
>
> On Tue, Sep 19, 2017 at 10:29 AM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Team,
>>
>> A quick followup on this earlier notice: A final version of the Sea Level Rise & Storm Surge report is now available for your review in this shared folder (please do not distribute.)
>>
>> It is our intent to make the report available through both IRMA and our public-facing Sea Level Change web page in late September, early October.
>>
>> Please reach out to me by COB today if you have any concerns with proceeding. Otherwise, we will request WASO Comms provide notice to the Department at their discretion.
>>
>> Best,
>>
>> L
>>
>> On Tue, Aug 29, 2017 at 3:26 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>>
>>> Guy, Brian & Ray,
>>>
>>> As you are probably aware, several members of our team have collaborated on a completed report entitled *Sea Level Rise and Storm Surge Projections for the National Park Service*. We are coordinating with WASO Comms for a soft, internal release on Friday, September 15. On that date, the report will be made available on both IRMA and our public-facing Sea Level Change web page, likely with a supporting post to InsideNPS.
>>>
>>> The primary audience for the report is park planners and managers. Additionally, the report is a synthesis of existing publicly available data sets. As such, we feel an internal release is most appropriate, and we will not pursue a media release.
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- a briefing statement
- a draft post to be published on InsideNPS
- a copy of the final report (not for distribution)

Please review these materials at your earliest convenience. Please take note that--per the communication plan--we are relying on WASO Comms to provide notice to DOI, as appropriate.

Finally, the report authors are ready to deliver a webinar briefing for relevant NPS personnel at 1:00 PM MT on Thursday, September 7, if necessary and/or requested. We can coordinate this webinar through our office.

Thanks,

L

Larry Perez, Communications Coordinator
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Office: 970-267-2136
Email: larry_perez@nps.gov

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Email: larry_perez@nps.gov

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Bryan Faehner
National Park Service
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MIB Room 2642
202-513-7256 (office)
202-604-5076 (cell)

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Larry Perez, Communications Coordinator
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Email: larry_perez@nps.gov

FUTURE PARK LEADERS of EMERGING CHANGE

NOW ACCEPTING PROJECT PROPOSALS FOR 2018!

222 Fwd_ Update_ Sea Level Rise & Storm Surge Report.pdf

From:	Rebecca Beavers
To:	Larry Perez
Subject:	Fwd: Update: Sea Level Rise & Storm Surge Report
Date:	Tuesday, September 26, 2017 10:14:24 AM

Can we ask Fagan to post the report on Irma with internal/ sensitive access?

Sent from my iPhone

Begin forwarded message:

> **From:** "Johnson, Chalmers-Fagan" <fagan_johnson@nps.gov>
> **Date:** September 26, 2017 at 9:04:17 AM MDT
> **To:** "Perez, Larry" <larry_perez@nps.gov>, Rebecca Beavers <rebecca_beavers@nps.gov>
> **Subject: Re: Update: Sea Level Rise & Storm Surge Report**
>
> Take a look at the PDF here:
>
> https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ
>
> Those appendix tables would not export to PDF that cleanly, and it took me about six hours of manual tagging to make them Section 508 accessible.
>
> Let me know if this works, and I'll activate the Data Store record and upload it (make it public).
>
> Thanks.
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> Inventory & Monitoring Division
> 1201 Oakridge Drive, Suite 150
> Fort Collins, Colorado 80525
>
> Email: fagan_johnson@nps.gov
> Phone: 970-267-2190
>
> *"What's another word for Thesaurus?"* Steven Wright
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> > This is at the top of my queue, when they have it fixed.

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Just a quick update on this:

We are *very* close to having a final version...should be able to get it to you by COB Tuesday.

Thanks, and have a great weekend!

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On Fri, Sep 8, 2017 at 11:59 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

Sounds good.

As long as the report was not released outside the NPS yet, you can edit anything between the first four pages (front cover to disclaimer page) and the last two pages (back cover pages).

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223 Re_ Update_ Sea Level Rise & Storm Surge Report.pdf

From:	Perez, Larry
To:	Johnson, Chalmers-Fagan
Cc:	Rebecca Beavers
Subject:	Re: Update: Sea Level Rise & Storm Surge Report
Date:	Tuesday, September 26, 2017 11:28:24 AM

Fagan,

This looks good to me. Great job whipping those tables into compliance! :)

I added document metadata, set the bookmarks panel to open automatically, and saved a new version with "508 compliant" in the file name. I've uploaded this file to the same share folder, and we should plan to roll with that version.

Rebecca, Cat, and I are currently discussing how we would like to make this available on IRMA, so please do not upload until I touch base with you once more.

Many, many thanks for your persistent work on this,

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FUTURE PARK LEADERS
of EMERGING CHANGE

NOW ACCEPTING PROJECT PROPOSALS FOR 2018!

224 Re_ Update_ Sea Level Rise & Storm Surge Report(1).pdf

From: Hoffman, Cat
To: Perez, Larry
Cc: Rebecca Beavers
Subject: Re: Update: Sea Level Rise & Storm Surge Report
Date: Tuesday, September 26, 2017 11:35:36 AM

My understanding (correct me if I'm wrong) is that (b) (5) [redacted]

[redacted] I can provide more details next time we talk.

If I missed something, or there's a specific reason we would need to do this now, let me know.

Cat

On Tue, Sep 26, 2017 at 11:09 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> I would support this, but I'm not the final arbiter.
>
> Cat, what do you think?
>
> -L
>
> On Tue, Sep 26, 2017 at 10:14 AM, Rebecca Beavers <rebecca_beavers@nps.gov> wrote:
>
> > (b) (5) [redacted]
> >
> > Sent from my iPhone
> >
> > Begin forwarded message:
> >
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FIND YOUR PARK

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cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

225 Re_ Update_ Sea Level Rise & Storm Surge Report(2).pdf

From:	Perez, Larry
To:	Cat Hoffman
Cc:	Rebecca Beavers
Subject:	Re: Update: Sea Level Rise & Storm Surge Report
Date:	Thursday, September 28, 2017 3:51:54 PM

Rebecca & Cat,

Just closing the loop on this email thread:

Fagan has kindly wrapped up all compliance work on the report and leaves it in our hands. A copy of the 508 compliant report can be found here.

He has also created a record for the report (which is available only to us) to use for upload whenever we are ultimately ready to do so.

We can discuss more on Tuesday,

-L

On Tue, Sep 26, 2017 at 11:34 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> Okay.
>
> Please use the IRMA record that I created for you, and do not create a duplicate one.
>
> https://irma.nps.gov/DataStore/Reference/Profile/2239974
>
> Why?
>
> The DOI Soclitor's Office mandates that the NRR, TIC, and IRMA ID values match in all of those systems, as well as in all of their individual off-site backup solutions (per records management policy).
>
> We can't "get back" or change the previously archived records...
>
> Thanks.
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> And, we cannot change the date that was originally assigned later.
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Thanks.

Fagan Johnson
Web and Report Specialist
National Park Service
Inventory & Monitoring Division
1201 Oakridge Drive, Suite 150
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Email: fagan_johnson@nps.gov
Phone: 970-267-2190

> *"What's another word for Thesaurus?"* Steven Wright

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>
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Thanks and have a great weekend,

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> **NOW ACCEPTING PROJECT PROPOSALS FOR 2018!**

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of EMERGING CHANGE

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226 Fwd_ Update_ Sea Level Rise & Storm Surge Report(1).pdf

From: Rebecca Beavers
To: Hal Pranger
Subject: Fwd: Update: Sea Level Rise & Storm Surge Report
Date: Tuesday, November 14, 2017 8:12:17 AM

FYI

Sent from my iPhone

Begin forwarded message:

> **From:** "Johnson, Chalmers-Fagan" <fagan_johnson@nps.gov>
> **Date:** November 13, 2017 at 4:39:58 PM MST
> **To:** "Perez, Larry" <larry_perez@nps.gov>
> **Cc:** Rebecca Beavers <rebecca_beavers@nps.gov>
> **Subject: Re: Update: Sea Level Rise & Storm Surge Report**
>
> Someone needs to upload the final version to the Data Store (official online archive for all NRR reports), and activate it (make it public).
>
> https://irma.nps.gov/DataStore/Reference/Profile/2239974
>
> We need to do this very, very, very soon.
>
> The TIC office has a "published" date last April (the date that I first gave it a new report number...).
>
> A vast majority of reports are uploaded and made public within 5 working days after we send back the final review...
>
> Thanks.
>
> Fagan Johnson
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> Fort Collins, Colorado 80525
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> Email: fagan_johnson@nps.gov
> Phone: 970-267-2190
>
> *"What's another word for Thesaurus?"* Steven Wright
>
> On Tue, Sep 26, 2017 at 11:34 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
> > Okay.

Please use the IRMA record that I created for you, and do not create a duplicate one.

> https://irma.nps.gov/DataStore/Reference/Profile/2239974

Why?

> The DOI Soclitor's Office mandates that the NRR, TIC, and IRMA ID values match in all of those systems, as well as in all of their individual off-site backup solutions (per records management policy).
>
> We can't "get back" or change the previously archived records...

Thanks.

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> *"What's another word for Thesaurus?"* Steven Wright

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> Fagan,
>
> This looks good to me. Great job whipping those tables into compliance! :)
>
> I added document metadata, set the bookmarks panel to open automatically, and saved a new version with "508 compliant" in the file name. I've uploaded this file to the same share folder, and we should plan to roll with that version.
>
> Rebecca, Cat, and I are currently discussing how we would like to make this available on IRMA, so please do not upload until I touch base with you once more.
>
> Many, many thanks for your persistent work on this,
>
> L :)

On Tue, Sep 26, 2017 at 9:04 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:

> Take a look at the PDF here:
>
> https://drive.google.com/drive/folders/0Bx0uAOormwkIMkYtLTU3M0pUdDQ
>
> Those appendix tables would not export to PDF that cleanly, and it took me about six hours of manual tagging to make them Section 508 accessible.
>
> Let me know if this works, and I'll activate the Data Store record and upload it (make it public).
>
> Thanks.
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>
> On Thu, Sep 21, 2017 at 3:44 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
>> It may be 1-3 working days until I can export this to PDF.
>>
>> A MS Office patch really messed-up my MS Word last night, and I'm pretty much dead-in-the-water until IT un-installs the patch.
>>
>> Problems with tables, and especially exporting tables to PDF (cells export blank with no text in them).
>>
>> This is at the top of my queue, when they have it fixed.
>>
>> Thanks.

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"What's another word for Thesaurus?" Steven Wright

On Wed, Sep 20, 2017 at 8:15 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Thanks for touching base on this today, Fagan.
>
> As we discussed, we'll count on you to work your magic in exporting this file and making sure its compliant.
>
> I'll continue to keep you posted regarding our expected release date as things develop.
>
> Best,
>
> L
>
> On Wed, Sep 20, 2017 at 3:02 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
>> Fagan,
>>
>> Here is the final version of the SLR/SS report.
>>
>> From here on out, we should only be working with this version, dated 2017-09-19 in the file name.
>>
>> I'll stop down to discuss in a moment.
>>
>> -L
>>
>> On Fri, Sep 15, 2017 at 4:11 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>>
>>> Okay.
>>>
>>> Let me know when you have it uploaded and made public.
>>>
>>> Fagan Johnson
>>> Web and Report Specialist
>>> National Park Service

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On Fri, Sep 15, 2017 at 4:07 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Fagan,
>
> Just a quick update on this:
>
> We are *very* close to having a final version...should be able to get it to you by COB Tuesday.
>
> Thanks, and have a great weekend!
>
> L
>
> On Fri, Sep 8, 2017 at 11:59 AM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
>> Sounds good.
>>
>> As long as the report was not released outside the NPS yet, you can edit anything between the first four pages (front cover to disclaimer page) and the last two pages (back cover pages).
>>
>> Just make sure to update the dynamic lists of Contents, Figures, etc. just before you export the final to PDF format.
>>
>> **Oh, and for future reference**
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>> You should only ask for new report numbers when you know for sure that you will be uploading the final report PDF within 3-6 working days after we send the final reviewed document back to you.
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228 Re_ Update_ Sea Level Rise & Storm Surge Report(4).pdf

From:	Hoffman, Cat
To:	Rebecca Beavers
Cc:	Larry Perez
Subject:	Re: Update: Sea Level Rise & Storm Surge Report
Date:	Tuesday, November 14, 2017 8:48:48 AM

I had a call with Ray yesterday....asked about status of getting a meeting together with Shawn Benge and Shawn Norton to get on the same page with SLR and messaging. He'll followup and get back to me.

On Tue, Nov 14, 2017 at 8:15 AM, Rebecca Beavers <rebecca_beavers@nps.gov> wrote:

> Fagan:
>
> Larry will follow up with you in person.
>
> Sent from my iPhone
>
> On Nov 13, 2017, at 4:40 PM, Johnson, Chalmers-Fagan <fagan_johnson@nps.gov> wrote:
>
> Someone needs to upload the final version to the Data Store (official online archive for all NRR reports), and activate it (make it public).
>
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Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
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Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers
Climate Change Response Resources

229 Re_ do you have any topics you wish me to share....pdf

From:	Cat Hoffman
To:	Olliff, S
Subject:	Re: do you have any topics you wish me to share from the CCRP for the NPS Regional Climate Change Contact call next week?
Date:	Sunday, December 10, 2017 10:11:19 AM

Thanks Tom; hope you also had a good Thanksgiving. It flew by...been in (b) (6) [redacted]

Headed to D.C. tomorrow for some meetings. On the call you could let everyone know we received some good comments on our strategic plan. Will revise and get it out early in the new year. Note that this serves as our platform for an integrated workplan across all CCRP team.

Also; we expect to (b) (5) [redacted] -- Maria Caffrey's sea level rise projections, (b) (5) [redacted]

Cat

sent from my iPhone

On Dec 7, 2017, at 12:20 PM, Olliff, S <tom_olliff@nps.gov> wrote:

> I saw that you are unable to attend; however, please let me know if you have any information you want me to share from the CCRP perspective.
>
> Thanks! Hope you had a good Thanksgiving, best, Tom
>
> Tom Olliff
> Great Northern LCC Co-Coordinator
> NPS IMR Chief, Landscape Conservation and Climate Change
> 2327 University Way, Suite 2
> Bozeman, MT 59715
> (o) 406.994.7920
> (c) 406.581.2763
>
> www.greatnorthernlcc.org

231 Fwd_ status update on two reports.pdf

From:	Hoffman, Cat
To:	Rebecca Beavers; Shawn Norton
Cc:	Jeffrey Olson; Larry Perez
Subject:	Fwd: status update on two reports
Date:	Wednesday, December 20, 2017 11:57:09 AM

Hi Rebecca and Shawn -- I'm headed to the airport in 5 minutes. Could one of you get back to Jeff on this question?

thanks.

Cat

---------- Forwarded message ----------
From: **Olson, Jeffrey** <jeffrey_olson@nps.gov>
Date: Wed, Dec 20, 2017 at 11:53 AM
Subject: Re: status update on two reports
To: "Hoffman, Cat" <cat_hawkins_hoffman@nps.gov>

How did the SER parks hit by the two hurricanes this past season fare/compare to these reports?

On Wed, Dec 20, 2017 at 1:41 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:

> Hi all -- Before I leave for the holidays, I wanted to provide a status update and "next steps" for [redacted]
>
> [redacted]
>
> ***Sea Level Rise and Storm Surge Projections for the National Park Service;*** *Natural Resource Report Series NPS/NRSS/NRR.* Supported by CCRP, and conducted through agreement with the University of Colorado Boulder (Dr. Maria Caffrey). NPS lead is Rebecca Beavers.
>
>> This report has undergone peer review and will be part of the NRSS Natural Resource Report Series. A site is also being prepared in conjunction with the Park Atlas to enable parks to access the data developed through this project. Consistent with the approved NPS core messages regarding climate change, the report provides scientific modeling and analyses to help coastal park managers understand potential sea level rise levels specific to their parks. I've reviewed the document and support having it

completed in final design and disseminated through the NRR series, together with the associated data provided through the Park Atlas.

Next steps: Pending final design/layout (and preparation for the NRR series for the Caffrey et al report), both documents are ready for dissemination. Larry Perez is prepared to work with the NPS leads for both reports (Shawn Norton, Rebecca Beavers) in liaison with WASO Comms to determine the most efficient approach to provide information about, and access to the reports.

If you have concerns, questions, or suggestions, please let me know.

Cat

Sea Level Change Report_final_fagan_edits by Ca...

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
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Adaptation websites: public, NPS managers
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--
Jeffrey G. Olson
Public Affairs Officer
The National Park Service
1849 C Street NW Room 3310
Washington, DC 20240

Office: 202-513-7261
Mobile: 202-230-2088

www.nps.gov

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Adaptation websites: public, NPS managers
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233 Re_ status update on two reports(1).pdf

From:	Cat Hoffman
To:	Norton, Shawn
Cc:	Olson, Jeffrey; Rebecca Beavers; Larry Perez
Subject:	Re: status update on two reports
Date:	Wednesday, December 20, 2017 1:35:56 PM

There could still be some fragments or errant spaces from "accept changes."

Sent from my iPhone

On Dec 20, 2017, at 12:35 PM, Norton, Shawn <shawn_norton@nps.gov> wrote:

> Let me know where to look and I will review the error.
>
> thanks
>
> On Wed, Dec 20, 2017 at 1:59 PM, Olson, Jeffrey <jeffrey_olson@nps.gov> wrote:
>
>> Found what looks like the start of a sentence that's missing in the executive summary of the SLR Coastal Report doc. Larry, can you and I chat about this?
>>
>> On Wed, Dec 20, 2017 at 1:56 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>>
>>> Hi Rebecca and Shawn -- I'm headed to the airport in 5 minutes. Could one of you get back to Jeff on this question?
>>>
>>> thanks.
>>>
>>> Cat
>>>
>>> ---------- Forwarded message ----------
>>> From: **Olson, Jeffrey** <jeffrey_olson@nps.gov>
>>> Date: Wed, Dec 20, 2017 at 11:53 AM
>>> Subject: Re: status update on two reports
>>> To: "Hoffman, Cat" <cat_hawkins_hoffman@nps.gov>
>>>
>>> How did the SER parks hit by the two hurricanes this past season fare/compare to these reports?
>>>
>>> On Wed, Dec 20, 2017 at 1:41 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>>>
>>>> Hi all -- Before I leave for the holidays, I wanted to provide a status update and "next steps" for (b) (5) [redacted]
>>>>
>>>> (b) (5) [redacted]

(b) (5) [redacted]

Sea Level Rise and Storm Surge Projections for the National Park Service; *Natural Resource Report Series NPS/NRSS/NRR.* Supported by CCRP, and conducted through agreement with the University of Colorado Boulder (Dr. Maria Caffrey). NPS lead is Rebecca Beavers.

> This report has undergone peer review and will be part of the NRSS Natural Resource Report Series. A site is also being prepared in conjunction with the Park Atlas to enable parks to access the data developed through this project. Consistent with the approved NPS core messages regarding climate change, the report provides scientific modeling and analyses to help coastal park managers understand potential sea level rise levels specific to their parks. I've reviewed the document and support having it completed in final design and disseminated through the NRR series, together with the associated data provided through the Park Atlas.

Next steps: Pending final design/layout (and preparation for the NRR series for the Caffrey et al report), both documents are ready for dissemination. Larry Perez is prepared to work with the NPS leads for both reports (Shawn Norton, Rebecca Beavers) in liaison with WASO Comms to determine the most efficient approach to provide information about, and access to the reports.

If you have concerns, questions, or suggestions, please let me know.

Cat

Sea Level Change Report_final_fagan_edits by Ca...

--

Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
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Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
970-225-3567

Adaptation websites: public, NPS managers

Climate Change Response Resources

--
Jeffrey G. Olson
Public Affairs Officer
The National Park Service
1849 C Street NW Room 3310
Washington, DC 20240

Office: 202-513-7261
Mobile: 202-230-2088

www.nps.gov

--
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--
Shawn Norton
U.S. National Park Service

Washington DC Office
Branch Chief - Sustainable Operations
shawn_norton@nps.gov
Office: 202-354-1835

234 Re_ status update on two reports(2).pdf

From:	Norton, Shawn
To:	Olson, Jeffrey
Cc:	Hoffman, Cat; Rebecca Beavers; Larry Perez
Subject:	Re: status update on two reports
Date:	Wednesday, December 20, 2017 1:50:02 PM

Jeff-

We need to delete the word "finally". There should be no additional sentence.

thanks

On Wed, Dec 20, 2017 at 2:35 PM, Norton, Shawn <shawn_norton@nps.gov> wrote:

> Let me know where to look and I will review the error.
>
> thanks
>
> On Wed, Dec 20, 2017 at 1:59 PM, Olson, Jeffrey <jeffrey_olson@nps.gov> wrote:
>
>> Found what looks like the start of a sentence that's missing in the executive summary of the SLR Coastal Report doc. Larry, can you and I chat about this?
>>
>> On Wed, Dec 20, 2017 at 1:56 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>>
>>> Hi Rebecca and Shawn -- I'm headed to the airport in 5 minutes. Could one of you get back to Jeff on this question?
>>>
>>> thanks.
>>>
>>> Cat
>>>
>>> ---------- Forwarded message ----------
>>> From: **Olson, Jeffrey** <jeffrey_olson@nps.gov>
>>> Date: Wed, Dec 20, 2017 at 11:53 AM
>>> Subject: Re: status update on two reports
>>> To: "Hoffman, Cat" <cat_hawkins_hoffman@nps.gov>
>>>
>>> How did the SER parks hit by the two hurricanes this past season fare/compare to these reports?
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>>> On Wed, Dec 20, 2017 at 1:41 PM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>>>
>>>> Hi all -- Before I leave for the holidays, I wanted to provide a status update and "next steps" for (b) (5) [redacted]
>>>>
>>>> (b) (5) [redacted]

[redacted]

Sea Level Rise and Storm Surge Projections for the National Park Service; *Natural Resource Report Series NPS/NRSS/NRR.* Supported by CCRP, and conducted through agreement with the University of Colorado Boulder (Dr. Maria Caffrey). NPS lead is Rebecca Beavers.

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Cat

Sea Level Change Report_final_fagan_edits by Ca...

--

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--

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--
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Branch Chief - Sustainable Operations
shawn_norton@nps.gov
Office: 202-354-1835

235 Maria Caffrey completion of BRD project; SLR_SS....pdf

From:	Beavers, Rebecca
To:	Kevin Noon; Ellsworth, Alan
Cc:	Hal Pranger; Trevino, Dave; Lisa Norby; Cat Hawkins Hoffman; Larry Perez; Isabella Michel; Carol Walton
Subject:	Maria Caffrey completion of BRD project; SLR/SS Report; PIV card and computer
Date:	Friday, December 22, 2017 9:22:47 PM

BRD final GIP report/ SLR/Storm Surge Projections Report Status

Maria Caffrey turned in her final BRD project report today. Her major files have been transferred to the GRD shared drives (N & P); Rebecca & Hal have access to those files if needed.

The Sea Level/ Storm Surge Report has (b) (5) [redacted]. (b) (5) [redacted]

GRD Computer Maria has been using/ Save files for WRD Machine

GRD has requested the return of the computer that Maria Caffrey continued to use during her CCRP funded/BRD focused GIP position that concluded today. The GRD computer she was using is in her office, and the HelpDesk Ticket was submitted with a request to keep a copy of the computer profile, especially bookmarks, etc so those documents/links can be transferred to a WRD furnished machine when Maria is anticipated to start a new position with WRD in March 2018.

Please contact Kevin Noon or Alan Ellsworth for more details on that new position with WRD and associated computer.

PIV Card/ Active Directory Account

Maria Caffrey's Task Agreement with the University of Colorado Boulder extends until March 31, 2018 so her PIV credential & Active Directory Account "should" remain valid through that date. WRD will work to extend the PIV credential for her new position during 2018.

Please contact Kevin Noon or Alan Ellsworth for more details on that new position with WRD and associated extension of the PIV card/Active Directory Account.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

236 Fwd_ status update on two reports(1).pdf

From:	Perez, Larry
To:	Olson, Jeffrey
Subject:	Fwd: status update on two reports
Date:	Monday, January 08, 2018 11:58:31 AM
Attachments:	2017_12-19_DRAFT_Long-Term SLR Coastal Report_changes accepted.docx

Jeff, per our discussion: please see the 12/20 message below from Cat through Ray, Jen et al...

[redacted]

-L

---------- Forwarded message ----------
From: **Hoffman, Cat** <cat_hawkins_hoffman@nps.gov>
Date: Wed, Dec 20, 2017 at 11:41 AM
Subject: status update on two reports
To: Ray Sauvajot <Ray_Sauvajot@nps.gov>, Shawn Benge <shawn_benge@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Shawn Norton <shawn_norton@nps.gov>, Rebecca Beavers <rebecca_beavers@nps.gov>, Hal Pranger <harold_pranger@nps.gov>, Dave Steensen <dave_steensen@nps.gov>
Cc: Larry Perez <larry_perez@nps.gov>, Guy Adema <guy_adema@nps.gov>, Jennifer Wyse <jennifer_wyse@nps.gov>, Jeffrey Olson <jeffrey_olson@nps.gov>, Jeremy Barnum <jeremy_barnum@nps.gov>, David Anderson <d_l_anderson@nps.gov>, Ryan Scavo <ryan_scavo@nps.gov>

Hi all -- Before I leave for the holidays, I wanted to provide a status update and "next steps" for [redacted]

[redacted]

Sea Level Rise and Storm Surge Projections for the National Park Service; *Natural Resource Report Series NPS/NRSS/NRR.* Supported by CCRP, and conducted through agreement with the University of Colorado Boulder (Dr. Maria Caffrey). NPS lead is Rebecca Beavers.

> This report has undergone peer review and will be part of the NRSS Natural Resource Report Series. A site is also being prepared in conjunction with the Park Atlas to enable parks to access the data developed through this project. Consistent with the approved NPS core messages regarding climate change, the report provides scientific modeling

and analyses to help coastal park managers understand potential sea level rise levels specific to their parks. I've reviewed the document and support having it completed in final design and disseminated through the NRR series, together with the associated data provided through the Park Atlas.

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If you have concerns, questions, or suggestions, please let me know.

Cat

Sea Level Change Report_final_fagan_edits by Ca...

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Adaptation websites: public, NPS managers
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--

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Fax: 970-225-3585
Email: larry_perez@nps.gov

236 1 Attachment 2017_12-19_DRAFT_Long-Term SLR Coastal Report_1.pdf

(b) (5)

[redacted]

(b) (5)

[redacted]

(b) (5)

(b) (5)

(b) (5)

[redacted]

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[redacted]

(b) (5)

[redacted]

(b) (5)

[redacted]

(b) (5)

(b) (5)

(b) (5)

237 Meeting Notes.pdf

From:	Perez, Larry
To:	Olson, Jeffrey; Shawn Norton; Beavers, Rebecca
Subject:	Meeting Notes
Date:	Monday, January 08, 2018 12:09:19 PM

All,

Thanks very much for the productive call today. A quick followup:

Current Status of Each Publication

SLR & Storm Surge Projections Report
Fully peer reviewed, formatted, 508-compliant, & ready for release. Needs to be uploaded to IRMA. Action Item: Larry will work with NRSS IRMA leads to host the report online.

(b) (5) [redacted]

Intended Release Strategy

SLR & Storm Surge Report

Target Release Date: Thursday, February 15

- Report and data made available through IRMA with public access
- Report made available through the NPS Climate Change Subject Site
- Post announcement to Inside NPS
- Direct Distribution to 118 Coastal Parks
- Report author reports on findings as part of CCRP webinar series sometime later in the year (lead author currently out on maternity leave through March)

(b) (5) [redacted]

Action Item: Larry will update earlier release materials to reflect new plans & timelines.
Action Item: Jeff will discuss these plans with Jen Wyse and get back to us. Once comm plan and associated materials are updated, he will work through Jeremy Barnum to forward materials to the Department for review.

Larry Perez, Communications Coordinator
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1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Fax: 970-225-3585

Email: larry_perez@nps.gov

238 SL_SS manuscript submittal form & draft report.pdf

From: Beavers, Rebecca
To: Larry Perez
Subject: SL/SS manuscript submittal form & draft report
Date: Tuesday, January 16, 2018 1:26:38 PM
Attachments: Manuscript_Submittal_Form_2017_SL_SS.docx

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

FINAL VERSION 05 - 2017-09-19 FINAL Sea Level C...

238 1 Attachment Manuscript_Submittal_Form 2017_SL_SS.pdf

National Park Service

Natural Resource Publication Series

Natural Resource Stewardship and Science
National Park Service
U.S. Department of the Interior

Manuscript Submittal Form and Checklist

Fields marked by an asterisk are required

SECTION 1.

1. Manuscript submitter - the person submitting this manuscript for publication, e.g., project manager, author, editor

* **Name: Rebecca Beavers**

* **Mailing Address (street, city, state, zip): National Park Service, Geologic Resources Division, 12795 West Alameda Parkway, Lakewood, CO 80228**

* **Phone:** 303-987-6945

* **Email: Rebecca_beavers@nps.gov**

2. Title and author(s)

* **Title of manuscript:** Sea level rise and storm surge projections for the National Park Service

* **Authors (complete table)**

Author List Order	First Name	Middle Initial (optional)	Last Name
First	**Maria**	**A.**	**Caffrey**
Second	**Rebecca**	**L.**	**Beavers**
Third	**Patrick**	Click here to enter text.	**Gonzalez**
Fourth	**Cat**	Click here to enter text.	**Hawkins-Hoffman**
Fifth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Sixth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Seventh	Click here to enter text.	Click here to enter text.	Click here to enter text.
Eighth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Ninth	Click here to enter text.	Click here to enter text.	Click here to enter text.
Tenth	Click here to enter text.	Click here to enter text.	Click here to enter text.

3. * Report Series - select series that is appropriate for the manuscript

☐ **Natural Resource Data Series (NRDS) (proceed to sections 2 and 4 below)**

Intended for the timely release of basic data sets and routine data summaries that are based on data collection and data management methods documented in established, peer-reviewed protocols. While QA procedures have been completed to assure the accuracy of raw data values, *analysis or interpretation of the data has not been completed and should not be included in NRDS manuscripts.* (see NRDS guidance and tips)

☒ **Natural Resource Report (NRR) series (proceed to sections 3 and 4 below)**

Intended for comprehensive information and analysis about natural resources and related topics concerning lands managed by NPS. NRR manuscripts may include quantitative data that are accompanied by analysis and/or interpretation; procedural documents such as protocols and standard operating procedures; planning or policy information; and/or resource management information.

Note: If the manuscript meets criteria for 'Highly Influential Scientific or Scholarly Information' as defined by the OMB Peer Review Bulletin (i.e., provides the sole or major component of information used in decision-making; or, by itself, leads to a change in the direction of decision-making or to a decision that creates a clear and substantial impact on important public policies or private sector decisions), publication should not occur in the NRR.

SECTION 2. NRDS Manuscript

This section applies only if you are publishing in the **Natural Resource Data Series**.

No peer review is required for these reports; however, program management review is recommended.

*** Citation or link (preferred) to protocol associated with report:**

n/a

SECTION 3. NRR Manuscript

This section applies only if you are publishing in the **Natural Resource Report** *series*. This series requires peer review.

This section should be completed by the program manager who is assuming responsibility for the content of the manuscript. **Note**: Authors can never hold the role of Program Manager or Peer Review Manager for a manuscript.

Current NPS peer review guidance requires that NPS scientific and scholarly activities comply with OMB Final Information Quality Bulletin for Peer Review (2004; 70 FR 2664-2677), and NPS Director's Order (DO) #11B: Ensuring Quality of Information Disseminated by the National Park Service.

Peer review of the manuscript must comply with the NPS Interim Guidance on Peer Review. If the manuscript is submitted by or on behalf of the Inventory and Monitoring Division, it must also adhere to IMD-specific guidance

3.1. Peer Review Manager

The peer review manager oversees the peer review process of this report, and assumes responsibility for the manuscript fully meeting NPS peer review guidance. Manuscripts submitted by the Inventory and Monitoring Division must also meet the latest version of the IMD Peer Review Policy (NPS-only).

The peer review manager recommends, to the program manager, the technical acceptance of the manuscript in a written record documenting the process. The peer review manager is also responsible for maintaining all records associated with the peer review process, including correspondence, comments, and responses.

*** Peer Review Manager Name: John Gross**

*** Title: Climate Change Ecologist**

3.2. Peer Review Summary

Briefly describe the major review comments addressed, and areas of the report that were revised during the peer review conducted by the Peer Review Manager.

Peer review was carried out using both internal and external reviewers. Reviewers were selected based on their expertise in one or more fields relating to coastal climate change, sea level change, or storm surge. The following people reviewed the document: Amanda Babson (NPS), Ann Gallagher (NPS), Larry Perez (NPS), Steve Nerem (University of Colorado), Bob Glahn (emeritus, NOAA), Doug Marcy (NOAA), Chris Zervas (NOAA), Rob Thieler (USGS), and Claudia Tebaldi (Climate Central). All peer review comments have been compiled in either spreadsheets as PDFs. Desciptions of how each comment was addressed are included in the spreadsheets. Comments covered the entire report. Peer reviewers were not supplied the GIS data referenced in this report. The GIS data will undergo a separate review.

Provide confirmation that peer and management review comments have been adequately incorporated into the final manuscript.

The report authors were responsible for the incorporation of peer and management comments into the final manuscript. These edits were reviewed by peer review manager John Gross to ensure that their edits adequately addressed the peer and management comments.

☐ Yes ☒ No	Does the manuscript include any sensitive or commercially valuable information that may potentially jeopardize a park resource or that might justify a management review by a qualified individual? If yes, please explain Click here to enter text.

☐ Yes

☒ No

Is there policy-sensitive material in the manuscript that might justify a management review by an appropriate reviewer who can verify consistency with or clear and appropriate relation to NPS policy? A management review should be conducted if any material might not be consistent with NPS policy. If one of the reviewers is qualified to conduct such a review and has already done so, please explain.

Click here to enter text.

SECTION 4. Approval and Publication

4.1 Program Manager Approval

The NPS program manager has final authority to approve publication of the manuscript, and assumes responsibility for this report's adherence to scientific integrity, administrative and policy standards.

*** Program Manager Name: Cat Hawkins-Hoffman**

*** Title: Chief, Climate Change Response Program**

*** Date Approved for Publication: 4/14/2017**

4.2. Report Numbers and Data Store Record Owners

Provide the name and email address of additional NPS employees who should receive the final publication review notice from the series manager, and who should review the associated NPS Data Store record.

Name: Rebecca Beavers

Email: Rebecca_Beavers@nps.gov

Name: Patrick Gonzalez

Email: Patrick_Gonzalez@nps.gov

The following information is completed by the publication series manager.

Report Series Number: Click here to enter text.

Technical Information Center (TIC) number: Click here to enter text.

NPS Data Store Reference Code: Click here to enter text.

Comments:
Click here to enter text.

This completed form is archived through the Natural Resource Publication Series. Archived forms are available to NPS management and other U.S. Government oversight entities upon request.

Series Manager – Fagan Johnson (Fagan_johnson@nps.gov, 970-267-2190)

239 Re_ SL_SS manuscript submittal form & draft report.pdf

From:	Beavers, Rebecca
To:	Perez, Larry
Subject:	Re: SL/SS manuscript submittal form & draft report
Date:	Tuesday, January 16, 2018 1:33:20 PM

Great.

Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
National Park Service | Geologic Resources Division
303-987-6945 (Office) | 720-519-5085 (mobile) | rebecca_beavers@nps.gov

On Tue, Jan 16, 2018 at 1:29 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Thanks, Rebecca!
>
> And I can confirm from my files that the version dated 9/19 was the one we forwarded to Fagan to make compliant.
>
> So I think we're set here. I'll submit via SharePoint and follow up with you and Fagan via email.
>
> -L :)
>
> On Tue, Jan 16, 2018 at 1:26 PM, Beavers, Rebecca <rebecca_beavers@nps.gov> wrote:
>
> > Rebecca Beavers, Ph.D.| Coastal Geology & Adaptation Coordinator
> > National Park Service | Geologic Resources Division
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> >
> > **FINAL VERSION 05 - 2017-09-19 FINAL Sea Level C...**
>
> --
>
> Larry Perez, Communications Coordinator
> Climate Change Response Program
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> Fort Collins, CO 80525
> Office: 970-267-2136
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> Email: larry_perez@nps.gov

241 Re_ status update on two reports(3).pdf

From:	Hoffman, Cat
To:	Perez, Larry
Subject:	Re: status update on two reports
Date:	Thursday, January 18, 2018 10:11:16 AM

Maria's report

On Thu, Jan 18, 2018 at 9:58 AM, Perez, Larry <larry_perez@nps.gov> wrote:

> So, to be clear...is he concerned about this exposure report or Maria's SLR/SS report?
>
> On Thu, Jan 18, 2018 at 9:54 AM, Hoffman, Cat <cat_hawkins_hoffman@nps.gov> wrote:
>
>> this is the last transmission to Ray -- so presumably this is the draft he is referencing re 'anthropogenic' concerns (vs an earlier draft).
>>
>> ---------- Forwarded message ----------
>> From: **Hoffman, Cat** <cat_hawkins_hoffman@nps.gov>
>> Date: Wed, Dec 20, 2017 at 11:41 AM
>> Subject: status update on two reports
>> To: Ray Sauvajot <Ray_Sauvajot@nps.gov>, Shawn Benge <shawn_benge@nps.gov>, Brian Carlstrom <brian_carlstrom@nps.gov>, Shawn Norton <shawn_norton@nps.gov>, Rebecca Beavers <rebecca_beavers@nps.gov>, Hal Pranger <harold_pranger@nps.gov>, Dave Steensen <dave_steensen@nps.gov>
>> Cc: Larry Perez <larry_perez@nps.gov>, Guy Adema <guy_adema@nps.gov>, Jennifer Wyse <jennifer_wyse@nps.gov>, Jeffrey Olson <jeffrey_olson@nps.gov>, Jeremy Barnum <jeremy_barnum@nps.gov>, David Anderson <d_l_anderson@nps.gov>, Ryan Scavo <ryan_scavo@nps.gov>
>>
>> Hi all -- Before I leave for the holidays, I wanted to provide a status update and "next steps" for [redacted] (b) (5)
>>
>> (b) (5)
>>
>> ***Sea Level Rise and Storm Surge Projections for the National Park Service;*** *Natural Resource Report Series NPS/NRSS/NRR.* Supported by CCRP, and conducted through agreement with the University of Colorado Boulder (Dr. Maria Caffrey). NPS lead is Rebecca Beavers.

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Adaptation websites: public, NPS managers
Climate Change Response Resources

242 For Ray.pdf

From:	Perez, Larry
To:	Cat Hoffman; Beavers, Rebecca
Subject:	For Ray
Date:	Friday, January 26, 2018 10:20:44 AM
Attachments:	2018-01-26 Recommended Edits.docx 2017-05-25 DRAFT Sea Level Change Report HL.pdf

Cat,

Attached are recommended edits, as well as a version of the full report with relevant sections highlighted. Let's discuss quickly in advance of your sharing with Ray.

Rebecca, thanks very much for your input on this.

-L

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
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242 1 Attachment 2018-01-26 Recommended Edits.pdf

First Paragraph of Executive Summary
Changing relative sea levels and the potential for increasing storm surges present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Third Paragraph of Executive Summary
Sea level change and storm surge pose considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures located along the coast. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety. These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

First Paragraph of Introduction
Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

Second Paragraph of Introduction
Peek et al. (2018) estimate that the cost of sea level rise in 100 National Park Service units could exceed $23 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks. [report to be cited as In Preparation]

Third Paragraph of Introduction
When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2-5 billion and a 500 year storm surge could cost $5-11 billion (Aerts et al. 2013). Under future scenarios of increasing greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015).

First Paragraph of Methods >> Sea Level Rise Data
Sea level rise is caused by numerous factors. Ice located on land and in the sea melts with the rise of mean global temperatures (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). The melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise.

First Paragraph of Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/y, although this rate accelerated over the latter part of the century. Slangan et al. (2016) found that emissions of greenhouse gases have been the primary driver of global sea level change since 1970 and that the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/y (Cazenave et al. 2014, Fasullo et al. 2016).

Caption of Figure 13

Radiative forcing for each of the Representative Concentration Pathways (RCPs). Positive radiative forcing means Earth receives more incoming energy from sunlight than it radiates to space. This net gain of energy will cause warming that can be measured as higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are slightly higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011.

Sixth Paragraph of Discussion

These estimates do not include the latest data on changing land levels. The IPCC included estimates of global isostatic adjustment (Equation 1) in their predictions, but those do not include changes in land level due to other factors, such as earthquakes and groundwater extraction. We expect the latest, state-of-the-art land level estimates to be released by NASA in 2018.

242 2 Attachment 2017-05-25 DRAFT Sea Level Change Report HL.pdf

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

ON THIS PAGE
Driftwood washed up on the shoreline of Redwood National Park, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

ON THE COVER
Fort Point National Historic Site and the Golden Gate Bridge, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

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National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available in digital format from the Climate Change Response Program website and the Natural Resource Publications Management website. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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NPS 999/137852, May 2017

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Photo 1. Looking out towards the Gulf of Mexico from Fort Jefferson, Dry Tortugas National Park. Photo credit: Used with permission from Rachel Sullivan Photography.

Executive Summary

Changing relative sea levels and the potential for increasing storm surges due to anthropogenic climate change present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Within the National Park Service, the National Capital Region is projected to experience the highest average rate of sea level change by 2100. The coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is projected to experience the highest storm surges based on historical data and NOAA storm surge models.

These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

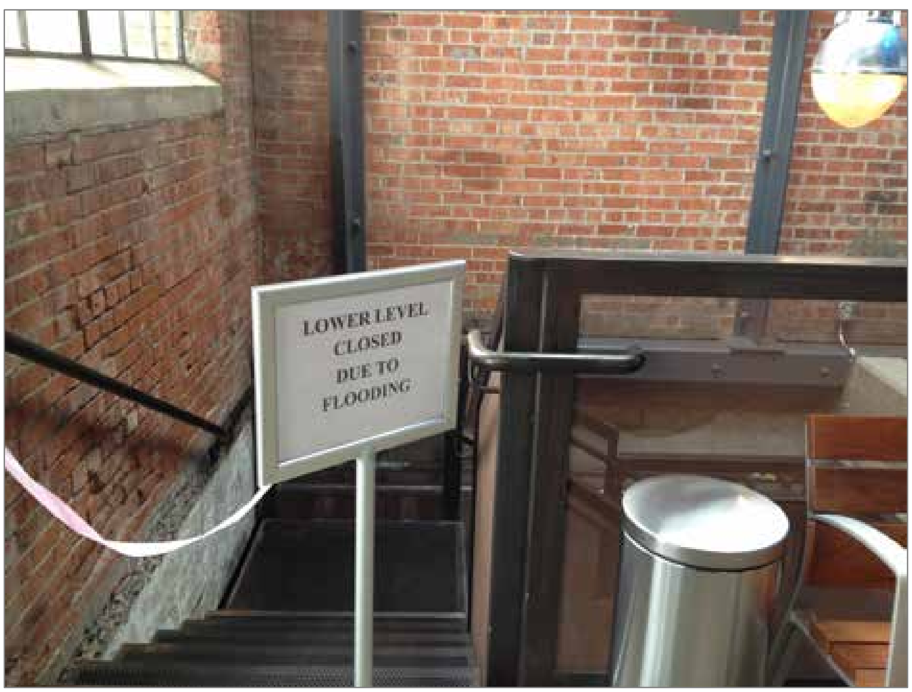

Photo 2. Basement flooding in the visitor center at Rosie the Riveter WWII Home Front National Historical Park. This photograph was taken on December 5, 2012 —12 years after the establishment of the park. Photo credit: Maria Caffrey.

Acknowledgments

This project was awarded funds through the NPS Servicewide Comprehensive Call (FY2013–2015) and augmented by funds from the Natural Resource Stewardship and Science Directorate's Geologic Resources Division and Climate Change Response Program. We would like to thank the members of the communication advisory team (Rebecca Beavers, Lynda Bell, Maria Caffrey, Janet Cakir, Will Elder, Stanton Enomoto, Ann Gallagher, Matt Holly, Shawn Norton, Larry Perez, and Ryan Stubblebine) and science advisory team (Amanda Babson, Rebecca Beavers, Maria Caffrey, Patrick Gonzalez, Steve Nerem, and Rob Thieler) for their time and input into this project.

We would also like to thank Susan Teel and Caroline Rohe at Gulf Islands National Seashore for assistance in designing two wayside exhibits. Likewise, we thank Julie Whitbeck, Aleutia Scott, Kristy Wallisch, and Stacy Meyers for helping design, review, and install a wayside at Jean Lafitte National Historical Park and Preserve. Elizabeth Rogers and Kathy Krause helped design a wayside for Fire Island National Seashore. Doug Wilder, Dorothy Friday, and Neal Jander designed the online map viewer. We would also like to thank Jason Kenworthy, Rebecca Port, Michael Barthelmes, Bob Glahn, Doug Marcy, Chris Zervas, and Claudia Tebaldi for their assistance in editing and reviewing this document. Finally, we thank the National Oceanic and Atmospheric Administration for and the Intergovernmental Panel on Climate Change for providing the respective storm surge and sea level rise data cited throughout this document.

List of Terms

The following list of terms are defined here as they will be used in this report.

Bathtub model: A simplification of the sea as bathtub of water to simulate a change in water level relative to the land. This model does not include other factors such changes in erosion or accretion that change alter the geometry of the coastline.

Flooding: The temporary occurrence of water on the land.

Inundation: The permanent impoundment of water on what had previously been dry land.

Isostatic rebound: A change in land level caused by a change in loadings on the Earth's crust. The most common cause of isostatic rebound is the loading of continental ice during the Last Glacial Maximum in North America. The North American land surface is still returning to equilibrium after the melting of this continental ice in an effort to return to equilibrium with its original pre-loading state.

National Park Service unit: Property owned or managed by the National Park Service.

Relative sea level: Where the water level can be found compared to some reference point on land. This term is most frequently used in discussion of *changes* in relative sea level. A change in relative sea level could be caused by a change in water volume or a change in land level (or some combination of these two factors).

Sea level: The average level of the seawater surface.

Sea level change: This term is frequently used in reference to *relative* sea level change. This is the product of two main factors, 1) an increase in the volume of ocean water, and 2) a change in land level. These two factors can be broken down further into other drivers that will be discussed in greater detail in other sections. This term is sometimes mistakenly confused with the term *sea level rise*.

Sea level rise: An increase in sea level. This is the result of an increase in ocean water volume caused principally by melting continental ice and thermal expansion. This term is not to be confused with increasing *relative* sea level, which can also be caused by decreasing land levels.

Introduction

Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Human activities continue to release carbon dioxide (CO_2) into the atmosphere, causing the Earth's atmosphere to warm (IPCC 2013, Mearns et al. 2013, Melillo et al. 2014). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

This report provides estimates of sea level change due to climate change for 118 National Park Service units and estimates of storm surge for 79 of those units. As temperature increases, sea levels rise due to a number of factors that will be discussed in greater detail. As sea levels incrementally rise, periods of flooding caused by storms and hurricanes exacerbate the growing problem of coastal inundation (see list of terms). Peek et al. (2015) estimated that the cost of sea level rise in 40 National Park Service units could exceed $40 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks.

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to anthropogenic climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2–5 billion and a 500 year storm surge could cost $5–11 billion (Aerts et al. 2013). Under future scenarios of increasing anthropogenic greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline. Increasing sea levels increase the likelihood of another Hurricane Sandy-sized storm surge striking New York City. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

Format of This Report

This report contains five sections (introduction, methods, results, discussion, and conclusion), and presents results per park alphabetically by region. The 118 park units studied for this project cover six administrative regions: the Northeast, Southeast, National Capital, Intermountain, Pacific West, and Alaska. The scope of this project focuses on sea levels. The scope of this project did not include projected changes in lake levels, although interior waterways and lakes, especially the Great Lakes, are vulnerable to the effects of climate change. Further explanation on how to access the data from this project is available in the methods sections and accompanying appendices.

Frequently Used Terms

Definitions of the most basic terms used in this report occur on page ix. However, some terms require greater explanation for their use. For example, we follow the advice of Flick et al. (2012) in differentiating between the terms *flooding* and *inundation*. While many choose to use these terms interchangeably, we use the term "flooding" to describe the temporary impoundment of water on land. This usually results from storm activity and other short-lived events, such as periodic tidal action, and will therefore be used here in reference to the effects of a storm surge on land. "Inundation" is used to refer to the gradual permanent submergence of land that will occur due to sea level rise.

The terms sea level rise and sea level change are also used differently. Sea level rise refers only to rising water levels resulting from an increase in global ocean volumes. In most parts of the United States this increase in water volume will lead to increasing relative sea levels. However, in some parts of the country relative sea level is *decreasing* due to isostatic rebound. Figure 1 shows current sea level trends based on tide gauge records for United States that span at least 30-years of data.

For example, the Southeast Region of Alaska is experiencing a decrease in relative sea level. Alaska's crust continues to rebound following the melting of large volumes of ice that occurred for centuries to millennia on land in the form of glaciers and ice fields. Alaska is tectonically complex with extensive faults that contribute to this crustal motion. Although the volume of ocean water in this region is increasing, the rate of sea level rise is less than the rate of isostatic rebound, resulting in a decrease in relative sea level. For this reason, we use the term "sea level change" as it includes regions that will experience a decrease in relative sea level (at least in the early part of this century) as well as those that will see increasing relative sea levels.

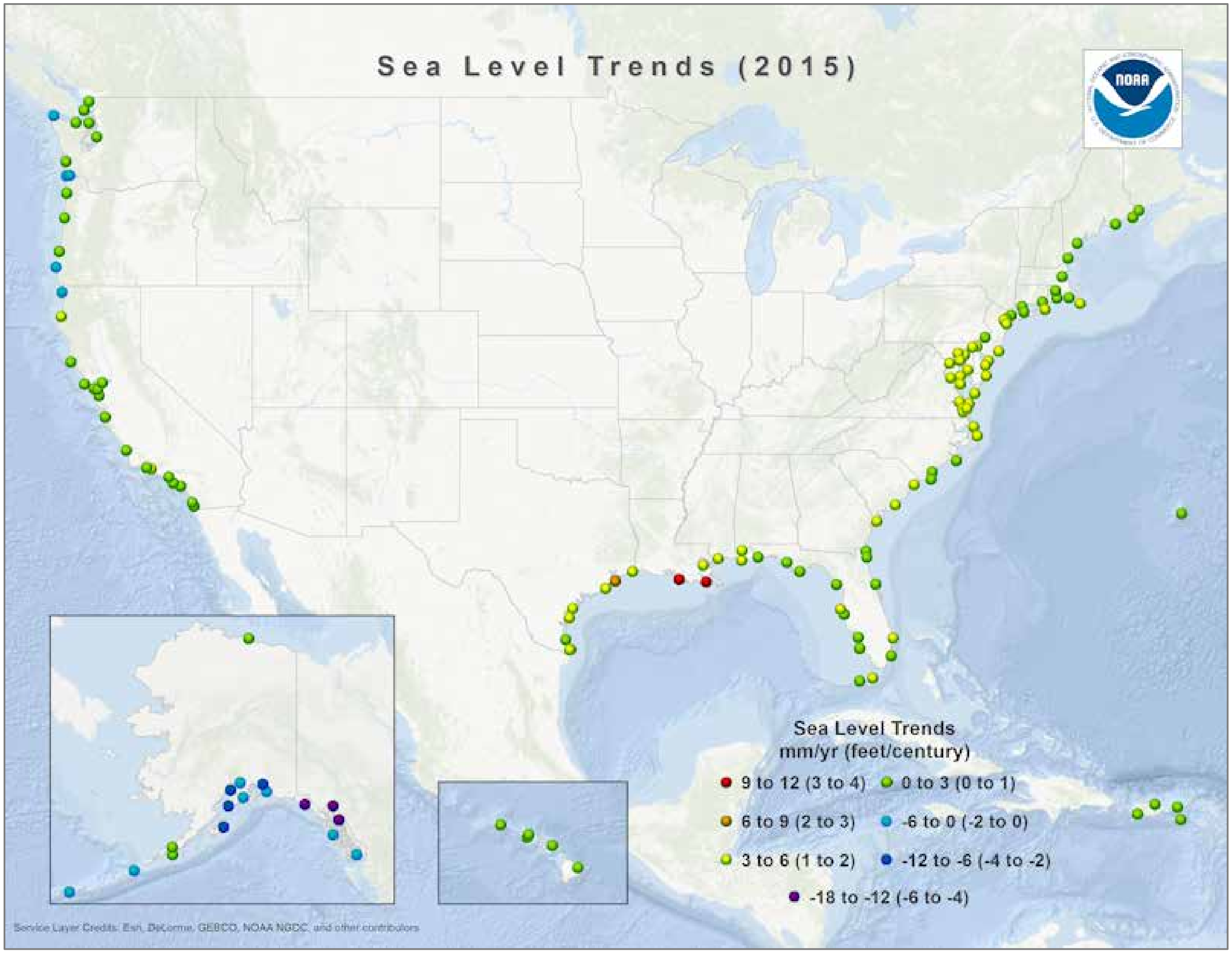

Figure 1. Sea level trends for the United States based on Zervas (2009), for all available data through 2015. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change. Stations depicted by yellow to red dots are experiencing greater than the global average (primarily driven by regional subsidence) and blue to purple dots are stations experiencing less than the global average (due to isostatic rebound or other tectonically-driven factors). Source: https://tidesandcurrents.noaa.gov/sltrends/slrmap.htm

Methods

This report summarizes work of a three-year project initiated in 2013, analyzing sea level change in 118 National Park Service units. Consultation with regional managers regarding units they considered to be potentially vulnerable to sea level change and/or storm surge resulted in selection of these 118 coastal park units (Appendix B). Project activities included the following:

1) Prepare sea level projections over multiple time horizons for each park unit.
2) Estimate potential exposure to storm surge using the National Oceanographic and Atmospheric Administration (NOAA) Sea, Lake, and Overland Surge from Hurricanes (SLOSH) Model and Tebaldi et al. (2012).
3) Create wayside exhibits[1] with information about the impacts of climate change in the coastal zone for three National Park Service units.

Based on recommendations from regional personnel, three National Park Service units were selected as sites for wayside exhibits: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore. The finished wayside designs are in Appendix C. Each design is different, customized to reflect the messaging and/or themes of each unit.

Sea Level Rise Data

Sea level rise is caused by numerous factors. As human activities release CO_2 and other greenhouse gases into the atmosphere, mean global temperatures increase (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). Rising global temperatures cause ice located on land and in the sea to melt. The melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise.

While the melting of sea ice is problematic from an oceanographic and heat budget perspective (primarily because it alters water temperatures and salinity and also because it changes the reflectance of solar energy from the surface), melting sea ice does not cause sea level rise. It is the melting of ice that is currently stored on land that raises global sea levels. Water level does not change when sea ice (ice wholly supported by water) melts. The volume of water in the sea remains the same whether it is frozen or liquid. The phase shift of water from solid to liquid does not displace an additional volume of water.

As ocean waters warm, the density of these waters also changes, causing thermal expansion. Thermal expansion was responsible for two-fifths of sea level rise from 1993 to 2010, while melting ice accounted for half (IPCC 2013). Table 1 lists the contribution to sea level rise from several key sources.

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[1] A wayside is an exhibit designed to be installed outside for visitors to learn about a particular subject (https://www nps.gov/hfc/products/waysides/).

Table 1. Observed global mean sea level budget (mm/y) for multiple time periods (IPCC 2013).

Source	1901–1990	1971–2010	1993–2010
Thermal expansion	n/a	0.08	1.1
Glaciers except in Greenland and Antarctica[a]	0.54	0.62	0.76
Glaciers in Greenland	0.15	0.06	0.10[b]
Greenland ice sheet	n/a	n/a	0.33
Antarctic ice sheet	n/a	n/a	0.27
Land water storage	-0.11	0.12	0.38
Total of contributions	**n/a**	**n/a**	**2.80**
Observed	**1.50**	**2.00**	**3.20**
Residual[c]	**0.50**	**0.20**	**0.40**

[a]Data until 2009, not 2010.

[b]This is not included in the total because these numbers have already been included in the Greenland ice sheet.

[c]This is calculated as observed global mean sea level rise – modeled glaciers – observed land water storage. See table 13.1 in IPCC (2013) for more details.

The IPCC sea level rise projections used in this analysis follow a *process-based model* approach, which estimates sea level based on the underlying physical processes. This contrasts with *semi-empirical* models that combine past sea level observations with other variables or theoretical considerations, including, in some cases, expert opinion (surveys or interviews of professionals) (Rahmstorf 2010, Orlic and Pasaric 2013). Often the semi-empirical approach yields higher sea level estimates. IPCC (2013) uses coupled atmosphere-ocean general circulation models (AOGCMs) to simulate the processes of change rather than the statistical inferences of the semi-empirical approach. AOGCMs are considered a process-based technique, although some variables derive from semi-empirical methods (IPCC 2013).

Sea level rise estimates for 2050 and 2100 were taken directly from the IPCC (2013) regional climate models (RCMs) downscaled to a spatial grid resolution of 1˚ x 1˚ from AOGCMs. Because many park units require estimates for shorter time horizons that fit more closely with the expected lifetime of various projects, sea level rise projections for 2030 were calculated using IPCC RCM data for each sea level rise driver shown in Table 2, interpolated to 2030 for each RCP. All projections are reported relative to the period 1986–2005 (see Appendix B for further discussion). All geographic information systems (GIS) maps display the projected sea level on top of mean higher-high water (MHHW) using the most recent tidal datum epoch (1983–2001). MHHW is calculated by averaging the highest daily water level over a 19-year tidal datum epoch.

Table 2. Median values for projections of global mean sea level rise and contributions of individual sources, for 2100, relative to 1986-2005, in meters (IPCC 2013).

Source	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Thermal expansion	0.15	0.20	0.22	0.32
Glaciers	0.11	0.13	0.14	0.18
Greenland ice sheet surface mass balance[a]	0.03	0.05	0.05	0.10
Antarctic ice sheet surface mass balance	-0.02	-0.03	-0.03	-0.05
Greenland ice sheet rapid dynamics	0.04	0.04	0.04	0.05
Antarctic ice sheet rapid dynamics	0.08	0.08	0.08	0.08
Land water storage	0.05	0.05	0.05	0.05
Sea level rise	**0.44**	**0.53**	**0.55**	**0.74**

[a]Changes in ice mass derived through direct observation and satellite data.

The standard error (σ) for each site estimate was not calculated because it was beyond the scope of this project. However, it can be calculated using the following equation and data available from the IPCC (2013, supplementary material):

Eq 1. $$\sigma_{tot}^2 = \left(\sigma_{steric/dyn} + \sigma_{smb\_a} + \sigma_{smb\_g}\right)^2 + \sigma_{glac}^2 + \sigma_{IBE}^2 + \sigma_{GIA}^2 + \sigma_{LW}^2 + \sigma_{dyn\_a}^2 + \sigma_{dyn\_g}^2$$

Where: *steric/dyn* = the global thermal expansion uncertainty plus dynamic sea surface height; *smb_a* = the Antarctic ice sheet surface mass balance uncertainty; *smb_g* = the Greenland ice sheet surface mass balance uncertainty; glac = glacier uncertainty; *IBE* = the inverse barometer effect uncertainty; *GIA* = global isostatic adjustment; *LW* = the land water uncertainty; *dyn_a* = Antarctica ice sheet rapid dynamics uncertainty; and, *dyn_g* = Greenland ice sheet rapid dynamics uncertainty.

Initial data were exported as GeoTIFF files for use in ArcGIS. For parks that crossed more than one pixel, an average sea level rise was calculated by weighting pixel values by the length of park shoreline in each pixel. A standard bathtub model approach was used to identify areas of projected inundation and flooding. In this method, projected sea level under climate change was determined by adding the IPCC RCM value to the current mean higher high water level. The land that would be at or below a projected sea level was then determined by analyzing digital elevation models (DEMs) of land elevation at spatial resolutions of 500 to 7000 m, depending on data availability for the areas of each park. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast). Areas of inundation and flooding are denoted in the maps (Appendix A) in blue. Additional low-lying areas that could be potentially inundated or flooded are shown in green (Figure 2). These low-lying areas do not appear to have any inlet or other pathway for water (based on our elevation datasets), although they should still be considered vulnerable to exposure to either groundwater seepage or potential flooding via breaching. The lack of high-resolution DEMs and time constraints prevented us from attempting a dynamic modeling approach (see limitations below). Maps were created to illustrate inundation for all park units for 2050 and

2100 under RCP4.5 and RCP8.5. These two represent a plausible range of scenarios between significant policy response (RCP4.5) and business as usual (RCP8.5).

Figure 2. An example of how areas of inundation appear in ArcGIS. In this example for the Toms Cove area of Assateague Island National Seashore, areas of inundation (RCP4.5 2050) appear in blue. Green shading indicates other low lying areas that are blocked from inundation by some impediment, but nonetheless could experience flooding should the physical barrier be removed or breached.

Storm Surge Data

NOAA SLOSH data estimate potential storm surge height at current (most recent tidal datum) sea level (NOAA 2016). The NOAA SLOSH model comprises the following three products (P-Surge, MEOW, and MOMs) that utilize three different modeling approaches (probabilistic, deterministic, and composite) to estimate storm surge.

P-Surge (also known as the tropical cyclone storm surge probabilities product) uses a probabilistic approach by examining past events to estimate the storm surge generated by a cyclone that is present and within 72-hours of landfall. It statistically evaluates National Hurricane Center data (calculated in part using a deterministic approach) including the official projected cyclone track and historical forecasting errors. It also incorporates astronomical tide calculations and variations in the radius of

maximum wind into this estimate. These rates of motion variables are then fit to a Cartesian or polar (depending on the location) grid (Jalesnianski et al. 1992).

The Maximum Envelope Of Water (MEOW) calculates flooding using past SLOSH output to create a composite estimate of the potential storm surge generated by a hypothetical storm. This product generates a worst-case scenario based on a hypothetical storm category that includes forward speed, trajectory of the storm when it strikes the coastline, and initial (mean vs. high) tide level that will also incorporate any historical uncertainty from previous landfall forecasts.

The final SLOSH product is the MOM (Maximum of MEOWs) model. MOM is a further composite approach that uses the forward speed, trajectory, and initial tide level data that is also used by MEOW to create a worst-of-the-worst scenario (or "perfect storm"). Storms are simulated for 32 regions (also known as operational basins, Figure 3) defined by NOAA. Data was imported into ArcGIS using the SLOSH display program. Maps were generated showing storm surge for all possible Saffir-Simpson hurricane categories for each site. While most sites had data for Saffir-Simpson hurricane categories 1–5 (Table 3), a few sites, such as Acadia National Park, were missing the highest category. NOAA did not model this scenario because it is considered extremely unlikely at a location that far north in the Atlantic Ocean.

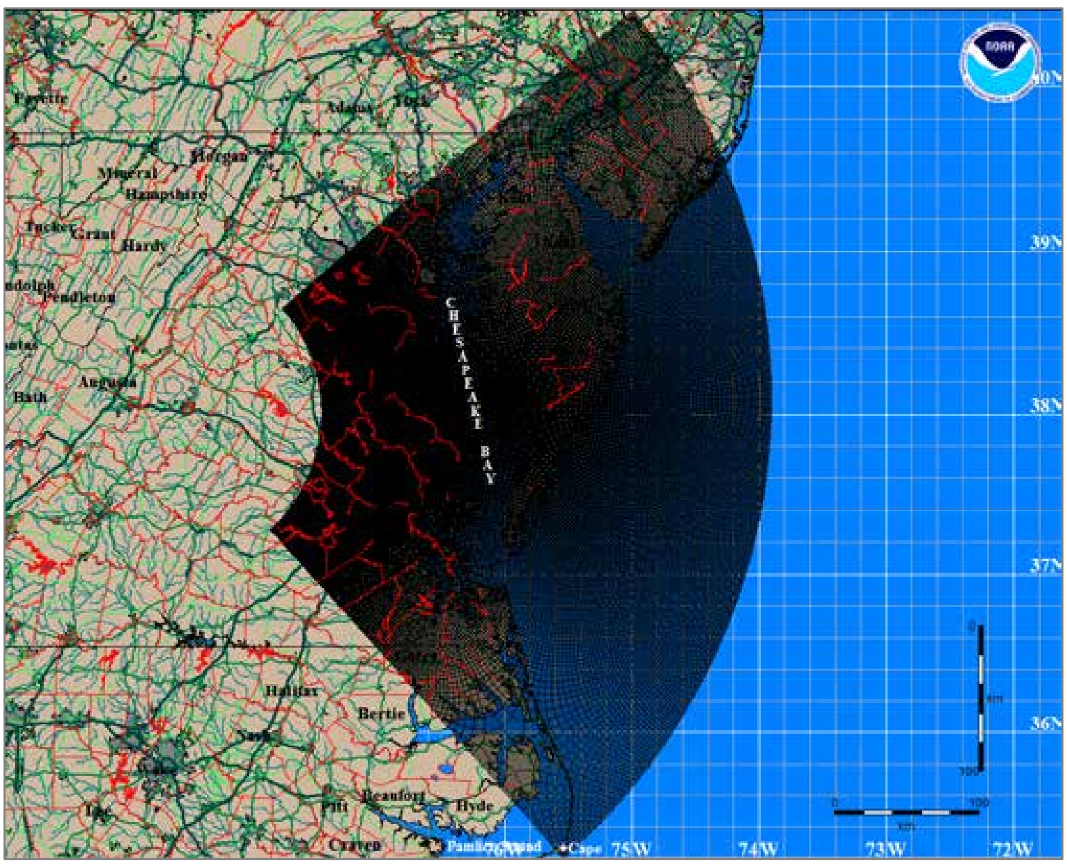

Figure 3. An example of the extent of an operational basin shown in NOAA's SLOSH display program (http://www.nhc.noaa.gov/surge/slosh.php). The black area is the full extent of the operational basin for Chesapeake Bay.

Table 3. Saffir-Simpson hurricane categories.

Saffir-Simpson Hurricane Category	Sustained Wind Speed (miles per hour, mph; knots, kt; kilometers per hour, km/h)
1	74–95 mph; 64–82 kt; 118–153 km/h
2	96–110 mph; 83–95 kt; 154–177 km/h
3	111–129 mph; 96–112 kt; 178–208 km/h
4	130–165 mph; 113–136 kt; 209–251 km/h
5	More than 157 mph; 137 kt; 252 km/h

SLOSH MOM was used to estimate potential storm surge in 79 coastal park units. Unfortunately, MOM data do not exist for the remaining 39 units, so we supplemented this with data from Tebaldi et al. (2012) wherever possible. Tebaldi et al. (2012) used 55 long-term tide gauge records to calculate potential sea level and storm surge estimates above mean high water levels. We used the current 50-year and 100-yr return level data from their paper for any parks near a tide gauge. Unfortunately, due to insufficient coverage by tide gauges in this area, we were unable to use either Tebaldi et al. (2012) or SLOSH MOM data for the Alaska, Guam, and American Samoa park units. It is important to note that the Tebaldi (2012) and SLOSH MOM data differ in their methods of calculation making it inadvisable to compare storm surge values from the Pacific West Region to other regions. However, this method had to be used due to the lack of SLOSH MOM data for the Pacific West Region.

We recommend that parks planning for future hurricanes use information from one hurricane category higher than any previous storm experienced. Historical hurricane data from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010) is listed in Appendix D (Table D3) to allow staff to determine the highest Saffir-Simpson category hurricane to strike within 10 miles of each park unit. Applying information from one storm category higher than historical data may more closely approximate what could happen in the future, as storms are projected to be more intense under continued climate change (Emanuel 2005, Webster et al. 2005, Mendelsohn et al. 2012). However, we recommend caution in using this approach for any detailed (site-level) planning due to limitations discussed in the following section of this report.

Limitations

All projects of this nature have limitations that should be clearly described to ensure appropriate use and interpretation of these data.

Every effort has been made to incorporate any parks established after this project began (e.g. Harriet Tubman Underground Railroad National Monument); however, some maps might be missing due to lack of available boundary data in new units.

Sea level and storm surge estimates were derived using separate programs from the IPCC and NOAA, respectively. These numbers were then imported into GIS maps using the program ArcGIS. We used a bathtub modeling approach to map the extent of sea level rise and storm surge over every unit. Bathtub modeling simply simulates how high or how far inland water will go under different

climate change scenarios. It does not recognize changes in topography or other environmental or artificial systems that may exist or occur in response to encroaching water. Although the bathtub model is the most widely used technique for modeling inundation, it is also a simplistic approach to simulating how sea level rise will affect a landscape (Storlazzi et al. 2013). Dynamic models could simulate changes in flow around buildings or estimate how topographic features such as dune systems may migrate in response to inundation and flooding, but dynamic models also vary, which can be a severe limitation in trying to standardize data for summary analysis and comparison.

The maps provided through this analysis vary in horizontal and vertical accuracy depending on which digital elevation model (DEM) data were available at the time of mapping. This is discussed in more detail in the metadata that accompany each map. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast/) which uses source elevation data that either meet or exceed current Federal Emergency Management mapping specifications. These NOAA digital coast data were required to have a minimum root mean square error of 18.5 cm for low lying areas that were then corrected for MHHW using the NOAA VDatum model (Parker et al. 2003). USGS data were used for areas, such as Alaska, where digital coastal data were not available. We recommend referring to Schmid et al. (2014) for further discussion on potential uncertainty of this technique.

Although SLOSH MOM has the widest geographic storm surge coverage of any model in the US, storm surge data were not available for every part of the coastline. Every effort has been made by this project to bridge any gaps where SLOSH MOM does not exist. While the Tebaldi et al. (2012) data cover the California, Oregon, Washington, and southern Alaskan coastlines, they do not cover northern Alaskan, American Samoan, or Guam coastlines. These coastlines are vulnerable to storm surge but we could not find data that satisfied our standards of accuracy sufficiently to be included in our mapping efforts.

Furthermore, storm surge maps are only intended as a rough guide of how flooding caused by storm surge will look today. As more of the coastline becomes inundated we can expect coastal flooding patterns to also change accordingly. The SLOSH model is a multiple scenario approach that uses previous storms to estimate future storm surge. It cannot take into account changes in future basin morphology that could affect the fluid dynamics and propagation of coastal flooding.

SLOSH MOM is modeled using mean sea level (0 m NAVD88) and what NOAA terms "high tide" (which is not tied to the local tidal datum, but is actually a round number based on the modeled average high tide for the region). Jalesnianski et al. (1992) estimate surge estimates to be accurate +/- 20%, although Glahn et al. (2009) discuss how others have found the P-Surge model to be more accurate than originally estimated. Such factors must be kept in mind when using these numbers for mapping.

Land Level Change

It is important to include changes in land level while interpreting changes in sea level. The IPCC (2013) includes a limited amount of data regarding changes in relative sea level in their calculations of sea level change. Our sea level rise results include the IPCC estimates of how changes in land

level will change over time based on estimates of glacial isostatic adjustment. Land level change is an important variable when calculating relative sea level. Land levels have changed over time in response to numerous factors. Changes in various land-based loadings—such as ice sheets during the last glacial maximum—has been a significant cause of land level change in the U.S. Post-glacial isostatic rebound is the result of this pressure being released after the removal of ice sheets on the Earth's crust. Land level can also be altered by other factors such as tectonic shifts, particularly along the Alaska and continental U.S. Pacific coastlines. These drivers can often prompt a relative increase or decrease in land level depending on location. Other factors such as aquifer drawdown and the draining of coastal swamps can create decreases in relative land level.

Quantifying how land levels are changing is difficult given the paucity of data available prior to modern satellite data. An upcoming NASA publication on land-based movement (Nerem pers. comm.) will help to address this data need, providing numbers for land-based movement across the country. Data from the NASA report can then be incorporated with sea level rise numbers from this analysis using the following equation (after Lentz et al. 2016):

Eq. 2 $$\mathrm{a}e = E_0 - e_i + R$$

Where; ae is the adjusted elevation, E_0 is the initial land elevation, e_i is the future sea level for either 2030, 2050, or 2100, and R is the current rate of land movement over time due to isostatic adjustments.

In the interim, tide gauges can provide further data regarding changes in land level, but should be used cautiously. We have listed tide gauge data for the rate of change in land level for tide gauges nearest to all units for this study in Appendix D; however, only Fort Pulaski National Monument and Golden Gate National Recreation Area have a long-term tide gauge on site. This lack of nearby long-term data can limit the accuracy of these numbers if they are applied to sea level change projections for almost all other parks units. We indicate in Table D1 which of the nearest tides gauges we do not recommend using to estimate land movement. This is because in many case the boundary of the park unit is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. Land level changes were only reported for long-term tide gauges that had at least thirty years of data in order to ensure a statistically robust dataset. Based on these limited records, we estimate that seven park units are currently experiencing decreasing relative sea levels (Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park), although we cannot be certain of this number given that many of the park units are some distance from a tide gauge. We expect the release of the NASA data (Nerem pers. comm.) to help refine these estimates.

A discussion of the applicability of these land level numbers (with a natural resources manager or similar expert) should accompany use of individual park maps from this analysis to ensure that the nearest tide gauge to any particular project site is appropriate. Current rates of subsidence at these tide gauges range between +7.6 mm/y (Grand Isle, Louisiana) and -19 mm/y (Skagway, Alaska; Table D1). In selecting an appropriate tide gauge to use, variables including oceanographic setting, length of the record, completeness of data, and geography of the coastline must be considered. The

science team for this project decided against setting a threshold for how close a park unit should be to a long-term tide gauge based on considerations discussed above.

Where to Access the Data

All GIS data from this project are available at https://irma.nps.gov/Portal for archiving by park.

A website discussing this project is available at the following address:
https://www.nps.gov/subjects/climatechange/sealevelchange.htm

The raw IPCC (2013) data can be downloaded using the following link:
http://www.ipcc.ch/report/ar5/wg1/docs/ar5_wg1_ch13sm_datafiles.zip

Results

Sea level and storm surge maps are in Appendix A. A full list of the 118 park units and a table listing sea level projections by park are available in Appendix D. Following the methods outlined above, we found that sea level rise projections across the 118 park units average between 0.45 m (RCP2.6) and 0.67 m (RCP8.5) by 2100. However, this number masks how these projections will vary geographically. Figure 4 shows these projections in more detail and provides sea level estimates by region. Error bars in Figure 4 denote the standard deviation for each average per region, further revealing how these numbers can vary. A high standard deviation and range signals that sea level estimates vary between units within regions, whereas a low standard deviation and small range are to be expected in smaller regions where sea level rise estimates do not cover such a large geographic area.

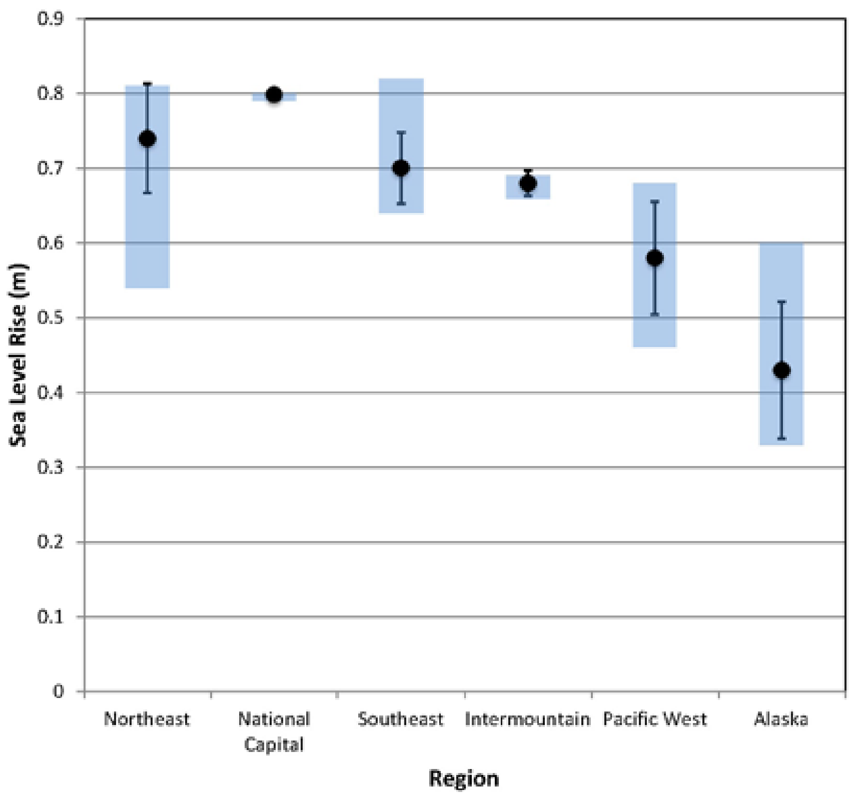

Figure 4. Projected future sea level by NPS region for 2100 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Based on the averages per region, we found that the shoreline within the National Capital Region is projected to experience the highest sea level rise by 2100 (0.80 m RCP8.5), although this number does not include the full extent of changes in land level over the same time interval. The shoreline near Wright Brothers National Memorial in the Southeast Region has the highest overall projected sea level rise (0.82 m, RCP8.5, 2100). Glacier Bay Preserve and Klondike Gold Rush National

Historical Park are tied for lowest projected sea level rise at 0.33 m using RCP8.5 for 2100. The Alaska Region also has the highest standard deviation among park units. The National Capital Region conversely has very little standard deviation due to the compact nature of the region (meaning that all of the parks units fell within the same raster cell). This is not to say that all of the parks will experience exactly the same rate of sea level rise, but that the IPCC model projected that sea levels could rise up to an average 0.80 m (RCP8.5) for that region by 2100. The sea level rise maps (discussed in the National Capital section below) illustrate differences among the National Capital parks in more detail.

Comparing RCP8.5 data for 2030 and 2050 (Figures 5 and 6, respectively) shows the Northeast Region almost tied with the National Capital Region in 2030 based on average projected sea level rise, with the National Capital Region ranked highest. The Alaska Region ranks lowest for all three time intervals followed by the Pacific Northwest region, Intermountain Region, and Southeast Region. The Northeast Region ranks second highest for 2050 and 2100.

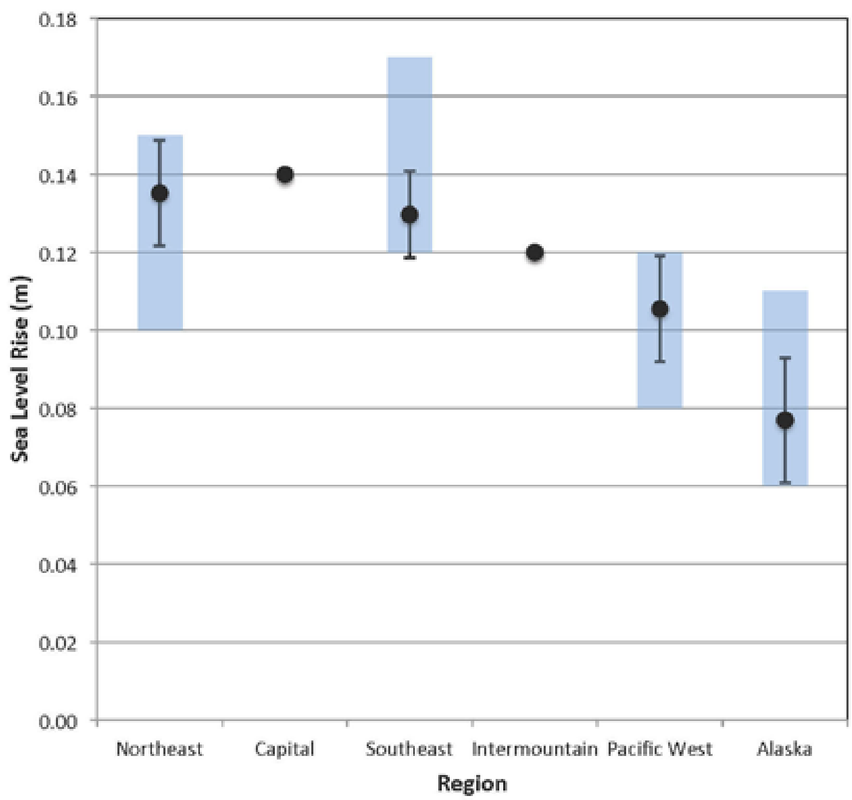

Figure 5. Projected future sea level rise by NPS region for 2030 under RCP8.5 (the “business as usual” climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

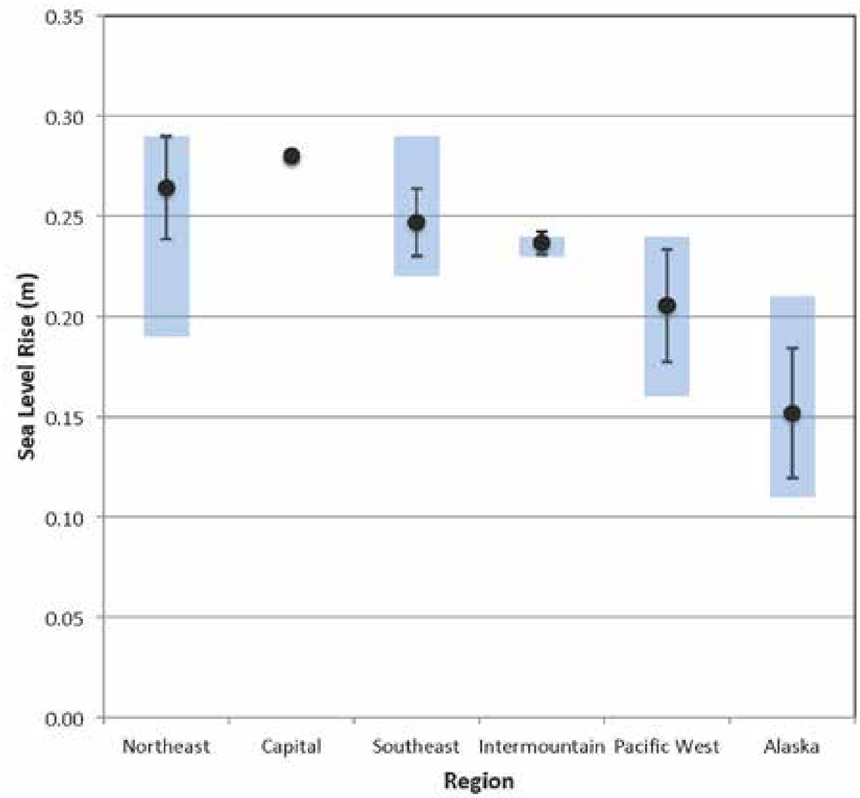

Figure 6. Projected future sea level rise by NPS region for 2050 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Storm surge was mapped for 79 park units. We list data for one storm category higher than the highest historical storm in Table D3 in Appendix D. Some (31) park units did not have a historical storm path occurrence within 10 miles of their boundaries, so a Saffir-Simpson hurricane 1 was simulated for these locations. The lack of a historical storm does not mean that these parks are not subject to strong storms. It may merely be that these parks are in regions that either do not have extensive historical records or they experience strong storms, such as nor'easters, that behave differently and are not part of the NOAA database.

The Southeast Region has the strongest historical hurricanes (average of highest recorded storm categories = 2.79), followed by the Intermountain Region (average = 2.33), National Capital Region (average = 1.90), and the Northeast (average = 1.03). None of the historical data intersected with the 10-mile (16.1 km) buffers around the Alaska Region parks. The Pacific West Region has experienced some tropical depressions, particularly in Hawaii, but most of their storm surges are driven by other phenomena, such as mid-latitude cyclones or extreme tides (sometimes colloquially referred to as king tides). The strongest (highest winds) and most intense (lowest pressure at landfall) recorded historical storm to have impacted a park unit was the "Labor Day Hurricane" that passed within 10 miles of Everglades National Park in 1935. While this storm may have been the highest intensity storm, it is certainly not the most damaging or costly storm in National Park Service history.

Northeast Region

Colonial National Historical Park, Fort Monroe National Monument, and Petersburg National Battlefield have the highest projected sea level rise in 2050 and 2100, and, together with Edgar Allen Poe National Historic Site, Fort McHenry National Monument and Historic Shrine, Independence National Historical Park, and Thaddeus Kosciusko National Memorial (parks near coastlines) they also have the highest projected sea level rise for 2030. However, while these parks may have ranked highly, caution should be used in applying these results. Many of these parks do not have coastline and so these projections are based on sea level rise for the coastline adjacent to these parks. The maps in Appendix A show how the projected sea level rise may affect each of these parks. Colonial National Historical Park, Fort McHenry, and Fort Monroe National Monument are the only park units of this highest rise grouping that contain coastline with their boundaries.

Figure 7 shows the range of sea level projections for the Northeast Region for 2100, averaging between 0.49 m (RCP2.6) and 0.74 m (RCP8.5) of sea level rise by the end of the century. Acadia National Park had the lowest projected rates of sea level rise for 2030 (0.08–0.10 m), 2050 (0.14–0.19 m), and 2100 (0.28–0.54 m).

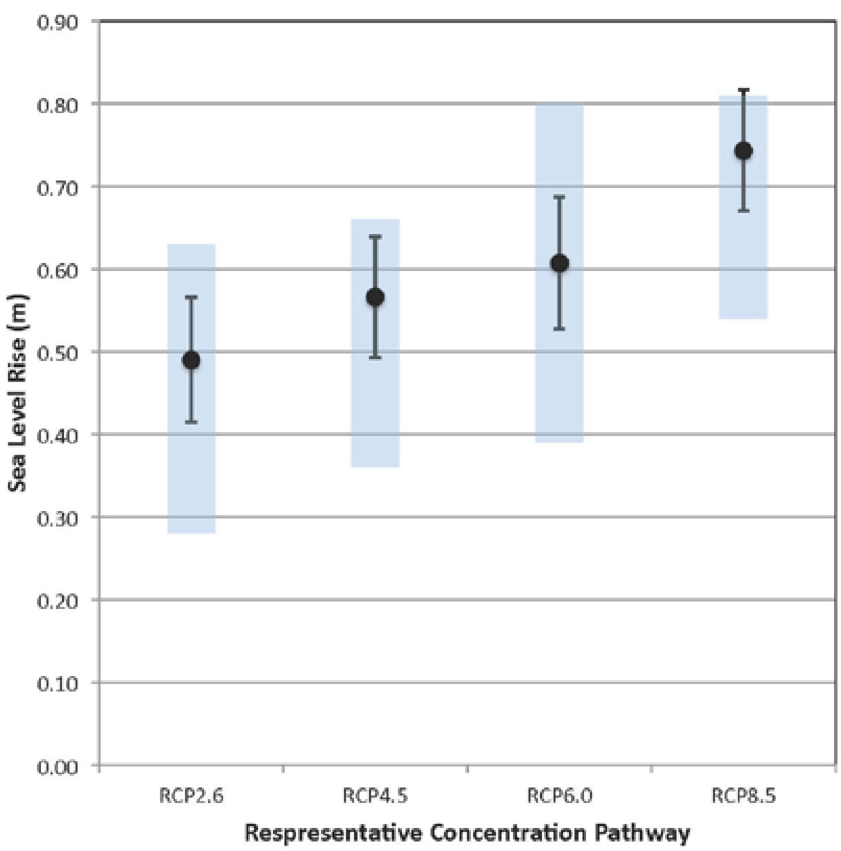

Figure 7. Projected future sea level rise by 2100 for the NPS Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each category.

Regarding storm surge, the highest recorded storm to have travelled within 10 miles of any of the 29 parks units identified for study was an officially unnamed hurricane in 1869 known colloquially as Saxby's Gale, which was classified as a Saffir-Simpson 3 hurricane. The storm path passed present-day Boston National Historical Park and Roger Williams National Memorial. Figure 8 shows the estimated extent and height of a storm surge from category 3 hurricane striking Boston Harbor Islands National Recreation Area at mean tide.

Figure 8. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at high tide near Boston Harbor Islands National Recreation Area. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Southeast Region

Historically, the Southeast Region has the highest intensity storms (highest Saffir-Simpson storm category); Everglades National Park has recorded a category 5 hurricane within 10 miles of its boundary, the colored areas in Figure 9 indicate the potential height and extent of a storm generated by two different categories of hurricane. A category 2 hurricane could completely flood the park.

Future storm surges will be exacerbated by future sea level rise nationwide; this could be especially dangerous for the Southeast Region where they already experience hurricane-strength storms.

Moreover, sea level rise projections only include changes in land movement due to glacial isostatic adjustment and do not include the full range of drivers of potential changes in land level. Using Table D1 from Appendix D as a rough guide, changing land level for parks near tide gauges can be evaluated. For example, the Eugene Island, Louisiana tide gauge's current rate of sea level rise is the highest in the country at 9.65 mm/y, owing in part to the large rate of subsidence in the region (Figure 1). Using the nearest tide gauge to Jean Lafitte National Historical Park and Preserve (Grand Isle, Louisiana, gauge 8761724) we can estimate that land will subside by 7.60 mm/y. Applying this estimate of subsidence (using a baseline of 1992) to our RCP8.5 projections, the park could experience approximately 0.41 m of *relative* sea level rise by 2030 followed by 0.69 m by 2050 and 1.50 m by 2100. This is an inexact estimate of the land movement for the park given that Jean Lafitte National Historical Park and Preserve is approximately 60 miles (97 km) from the tide gauge; still, factoring in changes in land level, we can see that relative change in sea level is more than double the projected change in sea level using the IPCC estimates alone.

This analysis projects that, by 2100, the shoreline adjacent to Wright Brothers National Memorial may have the greatest sea level rise among the Southeast Region's parks (0.82 m RCP8.5). Given elevations within the park, this may not inundate a large area of the memorial, unless combined with other factors such as a storm surge. For example, the park may be almost completely flooded if a category 2 or higher hurricane strikes on top of inundation from sea level rise.

Nearby Cape Hatteras and Cape Lookout National Seashores are projected to experience sea level rise of up to 0.79 m and 0.76 m, respectively (RCP8.5) by 2100, resulting in large areas of inundation. While sea level rise around these national seashores may not be as high as what has been projected for Wright Brothers National Memorial, they serve as examples of how caution must be used when using these numbers to assess which park units are most vulnerable to sea level rise. Other factors, such as percent of exposed land, changes in land movement, and adaptive capacity must also be taken into account for vulnerability analyses (Peek et al. 2015).

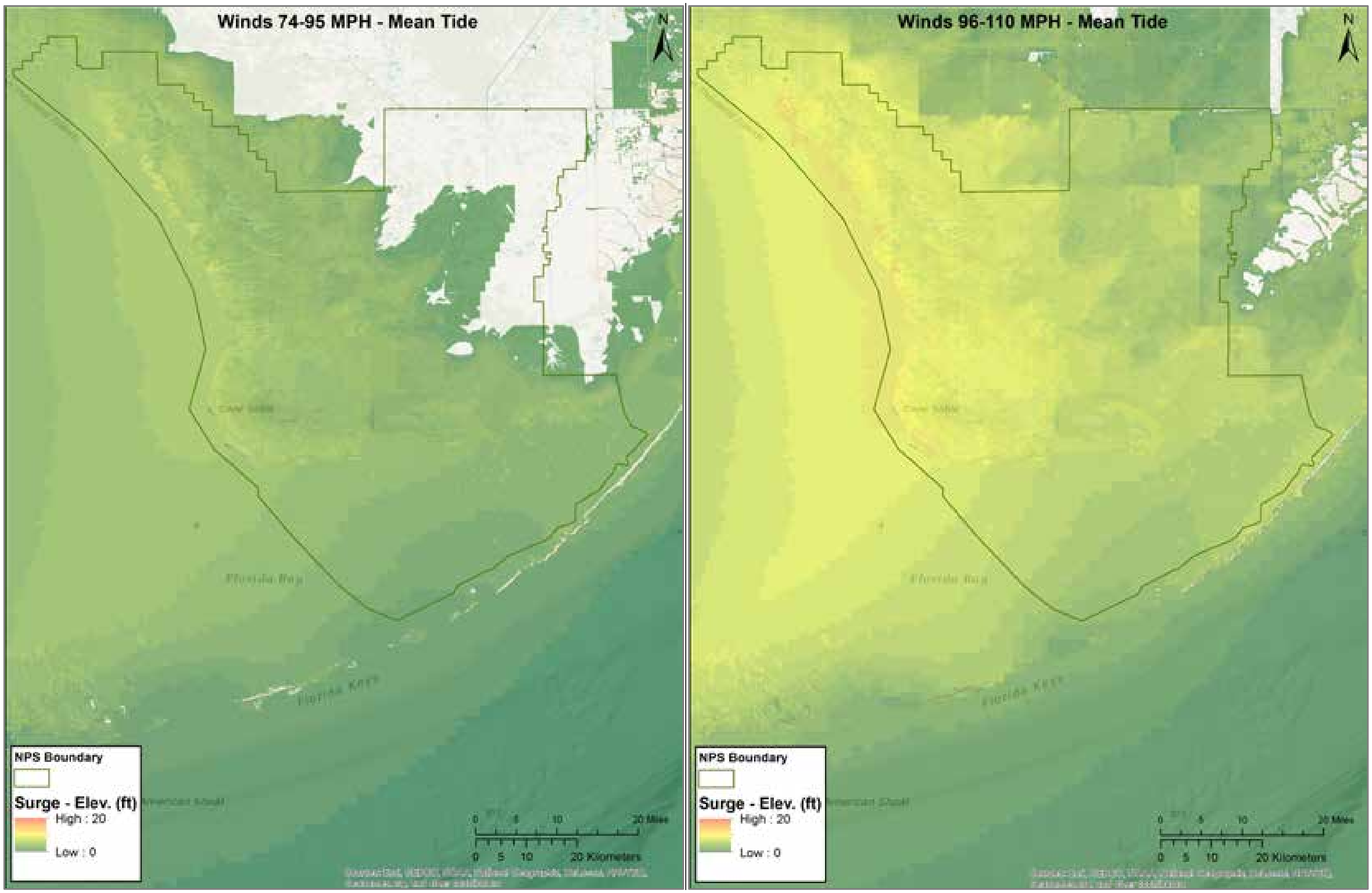

Figure 9. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide (right). Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

National Capital

National Capital Region has minimal variability in projected sea level rise because all park units selected for study are adjacent to the same section of coastline that was modeled. Their proximity also explains why they share the same storm history. Despite these similarities, projected sea level rise may affect each individual park unit differently based on local topography. The strongest storm recorded within 10 miles (16.1 km) of the National Capital Region parks was a Saffir-Simpson category 2 hurricane that struck the city in 1878. While the 1878 storm caused relatively little damage, we can expect a significantly larger amount of damage if a similar storm struck the city again given considerable development now existing in the area. Figure 10 shows the extent of flooding caused by a Saffir-Simpson category 2 hurricane. A storm surge measuring more than 3 m could travel up the Potomac River causing large amounts of flooding. Such a storm surge could be worse by the end of this century given projected sea level rise around the Capital Region of up to 0.8 m.

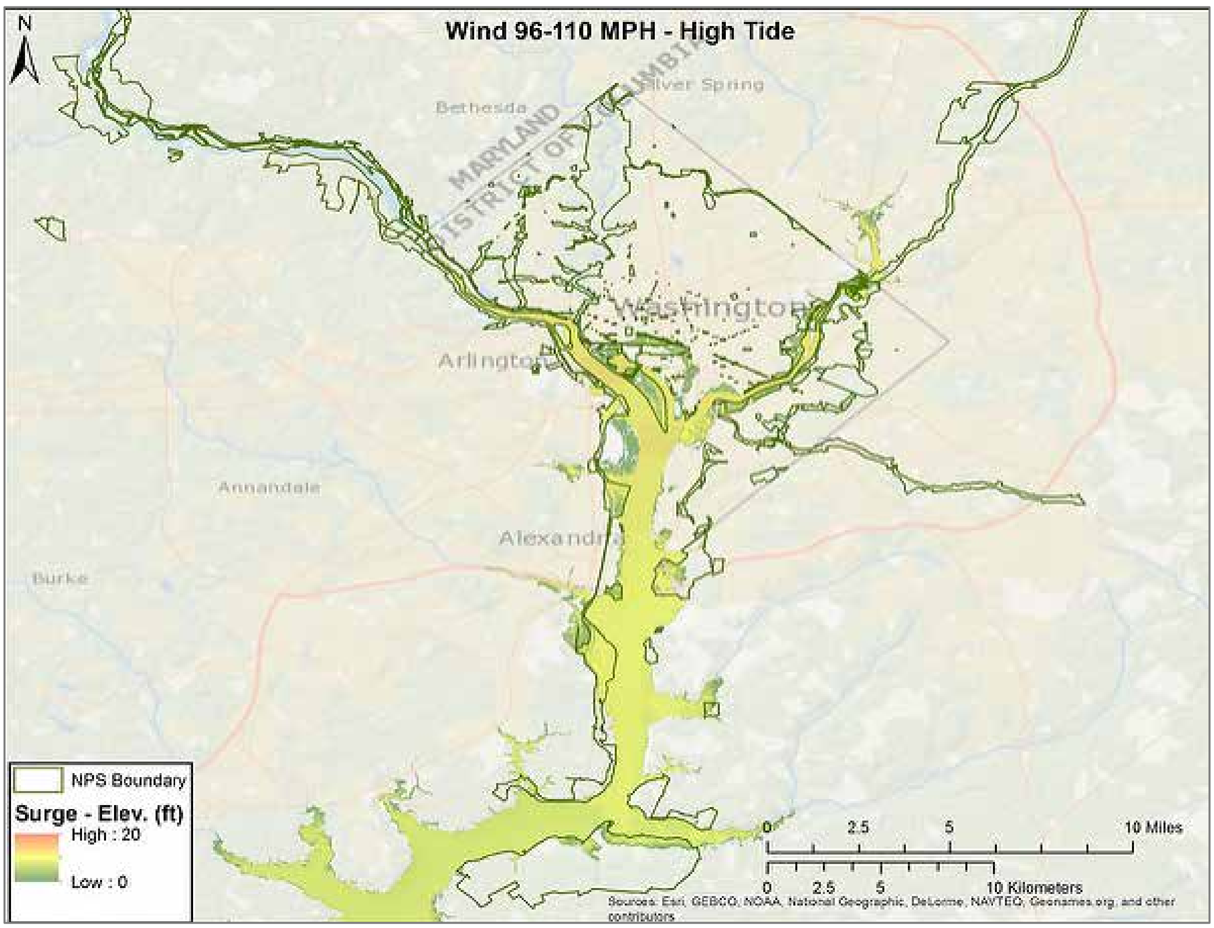

Figure 10. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

IPCC/SLOSH models showed either storm surge or sea level rise (or some combination of the two) affecting every National Capital Region park included in this analysis, with the exception of Harpers Ferry National Historical Park. Our mapping efforts revealed that Harpers Ferry National Historical Park (located approximately 149 m above sea level) is unlikely to experience any impacts of sea level rise due to its elevation and is unlikely to be damaged by storm surge from a hurricane, given its relatively protected location behind several dams along the Potomac and Shenandoah Rivers.

Sea level rise alone is not expected to spread very far into Washington D.C., although a large section on the east side of Theodore Roosevelt Island could be inundated. However, storm surge flooding on top of this sea level rise would have widespread impacts.

Intermountain Region

The Intermountain Region covers mostly inland park units stretching from Texas to Montana. Within the region, only three park units in Texas are subject to sea level change: Big Thicket National Preserve, Palo Alto Battlefield National Historical Park, and Padre Island National Seashore. Of these, Padre Island National Seashore may experience the greatest effects of sea level and storm surge; sea level is projected to rise 0.46–0.69 m (RCP2.6–8.5, Figure 11) by 2100. The same amount of sea level rise is projected for the shoreline near Palo Alto Battlefield National Historical Park, but inundation is not projected to extend far enough to reach the park. Palo Alto Battlefield National Historical Park has no history of being within 10 miles of any hurricane, making the site unlikely to be flooded by storm surge. SLOSH MOM models for the park unit show that that the region would have to have either a Saffir-Simpson category 4 hurricane striking at high tide or a category 5 hurricane striking at any tide in order for the park to experience any storm surge. On the other hand, Figure 12 shows that Padre Island National Seashore, located to the east of Palo Alto Battlefield National Historical Park, historically was within 10 miles of a category 4 hurricane. SLOSH MOM data show that should a category 4 hurricane occur here again, it would likely flood almost the entire island.

Storm surge could potentially travel up the Neches River and flood the southernmost part of Big Thicket National Preserve, although both artificial and natural storm surge defenses in Beaumont, Texas, to the south of the preserve, may buffer it from any surge.

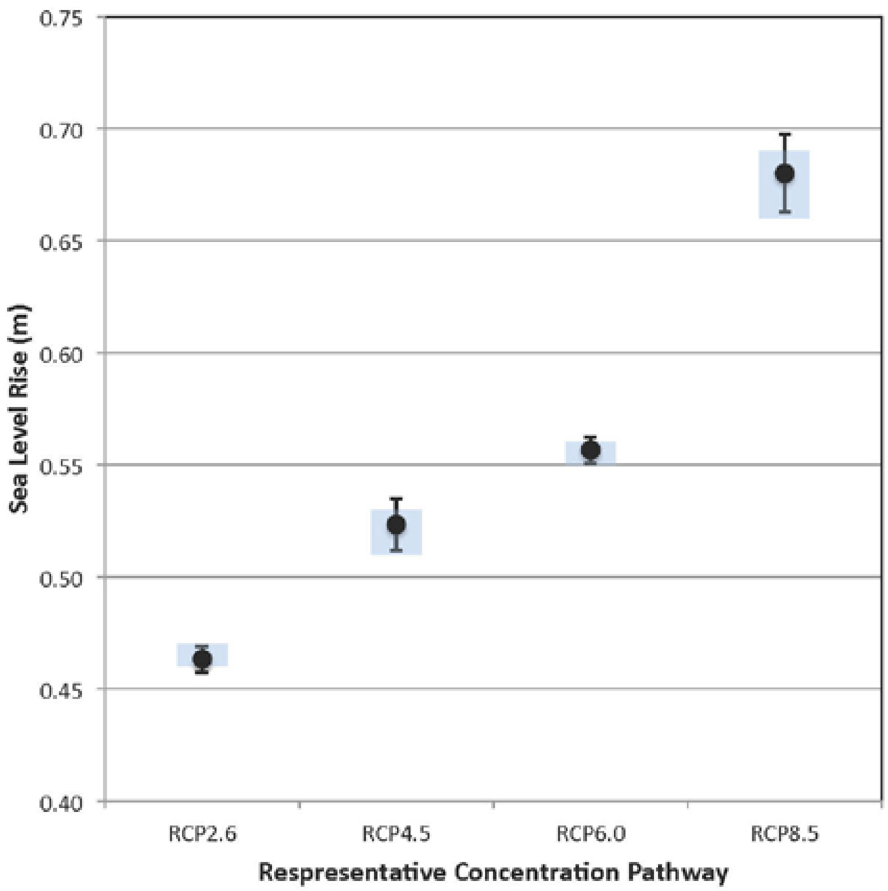

Figure 11. Projected future sea level rise by 2100 for the NPS Intermountain Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation from each mean. Blue bars mark the full range of sea level estimates for each category.

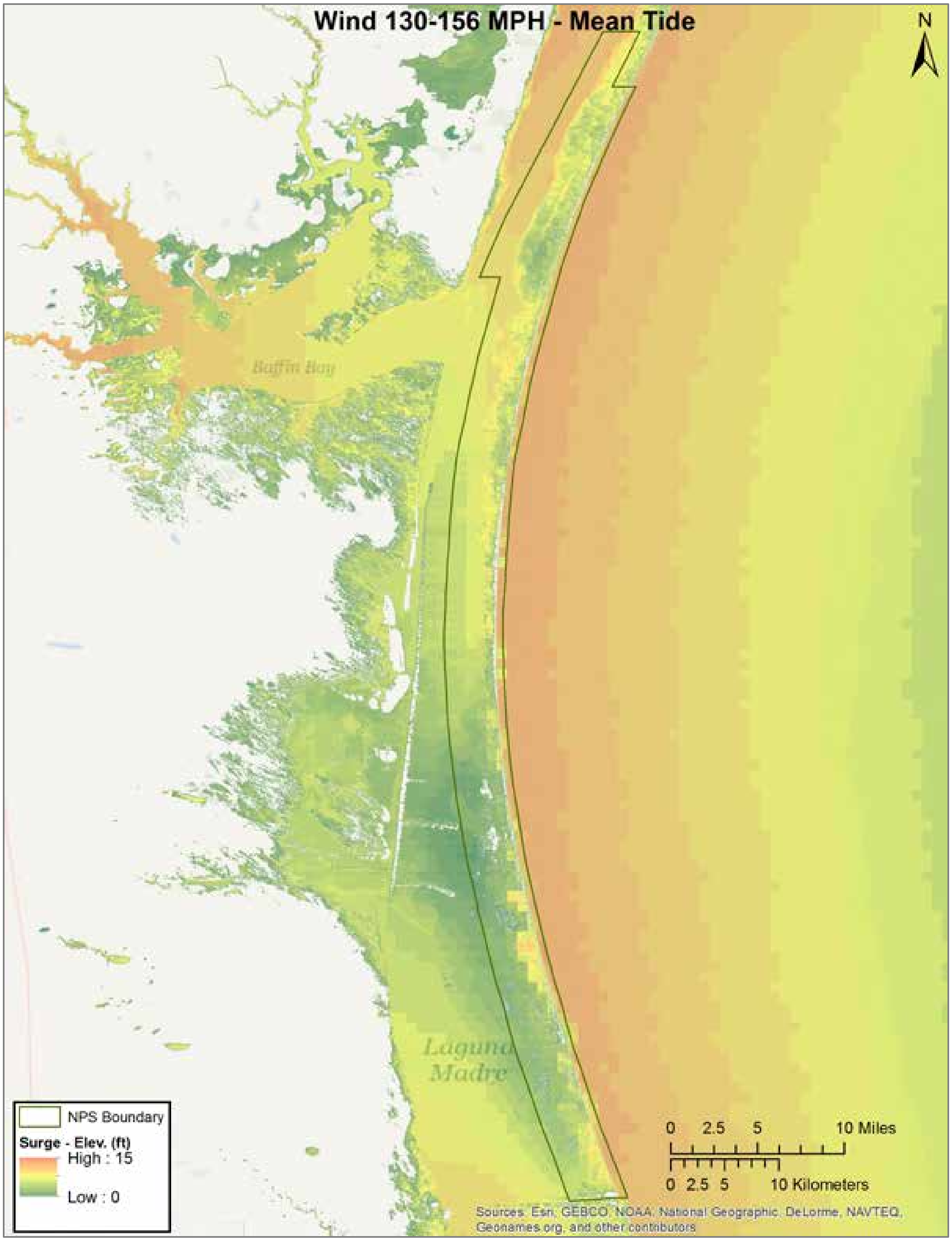

Figure 12. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Pacific West Region

The Pacific West Region identified 24 park units for analysis in this study that could be vulnerable to sea level rise and/or storm surge. These units occur over a large area that includes California, Oregon, Washington, Hawaii, American Samoa, and Guam. War in the Pacific National Historical Park in Guam has the highest projected sea level rise at 0.68 m (RCP8.5) by 2100, and shares the highest projected sea level rise with almost all of the Hawaiian park units in 2030 and 2050. The average projected sea level rise range is 0.40–0.58 m (RCP2.6–8.5) by 2100 for the whole region; high standard deviations (0.04 m and 0.08 m for RCP2.6 and RCP8.5, respectively) indicate that park-specific projections vary widely across the region.

At the other end of the spectrum, projected sea level rise around Washington's Olympic Peninsula and in the San Juan Islands, affecting Ebey's Landing National Historical Reserve, Olympic National Park, and San Juan Island Historical Park, is expected to occur more slowly, reaching a maximum 0.46 m (RCP8.5) by 2100. This region is subject to tectonic shifts and continuing land movement due to isostatic rebound, further complicating sea level projections. Long-term tide gauge records at Neah Bay, Washington (gauge 9443090), and Tofino, British Columbia, Canada (gauge 822-116), show relative sea levels currently decreasing while tide gauges in Port Angeles, Washington (gauge 9444090), Victoria, Canada (gauge 822-101), and Seattle, Washington (gauge 9447130), show it to be increasing (Zervas 2009). Our projections indicate rising sea level in this region throughout this century, although further investigation of localized changes in land movement could shed more light on this matter.

Park units in the Pacific West Region need to be concerned about potential future storms that could travel along the eastern Pacific Ocean's increasingly warmer waters. Because of the relative lack of hurricanes in this region historically, we used data from Tebaldi et al. (2012), which includes anomalous surges that could be created by storms, and other factors (very high tides sometimes referred to as king tides). Based on the Tebaldi et al. (2012) data, La Jolla, California (gauge 9410230), has the lowest 100-year storm surge (0.95 m) and Toke Point, Washington (gauge 9440910), has the highest 100-year storm surge (1.96 m) in the Pacific West Region. Tebaldi et al. (2012) did not analyze storm data for Hawaii, Guam, or American Samoa, although IBTrACS (Knapp et al. 2010) does have hurricane records for these areas. Only tropical depressions have been recorded within 10 miles of almost all of the Hawaiian park units we analyzed (Haleakala National Park, Hawaii Volcanoes National Park, Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puukohola Heiau National Historic Site, and World War II Valor in the Pacific National Monument).

Alaska Region

The Alaska Region has the lowest average projected sea level rise (0.28–0.43 m by 2100) compared to the five regions described above. Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park in southeastern Alaska share the lowest projected sea level rise (0.33 m, RCP8.5, 2100) while Bering Land Bridge National Preserve on the west coast of the state has the highest projected sea level rise (0.60 m, RCP8.5, 2100).

Figure 1 shows how current relative sea levels vary across the state. Land levels are rapidly rising in the southeast of the region due to isostatic rebound and other tectonic shifts. The net result of these increasing land levels is decreasing relative sea levels for at least the early part of this century. Relative sea level in Skagway, Alaska is decreasing at an average rate of 17.6 mm/y (Zervas 2009). Despite melting ice and other factors outlined in Table 1 that increase ocean water volume, the amount of rising water is insufficient to keep up with land level changes. Seven park units (Glacier Bay National Park, Glacier Bay National Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park) are identified as potentially having decreasing relative sea levels based on the nearest tide gauge data to each of these parks. None of these parks have long-term tide gauges with data spanning at least thirty years. A great strength of using the IPCC (2013) process-based model approach is that, unlike many other semi-empirical models, it does not rely on long-term tide gauge records to statistically project future sea levels. However, sea level projections in this analysis do not include changes in land level. The estimates that we report here represent the expected rise due to water volume expansion alone near to each of these park units. Table D1 shows how land levels are changing at long-term tide gauges across the country. However, given that all of these park units are located far from a tide gauge and that the region is relatively geologically complex, we do not recommend using the land movement numbers from the nearest tide gauge for any of the Alaskan parks.

Storm surge is also very difficult to model for this region. Historically, many of the parks had sea ice along the coastline that helped protect these parks from storm surge. Consequently, NOAA does not have SLOSH MOM models for this region. IBTrACS data (Knapp et al. 2010) show a few storm paths that have moved towards the region, but these types of storms typically do not make landfall once they move over colder waters. Alaska does hold the record for the highest intensity (lowest central pressure) storm (Duff 2015). A downgraded super typhoon, Nuri, struck Adak Island, Alaska, in 2014 with recorded winds gusting up to 122 mph. It is impossible to determine an average or peak historical storm surge without adequate tide gauge data.

Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/y, although this rate accelerated over the latter part of the century. Slangan et al. (2016) found that emissions of greenhouse gases from human activities have been the primary driver of global sea level change since 1970 and that the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/y (Cazenave et al. 2014, Fasullo et al. 2016).

The IPCC (2013) projects that, without greenhouse gas emissions reductions, this rate will increase, and that global average sea levels could rise by 0.40–0.63 m (RCP2.6–8.5) by 2100. We used regional sea level projections from the IPCC (2013) generated for 2050 and 2100 in combination with our interpolated projections for 2030 to estimate the amount of sea level rise 118 coastal national park units could experience in the future. Our projections are based on the new representative concentration pathways (Moss et al. 2010, Figure 13), using a process-based model approach.

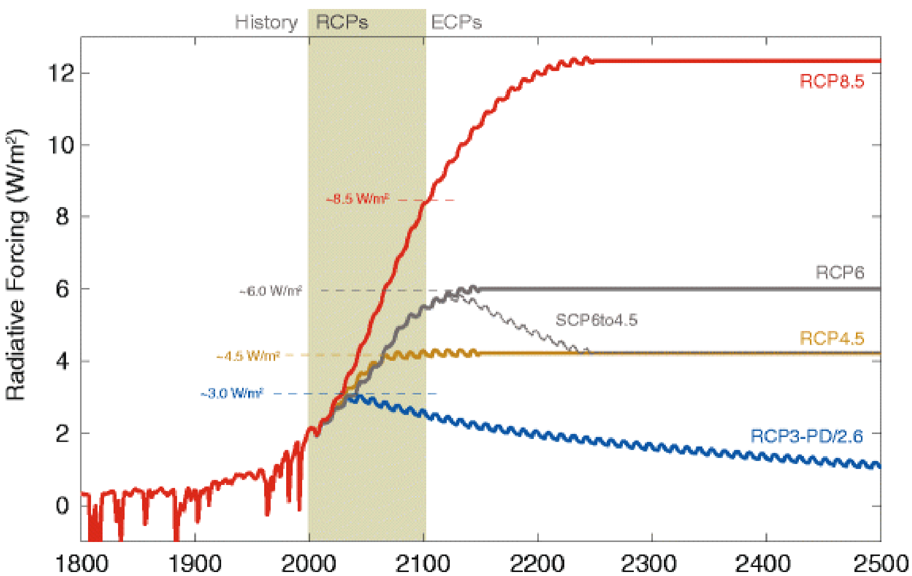

Figure 13. Radiative forcing for each of the Representative Concentration Pathways (RCPs). An increase in radiative forcing (due to the loading of anthropogenic gases into the atmosphere) will result in higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are slightly higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011.

Numerous academic articles use mostly semi-empirical models (Rahmstorf 2007) to estimate sea level rise regions across the U.S. The IPCC (2013) lists several semi-empirical sea level rise estimates, all of which result in projections of future sea level that are higher than the IPCC (2013) approach. The differences in these approaches can be attributed to many factors. For example, some of the older papers may have higher sea level estimates because they are based on the older IPCC SRES scenarios (e.g. Vermeer and Rahmstorf 2009, Grinsted et al. 2010, Jevrejeva et al. 2010). Other papers may include input from "expert elicitations" in their sea level projections, in which experts provide their opinion on how much sea level (or a related factor) could rise in the future (e.g. Bamber and Aspinall 2013, Jevrejeva et al. 2014, Horton et al. 2014). Some published articles criticize the IPCC sea level estimates as being too conservative or underestimating rates of future sea level change (e.g. Kerr 2013, Horton et al. 2014). Church et al. (2013) addresses these criticisms by explaining how the IPCC define the probability and likelihood of their estimates, and so they are not discussed in detail here. Recent analyses by Clark et al. (2015) further support the findings of the IPCC.

A key strength of the methods used in this analysis lies in providing a unified approach to identify how sea level change may affect all coastal park units across the National Park System, rather than relying on sea level data generated for specific areas. Our analyses revealed that the National Capital Region is projected to experience the greatest increase in sea level (not taking into account changes in land level). This rise will affect each of the region's units in different ways depending on the elevation of the individual unit, but it could be significant if combined with a storm surge from a storm such as the Saffir-Simpson category 2 hurricane in 1878.

At the individual park level, IPCC projections reveal the sea level along the coastline adjacent to Wright Brothers National Memorial could rise up 0.82 m (RCP8.5) by 2100, which could lead to significant flooding if the dynamic landforms are not able to keep pace with such high rates of sea level rise. In addition, storm surge impacts at this higher sea level would be significant. The Southeast Region as a whole is generally susceptible to inundation and flooding due to its low-lying nature in many places, particularly in Cape Hatteras and Cape Lookout National Seashores. Our sea level rise maps (Appendix A) highlight how much all of these park units may be affected.

These estimates do not include the latest data on changing land levels. The IPCC included estimates of global isostatic adjustment (Equation 1) in their predictions, but those do not include changes in land level due to other factors, such as earthquakes and groundwater extraction. We expect the latest, state-of-the-art land level estimates to be released by NASA in 2017. In the meantime, we can roughly estimate relative sea level change for a small number of parks based on current rates of subsidence gathered from nearby long-term tide gauge data. We project Jean Lafitte National Historical Park and Preserve to have the greatest relative sea level increase based on the current rate of land movement. Our sea level projections agree with current sea level trends in showing that the southeast Alaska region is experiencing the least amount of sea level rise of anywhere in the National Park System.

Sallenger et al. (2012) discussed how changes in Atlantic Ocean temperatures and salinity (resulting from changes in circulation) could lead to changes in sea level that could create a 1000-km long “hotspot” along the North Atlantic coast from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. We estimate that almost all of the coastal park units in this area would be flooded under these conditions.

It is unknown exactly to what degree future storm surge will affect the Alaskan park units. Accurate long-term (>30 years) storm surge data do not exist for the Alaska region. Even if such data did exist, it would be not be analogous to future conditions in the region because sea ice that had previously protected the shores for many of the western Alaska park units melts to reveal an easily erodible coastline (Frey et al. 2015). The warming of ocean waters in the Gulf of Alaska and Pacific Ocean could also make it more conducive for more storms like Typhoon Nuri to travel north without losing energy as under historic conditions.

The Pacific West Region shows high variability among parks. War in The Pacific National Historical Park in Guam ranks highest in projected sea level rise among units in the Pacific West Region. The large area of the region partly explains the relatively high standard deviation in results for the region. The tectonically complex setting of many of the region’s parks also complicates future sea level estimates. Changes in land movement are somewhat gradual nationwide in comparison to Alaska and the Pacific West Region, especially where earthquakes can rapidly change the position of the land relative to the sea.

Island park units in general are particularly exposed to the impacts of sea level change and storm surge. Many of the barrier island parks, such as Fire Island National Seashore, Assateague Island National Seashore, Palo Alto Battlefield National Historical Park, Gulf Islands National Seashore, and Cape Hatteras National Seashore, are all projected to experience sea level rise of over 0.69 m by 2100 (RCP8.5). This sea level rise, combined with storm surge, could be especially difficult for isolated island park units, such as the Caribbean park units, the National Park of American Samoa, and War in the Pacific National Historical Park, where access to aid in the event of a natural disaster may not be immediately available.

Conclusions

This report presents projections of sea level change (118 parks) and storm surge (79 parks) in coastal park units administered by the National Park Service. Sea level change and storm surge vary geographically, resulting in locally-specific challenges for adaptation and management. It is important to acknowledge that sea level change will affect some parts of Alaska differently than coastal parks in the rest of the country. Northwest Alaska can expect relative sea levels to increase over time; while in southeast Alaska, relative sea levels may continue to decrease over the first part of this century, followed by an increase in relative sea level towards the end of the century.

This project is an important first step in assessing how changes in sea level and storm surge may affect national park units. Using sea level rise and storm surge information, parks can begin to plan for effects on resources, facilities, access, and other areas of management. While methods used here are not appropriate for combining the separate sea level rise and storm surge results, parks should be aware of the potential for synergistic effects of sea level rise and storm surge causing impacts larger than either may cause individually. It is clear that more research can be done on these complex issues to assess how these changes may affect parks and regions. These data can inform future projects related to both natural and cultural resources as well as the planning and management of infrastructure.

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Appendix A

Links to Data Sources

Maps were created for this project using NOAA DEM data. For further information regarding our methods refer to methods section on page 3.

Digital versions of our sea level rise maps will be available at www.irma.gov

Storm surge maps are also available on www.irma.gov and
www.flickr.com/photos/125040673@N03/albums/with/72157645643578558

Appendix B

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with regional managers. Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.

Q. Who originally identified which park units should be used in this study?

A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific West Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. In what instance did you use data from Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to provide data for park units in California, Oregon, Washington, and southern Alaska. The following parks used Tebaldi et al. (2012) data: Cabrillo National Monument, Channel Islands National Park, Ebey's Landing National Historical Reserve, Fort Point National Historic Site, Fort Vancouver National Historic Site, Golden Gate National Recreation Area, Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, Rosie the Riveter WWII Home Front National Historical Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012). These parks are: Aniakchak Preserve, Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Glacier Bay National Park and Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park, War in the Pacific National Historical Park, and Wrangell – St. Elias National Park and Preserve.

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into the northern latitudes of that region.

Q. Why are the storm surge maps in NAVD88?

A. That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on sea level and storm surge projections for some parks?

A. The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America to refer to the "elevation" of a location. It uses a fixed value for the height of North America's mean sea level. While this is a popular datum for mapping, it has the limitation that it is based on the observed mean sea level for a single location: Rimouski, Canada. As you move further away from this location you can expect actual sea level to differ from the mean sea level at Rimouski. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station:
https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

A. All parks are different, as are all projects. Your choice of scenario may depend on many different factors including risk tolerance and expected time horizon of the project. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. (2009). Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). IPCC global sea level rise projections range between 0.26 m (RCP2.6 minimum likely range) and 0.82 m (RCP8.5 maximum likely range) by 2100. The standard error of the IPCC is explained in greater detail in the Chapter 13 supplementary material in AR5 (IPCC 2013). An explanation on the horizontal and vertical accuracy of the digital elevation models used for mapping can be found in the metadata that accompanies the map data on www.irma.gov. DEM data were required to have a ≤18.5 cm root mean square error vertical accuracy before they were converted to MHHW. An exception to this was in Alaska where these data were not available.

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent a maximum based on a typical storm surge category. As described above, there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, periodic changes in regional water temperatures (caused by phenomena such as El Niño and La Niña) will impact water levels that will add to any storm surge. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of all man-made structures, such as flood barriers, levees, and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Higher sea level and permanent inundation will change the way waves propagate within a basin. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. As sea level changes, the fluid dynamics of a particular region will also change. For example, tidal distance will change as water levels rise, which will alter the spatial extent of a storm surge as well as potentially impacting wave height. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www.nhc.noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bathtub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact park, region, or Climate Change Response Program staff for assistance. It may be possible to interpolate projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing sources.

Q. What are other impacts from sea level rise that parks should consider?

A. Impacts from sea level rise could include, but are not limited to, increased erosion, damaged cultural resources, damage to above and below ground infrastructure, difficulty accessing inundated infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems. For more information on the topic, please see the Coastal Adaptation Strategies Handbook at: http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

Appendix C

Waysides

The following pages show the final designs for waysides that were installed in parks as part of the funding for this project. Gulf Islands National Seashore received two waysides that were received in 2015. Jean Lafitte National Historical Park and Preserve and Fire Island National Seashores waysides were installed in 2016.

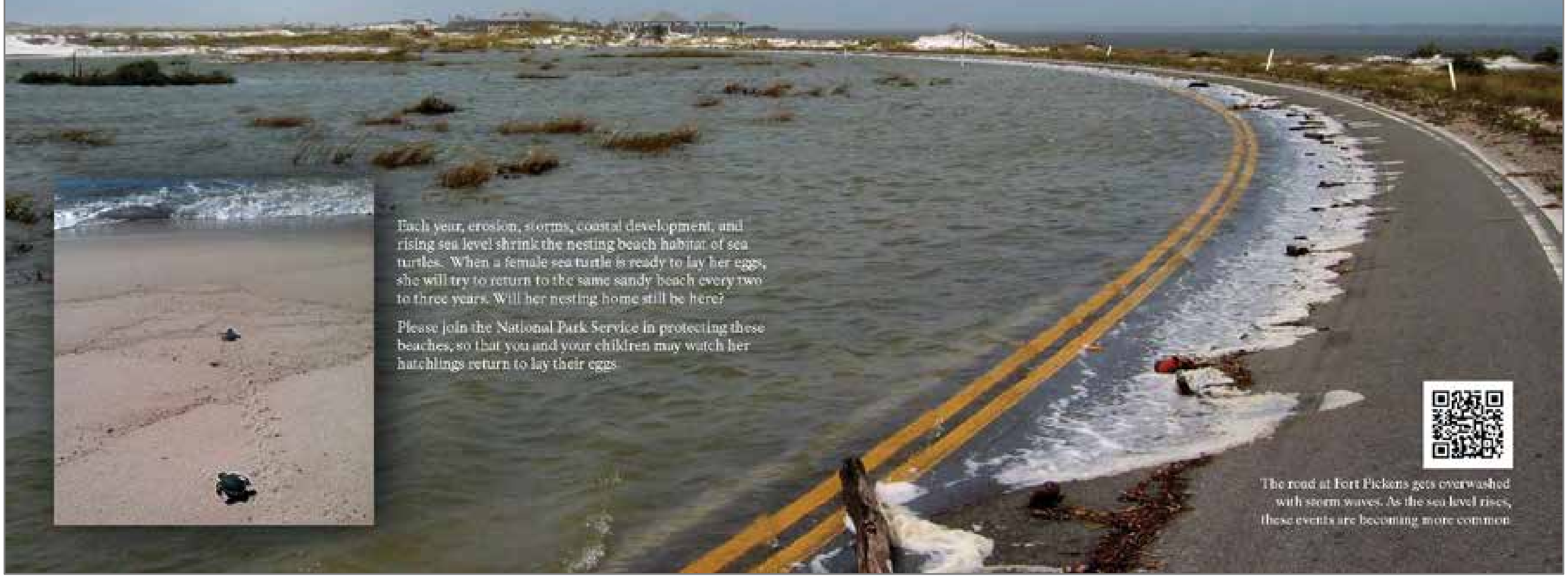
See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the snow white beaches, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

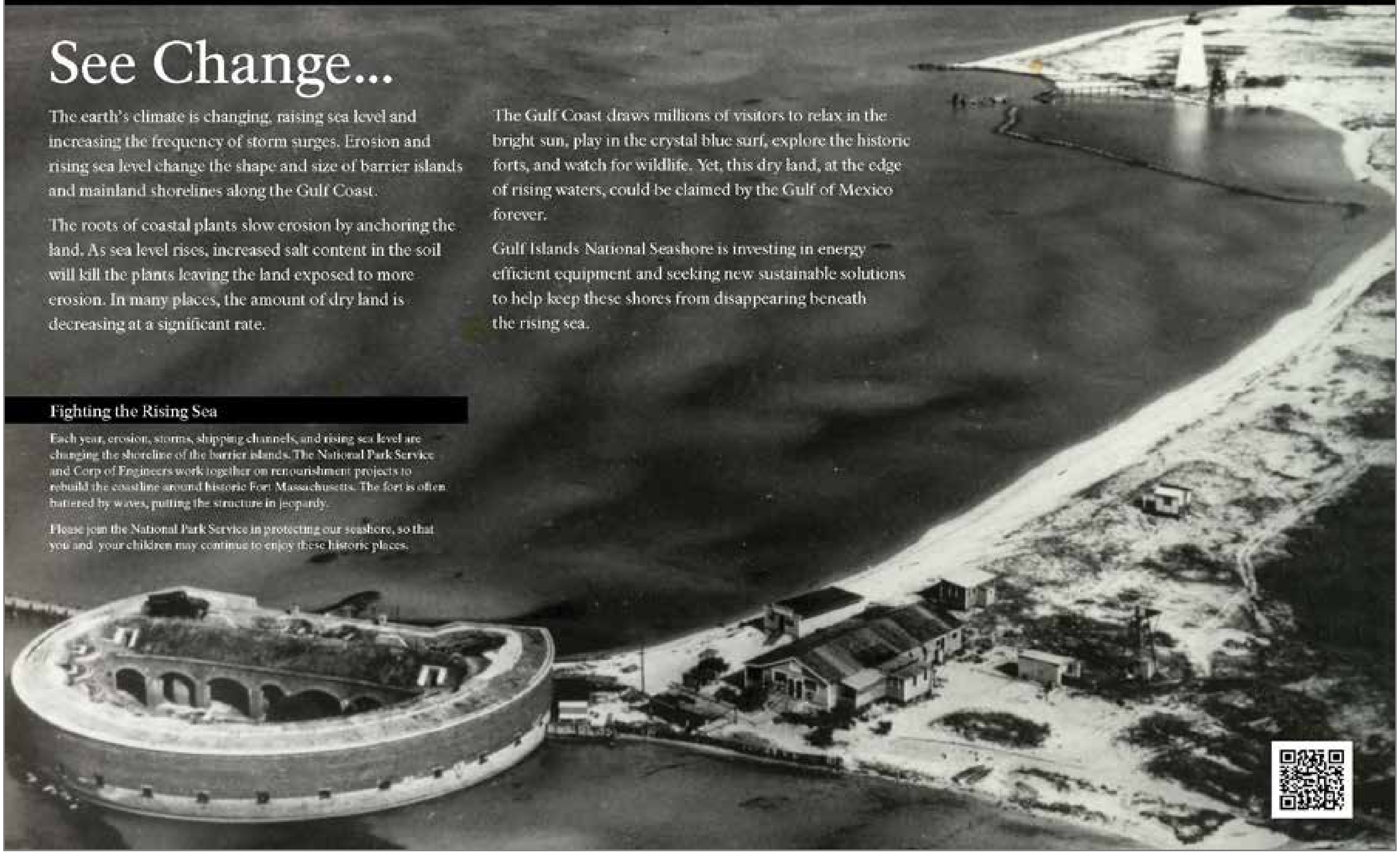
Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.



Each year, erosion, storms, coastal development, and rising sea level shrink the nesting beach habitat of sea turtles. When a female sea turtle is ready to lay her eggs, she will try to return to the same sandy beach every two to three years. Will her nesting home still be here?

Please join the National Park Service in protecting these beaches, so that you and your children may watch her hatchlings return to lay their eggs.

The road at Fort Pickens gets overwashed with storm waves. As the sea level rises, these events are becoming more common.



See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the historic forts, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Fighting the Rising Sea

Each year, erosion, storms, shipping channels, and rising sea level are changing the shoreline of the barrier islands. The National Park Service and Corp of Engineers work together on renourishment projects to rebuild the coastline around historic Fort Massachusetts. The fort is often battered by waves, putting the structure in jeopardy.

Please join the National Park Service in protecting our seashore, so that you and your children may continue to enjoy these historic places.

Sinking Land, Rising Water

This is the Barataria Basin, built of soil washed to this area by the Mississippi River. This soil is still compacting and sinking, a process called subsidence. Most of the Barataria Preserve is less than two feet above sea level, and its subsidence rate is nearly half an inch a year.

Meanwhile, glaciers and polar ice sheets are melting and our warming climate is heating oceans everywhere, making their waters expand just like water does when you heat it on the stove. Everywhere on the planet, the oceans are a little higher every day.

The combination of the Barataria Basin's sinking land and global sea level rise means that the ocean is creeping in faster here than almost anywhere else in North America.

- Floods are becoming more frequent and lasting longer
- Coastal wetlands are disappearing as land sinks and water rises
- Less land is available to buffer Gulf of Mexico storms
- Storm and flooding threats to homes, communities, and infrastructure like highways, ports, and energy facilities are increasing
- Salt water from the Gulf is moving into freshwater wetlands, killing the plants that hold the land together
- Death of plants, animals, and microbes that cannot tolerate increased flooding or salt water

The photo shows two feet of flooding on Barataria Boulevard after Hurricane Isaac in August 2012. The map shows predicted consequences of 18 inches of sea level rise in the preserve; blue areas would be flooded and brown areas would remain land.

See Change In A Changing Climate

Natural landscape change can be nearly imperceptible on a barrier island, as the wind and waves gradually shape the shoreline, beach, and dunes. Natural changes can also be obvious and happen quickly during storms like hurricanes and nor'easters. Looking ahead, storms will have a greater impact on Fire Island due to climate change.

When we burn fossil fuels, carbon dioxide is released into the atmosphere and acts like a heat trapping blanket around our planet. Heat that would normally escape from the atmosphere is retained, warming the Earth, and changing climate patterns. As ocean waters warm and ice on land melts, sea level rises and impacts Fire Island and coastlines all over the world. The future of this barrier island is in jeopardy due to these human-induced climate change effects.

Fire Island protects mainland Long Island against storms and is a stunning setting for recreation, education, and inspiration. It also provides critical habitat for plants and wildlife. We must do what we can to protect this special place. By using renewable energy sources and reducing our dependence on fossil fuels, we can take steps today to preserve barrier island systems and processes, and help build natural resilience to future storms and sea-level rise.

Storm Stories

On October 29, 2012, Hurricane Sandy struck Fire Island National Seashore and changed the lay of the land. During the storm high water and large waves scoured sand from the beach and dunes, moved sand across the width of the island, and carved the breach, pictured here, through the barrier island. The storm was the strongest in recorded history to make landfall in this region.

To learn more about how climate change is impacting the Seashore, please visit www.nps.gov/fiis/learn/climatechange.htm

Background photo credit: C. Flagg

Appendix D

Data Tables

Table D1. The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region	Acadia National Park	Bar Harbor, ME (8413320)	N	60	0.750
	Assateague Island National Seashore‡	Lewes, DE (8557380)	N	88	1.660
	Boston Harbor Islands National Recreation Area	Boston, MA (8443970)	N	86	0.840
	Boston National Historical Park	Boston, MA (8443970)	N	86	0.840
	Cape Cod National Seashore	Woods Hole, MA (8447930)	N	75	0.970
	Castle Clinton National Monument	New York, The Battery, NY (8518750)	N	151	1.220
	Colonial National Historical Park	Sewells Point, VA (8638610)	N	80	2.610
	Edgar Allen Poe National Historic Site	Philadelphia, PA (8545240)	N	107	1.060
	Federal Hall National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	Fire Island National Seashore	Montauk, NY (8510560)	N	60	1.230
	Fort McHenry National Monument and Historic Shrine	Baltimore, MD (8574680)	N	105	1.330

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

‡It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region (continued)	Fort Monroe National Monument‡	Sewells Point, VA (8638610)	N	80	2.610
	Gateway National Recreation Area*‡	Sandy Hook, NJ (8531680)	N	75	2.270
	General Grant National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	George Washington Birthplace National Monument‡	Solomons Island, MD (8577330)	N	70	1.830
	Governors Island National Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
	Hamilton Grange National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	Harriet Tubman Underground Railroad National Monument	Cambridge, MD (8571892)	N	64	1.900
	Independence National Historical Park	Philadelphia, PA (8545240)	N	107	1.060
	New Bedford Whaling National Historical Park	Woods Hole, MA (8447930)	N	75	0.970
	Petersburg National Battlefield‡	Sewells Point, VA (8638610)	N	80	2.610
	Roger Williams National Memorial	Providence, RI (8454000)	N	69	0.300

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region (continued)	Sagamore Hill National Historic Site	Kings Point, NY (8516945)	N	76	0.670
	Saint Croix Island International Historic Site‡	Eastport, ME (8410140)	N	78	0.350
	Salem Maritime National Historic Site	Boston, MA (8443970)	N	86	0.840
	Saugus Iron Works National Historic Site	Boston, MA (8443970)	N	86	0.840
	Statue of Liberty National Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
	Thaddeus Kosciuszko National Memorial	Philadelphia, PA (8545240)	N	107	1.060
	Theodore Roosevelt Birthplace National Historic Site	New York, The Battery, NY (8518750)	N	151	1.220
Southeast Region	Big Cypress National Preserve	Naples, FL (8725110)	N	42	0.270
	Biscayne National Park‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
	Buck Island Reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Canaveral National Seashore	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Cape Hatteras National Seashore*‡	Beaufort, NC (8656483)	N	54	0.790
	Cape Lookout National Seashore	Beaufort, NC (8656483)	N	54	0.790
	Castillo De San Marcos National Monument‡	Mayport, FL (8720218)	N	79	0.590
	Charles Pinckney National Historic Site	Charleston, SC (8665530)	N	86	1.240
	Christiansted National Historic Site‡	San Juan, Puerto Rico (9755371)	N	45	-0.202
	Cumberland Island National Seashore‡	Fernandina Beach, FL (8720030)	N	110	0.600
	De Soto National Memorial	St. Petersburg, FL (8726520)	N	60	0.920
	Dry Tortugas National Park‡	Key West, FL (8724580)	N	94	0.500
	Everglades National Park*‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
	Fort Caroline National Memorial‡	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Frederica National Monument‡	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Matanzas National Monument‡	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Fort Pulaski National Monument	Fort Pulaski, GA (8670870)	Y	72	1.360
	Fort Raleigh National Historic Site‡	Beaufort, NC (8656483)	N	54	0.790
	Fort Sumter National Monument‡	Charleston, SC (8665530)	N	86	1.240
	Gulf Islands National Seashore (Alabama section)*‡	Dauphin Island, AL (8735180)	N	41	1.220
	Gulf Islands National Seashore (Florida section)*‡	Pensacola, FL (8729840)	N	84	0.330
	Jean Lafitte National Historical Park and Preserve‡	Grand Isle, LA (8761724)	N	60	7.600
	Moores Creek National Battlefield‡	Wilmington, NC (8658120)	N	72	0.430
	New Orleans Jazz National Historical Park‡	Grand Isle, LA (8761724)	N	60	7.600
	Salt River Bay National Historical Park and Ecological Preserve‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	San Juan National Historic Site	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Timucuan Ecological and Historic Preserve‡	Fernandina Beach, FL (8720030)	N	110	0.600

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Virgin Islands Coral reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Virgin Islands National Park‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Wright Brothers National Memorial‡	Sewells Point, VA (8638610)	N	80	2.610
National Capital Region	Anacostia Park	Washington, DC (8594900)	N	83	1.340
	Chesapeake and Ohio Canal National Historical Park	Washington, DC (8594900)	N	83	1.340
	Constitution Gardens	Washington, DC (8594900)	N	83	1.340
	Fort Washington Park	Washington, DC (8594900)	N	83	1.340
	George Washington Memorial Parkway	Washington, DC (8594900)	N	83	1.340
	Harpers Ferry National Historical Park	Washington, DC (8594900)	N	83	1.340
	Korean War Veterans Memorial	Washington, DC (8594900)	N	83	1.340
	Lincoln Memorial	Washington, DC (8594900)	N	83	1.340
	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Washington, DC (8594900)	N	83	1.340
	Martin Luther King Jr. Memorial	Washington, DC (8594900)	N	83	1.340

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
National Capital Region (continued)	National Mall	Washington, DC (8594900)	N	83	1.340
	National Mall and Memorial Parks	Washington, DC (8594900)	N	83	1.340
	National World War II Memorial	Washington, DC (8594900)	N	83	1.340
	Piscataway Park	Washington, DC (8594900)	N	83	1.340
	Potomac Heritage National Scenic Trail	Washington, DC (8594900)	N	83	1.340
	President's Park (White House)	Washington, DC (8594900)	N	83	1.340
	Rock Creek Park	Washington, DC (8594900)	N	83	1.340
	Theodore Roosevelt Island Park	Washington, DC (8594900)	N	83	1.340
	Thomas Jefferson Memorial	Washington, DC (8594900)	N	83	1.340
	Vietnam Veterans Memorial	Washington, DC (8594900)	N	83	1.340
	Washington Monument	Washington, DC (8594900)	N	83	1.340
Intermountain Region	Big Thicket National Preserve‡	Sabine Pass, TX (8770570)	N	49	3.850
	Palo Alto Battlefield National Historical Park‡	Port Isabel, TX (8779770)	N	63	2.160
	Padre Island National Seashore*	Padre Island, TX (8779750)	N	49	1.780

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Pacific West Region	American Memorial Park‡	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
	Cabrillo National Monument	San Diego, CA (9410170)	N	101	0.370
	Channel Islands National Park‡	Santa Monica, CA (9410840)	N	74	-0.280
	Ebey's Landing National Historical Reserve‡	Friday Harbor, WA (9449880)	N	73	-0.580
	Fort Point National Historic Site	San Francisco, CA (9414290)	Y	110	0.360
	Fort Vancouver National Historic Site‡	Astoria, OR (9439040)	N	82	-2.100
	Golden Gate National Recreation Area	San Francisco, CA (9414290)	N	110	0.360
	Haleakala National Park*‡	Kahului, HI (1615680)	N	60	0.510
	Hawaii Volcanoes National Park*‡	Hilo, HI (1617760)	N	80	1.470
	Kaloko-Honokohau National Historical Park‡	Hilo, HI (1617760)	N	80	1.470
	Lewis and Clark National Historical Park	Astoria, OR (9439040)	N	82	-2.100
	National Park of American Samoa	Pago Pago, American Samoa (1770000)	N	59	0.370
	Olympic National Park*‡	Seattle, WA (9447130)	N	109	0.540

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Pacific West Region (continued)	Point Reyes National Seashore‡	San Francisco, CA (9414290)	N	110	0.360
	Port Chicago Naval Magazine National Memorial‡	Alameda, CA (9414750)	N	68	-0.780
	Pu'uhonua O Honaunau National Historical Park*‡	Hilo, HI (1617760)	N	80	1.470
	Puukohola Heiau National Historic Site*‡	Hilo, HI (1617760)	N	80	1.470
	Redwood National and State Parks	Crescent City, CA (9419750)	N	74	-2.380
	Rosie the Riveter WWII Home Front National Historical Park*	Alameda, CA (9414750)	N	68	-0.780
	San Francisco Maritime National Historical Park	San Francisco, CA (9414290)	N	110	0.360
	Santa Monica Mountains National Recreation Area	Santa Monica, CA (9410840)	N	74	-0.280
	War in the Pacific National Historical Park‡	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
	World War II Valor in the Pacific National Monument‡	Honolulu, HI (1612340)	N	102	-0.180
Alaska Region	Aniakchak Preserve*‡	Unalaska, AK (9462620)	N	50	-7.250
	Bering Land Bridge National Preserve‡	No data	No data	No data	No data

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Alaska Region (continued)	Cape Krusenstern National Monument‡	No data	No data	No data	No data
	Glacier Bay National Park*‡	Juneau, AK (9452210)	N	71	-14.620
	Glacier Bay Preserve*‡	Juneau, AK (9452210)	N	71	-14.620
	Katmai National Park‡	Seldovia, AK (9455500)	N	43	-11.420
	Kenai Fjords National Park‡	Seward, AK (9455090)	N	43	-3.820
	Klondike Gold Rush National Historical Park‡	Skagway, AK (9452400)	N	63	-18.960
	Lake Clark National Park‡	Seldovia, AK (9455500)	N	43	-11.420
	Sitka National Historical Park‡	Sitka, AK (9451600)	N	83	-3.710
	Wrangell – St. Elias National Park‡	Cordova, AK (9454050)	N	43	3.450
	Wrangell – St. Elias National Preserve‡	Cordova, AK (9454050)	N	43	3.450

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region	Acadia National Park	2030	0.08	0.09	0.09	0.1
		2050	0.14	0.16	0.16	0.19
		2100	0.28	0.36	0.39	0.54
	Assateague Island National Seashore§	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Boston Harbor Islands National Recreation Area	2030	0.11‡	0.11	0.11‡	0.11
		2050	0.19‡	0.2	0.20‡	0.22
		2100	0.37‡	0.45	0.50‡	0.62
	Boston National Historical Park	2030	0.11‡	0.11	0.11‡	0.11
		2050	0.19‡	0.2	0.20‡	0.22
		2100	0.37‡	0.45	0.50‡	0.62
	Cape Cod National Seashore§	2030	0.13	0.15	0.13	0.15
		2050	0.23	0.27	0.23	0.29
		2100	0.45	0.51	0.57	0.69
	Castle Clinton National Monument*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Colonial National Historical Park	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Edgar Allen Poe National Historic Site*	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Federal Hall National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Fire Island National Seashore[§]	2030	0.14	0.14	0.14	0.14
		2050	0.25	0.26	0.25	0.27
		2100	0.5	0.58	0.62	0.76
	Fort McHenry National Monument and Historic Shrine	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Fort Monroe National Monument	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Gateway National Recreation Area	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	General Grant National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	George Washington Birthplace National Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Governors Island National Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Hamilton Grange National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Harriet Tubman Underground Railroad National Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Independence National Historical Park*	2030	0.16‡	0.15	0.15‡	0.14
		2050	0.27‡	0.27	0.27‡	0.28
		2100	0.54‡	0.62	0.68‡	0.79
	New Bedford Whaling National Historical Park*	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Petersburg National Battlefield*	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Roger Williams National Memorial*	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Sagamore Hill National Historic Site	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Saint Croix Island International Historic Site	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.26	0.26	0.27
		2100	0.52	0.59	0.64	0.76

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Salem Maritime National Historic Site	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Saugus Iron Works National Historic Site	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Statue of Liberty National Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Thaddeus Kosciuszko National Memorial*	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Theodore Roosevelt Birthplace National Historic Site*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
Southeast Region	Big Cypress National Preserve[§]	2030	0.13	0.13	0.12	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.46	0.54	0.55	0.69

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Biscayne National Park	2030	0.14[‡]	0.13	0.12	0.12
		2050	0.24[‡]	0.23	0.21	0.24
		2100	0.47[‡]	0.53	0.53	0.68
	Buck Island Reef National Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Canaveral National Seashore	2030	0.14[‡]	0.13	0.13[‡]	0.12
		2050	0.25[‡]	0.24	0.24[‡]	0.24
		2100	0.50[‡]	0.54	0.59[‡]	0.68
	Cape Hatteras National Seashore	2030	0.15[‡]	0.15	0.15	0.14
		2050	0.26[‡]	0.28	0.28	0.28
		2100	0.53[‡]	0.63	0.68	0.79
	Cape Lookout National Seashore[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	Castillo De San Marcos National Monument	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Charles Pinckney National Historic Site*	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Christiansted National Historic Site	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Cumberland Island National Seashore	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	De Soto National Memorial	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.56	0.57	0.72
	Dry Tortugas National Park§	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.24
		2100	0.47	0.54	0.56	0.69
	Everglades National Park§	2030	0.13	0.13	0.12	0.17
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.54	0.68

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Fort Caroline National Memorial	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Frederica National Monument	2030	0.14	0.13	0.12	0.12
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.54	0.54	0.69
	Fort Matanzas National Monument	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Pulaski National Monument[§]	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Fort Raleigh National Historic Site	2030	0.15[‡]	0.15	0.15	0.14
		2050	0.27[‡]	0.28	0.28	0.28
		2100	0.53[‡]	0.63	0.68	0.79
	Fort Sumter National Monument	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Gulf Islands National Seashore§	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.55	0.57	0.7
	Jean Lafitte National Historical Park and Preserve†§	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Moores Creek National Battlefield*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	New Orleans Jazz National Historical Park*	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Salt River Bay National Historic Park and Ecological Preserve	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	San Juan National Historic Site	2030	0.12	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.22
		2100	0.43	0.49	0.5	0.64

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Timucuan Ecological and Historic Preserve	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	Virgin Islands Coral Reef National Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	Virgin Islands National Park[§]	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	Wright Brothers National Memorial*	2030	0.15[‡]	0.16	0.16	0.15
		2050	0.27[‡]	0.29	0.28	0.29
		2100	0.53[‡]	0.65	0.7	0.82
National Capital Region	Anacostia Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Chesapeake & Ohio Canal National Historical Park[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Constitution Gardens*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Fort Washington Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	George Washington Memorial Parkway§	2030	0.15‡	0.15	0.15‡	0.14
		2050	0.26‡	0.27	0.26‡	0.28
		2100	0.53‡	0.62	0.66‡	0.79
	Harpers Ferry National Historical Park*§	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79
	Korean War Veterans Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Lincoln Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Martin Luther King Jr. Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National Mall*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National Mall & Memorial Parks*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National World War II Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Piscataway Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Potomac Heritage National Scenic Trail	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	President's Park (White House)*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Rock Creek Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Theodore Roosevelt Island Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Thomas Jefferson Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Vietnam Veterans Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Washington Monument*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
Intermountain Region	Big Thicket National Preserve*	2030	0.14‡	0.12	0.12‡	0.12
		2050	0.23‡	0.23	0.22‡	0.23
		2100	0.47‡	0.51	0.55‡	0.66
	Palo Alto Battlefield National Historical Park*§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
	Padre Island National Seashore§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
Pacific West Region	American Memorial Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	Cabrillo National Monument	2030	0.1	0.1	0.09	0.1
		2050	0.17	0.17	0.17	0.19
		2100	0.35	0.4	0.41	0.53

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Channel Islands National Park§	2030	0.11	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.39	0.44	0.46	0.57
	Ebey's Landing National Historical Reserve	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Fort Point National Historic Site	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Fort Vancouver National Historic Site*	2030	0.12	0.11	0.11	0.1
		2050	0.21	0.2	0.19	0.19
		2100	0.42	0.45	0.47	0.55
	Golden Gate National Recreation Area§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.18	0.17	0.19
		2100	0.37	0.42	0.43	0.54
	Haleakala National Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Hawaii Volcanoes National Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Kalaupapa National Historical Park§	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.66
	Kaloko-Honokohau National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Lewis and Clark National Historical Park§	2030	0.12	0.1	0.1	0.1
		2050	0.2	0.19	0.18	0.19
		2100	0.4	0.44	0.46	0.53
	National Park of American Samoa	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.65
	Olympic National Park§	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Point Reyes National Seashore§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.19	0.18	0.19
		2100	0.38	0.43	0.45	0.55
	Port Chicago Naval Magazine National Memorial	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Pu'uhonua O Honaunau National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Puukohola Heiau National Historic Site	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.51	0.52	0.67
	Redwood National and State Parks	2030	0.12	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.4	0.44	0.46	0.56
	Rosie the Riveter WWII Home Front National Historical Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	San Francisco Maritime National Historical Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	San Juan Island National Historical Park	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Santa Monica Mountains National Recreation Area§	2030	0.12	0.11	0.1	0.11
		2050	0.2	0.2	0.19	0.2
		2100	0.4	0.45	0.46	0.58
	War in the Pacific National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	World War II Valor in the Pacific National Monument§	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.67
Alaska Region	Aniakchak Preserve§	2030	0.09‡	0.09	0.09	0.09
		2050	0.15‡	0.17	0.16	0.18
		2100	0.31‡	0.38	0.4	0.51

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Alaska Region (continued)	Bering Land Bridge National Preserve§	2030	0.11	0.11	0.1	0.11
		2050	0.18	0.19	0.18	0.21
		2100	0.37	0.44	0.45	0.6
	Cape Krusenstern National Monument§	2030	0.1	0.1	0.1	0.1
		2050	0.17	0.18	0.17	0.2
		2100	0.35	0.42	0.43	0.58
	Glacier Bay National Park†§	2030	0.07	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.12
		2100	0.23	0.25	0.28	0.34
	Glacier Bay Preserve†	2030	0.06	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.11
		2100	0.22	0.24	0.27	0.33
	Katmai National Park§	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.15	0.16
		2100	0.31	0.34	0.37	0.47
	Katmai National Preserve†§	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.14	0.16
		2100	0.3	0.33	0.34	0.45

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Alaska Region (continued)	Kenai Fjords National Park[†§]	2030	0.09[‡]	0.08	0.08[‡]	0.08
		2050	0.15[‡]	0.14	0.14[‡]	0.15
		2100	0.30[‡]	0.33	0.34[‡]	0.44
	Klondike Gold Rush National Historical Park[*†§]	2030	0.06[‡]	0.06	0.06[‡]	0.06
		2050	0.11	0.11	0.11[‡]	0.11
		2100	0.22	0.24	0.27	0.33
	Lake Clark National Park[*†]	2030	0.08	0.08	0.07	0.08
		2050	0.14	0.14	0.13	0.15
		2100	0.29	0.32	0.33	0.43
	Sitka National Historical Park[†]	2030	0.08	0.07	0.07	0.07
		2050	0.14	0.14	0.13	0.14
		2100	0.28	0.31	0.33	0.41
	Wrangell - St. Elias National Park[§]	2030	0.07	0.06	0.06	0.07
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.8	0.35
	Wrangell – St. Elias National Preserve[*§]	2030	0.07	0.06	0.06	0.06
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.29	0.35

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D3. IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Northeast Region	Acadia National Park	Hurricane, Saffir-Simpson category 1
	Assateague Island National Seashore	Hurricane, Saffir-Simpson category 1
	Boston Harbor Islands National Recreation Area	Hurricane, Saffir-Simpson category 2
	Boston National Historical Park	Hurricane, Saffir-Simpson category 3
	Cape Cod National Seashore	Hurricane, Saffir-Simpson category 2
	Castle Clinton National Monument	Hurricane, Saffir-Simpson category 1
	Colonial National Historical Park	Tropical storm
	Edgar Allen Poe National Historic Site	Extratropical storm
	Federal Hall National Memorial	Hurricane, Saffir-Simpson category 1
	Fire Island National Seashore	Hurricane, Saffir-Simpson category 2
	Fort McHenry National Monument and Historic Shrine	Tropical storm
	Fort Monroe National Monument	Tropical storm
	Gateway National Recreation Area	Hurricane, Saffir-Simpson category 1
	General Grant National Memorial	Hurricane, Saffir-Simpson category 1
	George Washington Birthplace National Monument	Extratropical storm
	Governors Island National Monument	Hurricane, Saffir-Simpson category 1
	Hamilton Grange National Memorial	Hurricane, Saffir-Simpson category 1
	Harriet Tubman Underground Railroad National Monument	Tropical storm
	Independence National Historical Park	Extratropical storm
	New Bedford Whaling National Historical Park	Extratropical storm
	Petersburg National Battlefield	Hurricane, Saffir-Simpson category 2
	Roger Williams National Memorial	Hurricane, Saffir-Simpson category 3
	Sagamore Hill National Historic Site	Hurricane, Saffir-Simpson category 2
	Saint Croix Island International Historic Site	Hurricane, Saffir-Simpson category 2
	Salem Maritime National Historic Site	Hurricane, Saffir-Simpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Northeast Region (continued)	Saugus Iron Works National Historic Site	Hurricane, Saffir-Simpson category 1
	Statue of Liberty National Monument	Hurricane, Saffir-Simpson category 1
	Thaddeus Kosciuszko National Memorial	Extratropical storm
	Theodore Roosevelt Birthplace National Historic Site	Hurricane, Saffir-Simpson category 1
Southeast Region	Big Cypress National Preserve	Hurricane, Saffir-Simpson category 4
	Biscayne National Park	Hurricane, Saffir-Simpson category 4
	Buck Island Reef National Monument	Hurricane, Saffir-Simpson category 2
	Canaveral National Seashore	Hurricane, Saffir-Simpson category 2
	Cape Hatteras National Seashore	Hurricane, Saffir-Simpson category 3
	Cape Lookout National Seashore	Hurricane, Saffir-Simpson category 3
	Castillo De San Marcos National Monument	Hurricane, Saffir-Simpson category 3
	Charles Pinckney National Historic Site	Hurricane, Saffir-Simpson category 4
	Christiansted National Historic Site	Hurricane, Saffir-Simpson category 4
	Cumberland Island National Seashore	Hurricane, Saffir-Simpson category 4
	De Soto National Memorial	Hurricane, Saffir-Simpson category 1
	Dry Tortugas National Park	Hurricane, Saffir-Simpson category 4
	Everglades National Park	Hurricane, Saffir-Simpson category 5
	Fort Caroline National Memorial	Hurricane, Saffir-Simpson category 2
	Fort Frederica National Monument	Hurricane, Saffir-Simpson category 1
	Fort Matanzas National Monument	Hurricane, Saffir-Simpson category 1
	Fort Pulaski National Monument	Hurricane, Saffir-Simpson category 2
	Fort Raleigh National Historic Site	Hurricane, Saffir-Simpson category 2
	Fort Sumter National Monument	Hurricane, Saffir-Simpson category 4
	Gulf Islands National Seashore	Hurricane, Saffir-Simpson category 4
	Jean Lafitte National Historical Park and Preserve	Hurricane, Saffir-Simpson category 2
	Moores Creek National Battlefield	Hurricane, Saffir-Simpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Southeast Region (continued)	New Orleans Jazz National Historical Park	Hurricane, Saffir-Simpson category 2
	Salt River Bay National Historic Park and Ecological Preserve	Hurricane, Saffir-Simpson category 4
	San Juan National Historic Site	Hurricane, Saffir-Simpson category 3
	Timucuan Ecological and Historic Preserve	Hurricane, Saffir-Simpson category 2
	Virgin Islands Coral Reef National Monument	Hurricane, Saffir-Simpson category 3
	Virgin Islands National Park	Hurricane, Saffir-Simpson category 3
	Wright Brothers National Memorial	Hurricane, Saffir-Simpson category 2
National Capital Region	Anacostia Park	Hurricane, Saffir-Simpson category 2
	Chesapeake & Ohio Canal National Historical Park	Hurricane, Saffir-Simpson category 2
	Constitution Gardens	Hurricane, Saffir-Simpson category 2
	Fort Washington Park	Hurricane, Saffir-Simpson category 2
	George Washington Memorial Parkway	Hurricane, Saffir-Simpson category 2
	Harpers Ferry National Historical Park	Extratropical storm
	Korean War Veterans Memorial	Hurricane, Saffir-Simpson category 2
	Lincoln Memorial	Hurricane, Saffir-Simpson category 2
	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Hurricane, Saffir-Simpson category 2
	Martin Luther King Jr. Memorial	Hurricane, Saffir-Simpson category 2
	National Mall	Hurricane, Saffir-Simpson category 2
	National Mall & Memorial Parks	Hurricane, Saffir-Simpson category 2
	National World War II Memorial	Hurricane, Saffir-Simpson category 2
	Piscataway Park	Hurricane, Saffir-Simpson category 2
	Potomac Heritage National Scenic Trail	Hurricane, Saffir-Simpson category 2
	President’s Park (White House)	Hurricane, Saffir-Simpson category 2
	Rock Creek Park	Hurricane, Saffir-Simpson category 2
	Theodore Roosevelt Island Park	Hurricane, Saffir-Simpson category 2
	Thomas Jefferson Memorial	Hurricane, Saffir-Simpson category 2

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
National Capital Region (continued)	Vietnam Veterans Memorial	Hurricane, Saffir-Simpson category 2
	Washington Monument	Hurricane, Saffir-Simpson category 2
Intermountain Region	Big Thicket National Preserve	Hurricane, Saffir-Simpson category 3
	Palo Alto Battlefield National Historical Park	No recorded historical storm
	Padre Island National Seashore	Hurricane, Saffir-Simpson category 4
Pacific West Region	American Memorial Park	Tropical storm
	Cabrillo National Monument	Tropical depression
	Channel Islands National Park	No recorded historical storm
	Ebey's Landing National Historical Reserve	No recorded historical storm
	Fort Point National Historic Site	No recorded historical storm
	Fort Vancouver National Historic Site	No recorded historical storm
	Golden Gate National Recreation Area	No recorded historical storm
	Haleakala National Park	Tropical depression
	Hawaii Volcanoes National Park	Tropical depression
	Kalaupapa National Historical Park	Tropical depression
	Kaloko-Honokohau National Historical Park	Tropical depression
	Lewis and Clark National Historical Park	No recorded historical storm
	National Park of American Samoa	No recorded historical storm
	Olympic National Park	No recorded historical storm
	Point Reyes National Seashore	No recorded historical storm
	Port Chicago Naval Magazine National Memorial	No recorded historical storm
	Pu'uhonua O Honaunau National Historical Park	No recorded historical storm
	Puukohola Heiau National Historic Site	Tropical depression
	Redwood National and State Parks	No recorded historical storm

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Pacific West Region (continued)	Rosie the Riveter WWII Home Front National Historical Park	No recorded historical storm
	San Francisco Maritime National Historical Park	No recorded historical storm
	San Juan Island National Historical Park	No recorded historical storm
	Santa Monica Mountains National Recreation Area	No recorded historical storm
	War in the Pacific National Historical Park	No recorded historical storm
	World War II Valor in the Pacific National Monument	Tropical depression
Alaska Region	Aniakchak Preserve	No recorded historical storm
	Bering Land Bridge National Preserve	No recorded historical storm
	Cape Krusenstern National Monument	No recorded historical storm
	Glacier Bay National Park	No recorded historical storm
	Glacier Bay Preserve	No recorded historical storm
	Katmai National Park	No recorded historical storm
	Katmai National Preserve	No recorded historical storm
	Kenai Fjords National Park	No recorded historical storm
	Klondike Gold Rush National Historical Park	No recorded historical storm
	Lake Clark National Park	No recorded historical storm
	Sitka National Historical Park	No recorded historical storm
	Wrangell - St. Elias National Park	No recorded historical storm
	Wrangell – St. Elias National Preserve	No recorded historical storm

NPS 999/137852, May 2017

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

244 Re_ Sea Level Rise Report Final Layout Policy R...(4).pdf

From:	Patrick Gonzalez NPS
To:	Larry Perez
Cc:	Hoffman, Cat; Beavers, Rebecca
Subject:	Re: Sea Level Rise Report Final Layout Policy Review
Date:	Wednesday, January 31, 2018 5:56:32 PM

Thanks, Larry. I'll wait for that version.

Patrick

From: "Perez, Larry" <larry_perez@nps.gov>
Subject: Re: Sea Level Rise Report Final Layout Policy Review
Date: January 31, 2018 at 1:49:15 PM PST
To: Patrick Gonzalez NPS <patrick_gonzalez@nps.gov>
Cc: "Beavers, Rebecca" <rebecca_beavers@nps.gov>, "Hoffman, Cat" <cat_hawkins_hoffman@nps.gov>

Hey Patrick,

Be aware that review is still in process. Once we have a final version, we will definitely get it to all authors for their concurrence.

More soon,

L

On Wed, Jan 31, 2018 at 2:33 PM, Patrick Gonzalez NPS <patrick_gonzalez@nps.gov> wrote:

> Hi Rebecca,
>
> The SharePoint link is not working from my network connection. When you have a moment, may you please e-mail me the file or post it on Google Drive if it the file size is too large. Also, perhaps you have already sent it to Maria Caffrey, but she, the lead author, is not on the e-mail below.
>
> Cat had mentioned that further edits might be made and I wish to see the final text since Maria has included me as an author.
>
> Thanks,
>
> Patrick
>
> ....
> Patrick Gonzalez, Ph.D.
>
> Principal Climate Change Scientist
> Natural Resource Stewardship and Science

U.S. National Park Service

Associate Adjunct Professor
Department of Environmental Science, Policy, and Management
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patrick_gonzalez@nps.gov
+1 (510) 643-9725
131 Mulford Hall, Berkeley, CA 94720-3114 USA
....

From: "Johnson, Chalmers-Fagan" <fagan_johnson@nps.gov>
Subject: Seal Level Rise Report Final Layout Policy Review
Date: January 30, 2018 at 4:32:53 PM PST
To: "Perez, Larry" <larry_perez@nps.gov>, Rebecca Beavers <rebecca_beavers@nps.gov>, Cat Hoffman <cat_hawkins_hoffman@nps.gov>, Patrick Gonzalez <patrick_gonzalez@nps.gov>
Cc: Tani Hubbard <tani_hubbard@nps.gov>, Margaret Beer <margaret_beer@nps.gov>, Alyssa Mcginnity <alyssa_s_mcginnity@contractor.nps.gov>

Hello Larry, Rebecca, everyone.

> For most reports, all of the steps below are completed within 2-10 working days of us sending the (this) final review email.
>
> Let's quickly publish it and make it public before someone decides to delay or stop publication again!

Three Remaining Steps
(Download detailed instructions for all three steps)

Step 1. Click on the link below to open the document directly on the SharePoint site:

> https://nrss.sharepoint.nps.gov/prg/nrpm/rpts/NRR-Reports/sea_level_change_1-2018/06%20-%202018-01-16%20FINAL%20Sea%20Level%20Change%20Report%20508_fagan.docx
>
> The online Manuscript Submittal Form for this report can be seen at:
>
> https://nrss.sharepoint.nps.gov/prg/nrpm/_layouts/15/FormServer.aspx?XmlLocation=/prg/nrpm/2018/Beavers_%

20Rebecca%20L.-2018-01-16T13_09_48.xml&ClientInstalled=false&Source=https%3A%2F%2Fnrss%2Esharepoint%2Enps%2Egov%2Fprg%2Fnrpm%2F2018%2FForms%2FAdmin%2Easpx

Step 2. Double-check and approve my updates (Larry and Rebecca).

a) Make your absolute final edits (if any), and send the final result back to me to make a final PDF.

You can change anything you like between the table of Appendices and the inside back cover.

b) I will send the final PDF back to you for one final check before I do the 508 tagging and upload it to IRMA.

Make sure that you can live with everything in the final PDF before I Section 508 tagging.

It takes me about 2 minutes per page to remediate the tags in a document of this size (about 184 minutes, or 3 hours).

Any changes after that point means creates a brand new document, and requires me to repeat the 508 tagging once again (another 3 hours of work).

Step 3. Activate the draft IRMA record that I created for you (Larry or Fagan?).

a) Go to this address to open the draft Data Store record that I created for you:

https://irma.nps.gov/DataStore/Reference/Profile/2249974

b) Click the *Actions* drop down menu near the top right of the screen and click *Edit* and update the Core and Subjects and Keywords information as you desire

Note: Search engines can only search on the information that you enter on these screens, and cannot search any uploaded PDF files.

c) Go to the *Files and Links* tab. On the *Add* drop down menu, choose the *Digital File*. Use the file upload tools to upload the final PDF.

d) To make the Data Store record public, click the *Activate* button at the bottom-right of the page.

(Download detailed instructions for all three steps)

That's it!

Fagan Johnson
Web and Report Specialist
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Email: fagan_johnson@nps.gov
Phone: 970-267-2190

"What's another word for Thesaurus?" Steven Wright

--

Larry Perez, Communications Coordinator
Climate Change Response Program
Natural Resource Stewardship and Science
1201 Oakridge Drive. Suite 200
Fort Collins, CO 80525
Office: 970-267-2136
Fax: 970-225-3585
Email: larry_perez@nps.gov

245 Fwd_ reconnecting.pdf

From: Perez, Larry
To: Olson, Jeffrey; Cat Hoffman
Subject: Fwd: reconnecting
Date: Thursday, February 01, 2018 4:39:10 PM

FYI--

---------- Forwarded message ----------
From: **Maria Caffrey** <maria.caffrey@colorado.edu>
Date: Thu, Feb 1, 2018 at 3:49 PM
Subject: Re: reconnecting
To: Elizabeth Shogren <shogrenelizabeth@gmail.com>
Cc: "larry_perez@nps.gov" <larry_perez@nps.gov>

Hi Elizabeth!

Great to hear from you again. Congratulations on the new position!

I'm still [redacted] at the moment and so I'm not entirely sure on the latest information regarding the report. I don't [redacted], so I don't have access to my federal email until I'm in the office to catch up.

I'm copying Larry Perez on this email. He is the head of communications for the NPS climate response program. I left the report with his team before I took off so he will have the most up to date information on the status of the report.

Cheers

Maria Caffrey, Ph.D.

Office: (303) 969-2097
Cell: (303) 518-3419
mariacaffrey.com

> On Feb 1, 2018, at 12:32 PM, Elizabeth Shogren <shogrenelizabeth@gmail.com> wrote:
>
> Hi Maria,
>
> I see from your twitter feed that you recently [redacted]. Congratulations!
>
> We spoke when I was at NPR and High Country News. I'm starting a new job as a science reporter for Reveal from the Center for Investigative Reporting. Now that the scope of my job is nationwide, I'd be eager to talk with you more about some of your findings about sea—level rise in parks.
>
> I start my job on Monday, so it would be great to speak with you early next week if you have time in your schedule. Do you have a draft report that I could read? Thanks much,
>
> Elizabeth Shogren

> 202-744-1498

--

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Fort Collins, CO 80525
Office: 970-267-2136
Fax: 970-225-3585
Email: larry_perez@nps.gov

246 Re_ reconnecting.pdf

From: Olson, Jeffrey
To: Perez, Larry
Cc: Cat Hoffman
Subject: Re: reconnecting
Date: Monday, February 05, 2018 3:40:04 PM

Go ahead and reply to Ms. Shogren. Please copy me.

On Mon, Feb 5, 2018 at 5:33 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Hey Jeff,
>
> After her (b) (6) [redacted], Maria will be returning to work for the NRSS under WRD.
>
> If you're amenable, I will reply to Elizabeth Shogren with the info you provided. (Though you are welcome to as well should you prefer.)
>
> Thanks,
>
> L
>
> On Mon, Feb 5, 2018 at 6:33 AM, Olson, Jeffrey <jeffrey_olson@nps.gov> wrote:
>
>> Larry,
>> Thanks for the note. Can you please let Maria know that we aren't releasing a draft of the report and that it's working its way through Ray's office. And, do you know if Maria is going to be an NPS employee when (b) (6) [redacted]?
>> Jeff
>>
>> On Thu, Feb 1, 2018 at 6:39 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>>
>>> FYI--
>>>
>>> ---------- Forwarded message ----------
>>> From: **Maria Caffrey** <maria.caffrey@colorado.edu>
>>> Date: Thu, Feb 1, 2018 at 3:49 PM
>>> Subject: Re: reconnecting
>>> To: Elizabeth Shogren <shogrenelizabeth@gmail.com>
>>> Cc: "larry_perez@nps.gov" <larry_perez@nps.gov>
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>>>
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>>>
>>> I'm copying Larry Perez on this email. He is the head of communications for the NPS climate response program. I left the report with his team before I took off so he will have the most up to date information on the status of the report.
>>>
>>> Cheers

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mariacaffrey.com

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> Hi Maria,
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> I see from your twitter feed that you recently [redacted]. Congratulations!
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> We spoke when I was at NPR and High Country News. I'm starting a new job as a science reporter for Reveal from the Center for Investigative Reporting. Now that the scope of my job is nationwide, I'd be eager to talk with you more about some of your findings about sea—level rise in parks.
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>
> Elizabeth Shogren
> 202-744-1498

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--
Jeffrey G. Olson
Public Affairs Officer
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1849 C Street NW Room 3310
Washington, DC 20240

Office: 202-513-7261

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> Larry Perez, Communications Coordinator
> Climate Change Response Program
> Natural Resource Stewardship and Science
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> Fort Collins, CO 80525
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Washington, DC 20240

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Mobile: 202-230-2088

www.nps.gov

247 Re_ reconnecting(1).pdf

From:	Elizabeth Shogren
To:	Perez, Larry
Cc:	Maria Caffrey; Olson, Jeffrey
Subject:	Re: reconnecting
Date:	Monday, February 05, 2018 4:52:18 PM

Hi Larry,

I first spoke with Maria about her work when I did this story for NPR in 2014.
https://www.npr.org/2014/01/01/258889938/archeologists-race-against-time-in-warming-arctic-coasts.
Please let me know when you are ready to release the report.

Sincerely,

Elizabeth Shogren

> On Feb 5, 2018, at 6:45 PM, Perez, Larry <larry_perez@nps.gov> wrote:
>
> Hello, Elizabeth.
>
> Thanks for your interest in the forthcoming sea level rise and storm surge report.
>
> The report is currently undergoing internal review and we do not yet have a definitive publication date.
>
> As you might understand, we will not be sharing any drafts prior to publication.
>
> Best,
>
> Larry
>
> On Thu, Feb 1, 2018 at 3:49 PM, Maria Caffrey <maria.caffrey@colorado.edu> wrote:
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>>
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>> Cheers
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>> Maria Caffrey, Ph.D.

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>
> Elizabeth Shogren
> 202-744-1498

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Fax: 970-225-3585
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248 SLR report; will discuss.pdf

From:	Hoffman, Cat
To:	Larry Perez
Subject:	SLR report; will discuss
Date:	Monday, February 05, 2018 5:26:31 PM
Attachments:	2017-05-25 DRAFT Sea Level Change Report HL_CHH.docx 2018-01-26 Recommended Edits_CHH.docx

--
Cat Hawkins Hoffman
National Park Service

Chief, NPS Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525
cat_hawkins_hoffman@nps.gov
office: 970-225-3567
cell: 970-631-5634

Adaptation websites: public, NPS managers
Climate Change Response Resources

248 1 Attachment 2017-05-25 DRAFT Sea Level Change Report HL_C.pdf

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

ON THIS PAGE
Driftwood washed up on the shoreline of Redwood National Park, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

ON THE COVER
Fort Point National Historic Site and the Golden Gate Bridge, California.
Photograph courtesy of Maria Caffrey, University of Colorado.

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2017/1425

Maria A. Caffrey[1], Rebecca L. Beavers[2], Patrick Gonzalez[3], Cat Hawkins-Hoffman[4]

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1201 Oakridge Drive, #150
Fort Collins, CO 80525

May 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available in digital format from the Climate Change Response Program website and the Natural Resource Publications Management website. To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

Please cite this publication as:

Caffrey, M. A., R. L. Beavers, P. Gonzalez, and C. Hawkins-Hoffman. 2017. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2017/1425. National Park Service, Fort Collins, Colorado.

NPS 999/137852, May 2017

Contents

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Photographs

Appendices

Photo 1. Looking out towards the Gulf of Mexico from Fort Jefferson, Dry Tortugas National Park. Photo credit: Used with permission from Rachel Sullivan Photography.

Executive Summary

Comment 1 Changing relative sea levels and the potential for increasing storm surges due to anthropogenic climate change present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Within the National Park Service, the National Capital Region is projected to experience the highest average rate of sea level change by 2100. The coastline adjacent to Wright Brothers National Memorial in the Southeast Region is projected to experience the highest sea level rise by 2100. The Southeast Region is projected to experience the highest storm surges based on historical data and NOAA storm surge models.

Comment 2These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.

Photo 2. Basement flooding in the visitor center at Rosie the Riveter WWII Home Front National Historical Park. This photograph was taken on December 5, 2012 —12 years after the establishment of the park. Photo credit: Maria Caffrey.

Acknowledgments

This project was awarded funds through the NPS Servicewide Comprehensive Call (FY2013–2015) and augmented by funds from the Natural Resource Stewardship and Science Directorate's Geologic Resources Division and Climate Change Response Program. We would like to thank the members of the communication advisory team (Rebecca Beavers, Lynda Bell, Maria Caffrey, Janet Cakir, Will Elder, Stanton Enomoto, Ann Gallagher, Matt Holly, Shawn Norton, Larry Perez, and Ryan Stubblebine) and science advisory team (Amanda Babson, Rebecca Beavers, Maria Caffrey, Patrick Gonzalez, Steve Nerem, and Rob Thieler) for their time and input into this project.

We would also like to thank Susan Teel and Caroline Rohe at Gulf Islands National Seashore for assistance in designing two wayside exhibits. Likewise, we thank Julie Whitbeck, Aleutia Scott, Kristy Wallisch, and Stacy Meyers for helping design, review, and install a wayside at Jean Lafitte National Historical Park and Preserve. Elizabeth Rogers and Kathy Krause helped design a wayside for Fire Island National Seashore. Doug Wilder, Dorothy Friday, and Neal Jander designed the online map viewer. We would also like to thank Jason Kenworthy, Rebecca Port, Michael Barthelmes, Bob Glahn, Doug Marcy, Chris Zervas, and Claudia Tebaldi for their assistance in editing and reviewing this document. Finally, we thank the National Oceanic and Atmospheric Administration for and the Intergovernmental Panel on Climate Change for providing the respective storm surge and sea level rise data cited throughout this document.

List of Terms

The following list of terms are defined here as they will be used in this report.

Bathtub model: A simplification of the sea as bathtub of water to simulate a change in water level relative to the land. This model does not include other factors such changes in erosion or accretion that change alter the geometry of the coastline.

Flooding: The temporary occurrence of water on the land.

Inundation: The permanent impoundment of water on what had previously been dry land.

Isostatic rebound: A change in land level caused by a change in loadings on the Earth's crust. The most common cause of isostatic rebound is the loading of continental ice during the Last Glacial Maximum in North America. The North American land surface is still returning to equilibrium after the melting of this continental ice in an effort to return to equilibrium with its original pre-loading state.

National Park Service unit: Property owned or managed by the National Park Service.

Relative sea level: Where the water level can be found compared to some reference point on land. This term is most frequently used in discussion of *changes* in relative sea level. A change in relative sea level could be caused by a change in water volume or a change in land level (or some combination of these two factors).

Sea level: The average level of the seawater surface.

Sea level change: This term is frequently used in reference to *relative* sea level change. This is the product of two main factors, 1) an increase in the volume of ocean water, and 2) a change in land level. These two factors can be broken down further into other drivers that will be discussed in greater detail in other sections. This term is sometimes mistakenly confused with the term *sea level rise*.

Sea level rise: An increase in sea level. This is the result of an increase in ocean water volume caused principally by melting continental ice and thermal expansion. This term is not to be confused with increasing *relative* sea level, which can also be caused by decreasing land levels.

Introduction

Comment 3 Global sea level is rising. While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Human activities continue to release carbon dioxide (CO2) into the atmosphere, causing the Earth's atmosphere to warm (IPCC 2013, Mearns et al. 2013, Melillo et al. 2014). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi- empirical techniques that commonly generate higher numbers.

This report provides estimates of sea level change due to climate change for 118 National Park Service units and estimates of storm surge for 79 of those units. As temperature increases, sea levels rise due to a number of factors that will be discussed in greater detail. As sea levels incrementally rise, periods of flooding caused by storms and hurricanes exacerbate the growing problem of coastal inundation (see list of terms). Comment 4 Peek et al. (2015) estimated that the cost of sea level rise in 40 National Park Service units could exceed $40 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks.

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). Comment 5 This single storm cannot be attributed to anthropogenic climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2□5 billion and a 500 year storm surge could cost $5□11 billion(Aerts et al. 2013). Comment 5, contd. Under future scenarios of increasing anthropogenic greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015). When this change in storm intensity (and therefore, storm surge) is combined with sea level rise, we expect to see increased coastal flooding and the permanent loss of land across much of the United States coastline. Increasing sea levels increase the likelihood of another Hurricane Sandy-sized storm surge striking New York City. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

Format of This Report

This report contains five sections (introduction, methods, results, discussion, and conclusion), and presents results per park alphabetically by region. The 118 park units studied for this project cover six administrative regions: the Northeast, Southeast, National Capital, Intermountain, Pacific West, and Alaska. The scope of this project focuses on sea levels. The scope of this project did not include projected changes in lake levels, although interior waterways and lakes, especially the Great Lakes, are vulnerable to the effects of climate change. Further explanation on how to access the data from this project is available in the methods sections and accompanying appendices.

Frequently Used Terms

Definitions of the most basic terms used in this report occur on page ix. However, some terms require greater explanation for their use. For example, we follow the advice of Flick et al. (2012) in differentiating between the terms *flooding* and *inundation*. While many choose to use these terms interchangeably, we use the term "flooding" to describe the temporary impoundment of water on land. This usually results from storm activity and other short-lived events, such as periodic tidal action, and will therefore be used here in reference to the effects of a storm surge on land. "Inundation" is used to refer to the gradual permanent submergence of land that will occur due to sea level rise.

The terms sea level rise and sea level change are also used differently. Sea level rise refers only to rising water levels resulting from an increase in global ocean volumes. In most parts of the United States this increase in water volume will lead to increasing relative sea levels. However, in some parts of the country relative sea level is *decreasing* due to isostatic rebound. Figure 1 shows current sea level trends based on tide gauge records for United States that span at least 30-years of data.

For example, the Southeast Region of Alaska is experiencing a decrease in relative sea level. Alaska's crust continues to rebound following the melting of large volumes of ice that occurred for centuries to millennia on land in the form of glaciers and ice fields. Alaska is tectonically complex with extensive faults that contribute to this crustal motion. Although the volume of ocean water in this region is increasing, the rate of sea level rise is less than the rate of isostatic rebound, resulting in a decrease in relative sea level. For this reason, we use the term "sea level change" as it includes regions that will experience a decrease in relative sea level (at least in the early part of this century) as well as those that will see increasing relative sea levels.

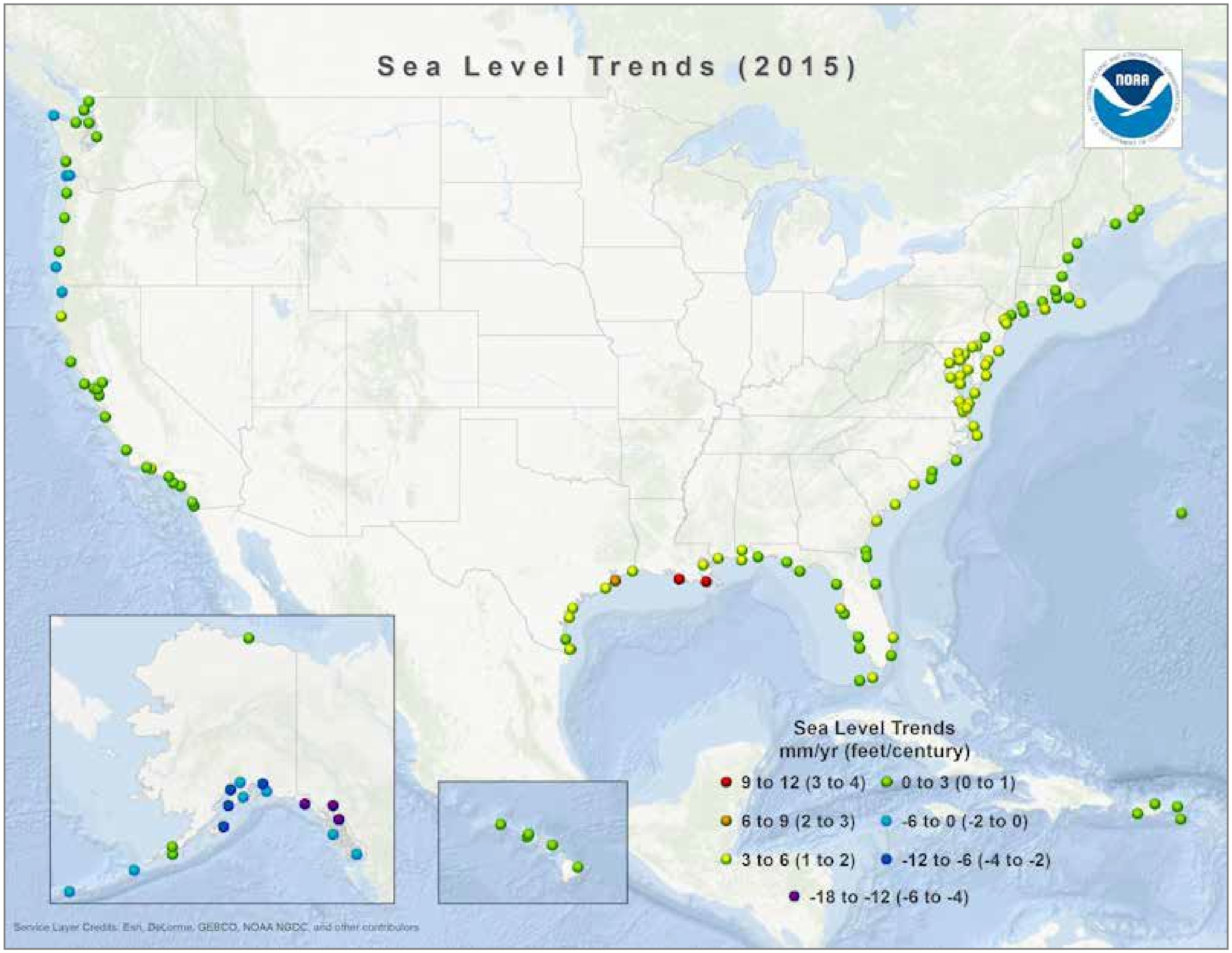

Figure 1. Sea level trends for the United States based on Zervas (2009), for all available data through 2015. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change. Stations depicted by yellow to red dots are experiencing greater than the global average (primarily driven by regional subsidence) and blue to purple dots are stations experiencing less than the global average (due to isostatic rebound or other tectonically-driven factors). Source: https://tidesandcurrents.noaa.gov/sltrends/slrmap.htm

Methods

This report summarizes work of a three-year project initiated in 2013, analyzing sea level change in 118 National Park Service units. Consultation with regional managers regarding units they considered to be potentially vulnerable to sea level change and/or storm surge resulted in selection of these 118 coastal park units (Appendix B). Project activities included the following:

1) Prepare sea level projections over multiple time horizons for each park unit.
2) Estimate potential exposure to storm surge using the National Oceanographic and Atmospheric Administration (NOAA) Sea, Lake, and Overland Surge from Hurricanes (SLOSH) Model and Tebaldi et al. (2012).
3) Create wayside exhibits[1] with information about the impacts of climate change in the coastal zone for three National Park Service units.

Based on recommendations from regional personnel, three National Park Service units were selected as sites for wayside exhibits: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore. The finished wayside designs are in Appendix C. Each design is different, customized to reflect the messaging and/or themes of each unit.

Sea Level Rise Data

Comment 6 Sea level rise is caused by numerous factors. As human activities release CO2 and other greenhouse gases into the atmosphere, mean global temperatures increase (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). Rising global temperatures cause ice located on land and in the sea to melt.
The melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise.

While the melting of sea ice is problematic from an oceanographic and heat budget perspective (primarily because it alters water temperatures and salinity and also because it changes the reflectance of solar energy from the surface), melting sea ice does not cause sea level rise. It is the melting of ice that is currently stored on land that raises global sea levels. Water level does not change when sea ice (ice wholly supported by water) melts. The volume of water in the sea remains the same whether it is frozen or liquid. The phase shift of water from solid to liquid does not displace an additional volume of water.

As ocean waters warm, the density of these waters also changes, causing thermal expansion. Thermal expansion was responsible for two-fifths of sea level rise from 1993 to 2010, while melting ice accounted for half (IPCC 2013). Table 1 lists the contribution to sea level rise from several key sources.

---

[1] A wayside is an exhibit designed to be installed outside for visitors to learn about a particular subject (https://www nps.gov/hfc/products/waysides/).

Table 1. Observed global mean sea level budget (mm/y) for multiple time periods (IPCC 2013).

Source	1901–1990	1971–2010	1993–2010
Thermal expansion	n/a	0.08	1.1
Glaciers except in Greenland and Antarctica[a]	0.54	0.62	0.76
Glaciers in Greenland	0.15	0.06	0.10[b]
Greenland ice sheet	n/a	n/a	0.33
Antarctic ice sheet	n/a	n/a	0.27
Land water storage	-0.11	0.12	0.38
Total of contributions	**n/a**	**n/a**	**2.80**
Observed	**1.50**	**2.00**	**3.20**
Residual[c]	**0.50**	**0.20**	**0.40**

[a]Data until 2009, not 2010.

[b]This is not included in the total because these numbers have already been included in the Greenland ice sheet.

[c]This is calculated as observed global mean sea level rise – modeled glaciers – observed land water storage. See table 13.1 in IPCC (2013) for more details.

The IPCC sea level rise projections used in this analysis follow a *process-based model* approach, which estimates sea level based on the underlying physical processes. This contrasts with *semi-empirical* models that combine past sea level observations with other variables or theoretical considerations, including, in some cases, expert opinion (surveys or interviews of professionals) (Rahmstorf 2010, Orlic and Pasaric 2013). Often the semi-empirical approach yields higher sea level estimates. IPCC (2013) uses coupled atmosphere-ocean general circulation models (AOGCMs) to simulate the processes of change rather than the statistical inferences of the semi-empirical approach. AOGCMs are considered a process-based technique, although some variables derive from semi-empirical methods (IPCC 2013).

Sea level rise estimates for 2050 and 2100 were taken directly from the IPCC (2013) regional climate models (RCMs) downscaled to a spatial grid resolution of 1˚ x 1˚ from AOGCMs. Because many park units require estimates for shorter time horizons that fit more closely with the expected lifetime of various projects, sea level rise projections for 2030 were calculated using IPCC RCM data for each sea level rise driver shown in Table 2, interpolated to 2030 for each RCP. All projections are reported relative to the period 1986–2005 (see Appendix B for further discussion). All geographic information systems (GIS) maps display the projected sea level on top of mean higher-high water (MHHW) using the most recent tidal datum epoch (1983–2001). MHHW is calculated by averaging the highest daily water level over a 19-year tidal datum epoch.

Table 2. Median values for projections of global mean sea level rise and contributions of individual sources, for 2100, relative to 1986-2005, in meters (IPCC 2013).

Source	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Thermal expansion	0.15	0.20	0.22	0.32
Glaciers	0.11	0.13	0.14	0.18
Greenland ice sheet surface mass balance[a]	0.03	0.05	0.05	0.10
Antarctic ice sheet surface mass balance	-0.02	-0.03	-0.03	-0.05
Greenland ice sheet rapid dynamics	0.04	0.04	0.04	0.05
Antarctic ice sheet rapid dynamics	0.08	0.08	0.08	0.08
Land water storage	0.05	0.05	0.05	0.05
Sea level rise	**0.44**	**0.53**	**0.55**	**0.74**

[a]Changes in ice mass derived through direct observation and satellite data.

The standard error (σ) for each site estimate was not calculated because it was beyond the scope of this project. However, it can be calculated using the following equation and data available from the IPCC (2013, supplementary material):

Eq 1. $$\sigma_{t}^2 = \left(\sigma_{steric/dyn} + \sigma_{smb\_a} + \sigma_{smb\_g}\right)^2 + \sigma_{glac}^2 + \sigma_{IBE}^2 + \sigma_{GIA}^2 + \sigma_{LW}^2 + \sigma_{dyn\_a}^2 + \sigma_{dyn\_g}^2$$

Where: *steric/dyn* = the global thermal expansion uncertainty plus dynamic sea surface height; *smb_a* = the Antarctic ice sheet surface mass balance uncertainty; *smb_g* = the Greenland ice sheet surface mass balance uncertainty; glac = glacier uncertainty; *IBE* = the inverse barometer effect uncertainty; *GIA* = global isostatic adjustment; *LW* = the land water uncertainty; *dyn_a* = Antarctica ice sheet rapid dynamics uncertainty; and, *dyn_g* = Greenland ice sheet rapid dynamics uncertainty.

Initial data were exported as GeoTIFF files for use in ArcGIS. For parks that crossed more than one pixel, an average sea level rise was calculated by weighting pixel values by the length of park shoreline in each pixel. A standard bathtub model approach was used to identify areas of projected inundation and flooding. In this method, projected sea level under climate change was determined by adding the IPCC RCM value to the current mean higher high water level. The land that would be at or below a projected sea level was then determined by analyzing digital elevation models (DEMs) of land elevation at spatial resolutions of 500 to 7000 m, depending on data availability for the areas of each park. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast). Areas of inundation and flooding are denoted in the maps (Appendix A) in blue. Additional low-lying areas that could be potentially inundated or flooded are shown in green (Figure 2). These low-lying areas do not appear to have any inlet or other pathway for water (based on our elevation datasets), although they should still be considered vulnerable to exposure to either groundwater seepage or potential flooding via breaching. The lack of high-resolution DEMs and time constraints prevented us from attempting a dynamic modeling approach (see limitations below). Maps were created to illustrate inundation for all park units for 2050 and

2100 under RCP4.5 and RCP8.5. These two represent a plausible range of scenarios between significant policy response (RCP4.5) and business as usual (RCP8.5).

Figure 2. An example of how areas of inundation appear in ArcGIS. In this example for the Toms Cove area of Assateague Island National Seashore, areas of inundation (RCP4.5 2050) appear in blue. Green shading indicates other low lying areas that are blocked from inundation by some impediment, but nonetheless could experience flooding should the physical barrier be removed or breached.

Storm Surge Data

NOAA SLOSH data estimate potential storm surge height at current (most recent tidal datum) sea level (NOAA 2016). The NOAA SLOSH model comprises the following three products (P-Surge, MEOW, and MOMs) that utilize three different modeling approaches (probabilistic, deterministic, and composite) to estimate storm surge.

P-Surge (also known as the tropical cyclone storm surge probabilities product) uses a probabilistic approach by examining past events to estimate the storm surge generated by a cyclone that is present and within 72-hours of landfall. It statistically evaluates National Hurricane Center data (calculated in part using a deterministic approach) including the official projected cyclone track and historical forecasting errors. It also incorporates astronomical tide calculations and variations in the radius of

maximum wind into this estimate. These rates of motion variables are then fit to a Cartesian or polar (depending on the location) grid (Jalesnianski et al. 1992).

The Maximum Envelope Of Water (MEOW) calculates flooding using past SLOSH output to create a composite estimate of the potential storm surge generated by a hypothetical storm. This product generates a worst-case scenario based on a hypothetical storm category that includes forward speed, trajectory of the storm when it strikes the coastline, and initial (mean vs. high) tide level that will also incorporate any historical uncertainty from previous landfall forecasts.

The final SLOSH product is the MOM (Maximum of MEOWs) model. MOM is a further composite approach that uses the forward speed, trajectory, and initial tide level data that is also used by MEOW to create a worst-of-the-worst scenario (or "perfect storm"). Storms are simulated for 32 regions (also known as operational basins, Figure 3) defined by NOAA. Data was imported into ArcGIS using the SLOSH display program. Maps were generated showing storm surge for all possible Saffir-Simpson hurricane categories for each site. While most sites had data for Saffir-Simpson hurricane categories 1–5 (Table 3), a few sites, such as Acadia National Park, were missing the highest category. NOAA did not model this scenario because it is considered extremely unlikely at a location that far north in the Atlantic Ocean.

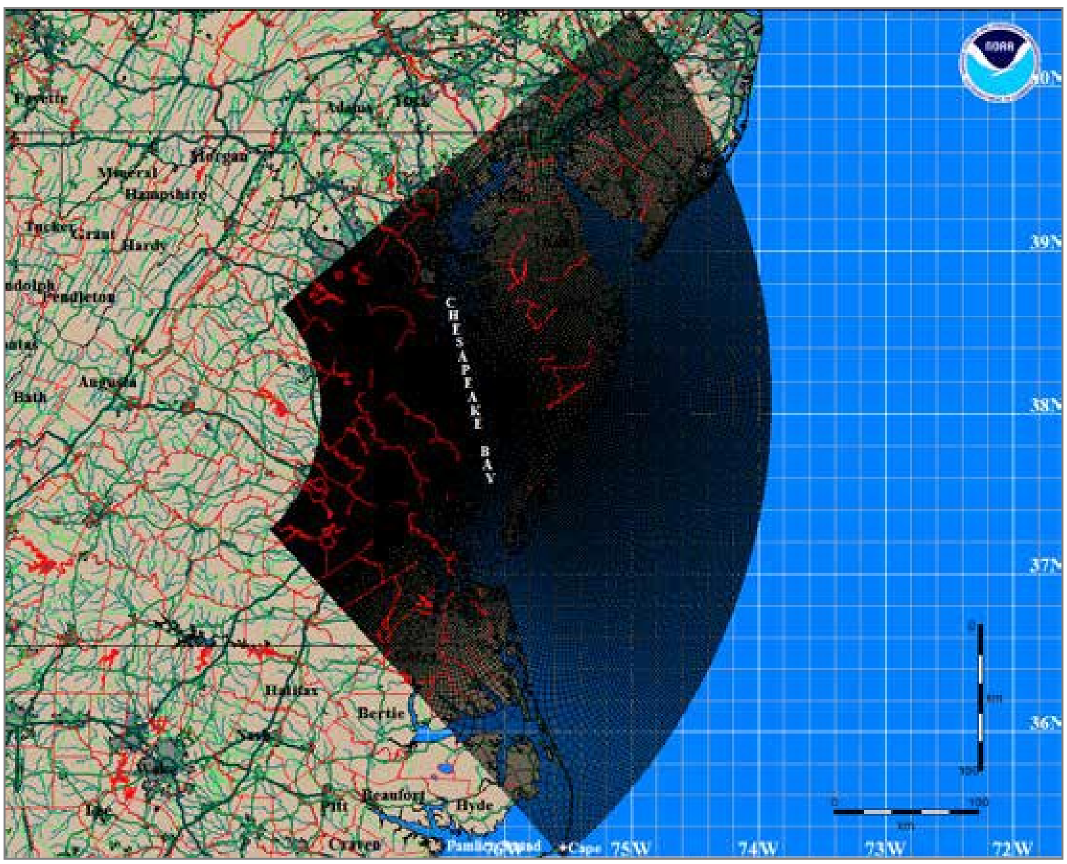

Figure 3. An example of the extent of an operational basin shown in NOAA's SLOSH display program (http://www.nhc.noaa.gov/surge/slosh.php). The black area is the full extent of the operational basin for Chesapeake Bay.

Table 3. Saffir-Simpson hurricane categories.

Saffir-Simpson Hurricane Category	Sustained Wind Speed (miles per hour, mph; knots, kt; kilometers per hour, km/h)
1	74–95 mph; 64–82 kt; 118–153 km/h
2	96–110 mph; 83–95 kt; 154–177 km/h
3	111–129 mph; 96–112 kt; 178–208 km/h
4	130–165 mph; 113–136 kt; 209–251 km/h
5	More than 157 mph; 137 kt; 252 km/h

SLOSH MOM was used to estimate potential storm surge in 79 coastal park units. Unfortunately, MOM data do not exist for the remaining 39 units, so we supplemented this with data from Tebaldi et al. (2012) wherever possible. Tebaldi et al. (2012) used 55 long-term tide gauge records to calculate potential sea level and storm surge estimates above mean high water levels. We used the current 50-year and 100-yr return level data from their paper for any parks near a tide gauge. Unfortunately, due to insufficient coverage by tide gauges in this area, we were unable to use either Tebaldi et al. (2012) or SLOSH MOM data for the Alaska, Guam, and American Samoa park units. It is important to note that the Tebaldi (2012) and SLOSH MOM data differ in their methods of calculation making it inadvisable to compare storm surge values from the Pacific West Region to other regions. However, this method had to be used due to the lack of SLOSH MOM data for the Pacific West Region.

We recommend that parks planning for future hurricanes use information from one hurricane category higher than any previous storm experienced. Historical hurricane data from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010) is listed in Appendix D (Table D3) to allow staff to determine the highest Saffir-Simpson category hurricane to strike within 10 miles of each park unit. Applying information from one storm category higher than historical data may more closely approximate what could happen in the future, as storms are projected to be more intense under continued climate change (Emanuel 2005, Webster et al. 2005, Mendelsohn et al. 2012). However, we recommend caution in using this approach for any detailed (site-level) planning due to limitations discussed in the following section of this report.

Limitations

All projects of this nature have limitations that should be clearly described to ensure appropriate use and interpretation of these data.

Every effort has been made to incorporate any parks established after this project began (e.g. Harriet Tubman Underground Railroad National Monument); however, some maps might be missing due to lack of available boundary data in new units.

Sea level and storm surge estimates were derived using separate programs from the IPCC and NOAA, respectively. These numbers were then imported into GIS maps using the program ArcGIS. We used a bathtub modeling approach to map the extent of sea level rise and storm surge over every unit. Bathtub modeling simply simulates how high or how far inland water will go under different

climate change scenarios. It does not recognize changes in topography or other environmental or artificial systems that may exist or occur in response to encroaching water. Although the bathtub model is the most widely used technique for modeling inundation, it is also a simplistic approach to simulating how sea level rise will affect a landscape (Storlazzi et al. 2013). Dynamic models could simulate changes in flow around buildings or estimate how topographic features such as dune systems may migrate in response to inundation and flooding, but dynamic models also vary, which can be a severe limitation in trying to standardize data for summary analysis and comparison.

The maps provided through this analysis vary in horizontal and vertical accuracy depending on which digital elevation model (DEM) data were available at the time of mapping. This is discussed in more detail in the metadata that accompany each map. DEM data for most regions were gathered from the NOAA digital coast website (https://coast.noaa.gov/digitalcoast/) which uses source elevation data that either meet or exceed current Federal Emergency Management mapping specifications. These NOAA digital coast data were required to have a minimum root mean square error of 18.5 cm for low lying areas that were then corrected for MHHW using the NOAA VDatum model (Parker et al. 2003). USGS data were used for areas, such as Alaska, where digital coastal data were not available. We recommend referring to Schmid et al. (2014) for further discussion on potential uncertainty of this technique.

Although SLOSH MOM has the widest geographic storm surge coverage of any model in the US, storm surge data were not available for every part of the coastline. Every effort has been made by this project to bridge any gaps where SLOSH MOM does not exist. While the Tebaldi et al. (2012) data cover the California, Oregon, Washington, and southern Alaskan coastlines, they do not cover northern Alaskan, American Samoan, or Guam coastlines. These coastlines are vulnerable to storm surge but we could not find data that satisfied our standards of accuracy sufficiently to be included in our mapping efforts.

Furthermore, storm surge maps are only intended as a rough guide of how flooding caused by storm surge will look today. As more of the coastline becomes inundated we can expect coastal flooding patterns to also change accordingly. The SLOSH model is a multiple scenario approach that uses previous storms to estimate future storm surge. It cannot take into account changes in future basin morphology that could affect the fluid dynamics and propagation of coastal flooding.

SLOSH MOM is modeled using mean sea level (0 m NAVD88) and what NOAA terms “high tide” (which is not tied to the local tidal datum, but is actually a round number based on the modeled average high tide for the region). Jalesnianski et al. (1992) estimate surge estimates to be accurate +/-20%, although Glahn et al. (2009) discuss how others have found the P-Surge model to be more accurate than originally estimated. Such factors must be kept in mind when using these numbers for mapping.

Land Level Change

It is important to include changes in land level while interpreting changes in sea level. The IPCC (2013) includes a limited amount of data regarding changes in relative sea level in their calculations of sea level change. Our sea level rise results include the IPCC estimates of how changes in land

level will change over time based on estimates of glacial isostatic adjustment. Land level change is an important variable when calculating relative sea level. Land levels have changed over time in response to numerous factors. Changes in various land-based loadings—such as ice sheets during the last glacial maximum—has been a significant cause of land level change in the U.S. Post-glacial isostatic rebound is the result of this pressure being released after the removal of ice sheets on the Earth's crust. Land level can also be altered by other factors such as tectonic shifts, particularly along the Alaska and continental U.S. Pacific coastlines. These drivers can often prompt a relative increase or decrease in land level depending on location. Other factors such as aquifer drawdown and the draining of coastal swamps can create decreases in relative land level.

Quantifying how land levels are changing is difficult given the paucity of data available prior to modern satellite data. An upcoming NASA publication on land-based movement (Nerem pers. comm.) will help to address this data need, providing numbers for land-based movement across the country. Data from the NASA report can then be incorporated with sea level rise numbers from this analysis using the following equation (after Lentz et al. 2016):

Eq. 2 $$\mathrm{a}e = \mathrm{E}_0 - e_\mathrm{i} + \mathrm{R}$$

Where; a*e* is the adjusted elevation, E_0 is the initial land elevation, e_i is the future sea level for either 2030, 2050, or 2100, and R is the current rate of land movement over time due to isostatic adjustments.

In the interim, tide gauges can provide further data regarding changes in land level, but should be used cautiously. We have listed tide gauge data for the rate of change in land level for tide gauges nearest to all units for this study in Appendix D; however, only Fort Pulaski National Monument and Golden Gate National Recreation Area have a long-term tide gauge on site. This lack of nearby long-term data can limit the accuracy of these numbers if they are applied to sea level change projections for almost all other parks units. We indicate in Table D1 which of the nearest tides gauges we do not recommend using to estimate land movement. This is because in many case the boundary of the park unit is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. Land level changes were only reported for long-term tide gauges that had at least thirty years of data in order to ensure a statistically robust dataset. Based on these limited records, we estimate that seven park units are currently experiencing decreasing relative sea levels (Glacier Bay National Park, Glacier Bay Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park), although we cannot be certain of this number given that many of the park units are some distance from a tide gauge. We expect the release of the NASA data (Nerem pers. comm.) to help refine these estimates.

A discussion of the applicability of these land level numbers (with a natural resources manager or similar expert) should accompany use of individual park maps from this analysis to ensure that the nearest tide gauge to any particular project site is appropriate. Current rates of subsidence at these tide gauges range between +7.6 mm/y (Grand Isle, Louisiana) and -19 mm/y (Skagway, Alaska; Table D1). In selecting an appropriate tide gauge to use, variables including oceanographic setting, length of the record, completeness of data, and geography of the coastline must be considered. The

science team for this project decided against setting a threshold for how close a park unit should be to a long-term tide gauge based on considerations discussed above.

Where to Access the Data

All GIS data from this project are available at https://irma.nps.gov/Portal for archiving by park.

A website discussing this project is available at the following address: https://www.nps.gov/subjects/climatechange/sealevelchange.htm

The raw IPCC (2013) data can be downloaded using the following link: http://www.ipcc.ch/report/ar5/wg1/docs/ar5_wg1_ch13sm_datafiles.zip

Results

Sea level and storm surge maps are in Appendix A. A full list of the 118 park units and a table listing sea level projections by park are available in Appendix D. Following the methods outlined above, we found that sea level rise projections across the 118 park units average between 0.45 m (RCP2.6) and 0.67 m (RCP8.5) by 2100. However, this number masks how these projections will vary geographically. Figure 4 shows these projections in more detail and provides sea level estimates by region. Error bars in Figure 4 denote the standard deviation for each average per region, further revealing how these numbers can vary. A high standard deviation and range signals that sea level estimates vary between units within regions, whereas a low standard deviation and small range are to be expected in smaller regions where sea level rise estimates do not cover such a large geographic area.

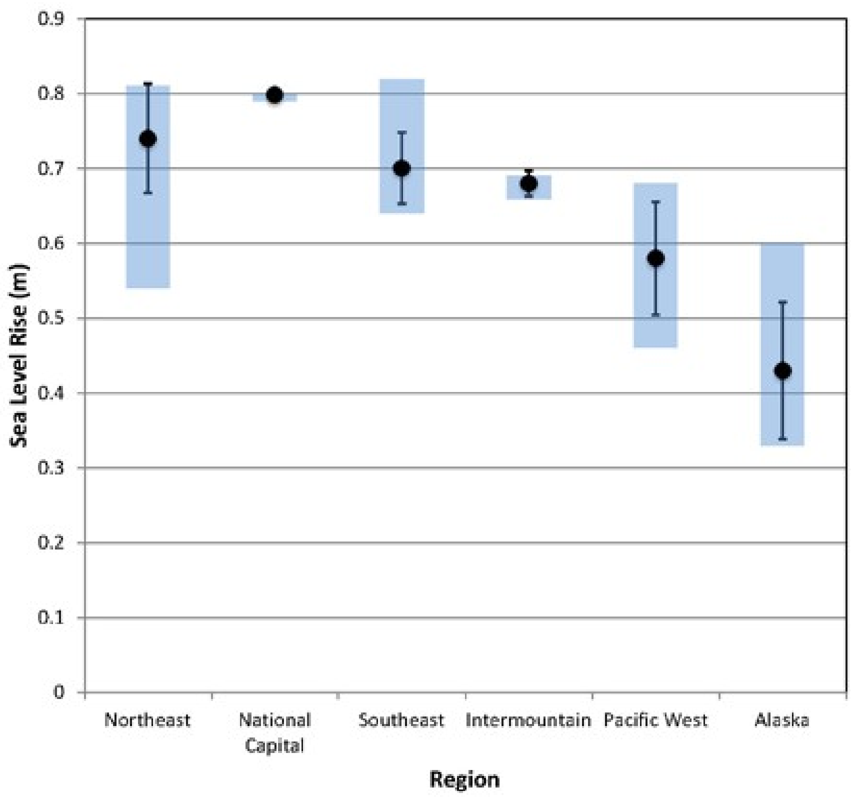

Figure 4. Projected future sea level by NPS region for 2100 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Based on the averages per region, we found that the shoreline within the National Capital Region is projected to experience the highest sea level rise by 2100 (0.80 m RCP8.5), although this number does not include the full extent of changes in land level over the same time interval. The shoreline near Wright Brothers National Memorial in the Southeast Region has the highest overall projected sea level rise (0.82 m, RCP8.5, 2100). Glacier Bay Preserve and Klondike Gold Rush National

Historical Park are tied for lowest projected sea level rise at 0.33 m using RCP8.5 for 2100. The Alaska Region also has the highest standard deviation among park units. The National Capital Region conversely has very little standard deviation due to the compact nature of the region (meaning that all of the parks units fell within the same raster cell). This is not to say that all of the parks will experience exactly the same rate of sea level rise, but that the IPCC model projected that sea levels could rise up to an average 0.80 m (RCP8.5) for that region by 2100. The sea level rise maps (discussed in the National Capital section below) illustrate differences among the National Capital parks in more detail.

Comparing RCP8.5 data for 2030 and 2050 (Figures 5 and 6, respectively) shows the Northeast Region almost tied with the National Capital Region in 2030 based on average projected sea level rise, with the National Capital Region ranked highest. The Alaska Region ranks lowest for all three time intervals followed by the Pacific Northwest region, Intermountain Region, and Southeast Region. The Northeast Region ranks second highest for 2050 and 2100.

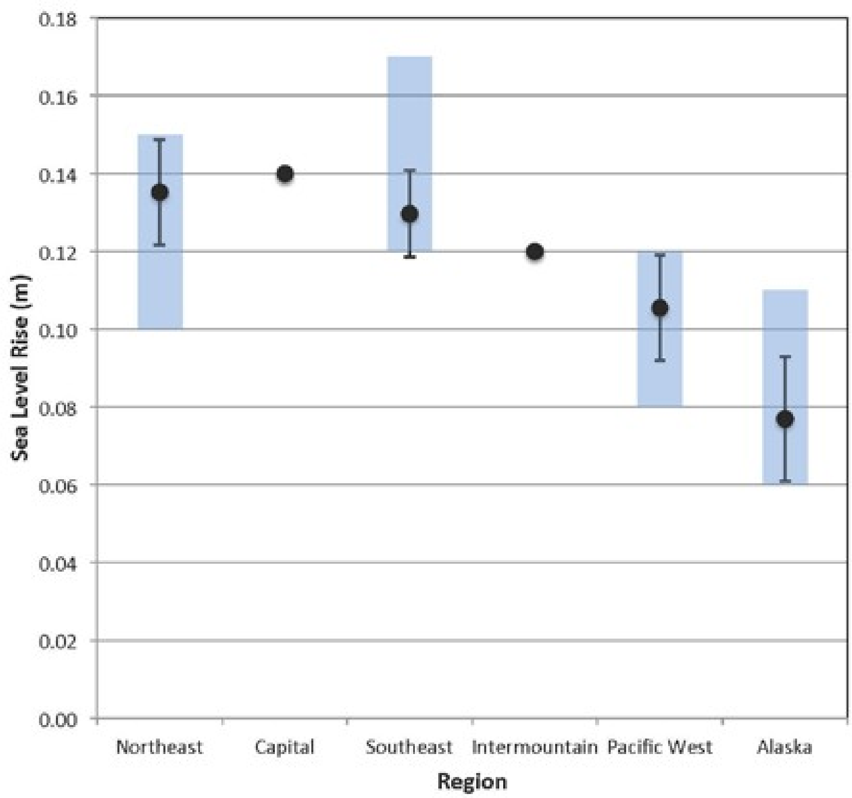

Figure 5. Projected future sea level rise by NPS region for 2030 under RCP8.5 (the “business as usual” climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

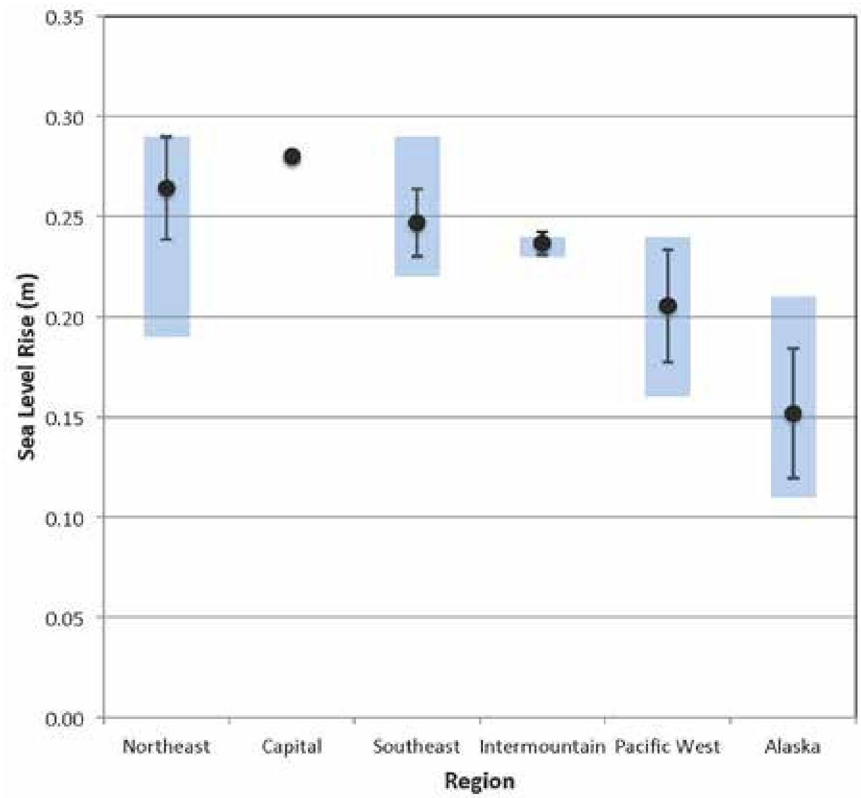

Figure 6. Projected future sea level rise by NPS region for 2050 under RCP8.5 (the “business as usual” climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

Storm surge was mapped for 79 park units. We list data for one storm category higher than the highest historical storm in Table D3 in Appendix D. Some (31) park units did not have a historical storm path occurrence within 10 miles of their boundaries, so a Saffir-Simpson hurricane 1 was simulated for these locations. The lack of a historical storm does not mean that these parks are not subject to strong storms. It may merely be that these parks are in regions that either do not have extensive historical records or they experience strong storms, such as nor’easters, that behave differently and are not part of the NOAA database.

The Southeast Region has the strongest historical hurricanes (average of highest recorded storm categories = 2.79), followed by the Intermountain Region (average = 2.33), National Capital Region (average = 1.90), and the Northeast (average = 1.03). None of the historical data intersected with the 10-mile (16.1 km) buffers around the Alaska Region parks. The Pacific West Region has experienced some tropical depressions, particularly in Hawaii, but most of their storm surges are driven by other phenomena, such as mid-latitude cyclones or extreme tides (sometimes colloquially referred to as king tides). The strongest (highest winds) and most intense (lowest pressure at landfall) recorded historical storm to have impacted a park unit was the “Labor Day Hurricane” that passed within 10 miles of Everglades National Park in 1935. While this storm may have been the highest intensity storm, it is certainly not the most damaging or costly storm in National Park Service history.

Northeast Region

Colonial National Historical Park, Fort Monroe National Monument, and Petersburg National Battlefield have the highest projected sea level rise in 2050 and 2100, and, together with Edgar Allen Poe National Historic Site, Fort McHenry National Monument and Historic Shrine, Independence National Historical Park, and Thaddeus Kosciusko National Memorial (parks near coastlines) they also have the highest projected sea level rise for 2030. However, while these parks may have ranked highly, caution should be used in applying these results. Many of these parks do not have coastline and so these projections are based on sea level rise for the coastline adjacent to these parks. The maps in Appendix A show how the projected sea level rise may affect each of these parks. Colonial National Historical Park, Fort McHenry, and Fort Monroe National Monument are the only park units of this highest rise grouping that contain coastline with their boundaries.

Figure 7 shows the range of sea level projections for the Northeast Region for 2100, averaging between 0.49 m (RCP2.6) and 0.74 m (RCP8.5) of sea level rise by the end of the century. Acadia National Park had the lowest projected rates of sea level rise for 2030 (0.08–0.10 m), 2050 (0.14–0.19 m), and 2100 (0.28–0.54 m).

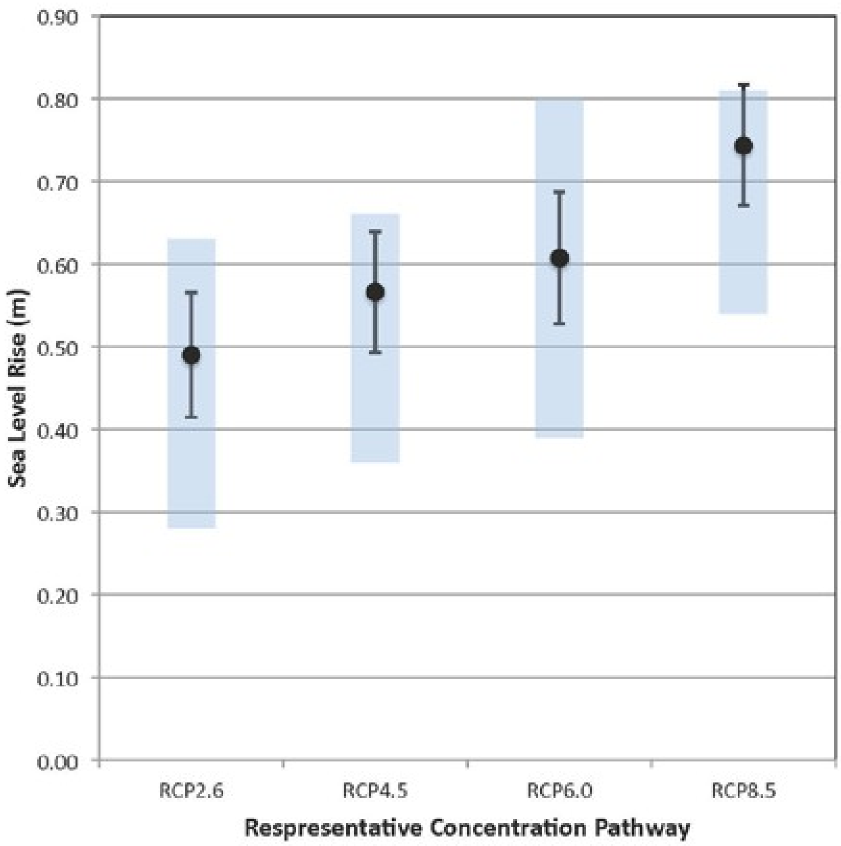

Figure 7. Projected future sea level rise by 2100 for the NPS Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each category.

Regarding storm surge, the highest recorded storm to have travelled within 10 miles of any of the 29 parks units identified for study was an officially unnamed hurricane in 1869 known colloquially as Saxby's Gale, which was classified as a Saffir-Simpson 3 hurricane. The storm path passed present-day Boston National Historical Park and Roger Williams National Memorial. Figure 8 shows the estimated extent and height of a storm surge from category 3 hurricane striking Boston Harbor Islands National Recreation Area at mean tide.

Figure 8. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at high tide near Boston Harbor Islands National Recreation Area. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Southeast Region

Historically, the Southeast Region has the highest intensity storms (highest Saffir-Simpson storm category); Everglades National Park has recorded a category 5 hurricane within 10 miles of its boundary, the colored areas in Figure 9 indicate the potential height and extent of a storm generated by two different categories of hurricane. A category 2 hurricane could completely flood the park.

Future storm surges will be exacerbated by future sea level rise nationwide; this could be especially dangerous for the Southeast Region where they already experience hurricane-strength storms.

Moreover, sea level rise projections only include changes in land movement due to glacial isostatic adjustment and do not include the full range of drivers of potential changes in land level. Using Table D1 from Appendix D as a rough guide, changing land level for parks near tide gauges can be evaluated. For example, the Eugene Island, Louisiana tide gauge's current rate of sea level rise is the highest in the country at 9.65 mm/y, owing in part to the large rate of subsidence in the region (Figure 1). Using the nearest tide gauge to Jean Lafitte National Historical Park and Preserve (Grand Isle, Louisiana, gauge 8761724) we can estimate that land will subside by 7.60 mm/y. Applying this estimate of subsidence (using a baseline of 1992) to our RCP8.5 projections, the park could experience approximately 0.41 m of *relative* sea level rise by 2030 followed by 0.69 m by 2050 and 1.50 m by 2100. This is an inexact estimate of the land movement for the park given that Jean Lafitte National Historical Park and Preserve is approximately 60 miles (97 km) from the tide gauge; still, factoring in changes in land level, we can see that relative change in sea level is more than double the projected change in sea level using the IPCC estimates alone.

This analysis projects that, by 2100, the shoreline adjacent to Wright Brothers National Memorial may have the greatest sea level rise among the Southeast Region's parks (0.82 m RCP8.5). Given elevations within the park, this may not inundate a large area of the memorial, unless combined with other factors such as a storm surge. For example, the park may be almost completely flooded if a category 2 or higher hurricane strikes on top of inundation from sea level rise.

Nearby Cape Hatteras and Cape Lookout National Seashores are projected to experience sea level rise of up to 0.79 m and 0.76 m, respectively (RCP8.5) by 2100, resulting in large areas of inundation. While sea level rise around these national seashores may not be as high as what has been projected for Wright Brothers National Memorial, they serve as examples of how caution must be used when using these numbers to assess which park units are most vulnerable to sea level rise. Other factors, such as percent of exposed land, changes in land movement, and adaptive capacity must also be taken into account for vulnerability analyses (Peek et al. 2015).

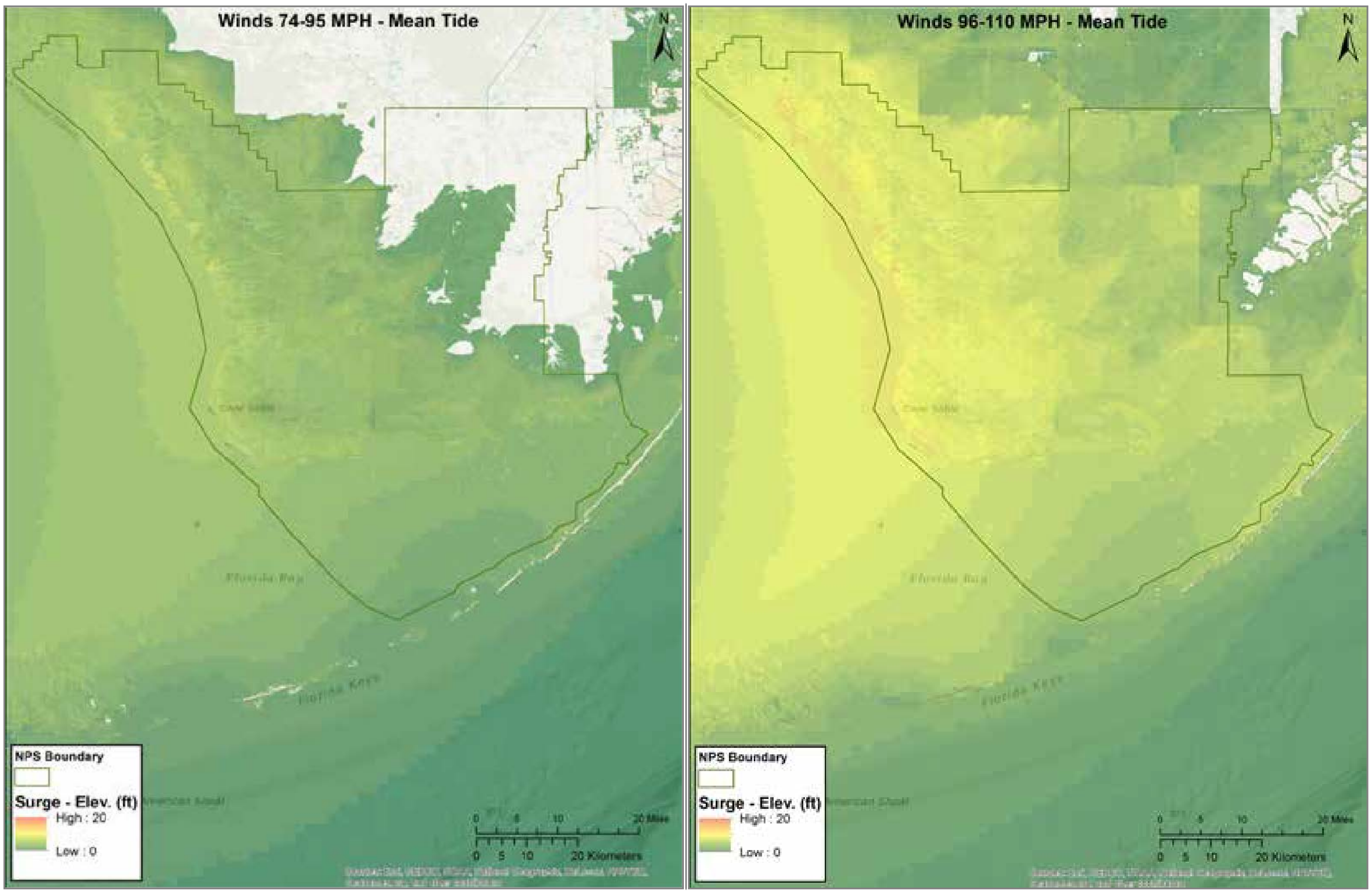

Figure 9. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide (right). Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

National Capital

National Capital Region has minimal variability in projected sea level rise because all park units selected for study are adjacent to the same section of coastline that was modeled. Their proximity also explains why they share the same storm history. Despite these similarities, projected sea level rise may affect each individual park unit differently based on local topography. The strongest storm recorded within 10 miles (16.1 km) of the National Capital Region parks was a Saffir-Simpson category 2 hurricane that struck the city in 1878. While the 1878 storm caused relatively little damage, we can expect a significantly larger amount of damage if a similar storm struck the city again given considerable development now existing in the area. Figure 10 shows the extent of flooding caused by a Saffir-Simpson category 2 hurricane. A storm surge measuring more than 3 m could travel up the Potomac River causing large amounts of flooding. Such a storm surge could be worse by the end of this century given projected sea level rise around the Capital Region of up to 0.8 m.

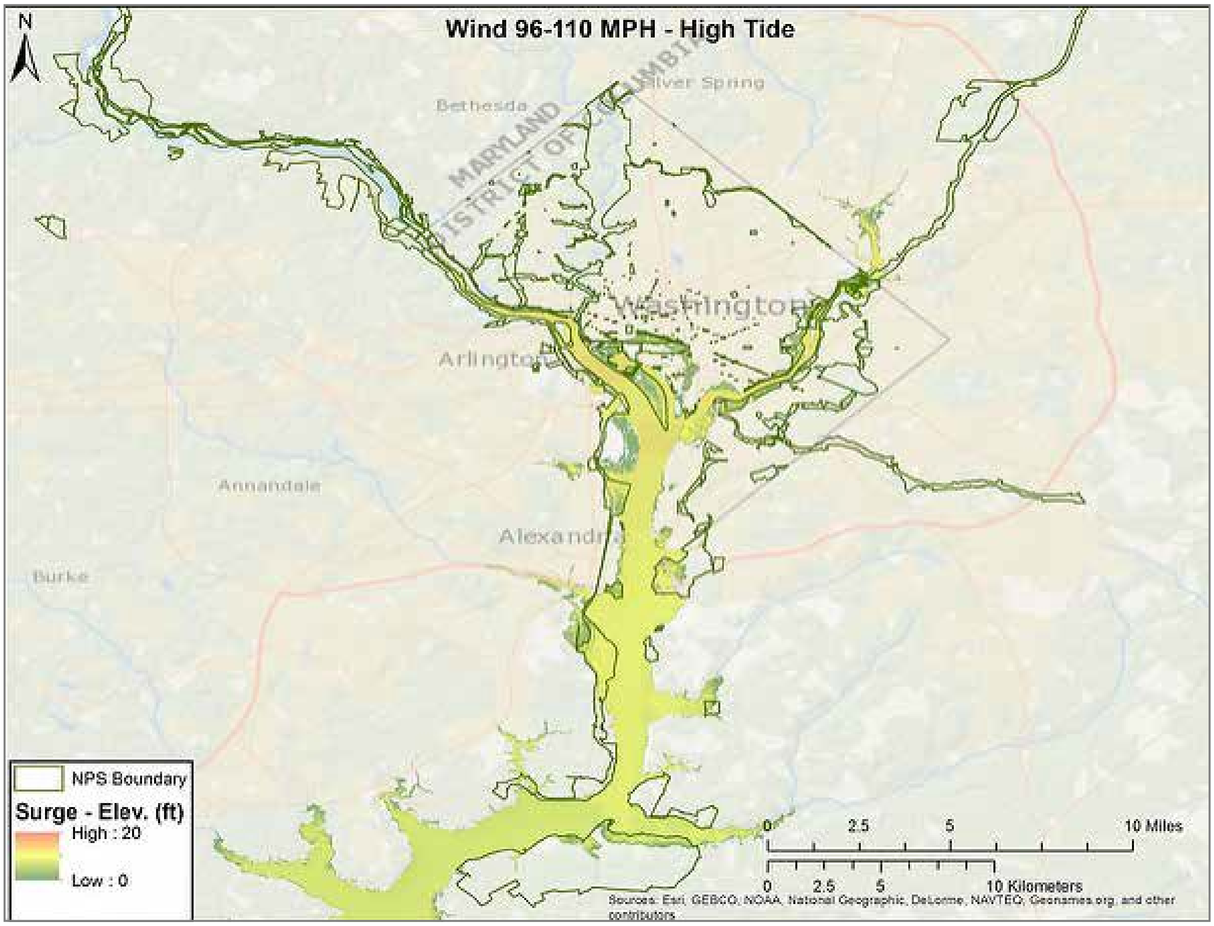

Figure 10. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

IPCC/SLOSH models showed either storm surge or sea level rise (or some combination of the two) affecting every National Capital Region park included in this analysis, with the exception of Harpers Ferry National Historical Park. Our mapping efforts revealed that Harpers Ferry National Historical Park (located approximately 149 m above sea level) is unlikely to experience any impacts of sea level rise due to its elevation and is unlikely to be damaged by storm surge from a hurricane, given its relatively protected location behind several dams along the Potomac and Shenandoah Rivers.

Sea level rise alone is not expected to spread very far into Washington D.C., although a large section on the east side of Theodore Roosevelt Island could be inundated. However, storm surge flooding on top of this sea level rise would have widespread impacts.

Intermountain Region

The Intermountain Region covers mostly inland park units stretching from Texas to Montana. Within the region, only three park units in Texas are subject to sea level change: Big Thicket National Preserve, Palo Alto Battlefield National Historical Park, and Padre Island National Seashore. Of these, Padre Island National Seashore may experience the greatest effects of sea level and storm surge; sea level is projected to rise 0.46–0.69 m (RCP2.6–8.5, Figure 11) by 2100. The same amount of sea level rise is projected for the shoreline near Palo Alto Battlefield National Historical Park, but inundation is not projected to extend far enough to reach the park. Palo Alto Battlefield National Historical Park has no history of being within 10 miles of any hurricane, making the site unlikely to be flooded by storm surge. SLOSH MOM models for the park unit show that that the region would have to have either a Saffir-Simpson category 4 hurricane striking at high tide or a category 5 hurricane striking at any tide in order for the park to experience any storm surge. On the other hand, Figure 12 shows that Padre Island National Seashore, located to the east of Palo Alto Battlefield National Historical Park, historically was within 10 miles of a category 4 hurricane. SLOSH MOM data show that should a category 4 hurricane occur here again, it would likely flood almost the entire island.

Storm surge could potentially travel up the Neches River and flood the southernmost part of Big Thicket National Preserve, although both artificial and natural storm surge defenses in Beaumont, Texas, to the south of the preserve, may buffer it from any surge.

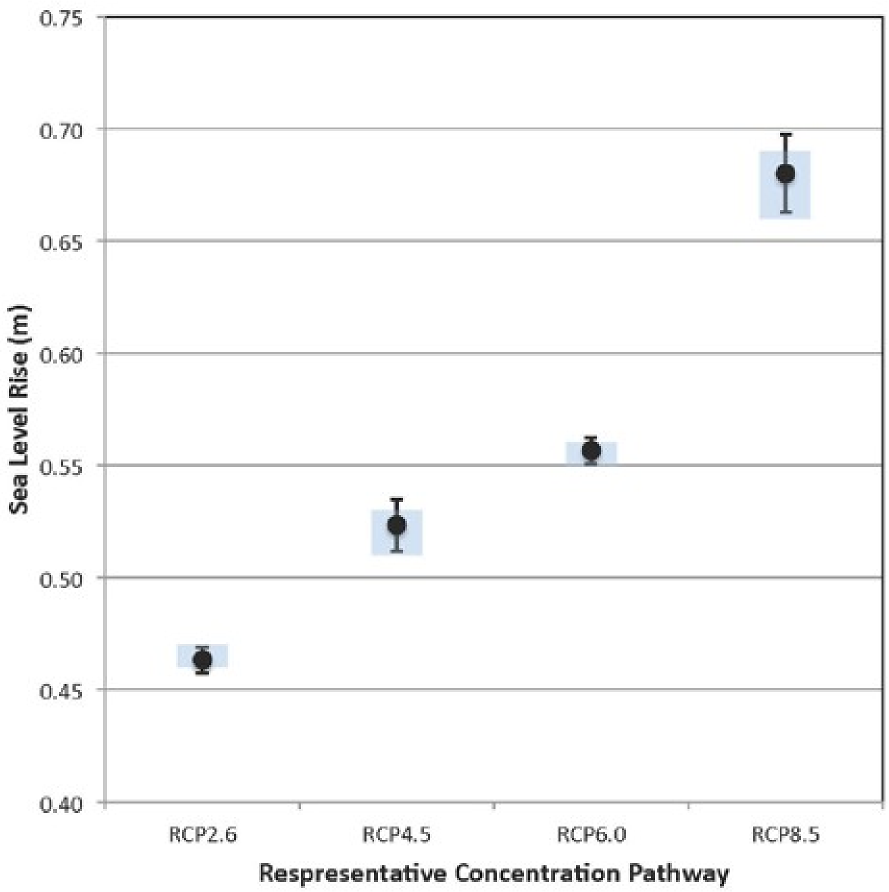

Figure 11. Projected future sea level rise by 2100 for the NPS Intermountain Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation from each mean. Blue bars mark the full range of sea level estimates for each category.

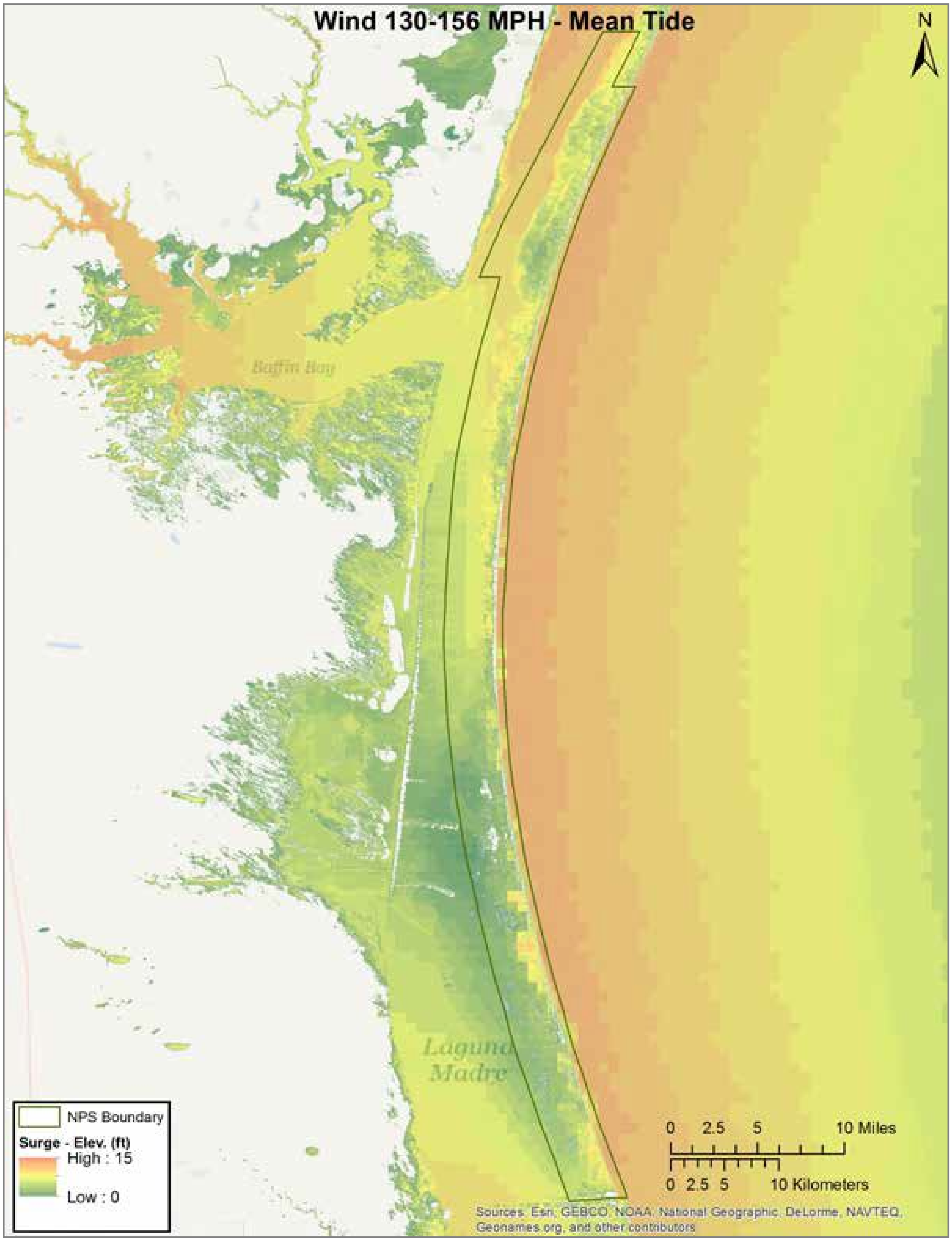

Figure 12. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

Pacific West Region

The Pacific West Region identified 24 park units for analysis in this study that could be vulnerable to sea level rise and/or storm surge. These units occur over a large area that includes California, Oregon, Washington, Hawaii, American Samoa, and Guam. War in the Pacific National Historical Park in Guam has the highest projected sea level rise at 0.68 m (RCP8.5) by 2100, and shares the highest projected sea level rise with almost all of the Hawaiian park units in 2030 and 2050. The average projected sea level rise range is 0.40–0.58 m (RCP2.6–8.5) by 2100 for the whole region; high standard deviations (0.04 m and 0.08 m for RCP2.6 and RCP8.5, respectively) indicate that park-specific projections vary widely across the region.

At the other end of the spectrum, projected sea level rise around Washington’s Olympic Peninsula and in the San Juan Islands, affecting Ebey’s Landing National Historical Reserve, Olympic National Park, and San Juan Island Historical Park, is expected to occur more slowly, reaching a maximum 0.46 m (RCP8.5) by 2100. This region is subject to tectonic shifts and continuing land movement due to isostatic rebound, further complicating sea level projections. Long-term tide gauge records at Neah Bay, Washington (gauge 9443090), and Tofino, British Columbia, Canada (gauge 822-116), show relative sea levels currently decreasing while tide gauges in Port Angeles, Washington (gauge 9444090), Victoria, Canada (gauge 822-101), and Seattle, Washington (gauge 9447130), show it to be increasing (Zervas 2009). Our projections indicate rising sea level in this region throughout this century, although further investigation of localized changes in land movement could shed more light on this matter.

Park units in the Pacific West Region need to be concerned about potential future storms that could travel along the eastern Pacific Ocean’s increasingly warmer waters. Because of the relative lack of hurricanes in this region historically, we used data from Tebaldi et al. (2012), which includes anomalous surges that could be created by storms, and other factors (very high tides sometimes referred to as king tides). Based on the Tebaldi et al. (2012) data, La Jolla, California (gauge 9410230), has the lowest 100-year storm surge (0.95 m) and Toke Point, Washington (gauge 9440910), has the highest 100-year storm surge (1.96 m) in the Pacific West Region. Tebaldi et al. (2012) did not analyze storm data for Hawaii, Guam, or American Samoa, although IBTrACS (Knapp et al. 2010) does have hurricane records for these areas. Only tropical depressions have been recorded within 10 miles of almost all of the Hawaiian park units we analyzed (Haleakala National Park, Hawaii Volcanoes National Park, Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puukohola Heiau National Historic Site, and World War II Valor in the Pacific National Monument).

Alaska Region

The Alaska Region has the lowest average projected sea level rise (0.28–0.43 m by 2100) compared to the five regions described above. Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park in southeastern Alaska share the lowest projected sea level rise (0.33 m, RCP8.5, 2100) while Bering Land Bridge National Preserve on the west coast of the state has the highest projected sea level rise (0.60 m, RCP8.5, 2100).

Figure 1 shows how current relative sea levels vary across the state. Land levels are rapidly rising in the southeast of the region due to isostatic rebound and other tectonic shifts. The net result of these increasing land levels is decreasing relative sea levels for at least the early part of this century. Relative sea level in Skagway, Alaska is decreasing at an average rate of 17.6 mm/y (Zervas 2009). Despite melting ice and other factors outlined in Table 1 that increase ocean water volume, the amount of rising water is insufficient to keep up with land level changes. Seven park units (Glacier Bay National Park, Glacier Bay National Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park) are identified as potentially having decreasing relative sea levels based on the nearest tide gauge data to each of these parks. None of these parks have long-term tide gauges with data spanning at least thirty years. A great strength of using the IPCC (2013) process-based model approach is that, unlike many other semi-empirical models, it does not rely on long-term tide gauge records to statistically project future sea levels. However, sea level projections in this analysis do not include changes in land level. The estimates that we report here represent the expected rise due to water volume expansion alone near to each of these park units. Table D1 shows how land levels are changing at long-term tide gauges across the country. However, given that all of these park units are located far from a tide gauge and that the region is relatively geologically complex, we do not recommend using the land movement numbers from the nearest tide gauge for any of the Alaskan parks.

Storm surge is also very difficult to model for this region. Historically, many of the parks had sea ice along the coastline that helped protect these parks from storm surge. Consequently, NOAA does not have SLOSH MOM models for this region. IBTrACS data (Knapp et al. 2010) show a few storm paths that have moved towards the region, but these types of storms typically do not make landfall once they move over colder waters. Alaska does hold the record for the highest intensity (lowest central pressure) storm (Duff 2015). A downgraded super typhoon, Nuri, struck Adak Island, Alaska, in 2014 with recorded winds gusting up to 122 mph. It is impossible to determine an average or peak historical storm surge without adequate tide gauge data.

Discussion

Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/y, although this rate accelerated over the latter part of the century. Comment 7 Slangan et al. (2016) found that emissions of greenhouse gases from human activities have been the primary driver of global sea level change since 1970 and that the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/y (Cazenave et al. 2014, Fasullo et al. 2016).

The IPCC (2013) projects that, without greenhouse gas emissions reductions, this rate will increase, and that global average sea levels could rise by 0.40–0.63 m (RCP2.6–8.5) by 2100. We used regional sea level projections from the IPCC (2013) generated for 2050 and 2100 in combination with our interpolated projections for 2030 to estimate the amount of sea level rise 118 coastal national park units could experience in the future. Our projections are based on the new representative concentration pathways (Moss et al. 2010, Figure 13), using a process-based model approach.

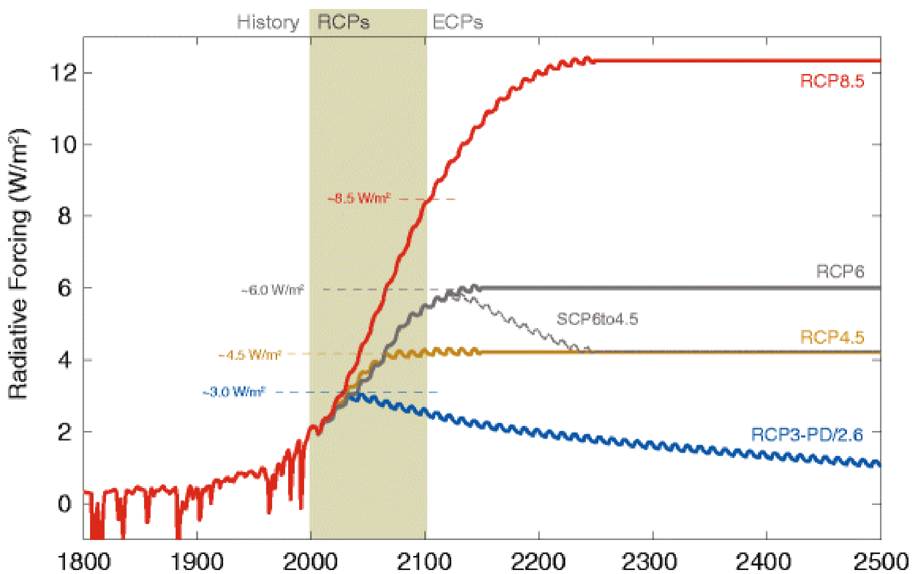

Figure 13. Radiative forcing for each of the Representative Concentration Pathways (RCPs). An increase in radiative forcing (due to the loading of anthropogenic gases into the atmosphere) will result in higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are slightly higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011.

Numerous academic articles use mostly semi-empirical models (Rahmstorf 2007) to estimate sea level rise regions across the U.S. The IPCC (2013) lists several semi-empirical sea level rise estimates, all of which result in projections of future sea level that are higher than the IPCC (2013) approach. The differences in these approaches can be attributed to many factors. For example, some of the older papers may have higher sea level estimates because they are based on the older IPCC SRES scenarios (e.g. Vermeer and Rahmstorf 2009, Grinsted et al. 2010, Jevrejeva et al. 2010). Other papers may include input from "expert elicitations" in their sea level projections, in which experts provide their opinion on how much sea level (or a related factor) could rise in the future (e.g. Bamber and Aspinall 2013, Jevrejeva et al. 2014, Horton et al. 2014). Some published articles criticize the IPCC sea level estimates as being too conservative or underestimating rates of future sea level change (e.g. Kerr 2013, Horton et al. 2014). Church et al. (2013) addresses these criticisms by explaining how the IPCC define the probability and likelihood of their estimates, and so they are not discussed in detail here. Recent analyses by Clark et al. (2015) further support the findings of the IPCC.

A key strength of the methods used in this analysis lies in providing a unified approach to identify how sea level change may affect all coastal park units across the National Park System, rather than relying on sea level data generated for specific areas. Our analyses revealed that the National Capital Region is projected to experience the greatest increase in sea level (not taking into account changes in land level). This rise will affect each of the region's units in different ways depending on the elevation of the individual unit, but it could be significant if combined with a storm surge from a storm such as the Saffir-Simpson category 2 hurricane in 1878.

At the individual park level, IPCC projections reveal the sea level along the coastline adjacent to Wright Brothers National Memorial could rise up 0.82 m (RCP8.5) by 2100, which could lead to significant flooding if the dynamic landforms are not able to keep pace with such high rates of sea level rise. In addition, storm surge impacts at this higher sea level would be significant. The Southeast Region as a whole is generally susceptible to inundation and flooding due to its low-lying nature in many places, particularly in Cape Hatteras and Cape Lookout National Seashores. Our sea level rise maps (Appendix A) highlight how much all of these park units may be affected.

These estimates do not include the latest data on changing land levels. The IPCC included estimates of global isostatic adjustment (Equation 1) in their predictions, but those do not include changes in land level due to other factors, such as earthquakes and groundwater extraction. Comment 9 We expect the latest, state-of-the-art land level estimates to be released by NASA in 2017. In the meantime, we can roughly estimate relative sea level change for a small number of parks based on current rates of subsidence gathered from nearby long-term tide gauge data. We project Jean Lafitte National Historical Park and Preserve to have the greatest relative sea level increase based on the current rate of land movement. Our sea level projections agree with current sea level trends in showing that the southeast Alaska region is experiencing the least amount of sea level rise of anywhere in the National Park System.

Sallenger et al. (2012) discussed how changes in Atlantic Ocean temperatures and salinity (resulting from changes in circulation) could lead to changes in sea level that could create a 1000-km long "hotspot" along the North Atlantic coast from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. We estimate that almost all of the coastal park units in this area would be flooded under these conditions.

It is unknown exactly to what degree future storm surge will affect the Alaskan park units. Accurate long-term (>30 years) storm surge data do not exist for the Alaska region. Even if such data did exist, it would be not be analogous to future conditions in the region because sea ice that had previously protected the shores for many of the western Alaska park units melts to reveal an easily erodible coastline (Frey et al. 2015). The warming of ocean waters in the Gulf of Alaska and Pacific Ocean could also make it more conducive for more storms like Typhoon Nuri to travel north without losing energy as under historic conditions.

The Pacific West Region shows high variability among parks. War in The Pacific National Historical Park in Guam ranks highest in projected sea level rise among units in the Pacific West Region. The large area of the region partly explains the relatively high standard deviation in results for the region. The tectonically complex setting of many of the region's parks also complicates future sea level estimates. Changes in land movement are somewhat gradual nationwide in comparison to Alaska and the Pacific West Region, especially where earthquakes can rapidly change the position of the land relative to the sea.

Island park units in general are particularly exposed to the impacts of sea level change and storm surge. Many of the barrier island parks, such as Fire Island National Seashore, Assateague Island National Seashore, Palo Alto Battlefield National Historical Park, Gulf Islands National Seashore, and Cape Hatteras National Seashore, are all projected to experience sea level rise of over 0.69 m by 2100 (RCP8.5). This sea level rise, combined with storm surge, could be especially difficult for isolated island park units, such as the Caribbean park units, the National Park of American Samoa, and War in the Pacific National Historical Park, where access to aid in the event of a natural disaster may not be immediately available.

Conclusions

This report presents projections of sea level change (118 parks) and storm surge (79 parks) in coastal park units administered by the National Park Service. Sea level change and storm surge vary geographically, resulting in locally-specific challenges for adaptation and management. It is important to acknowledge that sea level change will affect some parts of Alaska differently than coastal parks in the rest of the country. Northwest Alaska can expect relative sea levels to increase over time; while in southeast Alaska, relative sea levels may continue to decrease over the first part of this century, followed by an increase in relative sea level towards the end of the century.

This project is an important first step in assessing how changes in sea level and storm surge may affect national park units. Using sea level rise and storm surge information, parks can begin to plan for effects on resources, facilities, access, and other areas of management. While methods used here are not appropriate for combining the separate sea level rise and storm surge results, parks should be aware of the potential for synergistic effects of sea level rise and storm surge causing impacts larger than either may cause individually. It is clear that more research can be done on these complex issues to assess how these changes may affect parks and regions. These data can inform future projects related to both natural and cultural resources as well as the planning and management of infrastructure.

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Appendix A

Links to Data Sources

Maps were created for this project using NOAA DEM data. For further information regarding our methods refer to methods section on page 3.

Digital versions of our sea level rise maps will be available at www.irma.gov

Storm surge maps are also available on www.irma.gov and www.flickr.com/photos/125040673@N03/albums/with/72157645643578558

Appendix B

Frequently Asked Questions

Q. How were the parks in this project selected?

A. Parks were selected after consultation with regional managers. Regional managers were given a list of parks that authors considered to be vulnerable to sea level change and/or storm surge. This list was vetted by regional managers and their staff who added or subtracted park names based on their knowledge of the region.

Q. Who originally identified which park units should be used in this study?

A. The initial list of parks was approved by the following regional managers: Northeast Region, Amanda Babson (signed 11/27/13); Southeast Region, Shawn Benge (signed 11/14/13); National Capital Region, Perry Wheelock (signed 3/17/14); Intermountain Region, Patrick Malone signed on behalf of Tammy Whittington (signed 11/13/13); Pacific West Region, Jay Goldsmith (signed 11/26/13); Alaska Region, Robert Winfree (signed 11/15/13).

Q. What's the timeline of this project?

A. This is the culmination of a three-year project that was proposed in February 2012. Initial Fiscal year of funding was 2013.

Q. In what instance did you use data from Tebaldi et al. (2012)?

A. NOAA's Sea Lake and Overland Surge from Hurricanes (SLOSH) model does not include storm surge predictions for all of the parks used in this study. We used data from Tebaldi et al. (2012) where reasonable to provide data for park units in California, Oregon, Washington, and southern Alaska. The following parks used Tebaldi et al. (2012) data: Cabrillo National Monument, Channel Islands National Park, Ebey's Landing National Historical Reserve, Fort Point National Historic Site, Fort Vancouver National Historic Site, Golden Gate National Recreation Area, Klondike Gold Rush National Historical Park, Lewis and Clark National Historical Park, Olympic National Park, Port Chicago Naval Magazine National Scenic Trail, Point Reyes National Seashore, Redwood National Park, Rosie the Riveter WWII Home Front National Historical Park, San Francisco Maritime National Historical Park, San Juan Island National Historical Park, and Santa Monica Mountains National Recreation Area.

Q. Why don't all of the parks have storm surge maps?

A. Unfortunately some parks do not have enough data to complete a storm surge map. These were parks that were not modeled by NOAA's SLOSH MOM model or near any of the tide gauges used by Tebaldi et al. (2012). These parks are: Aniakchak Preserve, Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Glacier Bay National Park and Preserve, Katmai National Park, Kenai Fjords National Park, Lake Clark National Park, Sitka National Historical Park, War in the Pacific National Historical Park, and Wrangell – St. Elias National Park and Preserve.

Q. My park only has storm surge maps covering a few Saffir-Simpson categories. Why is that?

A. Some parks, particularly those in the Northeast Region, were not modeled by NOAA for the full range of Saffir-Simpson storm scenarios. This is because it is considered very unlikely that a Saffir-Simpson category 4 or 5 hurricane would be able to sustain itself into the northern latitudes of that region.

Q. Why are the storm surge maps in NAVD88?

A. That is the default datum for SLOSH data. This was a decision made by NOAA.

Q. What are the effects of NAVD88 on sea level and storm surge projections for some parks?

A. The North American Vertical Datum of 1988 (NAVD88) is a datum that is commonly used in North America to refer to the "elevation" of a location. It uses a fixed value for the height of North America's mean sea level. While this is a popular datum for mapping, it has the limitation that it is based on the observed mean sea level for a single location: Rimouski, Canada. As you move further away from this location you can expect actual sea level to differ from the mean sea level at Rimouski. For locations such as California this can result in a significant difference between observed mean sea level and NAVD88. Your natural resource or GIS specialist will likely have further information about your specific location. Alternatively you can look up the differences in your region by checking the datum information for your nearest tide gauge station: https://tidesandcurrents.noaa.gov/stations.html?type=Datums

Q. Which sea level change or storm surge scenario would you recommend I use?

A. All parks are different, as are all projects. Your choice of scenario may depend on many different factors including risk tolerance and expected time horizon of the project. The NPS has not yet released any guidance on which climate change scenarios to use for planning. We would recommend you contact the appropriate project lead, natural or cultural resource manager, or someone from the Climate Change Response Program for further guidance depending on your situation.

Q. How accurate are these numbers?

A. The accuracy of these data varies depending on the data source. SLOSH data has +/- 20% accuracy, although this is discussed in greater detail by Glahn et al. (2009). Further information about storm surge data generated by Tebaldi et al. can be found in Tebaladi et al. (2012). IPCC global sea level rise projections range between 0.26 m (RCP2.6 minimum likely range) and 0.82 m (RCP8.5 maximum likely range) by 2100. The standard error of the IPCC is explained in greater detail in the Chapter 13 supplementary material in AR5 (IPCC 2013). An explanation on the horizontal and vertical accuracy of the digital elevation models used for mapping can be found in the metadata that accompanies the map data on www.irma.gov. DEM data were required to have a ≤18.5 cm root mean square error vertical accuracy before they were converted to MHHW. An exception to this was in Alaska where these data were not available.

Q. We have had higher/lower storm surge numbers in the past. Why?

A. The numbers given here are meant to represent a maximum based on a typical storm surge category. As described above, there is likely to be some deviation around that number. Certain periods are also likely to result in higher than average storm surges. For example, periodic changes in regional water temperatures (caused by phenomena such as El Niño and La Niña) will impact water levels that will add to any storm surge. Likewise, changes in the North Atlantic Oscillation and Pacific Decadal Oscillation will also affect ocean conditions. This must be taken into account when using these numbers. All of these factors vary temporally and geographically, so contact your natural resource manager if you are unsure how this could impact your particular park unit.

Q. What other factors should I consider when looking at these numbers?

A. These projections do not include the impact of all man-made structures, such as flood barriers, levees, and dams. They also do not take into account how smaller features, such as dune systems or vegetation changes could impact coastal flooding. There are many meso- and micro-scale factors that need to be taken into account such as differences in topography, the presence/absence of any wetlands etc. It should also be expected that as sea levels change, areas of the shoreline will change accordingly, particularly due to erosion and accretion.

Q. Why don't you recommend that I add storm surge numbers on top of the sea level change numbers?

A. Higher sea level and permanent inundation will change the way waves propagate within a basin. Sea level change is expected to have a significant impact on the geomorphology of the coastline. Changing water levels will lead to areas of greater erosion in some areas as well as increasing accretion in other places. As sea level changes, the fluid dynamics of a particular region will also change. For example, tidal distance will change as water levels rise, which will alter the spatial extent of a storm surge as well as potentially impacting wave height. This is not something NOAA takes into account in their SLOSH model.

Q. Where can I get more information about the sea level models used in this study?

A. https://www.ipcc.ch/report/ar5/wg1/

Q. Where can I get more information about the NOAA SLOSH model?

A. http://www.nhc.noaa.gov/surge/slosh.php

Q. So, based on your maps, can I assume that my location will stay dry in the future?

A. No. As explained above, these numbers are accurate within a certain range. Also, these maps are based on "bathtub" models where water is simulated as rising over a static surface. In reality, your coastline will change in response to storms and other coastal dynamics. These numbers are intended for guidance only.

Q. Why do you use the period 1986–2005 as a baseline for your sea level rise projections?

A. We are following the standard approach used by the IPCC, USACE, and much of the academic literature. If you would like your estimate to start from a specific year you can do one of two things: 1) subtract the observed rate of sea level rise since 1992 for your location, or 2) contact park, region, or Climate Change Response Program staff for assistance. It may be possible to interpolate projections further to estimate the amount of rise the models estimate to have taken place between the baseline and whichever year you choose. We must caution that if you follow option 1 you will be introducing some inaccuracy to sea level projections, especially if you use data from a tide gauge that is not close to your location.

Q. The SLOSH/IPCC projections seem lower/higher than X source I've found. Why is that?

A. Projections can vary depending on a number of factors such as choice of model, approach, or the age of the study. We would recommend that you speak to a climate specialist when choosing sources.

Q. What are other impacts from sea level rise that parks should consider?

A. Impacts from sea level rise could include, but are not limited to, increased erosion, damaged cultural resources, damage to above and below ground infrastructure, difficulty accessing inundated infrastructure, increased groundwater intrusion, altered groundwater salinity, diminished space for recreational activities (possibly leading to conflict between different recreational users), and the complete loss or migration of certain coastal ecosystems. For more information on the topic, please see the Coastal Adaptation Strategies Handbook at: http://www.nps.gov/subjects/climatechange/coastalhandbook.htm

Appendix C

Waysides

The following pages show the final designs for waysides that were installed in parks as part of the funding for this project. Gulf Islands National Seashore received two waysides that were received in 2015. Jean Lafitte National Historical Park and Preserve and Fire Island National Seashores waysides were installed in 2016.

See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

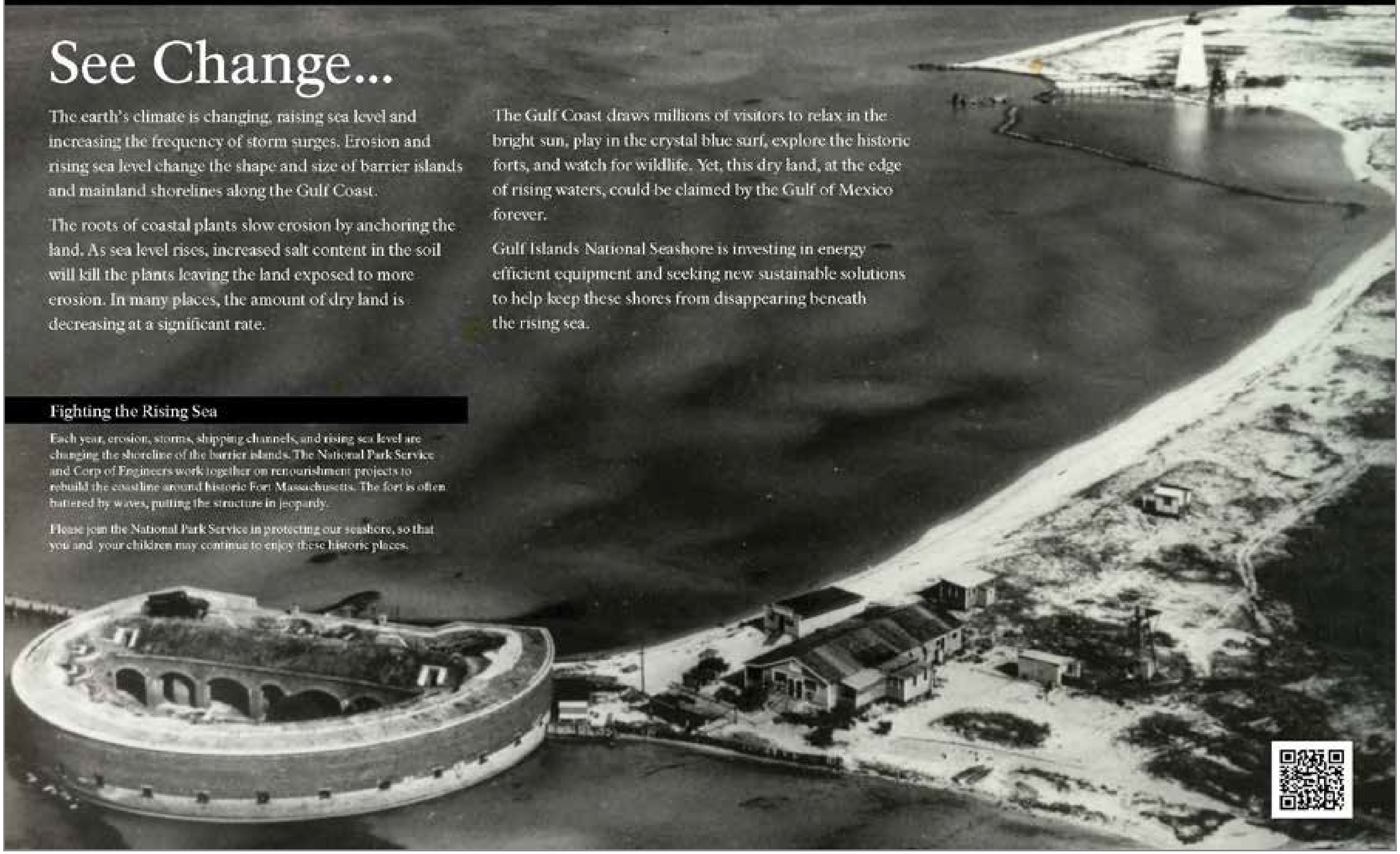
The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the snow white beaches, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Each year, erosion, storms, coastal development, and rising sea level shrink the nesting beach habitat of sea turtles. When a female sea turtle is ready to lay her eggs, she will try to return to the same sandy beach every two to three years. Will her nesting home still be here?

Please join the National Park Service in protecting these beaches, so that you and your children may watch her hatchlings return to lay their eggs.

The road at Fort Pickens gets overwashed with storm waves. As the sea level rises, these events are becoming more common



See Change...

The earth's climate is changing, raising sea level and increasing the frequency of storm surges. Erosion and rising sea level change the shape and size of barrier islands and mainland shorelines along the Gulf Coast.

The roots of coastal plants slow erosion by anchoring the land. As sea level rises, increased salt content in the soil will kill the plants leaving the land exposed to more erosion. In many places, the amount of dry land is decreasing at a significant rate.

The Gulf Coast draws millions of visitors to relax in the bright sun, play in the crystal blue surf, explore the historic forts, and watch for wildlife. Yet, this dry land, at the edge of rising waters, could be claimed by the Gulf of Mexico forever.

Gulf Islands National Seashore is investing in energy efficient equipment and seeking new sustainable solutions to help keep these shores from disappearing beneath the rising sea.

Fighting the Rising Sea

Each year, erosion, storms, shipping channels, and rising sea level are changing the shoreline of the barrier islands. The National Park Service and Corp of Engineers work together on renourishment projects to rebuild the coastline around historic Fort Massachusetts. The fort is often battered by waves, putting the structure in jeopardy.

Please join the National Park Service in protecting our seashore, so that you and your children may continue to enjoy these historic places.

Sinking Land, Rising Water

This is the Barataria Basin, built of soil washed to this area by the Mississippi River. This soil is still compacting and sinking, a process called subsidence. Most of the Barataria Preserve is less than two feet above sea level, and its subsidence rate is nearly half an inch a year.

Meanwhile, glaciers and polar ice sheets are melting and our warming climate is heating oceans everywhere, making their waters expand just like water does when you heat it on the stove. Everywhere on the planet, the oceans are a little higher every day.

The combination of the Barataria Basin's sinking land and global sea level rise means that the ocean is creeping in faster here than almost anywhere else in North America.

- Floods are becoming more frequent and lasting longer
- Coastal wetlands are disappearing as land sinks and water rises
- Less land is available to buffer Gulf of Mexico storms
- Storm and flooding threats to homes, communities, and infrastructure like highways, ports, and energy facilities are increasing
- Salt water from the Gulf is moving into freshwater wetlands, killing the plants that hold the land together
- Death of plants, animals, and microbes that cannot tolerate increased flooding or salt water

The photo shows two feet of flooding on Barataria Boulevard after Hurricane Isaac in August 2012. The map shows predicted consequences of 18 inches of sea level rise in the preserve; blue areas would be flooded and brown areas would remain land.


Fire Island National Seashore
National Park Service
U.S. Department of the Interior
See Change In A Changing Climate
Natural landscape change can be nearly imperceptible on a barrier island, as the wind and waves gradually shape the shoreline, beach, and dunes. Natural changes can also be obvious and happen quickly during storms like hurricanes and nor'easters. Looking ahead, storms will have a greater impact on Fire Island due to climate change.
When we burn fossil fuels, carbon dioxide is released into the atmosphere and acts like a heat trapping blanket around our planet. Heat that would normally escape from the atmosphere is retained, warming the Earth, and changing climate patterns. As ocean waters warm and ice on land melts, sea level rises and impacts Fire Island and coastlines all over the world. The future of this barrier island is in jeopardy due to these human-induced climate change effects.
Fire Island protects mainland Long Island against storms and is a stunning setting for recreation, education, and inspiration. It also provides critical habitat for plants and wildlife. We must do what we can to protect this special place. By using renewable energy sources and reducing our dependence on fossil fuels, we can take steps today to preserve barrier island systems and processes, and help build natural resilience to future storms and sea-level rise.
Storm Stories
On October 29, 2012, Hurricane Sandy struck Fire Island National Seashore and changed the lay of the land. During the storm high water and large waves scoured sand from the beach and dunes, moved sand across the width of the island, and carved the breach, pictured here, through the barrier island. The storm was the strongest in recorded history to make landfall in this region.
To learn more about how climate change is impacting the Seashore, please visit
www.nps.gov/fiis/learn/climatechange.htm
Background photo credit: C. Flagg

Appendix D

Data Tables

Table D1. The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region	Acadia National Park	Bar Harbor, ME (8413320)	N	60	0.750
	Assateague Island National Seashore‡	Lewes, DE (8557380)	N	88	1.660
	Boston Harbor Islands National Recreation Area	Boston, MA (8443970)	N	86	0.840
	Boston National Historical Park	Boston, MA (8443970)	N	86	0.840
	Cape Cod National Seashore	Woods Hole, MA (8447930)	N	75	0.970
	Castle Clinton National Monument	New York, The Battery, NY (8518750)	N	151	1.220
	Colonial National Historical Park	Sewells Point, VA (8638610)	N	80	2.610
	Edgar Allen Poe National Historic Site	Philadelphia, PA (8545240)	N	107	1.060
	Federal Hall National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	Fire Island National Seashore	Montauk, NY (8510560)	N	60	1.230
	Fort McHenry National Monument and Historic Shrine	Baltimore, MD (8574680)	N	105	1.330

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

‡It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)[†]	Rate of Subsidence (mm/y)
Northeast Region (continued)	Fort Monroe National Monument[‡]	Sewells Point, VA (8638610)	N	80	2.610
	Gateway National Recreation Area*[‡]	Sandy Hook, NJ (8531680)	N	75	2.270
	General Grant National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	George Washington Birthplace National Monument[‡]	Solomons Island, MD (8577330)	N	70	1.830
	Governors Island National Monument[‡]	New York, The Battery, NY (8518750)	N	151	1.220
	Hamilton Grange National Memorial	New York, The Battery, NY (8518750)	N	151	1.220
	Harriet Tubman Underground Railroad National Monument	Cambridge, MD (8571892)	N	64	1.900
	Independence National Historical Park	Philadelphia, PA (8545240)	N	107	1.060
	New Bedford Whaling National Historical Park	Woods Hole, MA (8447930)	N	75	0.970
	Petersburg National Battlefield[‡]	Sewells Point, VA (8638610)	N	80	2.610
	Roger Williams National Memorial	Providence, RI (8454000)	N	69	0.300

[†]Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Northeast Region (continued)	Sagamore Hill National Historic Site	Kings Point, NY (8516945)	N	76	0.670
	Saint Croix Island International Historic Site‡	Eastport, ME (8410140)	N	78	0.350
	Salem Maritime National Historic Site	Boston, MA (8443970)	N	86	0.840
	Saugus Iron Works National Historic Site	Boston, MA (8443970)	N	86	0.840
	Statue of Liberty National Monument‡	New York, The Battery, NY (8518750)	N	151	1.220
	Thaddeus Kosciuszko National Memorial	Philadelphia, PA (8545240)	N	107	1.060
	Theodore Roosevelt Birthplace National Historic Site	New York, The Battery, NY (8518750)	N	151	1.220
Southeast Region	Big Cypress National Preserve	Naples, FL (8725110)	N	42	0.270
	Biscayne National Park‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
	Buck Island Reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Canaveral National Seashore	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Cape Hatteras National Seashore*‡	Beaufort, NC (8656483)	N	54	0.790
	Cape Lookout National Seashore	Beaufort, NC (8656483)	N	54	0.790
	Castillo De San Marcos National Monument‡	Mayport, FL (8720218)	N	79	0.590
	Charles Pinckney National Historic Site	Charleston, SC (8665530)	N	86	1.240
	Christiansted National Historic Site‡	San Juan, Puerto Rico (9755371)	N	45	-0.202
	Cumberland Island National Seashore‡	Fernandina Beach, FL (8720030)	N	110	0.600
	De Soto National Memorial	St. Petersburg, FL (8726520)	N	60	0.920
	Dry Tortugas National Park‡	Key West, FL (8724580)	N	94	0.500
	Everglades National Park*‡	Miami Beach, FL (Inactive – 8723170)	N	51	0.690
	Fort Caroline National Memorial‡	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Frederica National Monument‡	Fernandina Beach, FL (8720030)	N	110	0.600
	Fort Matanzas National Monument‡	Daytona Beach Shores, FL (Inactive – 8721120)	N	59	0.620

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Fort Pulaski National Monument	Fort Pulaski, GA (8670870)	Y	72	1.360
	Fort Raleigh National Historic Site‡	Beaufort, NC (8656483)	N	54	0.790
	Fort Sumter National Monument‡	Charleston, SC (8665530)	N	86	1.240
	Gulf Islands National Seashore (Alabama section)*‡	Dauphin Island, AL (8735180)	N	41	1.220
	Gulf Islands National Seashore (Florida section)*‡	Pensacola, FL (8729840)	N	84	0.330
	Jean Lafitte National Historical Park and Preserve‡	Grand Isle, LA (8761724)	N	60	7.600
	Moores Creek National Battlefield‡	Wilmington, NC (8658120)	N	72	0.430
	New Orleans Jazz National Historical Park‡	Grand Isle, LA (8761724)	N	60	7.600
	Salt River Bay National Historical Park and Ecological Preserve‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	San Juan National Historic Site	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Timucuan Ecological and Historic Preserve‡	Fernandina Beach, FL (8720030)	N	110	0.600

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
Southeast Region (continued)	Virgin Islands Coral reef National Monument‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Virgin Islands National Park‡	San Juan, Puerto Rico (9755371)	N	45	-0.020
	Wright Brothers National Memorial‡	Sewells Point, VA (8638610)	N	80	2.610
National Capital Region	Anacostia Park	Washington, DC (8594900)	N	83	1.340
	Chesapeake and Ohio Canal National Historical Park	Washington, DC (8594900)	N	83	1.340
	Constitution Gardens	Washington, DC (8594900)	N	83	1.340
	Fort Washington Park	Washington, DC (8594900)	N	83	1.340
	George Washington Memorial Parkway	Washington, DC (8594900)	N	83	1.340
	Harpers Ferry National Historical Park	Washington, DC (8594900)	N	83	1.340
	Korean War Veterans Memorial	Washington, DC (8594900)	N	83	1.340
	Lincoln Memorial	Washington, DC (8594900)	N	83	1.340
	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Washington, DC (8594900)	N	83	1.340
	Martin Luther King Jr. Memorial	Washington, DC (8594900)	N	83	1.340

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Table D1 (continued). The nearest long-term tide gauge to each of the 118 national park service units used in this report.

Region	Park Unit	Nearest Tide Gauge	Is Tide Gauge Within The Park Boundary?	Length of Record Used (y)†	Rate of Subsidence (mm/y)
National Capital Region (continued)	National Mall	Washington, DC (8594900)	N	83	1.340
	National Mall and Memorial Parks	Washington, DC (8594900)	N	83	1.340
	National World War II Memorial	Washington, DC (8594900)	N	83	1.340
	Piscataway Park	Washington, DC (8594900)	N	83	1.340
	Potomac Heritage National Scenic Trail	Washington, DC (8594900)	N	83	1.340
	President's Park (White House)	Washington, DC (8594900)	N	83	1.340
	Rock Creek Park	Washington, DC (8594900)	N	83	1.340
	Theodore Roosevelt Island Park	Washington, DC (8594900)	N	83	1.340
	Thomas Jefferson Memorial	Washington, DC (8594900)	N	83	1.340
	Vietnam Veterans Memorial	Washington, DC (8594900)	N	83	1.340
	Washington Monument	Washington, DC (8594900)	N	83	1.340
Intermountain Region	Big Thicket National Preserve‡	Sabine Pass, TX (8770570)	N	49	3.850
	Palo Alto Battlefield National Historical Park‡	Port Isabel, TX (8779770)	N	63	2.160
	Padre Island National Seashore*	Padre Island, TX (8779750)	N	49	1.780

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Pacific West Region	American Memorial Park[‡]	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
	Cabrillo National Monument	San Diego, CA (9410170)	N	101	0.370
	Channel Islands National Park[‡]	Santa Monica, CA (9410840)	N	74	-0.280
	Ebey's Landing National Historical Reserve[‡]	Friday Harbor, WA (9449880)	N	73	-0.580
	Fort Point National Historic Site	San Francisco, CA (9414290)	Y	110	0.360
	Fort Vancouver National Historic Site[‡]	Astoria, OR (9439040)	N	82	-2.100
	Golden Gate National Recreation Area	San Francisco, CA (9414290)	N	110	0.360
	Haleakala National Park[*‡]	Kahului, HI (1615680)	N	60	0.510
	Hawaii Volcanoes National Park[*‡]	Hilo, HI (1617760)	N	80	1.470
	Kaloko-Honokohau National Historical Park[‡]	Hilo, HI (1617760)	N	80	1.470
	Lewis and Clark National Historical Park	Astoria, OR (9439040)	N	82	-2.100
	National Park of American Samoa	Pago Pago, American Samoa (1770000)	N	59	0.370
	Olympic National Park[*‡]	Seattle, WA (9447130)	N	109	0.540

[†]Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

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Pacific West Region (continued)	Point Reyes National Seashore‡	San Francisco, CA (9414290)	N	110	0.360
	Port Chicago Naval Magazine National Memorial‡	Alameda, CA (9414750)	N	68	-0.780
	Pu'uhonua O Honaunau National Historical Park*‡	Hilo, HI (1617760)	N	80	1.470
	Puukohola Heiau National Historic Site*‡	Hilo, HI (1617760)	N	80	1.470
	Redwood National and State Parks	Crescent City, CA (9419750)	N	74	-2.380
	Rosie the Riveter WWII Home Front National Historical Park*	Alameda, CA (9414750)	N	68	-0.780
	San Francisco Maritime National Historical Park	San Francisco, CA (9414290)	N	110	0.360
	Santa Monica Mountains National Recreation Area	Santa Monica, CA (9410840)	N	74	-0.280
	War in the Pacific National Historical Park‡	Marianas Islands, Guam (Inactive – 1630000)	N	46	-2.750
	World War II Valor in the Pacific National Monument‡	Honolulu, HI (1612340)	N	102	-0.180
Alaska Region	Aniakchak Preserve*‡	Unalaska, AK (9462620)	N	50	-7.250
	Bering Land Bridge National Preserve‡	No data	No data	No data	No data

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Alaska Region (continued)	Cape Krusenstern National Monument‡	No data	No data	No data	No data
	Glacier Bay National Park*‡	Juneau, AK (9452210)	N	71	-14.620
	Glacier Bay Preserve*‡	Juneau, AK (9452210)	N	71	-14.620
	Katmai National Park‡	Seldovia, AK (9455500)	N	43	-11.420
	Kenai Fjords National Park‡	Seward, AK (9455090)	N	43	-3.820
	Klondike Gold Rush National Historical Park‡	Skagway, AK (9452400)	N	63	-18.960
	Lake Clark National Park‡	Seldovia, AK (9455500)	N	43	-11.420
	Sitka National Historical Park‡	Sitka, AK (9451600)	N	83	-3.710
	Wrangell – St. Elias National Park‡	Cordova, AK (9454050)	N	43	3.450
	Wrangell – St. Elias National Preserve‡	Cordova, AK (9454050)	N	43	3.450

†Number of years used by the USACE to calculate sea level change (source: http://www.corpsclimate.us/ccaceslcurves(superseded).cfm)

‡It is not recommended that you use this tide gauge data to determine land level for this park. The boundary is located either too far away or on a different land mass to where the nearest tide gauge is, which increases the inaccuracy of this data. It is strongly recommended that you wait for the forthcoming NASA report on land level (Nerem in prep).

*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table D2. Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region	Acadia National Park	2030	0.08	0.09	0.09	0.1
		2050	0.14	0.16	0.16	0.19
		2100	0.28	0.36	0.39	0.54
	Assateague Island National Seashore[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Boston Harbor Islands National Recreation Area	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Boston National Historical Park	2030	0.11[‡]	0.11	0.11[‡]	0.11
		2050	0.19[‡]	0.2	0.20[‡]	0.22
		2100	0.37[‡]	0.45	0.50[‡]	0.62
	Cape Cod National Seashore[§]	2030	0.13	0.15	0.13	0.15
		2050	0.23	0.27	0.23	0.29
		2100	0.45	0.51	0.57	0.69
	Castle Clinton National Monument*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Colonial National Historical Park	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Edgar Allen Poe National Historic Site*	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Federal Hall National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Fire Island National Seashore[§]	2030	0.14	0.14	0.14	0.14
		2050	0.25	0.26	0.25	0.27
		2100	0.5	0.58	0.62	0.76
	Fort McHenry National Monument and Historic Shrine	2030	0.16[‡]	0.15	0.15[‡]	0.14
		2050	0.27[‡]	0.27	0.27[‡]	0.28
		2100	0.54[‡]	0.62	0.68[‡]	0.79
	Fort Monroe National Monument	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Gateway National Recreation Area	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	General Grant National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	George Washington Birthplace National Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Governors Island National Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Hamilton Grange National Memorial*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Harriet Tubman Underground Railroad National Monument	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Independence National Historical Park*	2030	0.16‡	0.15	0.15‡	0.14
		2050	0.27‡	0.27	0.27‡	0.28
		2100	0.54‡	0.62	0.68‡	0.79
	New Bedford Whaling National Historical Park*	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Petersburg National Battlefield*	2030	0.16	0.15	0.15	0.15
		2050	0.27	0.28	0.27	0.29
		2100	0.55	0.64	0.67	0.81
	Roger Williams National Memorial*	2030	0.13	0.13	0.12	0.13
		2050	0.22	0.23	0.22	0.25
		2100	0.45	0.53	0.55	0.7
	Sagamore Hill National Historic Site	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Saint Croix Island International Historic Site	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.26	0.26	0.27
		2100	0.52	0.59	0.64	0.76

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Northeast Region (continued)	Salem Maritime National Historic Site	2030	0.11‡	0.11	0.11‡	0.11
		2050	0.19‡	0.2	0.20‡	0.22
		2100	0.37‡	0.45	0.50‡	0.62
	Saugus Iron Works National Historic Site	2030	0.11‡	0.11	0.11‡	0.11
		2050	0.19‡	0.2	0.20‡	0.22
		2100	0.37‡	0.45	0.50‡	0.62
	Statue of Liberty National Monument	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
	Thaddeus Kosciuszko National Memorial*	2030	0.16‡	0.15	0.15‡	0.14
		2050	0.27‡	0.27	0.27‡	0.28
		2100	0.54‡	0.62	0.68‡	0.79
	Theodore Roosevelt Birthplace National Historic Site*	2030	0.15	0.14	0.14	0.14
		2050	0.26	0.25	0.25	0.27
		2100	0.52	0.58	0.62	0.77
Southeast Region	Big Cypress National Preserve§	2030	0.13	0.13	0.12	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.46	0.54	0.55	0.69

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Biscayne National Park	2030	0.14‡	0.13	0.12	0.12
		2050	0.24‡	0.23	0.21	0.24
		2100	0.47‡	0.53	0.53	0.68
	Buck Island Reef National Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Canaveral National Seashore	2030	0.14‡	0.13	0.13‡	0.12
		2050	0.25‡	0.24	0.24‡	0.24
		2100	0.50‡	0.54	0.59‡	0.68
	Cape Hatteras National Seashore	2030	0.15‡	0.15	0.15	0.14
		2050	0.26‡	0.28	0.28	0.28
		2100	0.53‡	0.63	0.68	0.79
	Cape Lookout National Seashore§	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	Castillo De San Marcos National Monument	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Charles Pinckney National Historic Site*	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Christiansted National Historic Site	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	Cumberland Island National Seashore	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	De Soto National Memorial	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.56	0.57	0.72
	Dry Tortugas National Park[§]	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.24
		2100	0.47	0.54	0.56	0.69
	Everglades National Park[§]	2030	0.13	0.13	0.12	0.17
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.54	0.68

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Fort Caroline National Memorial	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Frederica National Monument	2030	0.14	0.13	0.12	0.12
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.54	0.54	0.69
	Fort Matanzas National Monument	2030	0.14	0.13	0.13	0.13
		2050	0.23	0.24	0.22	0.24
		2100	0.47	0.56	0.56	0.7
	Fort Pulaski National Monument[§]	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72
	Fort Raleigh National Historic Site	2030	0.15[‡]	0.15	0.15	0.14
		2050	0.27[‡]	0.28	0.28	0.28
		2100	0.53[‡]	0.63	0.68	0.79
	Fort Sumter National Monument	2030	0.14	0.14	0.13	0.13
		2050	0.25	0.25	0.24	0.25
		2100	0.49	0.57	0.59	0.72

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Gulf Islands National Seashore§	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.48	0.55	0.57	0.7
	Jean Lafitte National Historical Park and Preserve†§	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Moores Creek National Battlefield*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.27
		2100	0.53	0.61	0.65	0.76
	New Orleans Jazz National Historical Park*	2030	0.14	0.13	0.13	0.12
		2050	0.24	0.23	0.23	0.24
		2100	0.48	0.54	0.56	0.68
	Salt River Bay National Historic Park and Ecological Preserve	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.23
		2100	0.44	0.5	0.51	0.64
	San Juan National Historic Site	2030	0.12	0.12	0.11	0.12
		2050	0.22	0.22	0.2	0.22
		2100	0.43	0.49	0.5	0.64

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

‡No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Southeast Region (continued)	Timucuan Ecological and Historic Preserve	2030	0.14	0.13	0.13	0.13
		2050	0.24	0.24	0.23	0.25
		2100	0.47	0.56	0.56	0.7
	Virgin Islands Coral Reef National Monument	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	Virgin Islands National Park[§]	2030	0.13	0.12	0.11	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.51	0.64
	Wright Brothers National Memorial*	2030	0.15[‡]	0.16	0.16	0.15
		2050	0.27[‡]	0.29	0.28	0.29
		2100	0.53[‡]	0.65	0.7	0.82
National Capital Region	Anacostia Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Chesapeake & Ohio Canal National Historical Park[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Constitution Gardens*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Fort Washington Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	George Washington Memorial Parkway[§]	2030	0.15[‡]	0.15	0.15[‡]	0.14
		2050	0.26[‡]	0.27	0.26[‡]	0.28
		2100	0.53[‡]	0.62	0.66[‡]	0.79
	Harpers Ferry National Historical Park*[§]	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.62	0.66	0.79
	Korean War Veterans Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Lincoln Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Martin Luther King Jr. Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National Mall*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National Mall & Memorial Parks*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	National World War II Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Piscataway Park*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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§Parks that cover two or more cells. Data were averaged between these parks based on percentage of shoreline in each cell. Adjacent cells were used in cases where boundaries crossed into null data cells.

Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Potomac Heritage National Scenic Trail	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	President's Park (White House)*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Rock Creek Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Theodore Roosevelt Island Park	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Thomas Jefferson Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
	Vietnam Veterans Memorial*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
National Capital Region (continued)	Washington Monument*	2030	0.15	0.15	0.15	0.14
		2050	0.26	0.27	0.26	0.28
		2100	0.53	0.63	0.66	0.8
Intermountain Region	Big Thicket National Preserve*	2030	0.14‡	0.12	0.12‡	0.12
		2050	0.23‡	0.23	0.22‡	0.23
		2100	0.47‡	0.51	0.55‡	0.66
	Palo Alto Battlefield National Historical Park*§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
	Padre Island National Seashore§	2030	0.13	0.13	0.13	0.12
		2050	0.23	0.23	0.22	0.24
		2100	0.46	0.53	0.56	0.69
Pacific West Region	American Memorial Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	Cabrillo National Monument	2030	0.1	0.1	0.09	0.1
		2050	0.17	0.17	0.17	0.19
		2100	0.35	0.4	0.41	0.53

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Channel Islands National Park§	2030	0.11	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.39	0.44	0.46	0.57
	Ebey's Landing National Historical Reserve	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Fort Point National Historic Site	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Fort Vancouver National Historic Site*	2030	0.12	0.11	0.11	0.1
		2050	0.21	0.2	0.19	0.19
		2100	0.42	0.45	0.47	0.55
	Golden Gate National Recreation Area§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.18	0.17	0.19
		2100	0.37	0.42	0.43	0.54
	Haleakala National Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Hawaii Volcanoes National Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Kalaupapa National Historical Park§	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.66
	Kaloko-Honokohau National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Lewis and Clark National Historical Park§	2030	0.12	0.1	0.1	0.1
		2050	0.2	0.19	0.18	0.19
		2100	0.4	0.44	0.46	0.53
	National Park of American Samoa	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.65
	Olympic National Park§	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	Point Reyes National Seashore§	2030	0.11	0.1	0.1	0.1
		2050	0.19	0.19	0.18	0.19
		2100	0.38	0.43	0.45	0.55
	Port Chicago Naval Magazine National Memorial	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	Pu’uhonua O Honaunau National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.5	0.52	0.67
	Puukohola Heiau National Historic Site	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.24
		2100	0.44	0.51	0.52	0.67
	Redwood National and State Parks	2030	0.12	0.11	0.1	0.1
		2050	0.2	0.19	0.18	0.2
		2100	0.4	0.44	0.46	0.56
	Rosie the Riveter WWII Home Front National Historical Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53

*Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

†Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Pacific West Region (continued)	San Francisco Maritime National Historical Park	2030	0.11	0.1	0.1	0.1
		2050	0.18	0.18	0.17	0.19
		2100	0.37	0.41	0.43	0.53
	San Juan Island National Historical Park	2030	0.1	0.09	0.09	0.08
		2050	0.17	0.16	0.16	0.16
		2100	0.34	0.37	0.39	0.46
	Santa Monica Mountains National Recreation Area[§]	2030	0.12	0.11	0.1	0.11
		2050	0.2	0.2	0.19	0.2
		2100	0.4	0.45	0.46	0.58
	War in the Pacific National Historical Park	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.22	0.24
		2100	0.44	0.51	0.54	0.68
	World War II Valor in the Pacific National Monument[§]	2030	0.13	0.12	0.12	0.12
		2050	0.22	0.22	0.21	0.23
		2100	0.44	0.5	0.52	0.67
Alaska Region	Aniakchak Preserve[§]	2030	0.09[‡]	0.09	0.09	0.09
		2050	0.15[‡]	0.17	0.16	0.18
		2100	0.31[‡]	0.38	0.4	0.51

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

[‡]No data was available for this scenario. Data from an adjacent cell was used in lieu.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Alaska Region (continued)	Bering Land Bridge National Preserve[§]	2030	0.11	0.11	0.1	0.11
		2050	0.18	0.19	0.18	0.21
		2100	0.37	0.44	0.45	0.6
	Cape Krusenstern National Monument[§]	2030	0.1	0.1	0.1	0.1
		2050	0.17	0.18	0.17	0.2
		2100	0.35	0.42	0.43	0.58
	Glacier Bay National Park[†§]	2030	0.07	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.12
		2100	0.23	0.25	0.28	0.34
	Glacier Bay Preserve[†]	2030	0.06	0.06	0.06	0.06
		2050	0.11	0.11	0.11	0.11
		2100	0.22	0.24	0.27	0.33
	Katmai National Park[§]	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.15	0.16
		2100	0.31	0.34	0.37	0.47
	Katmai National Preserve[†§]	2030	0.09	0.08	0.08	0.08
		2050	0.15	0.15	0.14	0.16
		2100	0.3	0.33	0.34	0.45

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D2 (continued). Sea level rise numbers by NPS unit. Results are sorted by region. Values are reported in meters. See table footnotes for further details.

Region	Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Alaska Region (continued)	Kenai Fjords National Park[†§]	2030	0.09[‡]	0.08	0.08[‡]	0.08
		2050	0.15[‡]	0.14	0.14[‡]	0.15
		2100	0.30[‡]	0.33	0.34[‡]	0.44
	Klondike Gold Rush National Historical Park*[†§]	2030	0.06[‡]	0.06	0.06[‡]	0.06
		2050	0.11	0.11	0.11[‡]	0.11
		2100	0.22	0.24	0.27	0.33
	Lake Clark National Park*[†]	2030	0.08	0.08	0.07	0.08
		2050	0.14	0.14	0.13	0.15
		2100	0.29	0.32	0.33	0.43
	Sitka National Historical Park[†]	2030	0.08	0.07	0.07	0.07
		2050	0.14	0.14	0.13	0.14
		2100	0.28	0.31	0.33	0.41
	Wrangell - St. Elias National Park[§]	2030	0.07	0.06	0.06	0.07
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.8	0.35
	Wrangell – St. Elias National Preserve*[§]	2030	0.07	0.06	0.06	0.06
		2050	0.12	0.12	0.11	0.12
		2100	0.23	0.26	0.29	0.35

[*]Parks that do not have shoreline. These numbers are for the nearest shoreline to the park.

[†]Parks that are likely to be significantly impacted by changes in land level that could result *decreasing* relative sea level in the short term followed by *increased* relative sea level by the end of the century. Refer to section methods for more information.

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Table D3. IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Northeast Region	Acadia National Park	Hurricane, Saffir-Simpson category 1
	Assateague Island National Seashore	Hurricane, Saffir-Simpson category 1
	Boston Harbor Islands National Recreation Area	Hurricane, Saffir-Simpson category 2
	Boston National Historical Park	Hurricane, Saffir-Simpson category 3
	Cape Cod National Seashore	Hurricane, Saffir-Simpson category 2
	Castle Clinton National Monument	Hurricane, Saffir-Simpson category 1
	Colonial National Historical Park	Tropical storm
	Edgar Allen Poe National Historic Site	Extratropical storm
	Federal Hall National Memorial	Hurricane, Saffir-Simpson category 1
	Fire Island National Seashore	Hurricane, Saffir-Simpson category 2
	Fort McHenry National Monument and Historic Shrine	Tropical storm
	Fort Monroe National Monument	Tropical storm
	Gateway National Recreation Area	Hurricane, Saffir-Simpson category 1
	General Grant National Memorial	Hurricane, Saffir-Simpson category 1
	George Washington Birthplace National Monument	Extratropical storm
	Governors Island National Monument	Hurricane, Saffir-Simpson category 1
	Hamilton Grange National Memorial	Hurricane, Saffir-Simpson category 1
	Harriet Tubman Underground Railroad National Monument	Tropical storm
	Independence National Historical Park	Extratropical storm
	New Bedford Whaling National Historical Park	Extratropical storm
	Petersburg National Battlefield	Hurricane, Saffir-Simpson category 2
	Roger Williams National Memorial	Hurricane, Saffir-Simpson category 3
	Sagamore Hill National Historic Site	Hurricane, Saffir-Simpson category 2
	Saint Croix Island International Historic Site	Hurricane, Saffir-Simpson category 2
	Salem Maritime National Historic Site	Hurricane, Saffir-Simpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Northeast Region (continued)	Saugus Iron Works National Historic Site	Hurricane, Saffir-Simpson category 1
	Statue of Liberty National Monument	Hurricane, Saffir-Simpson category 1
	Thaddeus Kosciuszko National Memorial	Extratropical storm
	Theodore Roosevelt Birthplace National Historic Site	Hurricane, Saffir-Simpson category 1
Southeast Region	Big Cypress National Preserve	Hurricane, Saffir-Simpson category 4
	Biscayne National Park	Hurricane, Saffir-Simpson category 4
	Buck Island Reef National Monument	Hurricane, Saffir-Simpson category 2
	Canaveral National Seashore	Hurricane, Saffir-Simpson category 2
	Cape Hatteras National Seashore	Hurricane, Saffir-Simpson category 3
	Cape Lookout National Seashore	Hurricane, Saffir-Simpson category 3
	Castillo De San Marcos National Monument	Hurricane, Saffir-Simpson category 3
	Charles Pinckney National Historic Site	Hurricane, Saffir-Simpson category 4
	Christiansted National Historic Site	Hurricane, Saffir-Simpson category 4
	Cumberland Island National Seashore	Hurricane, Saffir-Simpson category 4
	De Soto National Memorial	Hurricane, Saffir-Simpson category 1
	Dry Tortugas National Park	Hurricane, Saffir-Simpson category 4
	Everglades National Park	Hurricane, Saffir-Simpson category 5
	Fort Caroline National Memorial	Hurricane, Saffir-Simpson category 2
	Fort Frederica National Monument	Hurricane, Saffir-Simpson category 1
	Fort Matanzas National Monument	Hurricane, Saffir-Simpson category 1
	Fort Pulaski National Monument	Hurricane, Saffir-Simpson category 2
	Fort Raleigh National Historic Site	Hurricane, Saffir-Simpson category 2
	Fort Sumter National Monument	Hurricane, Saffir-Simpson category 4
	Gulf Islands National Seashore	Hurricane, Saffir-Simpson category 4
	Jean Lafitte National Historical Park and Preserve	Hurricane, Saffir-Simpson category 2
	Moores Creek National Battlefield	Hurricane, Saffir-Simpson category 1

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Southeast Region (continued)	New Orleans Jazz National Historical Park	Hurricane, Saffir-Simpson category 2
	Salt River Bay National Historic Park and Ecological Preserve	Hurricane, Saffir-Simpson category 4
	San Juan National Historic Site	Hurricane, Saffir-Simpson category 3
	Timucuan Ecological and Historic Preserve	Hurricane, Saffir-Simpson category 2
	Virgin Islands Coral Reef National Monument	Hurricane, Saffir-Simpson category 3
	Virgin Islands National Park	Hurricane, Saffir-Simpson category 3
	Wright Brothers National Memorial	Hurricane, Saffir-Simpson category 2
National Capital Region	Anacostia Park	Hurricane, Saffir-Simpson category 2
	Chesapeake & Ohio Canal National Historical Park	Hurricane, Saffir-Simpson category 2
	Constitution Gardens	Hurricane, Saffir-Simpson category 2
	Fort Washington Park	Hurricane, Saffir-Simpson category 2
	George Washington Memorial Parkway	Hurricane, Saffir-Simpson category 2
	Harpers Ferry National Historical Park	Extratropical storm
	Korean War Veterans Memorial	Hurricane, Saffir-Simpson category 2
	Lincoln Memorial	Hurricane, Saffir-Simpson category 2
	Lyndon Baines Johnson Memorial Grove on the Potomac National Memorial	Hurricane, Saffir-Simpson category 2
	Martin Luther King Jr. Memorial	Hurricane, Saffir-Simpson category 2
	National Mall	Hurricane, Saffir-Simpson category 2
	National Mall & Memorial Parks	Hurricane, Saffir-Simpson category 2
	National World War II Memorial	Hurricane, Saffir-Simpson category 2
	Piscataway Park	Hurricane, Saffir-Simpson category 2
	Potomac Heritage National Scenic Trail	Hurricane, Saffir-Simpson category 2
	President’s Park (White House)	Hurricane, Saffir-Simpson category 2
	Rock Creek Park	Hurricane, Saffir-Simpson category 2
	Theodore Roosevelt Island Park	Hurricane, Saffir-Simpson category 2
	Thomas Jefferson Memorial	Hurricane, Saffir-Simpson category 2

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
National Capital Region (continued)	Vietnam Veterans Memorial	Hurricane, Saffir-Simpson category 2
	Washington Monument	Hurricane, Saffir-Simpson category 2
Intermountain Region	Big Thicket National Preserve	Hurricane, Saffir-Simpson category 3
	Palo Alto Battlefield National Historical Park	No recorded historical storm
	Padre Island National Seashore	Hurricane, Saffir-Simpson category 4
Pacific West Region	American Memorial Park	Tropical storm
	Cabrillo National Monument	Tropical depression
	Channel Islands National Park	No recorded historical storm
	Ebey's Landing National Historical Reserve	No recorded historical storm
	Fort Point National Historic Site	No recorded historical storm
	Fort Vancouver National Historic Site	No recorded historical storm
	Golden Gate National Recreation Area	No recorded historical storm
	Haleakala National Park	Tropical depression
	Hawaii Volcanoes National Park	Tropical depression
	Kalaupapa National Historical Park	Tropical depression
	Kaloko-Honokohau National Historical Park	Tropical depression
	Lewis and Clark National Historical Park	No recorded historical storm
	National Park of American Samoa	No recorded historical storm
	Olympic National Park	No recorded historical storm
	Point Reyes National Seashore	No recorded historical storm
	Port Chicago Naval Magazine National Memorial	No recorded historical storm
	Pu'uhonua O Honaunau National Historical Park	No recorded historical storm
	Puukohola Heiau National Historic Site	Tropical depression
	Redwood National and State Parks	No recorded historical storm

Table D3 (continued). IBTrACS data (Knapp et al. 2010) were used to identify the highest recorded storm track to have passed within 10 miles of each of the park units.

Region	Park Unit	Highest Recorded Hurricane Within 10 mi (16.1 km)
Pacific West Region (continued)	Rosie the Riveter WWII Home Front National Historical Park	No recorded historical storm
	San Francisco Maritime National Historical Park	No recorded historical storm
	San Juan Island National Historical Park	No recorded historical storm
	Santa Monica Mountains National Recreation Area	No recorded historical storm
	War in the Pacific National Historical Park	No recorded historical storm
	World War II Valor in the Pacific National Monument	Tropical depression
Alaska Region	Aniakchak Preserve	No recorded historical storm
	Bering Land Bridge National Preserve	No recorded historical storm
	Cape Krusenstern National Monument	No recorded historical storm
	Glacier Bay National Park	No recorded historical storm
	Glacier Bay Preserve	No recorded historical storm
	Katmai National Park	No recorded historical storm
	Katmai National Preserve	No recorded historical storm
	Kenai Fjords National Park	No recorded historical storm
	Klondike Gold Rush National Historical Park	No recorded historical storm
	Lake Clark National Park	No recorded historical storm
	Sitka National Historical Park	No recorded historical storm
	Wrangell - St. Elias National Park	No recorded historical storm
	Wrangell – St. Elias National Preserve	No recorded historical storm

NPS 999/137852, May 2017

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

248 2 Attachment 2018-01-26 Recommended Edits_CHH.pdf

Comment 1: First Paragraph of Executive Summary (p vii)

~~Changing~~ Ongoing changes in relative sea levels and the potential for increasing storm surges present challenges to national park managers. This report summarizes work done by the University of Colorado in partnership with the National Park Service (NPS) to provide sea level rise and storm surge projections to coastal area national parks using information from the United Nations Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from National Oceanic and Atmospheric Administration (NOAA) models. This research is the first to analyze IPCC and NOAA projections of sea level and storm surge under climate change for U.S. national parks. Results illustrate potential future inundation and storm surge due to climate change under four greenhouse gas emissions scenarios. In addition to including multiple scenarios, the analysis considers multiple time horizons (2030, 2050 and 2100). This analysis provides sea level rise projections for 118 park units and storm surge projections for 79 of those parks.

Comment 2: Third Paragraph of Executive Summary (p vii)

These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service. Sea level change and storm surge pose considerable risks to infrastructure, archeological sites, lighthouses, forts, and other historic structures in coastal units of the national park system.~~located along the coast~~. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety. ~~These results are intended to inform park planning and adaptation strategies for resources managed by the National Park Service.~~

Comment 3: First Paragraph of Introduction (p 1) Sentence shown in green font hasn't changed from the draft report. Suggest changing it back to black font. Yellow highlight text is very user-unfriendly; can we fix this at the same time?

Global sea level is rising at an increasing rate. ~~While sea levels have been gradually rising since the last glacial maximum approximately 21,000 years ago (Clark et al. 2009, Lambeck et al. 2014), anthropogenic climate change has significantly increased the rate of global sea level rise~~ (Grinsted et al. 2010, Church and White 2011, Slangen et al. 2016, Fasullo et al. 2016). Continued warming of the atmosphere will cause sea levels to continue to rise, which will have a significant impact on how we protect and manage our public lands. The rate of warming depends on numerous factors considered by the Intergovernmental Panel on Climate Change (IPCC) under four different representative concentration pathways (RCPs; Moss et al. 2010, Meinshausen et al. 2011). Used as the basis for this report, the RCPs are climate change scenarios based on potential greenhouse gas concentration trajectories introduced in the fifth climate change assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013). The IPCC's process-based approach for estimating future sea levels contrasts with other estimates from semi-empirical techniques that commonly generate higher numbers.

Comment 4: Second Paragraph of Introduction (p 1)

Peek et al. (2018) estimate that the cost of sea level rise in 100 National Park Service units could exceed $23 billion if these units were exposed to one-meter of sea level rise. The aim of this report is to: 1) quantify projections of sea level rise over the next century based on the latest IPCC (2013) models, and 2) show how storm surge generated by hurricanes and extratropical storms could also affect these parks. [report to be cited as In Preparation]

Comment 5: Third Paragraph of Introduction (p 1)

When Hurricane Sandy struck New York City in 2012 it caused an estimated $19 billion in damage to public and private infrastructure (Tollefson 2013). This single storm cannot be attributed to climate change, but the storm surge occurred over a sea whose level had risen due to climate change. Extreme storms such as Hurricane Sandy have extreme costs. When Hurricane Sandy struck it was estimated to have a return period between a 398 year (Lin et al. 2016) and a 1570 year storm (Sweet et al. 2013). Currently, a 100 year storm surge in New York City could cost $2-5 billion and a 500 year storm surge could cost $5-11 billion (Aerts et al. 2013). Under future scenarios of increasing greenhouse gas emissions, models project increasing storm intensities (Mann and Emanuel 2006, Knutson et al. 2010, Lin et al. 2012, Ting et al. 2015).

Comment 6: First Paragraph of Methods >> Sea Level Rise Data (p 4)

Sea level rise is caused by numerous factors. Ice located on land and in the sea melts with the rise of mean global temperatures (IPCC 2013, Gillett et al. 2013, Frolicher et al. 2014). The melting of ice found on land, such as Greenland and Antarctica, is a significant driver of sea level rise.

Comment 7: First Paragraph of Discussion (p 26)
Global mean sea levels have been rising since the last glacial maximum (Lambeck and Chappell 2001, Clark and Mix 2002, Lambeck et al. 2014). Church and White (2006) estimated that twentieth century global sea levels rose at a rate of approximately 1.7 mm/y, although this rate accelerated over the latter part of the century. Slangan et al. (2016) found that emissions of greenhouse gases have been the primary driver of global sea level change since 1970 and that the rate of sea level rise has increased over time (Table 1). Satellite altimetry data shows that present-day global relative sea levels are increasing at approximately 3.3 mm/y (Cazenave et al. 2014, Fasullo et al. 2016).

Comment 8: Caption of Figure 13 (p 26)
Radiative forcing for each of the Representative Concentration Pathways (RCPs). Positive radiative forcing means Earth receives more incoming energy from sunlight than it radiates to space. This net gain of energy ~~will cause warming~~warms the earth, resulting in ~~that can be measured as~~ higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note how RCP4.5 (yellow line) projections are slightly higher than RCP6.0 (gray line) in the early part of this century. Source: Meinshausen et al. 2011. SAME CHANGE REQUIRED ON p v IN THE TABLE OF CONTENTS, LIST OF FIGURES

Comment 9: Sixth Paragraph of Discussion (p 27)
These estimates do not include the latest data on changing land levels. The IPCC included estimates of global isostatic adjustment (Equation 1) in their predictions, but those do not include changes in land level due to other factors, such as earthquakes and groundwater extraction. We expect the latest, state-of-the-art land level estimates to be released by NASA in 2018.

249 Report Location.pdf

From: Perez, Larry
To: Cat Hoffman
Subject: Report Location
Date: Saturday, February 10, 2018 12:23:07 PM

Cat,

I put the latest version of the Caffrey report here:

Z:\CCRP\Communication\300 - Adaptation\Coastal Adaptation\05 - 2018 SLR & SS Report

When you can, please review the results section per our call this week. Also, please review new comment on page 1 and feel free to edit as needed.

I will try to schedule a call with the report authors ASAP. Rebecca is out at NCTC all next week, so we'll shoot for early the week of Feb. 20.

-L

Larry Perez, Communications Coordinator
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Fort Collins, CO 80525
Office: 970-267-2136
Fax: 970-225-3585
Email: larry_perez@nps.gov

250 SLR _ SS Report Call.pdf

From:	Perez, Larry
To:	Beavers, Rebecca; Patrick Gonzalez
Cc:	Cat Hoffman
Subject:	SLR / SS Report Call
Date:	Saturday, February 10, 2018 1:01:23 PM

Rebecca & Patrick,

Cat and I would like to organize a call with all authors to review the report.

I propose we plan to meet via webinar at 2:00 MT on February 21...immediately following our large group call. I'll send a calendar invite shortly.

Rebecca, would you kindly forward the invite to Maria as well...we're hopeful she is willing and able to join.

Thanks,

L

Larry Perez, Communications Coordinator
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Office: 970-267-2136
Fax: 970-225-3585
Email: larry_perez@nps.gov

251 Re_ Report Location.pdf

From: Hoffman, Cat
To: Perez, Larry
Subject: Re: Report Location
Date: Friday, February 16, 2018 4:34:00 PM

See the "CHH" version of the report, back in the S: drive. Plus there's one comment in the document I want to discuss with you (relates to the document in S: folder called "COMMENT")

On Sat, Feb 10, 2018 at 12:23 PM, Perez, Larry <larry_perez@nps.gov> wrote:

> Cat,
>
> I put the latest version of the Caffrey report here:
>
> Z:\CCRP\Communication\300 - Adaptation\Coastal Adaptation\05 - 2018 SLR & SS Report
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> When you can, please review the results section per our call this week. Also, please review new comment on page 1 and feel free to edit as needed.
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>
> -L
>
> ____
>
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Adaptation websites: public, NPS managers
Climate Change Response Resources