National Park Service
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Natural Resource Stewardship and Science

Sea Level Rise and Storm Surge Projections for the National Park Service

Natural Resource Report Series NPS/NRSS/NRR—2018/1648

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

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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.

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Photo 1. Looking towards the Gulf of Mexico from Fort Jefferson, Dry Tortugas National Park. Photo credit: Used with permission from Rachel Sullivan Photography.

Executive Summary

Over one quarter of the units of the National Park System occur along ocean coastlines. Ongoing changes in relative sea levels and the potential for increasing storm surges due to anthropogenic climate change and other factors 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 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 the Outer Banks Group of parks 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. 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. Understanding projections for continued change can better guide protection of such resources for the benefit of long-term visitor enjoyment and safety.

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 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 managed by the National Park Service.

Radiative Forcing: Is the change in the incoming solar radiation minus the outgoing infrared radiation: the change in heat at the surface of the Earth. Positive radiative forcing means Earth receives more incoming energy from sunlight than it radiates to space. This net gain of energy warms the earth, resulting in higher global average temperatures.

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.

Storm surge: An abnormal rise of water caused by a storm, over and above the predicted astronomical tide.

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). Recent analyses reveal that the rate of sea level rise in the last century was greater than during any preceding century in at least 2,800 years (Kopp et al. 2016, Sweet et al. 2017). 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). Further warming of the atmosphere will cause sea levels to continue to rise, which will affect how we protect and manage our national parks. 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.

The Importance of Understanding Contemporary Sea Level Change for Parks

From rocky headlands to gentle beaches, some of the most splendid and beautiful places in the United States are national parks on our ocean shorelines. Over one quarter of all national park units are coastal parks, home to nesting shorebirds and sea turtles, historical forts and lighthouses, and opportunities for recreation and respite. Many are living witness to our national story – true icons of our history (Photo 3). But despite their great diversity, importance, and ability to provide windows to the past, changes in sea level affect them all.

Today's managers of these parks face new challenges—challenges unimagined by builders of the forts and lighthouses within them, challenges unprecedented for the species that inhabit them, and challenges unanticipated by those who secured these places as part of the National Park System. Knowledge of sea level projections must now augment managerial skills in park administration, resource protection and conservation, interpretation, and community and civic engagement. To support managers of coastal park units, this report provides projections for sea level change and storm surge under several scenarios. As a reference for staff, it also summarizes scientific understanding of the basis for these changes, and sources from which scientists develop sea level rise projections.

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 value of infrastructure at risk in 40 National Park Service units could cost billions of dollars if these units were exposed to one-meter of sea level rise.

The passage of Hurricane Sandy in 2012—and more recently Hurricanes Harvey, Irma, and Maria in 2017—caused extensive and costly damage to infrastructure and resources in numerous coastal national park units. While single storms cannot be wholly attributed to anthropogenic climate change, sea level rise associated with climate change exacerbates the effects of associated storm surges, which may be even further amplified during the highest astronomical tides as occurred during Hurricane Sandy (Kemp and Horton 2013). The impacts of extreme storms can bring extreme costs, as tallied through loss of visitor access, impacts to gateway communities and local economies, investments in recovery, and/or the irrevocable loss of unique resources. For example, repair of damage caused in national parks affected by Hurricane Sandy alone exceeded $370,000,000. 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, the permanent loss of land across much of the United States coastline, and in some locations, a much shorter return interval of flooding. For example, when Hurricane Sandy struck, it was estimated to have a return period between 398 (Lin et al. 2016) and 1570 (Sweet et al. 2013) years. Factoring in future sea level rise to these estimates reduces the potential return interval of a similar storm surge occurring in New York City by 2100 to between 50 years (Sweet et al. 2013) and 90 years (Lin et al. 2016).

The aim of this report is to: 1) quantify projections of sea level rise in coastal National Park Service units 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.

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” refers 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, Southeast 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.

Photo 3. A National Park Service ranger surveys damage from the aftermath of Hurricane Sandy at Statue of Liberty National Monument, NY. Photo credit: National Park Service.

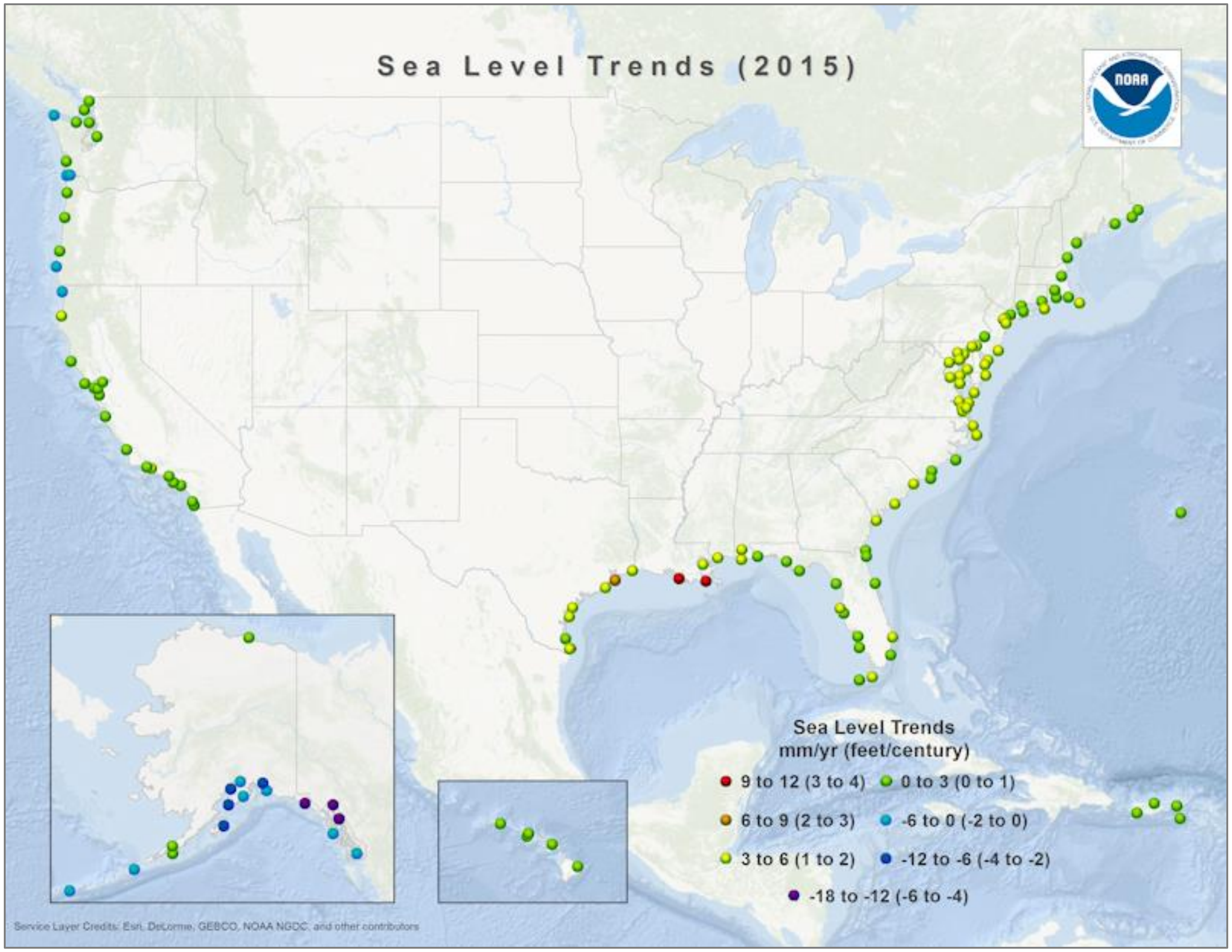

Figure 1. Sea level trends for the United States based on Zervas (2009), for all available data through 2015. Each dot represents the location of a long-term (>30 years) tide gauge station. Green dots represent stations that are experiencing the average global rate of sea level change. Stations depicted 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 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 site recommendations from regional personnel, three National Park Service units now have completed wayside exhibits in place: Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, and Fire Island National Seashore, each with customized designs that reflect the messaging and/or themes of each unit. This report provides results from the first two project activities: sea level rise projections, and potential exposure to storm surge.

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

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.

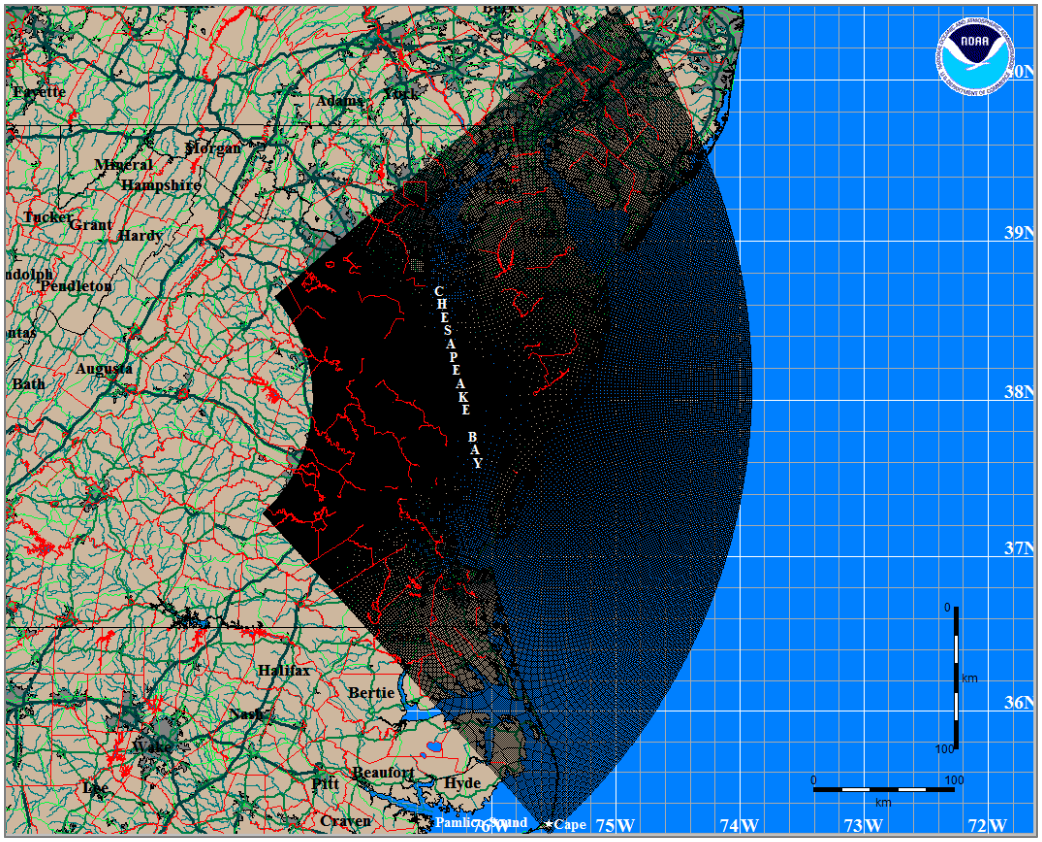

Figure 3. An example of the extent of an operational basin shown in NOAA's SLOSH display program (http://www.nhc.noaa.gov/surge/slosh.php). The black area is the full extent of the operational basin for Chesapeake Bay.

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, Saipan, and American Samoa park units. It is important to note that the Tebaldi et al. (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 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 Samoa, Saipan, 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 wetlands 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 $ae = E_0 - e_i + R$

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 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 cases 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.

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.

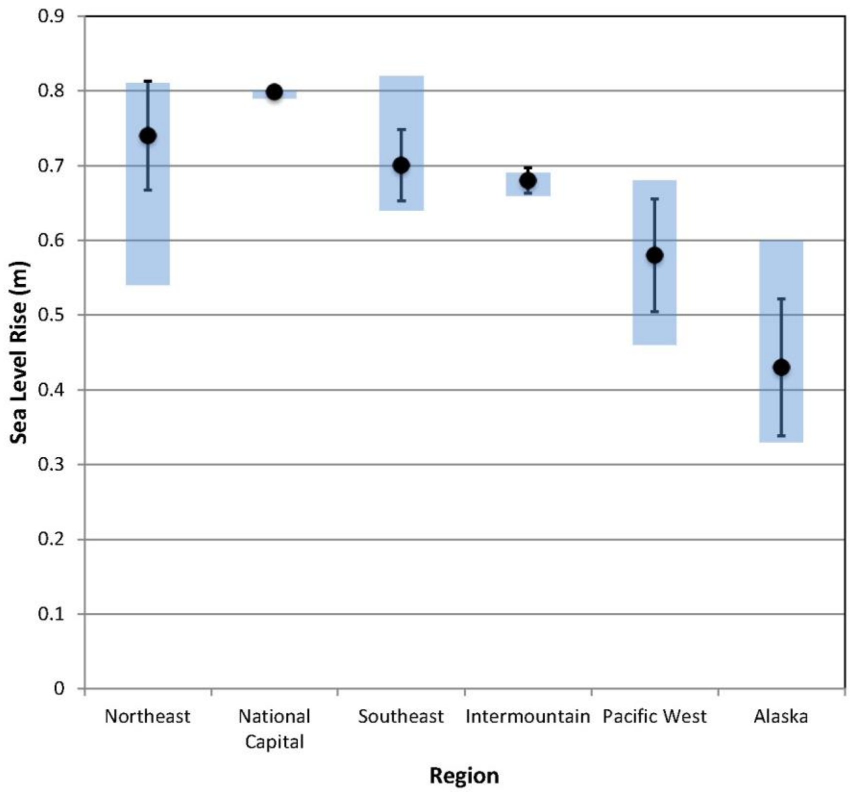

Figure 4. Projected future sea level by NPS region for 2100 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full 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.

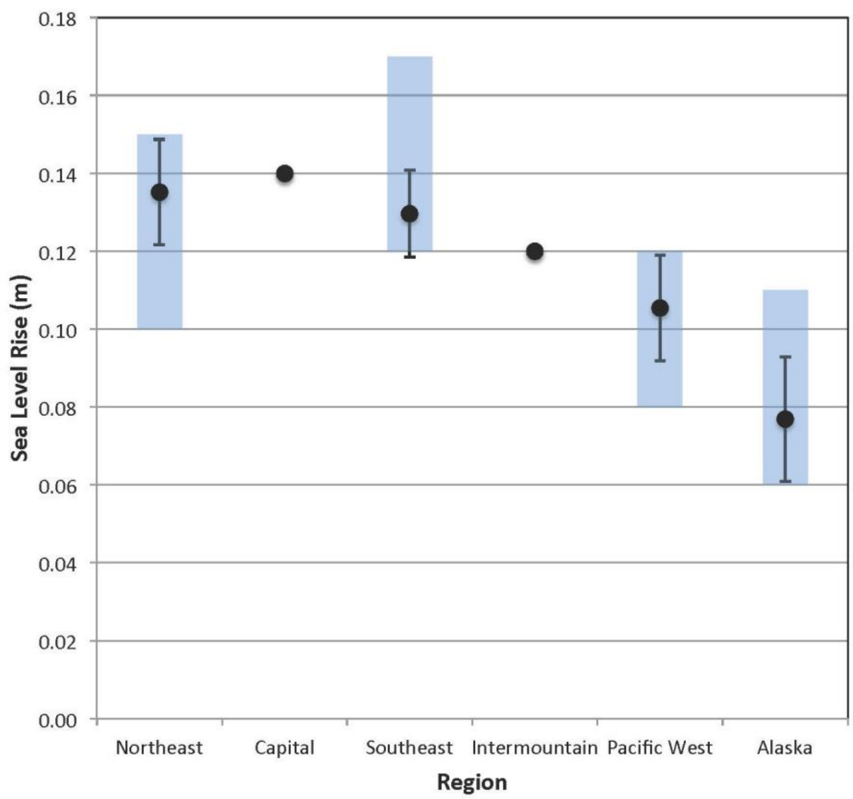

Figure 5. Projected future sea level rise by NPS region for 2030 under RCP8.5 (the “business as usual” climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the full range of sea level estimates for each region.

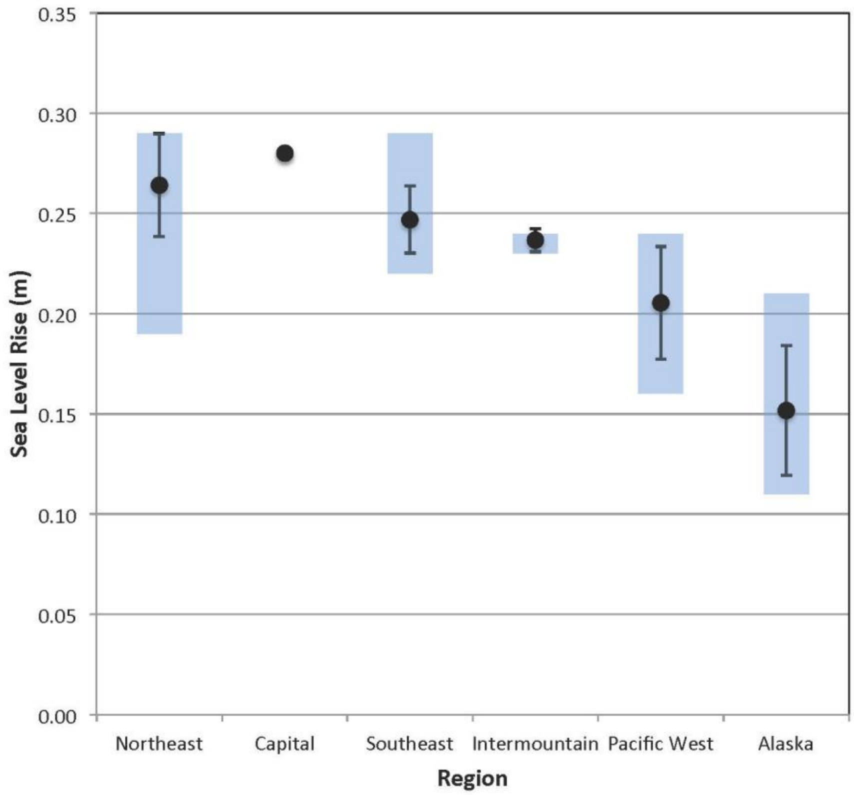

Figure 6. Projected future sea level rise by NPS region for 2050 under RCP8.5 (the "business as usual" climate change scenario). Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark the 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).

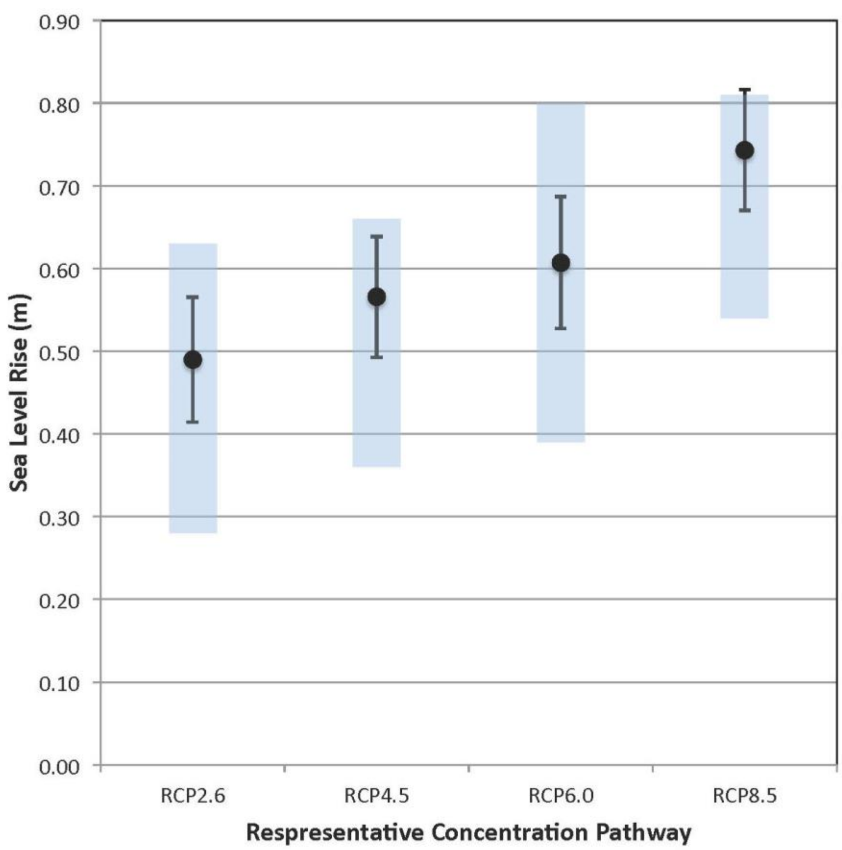

Figure 7. Projected future sea level rise by 2100 for the NPS Northeast Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation of each mean. Blue bars mark 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.

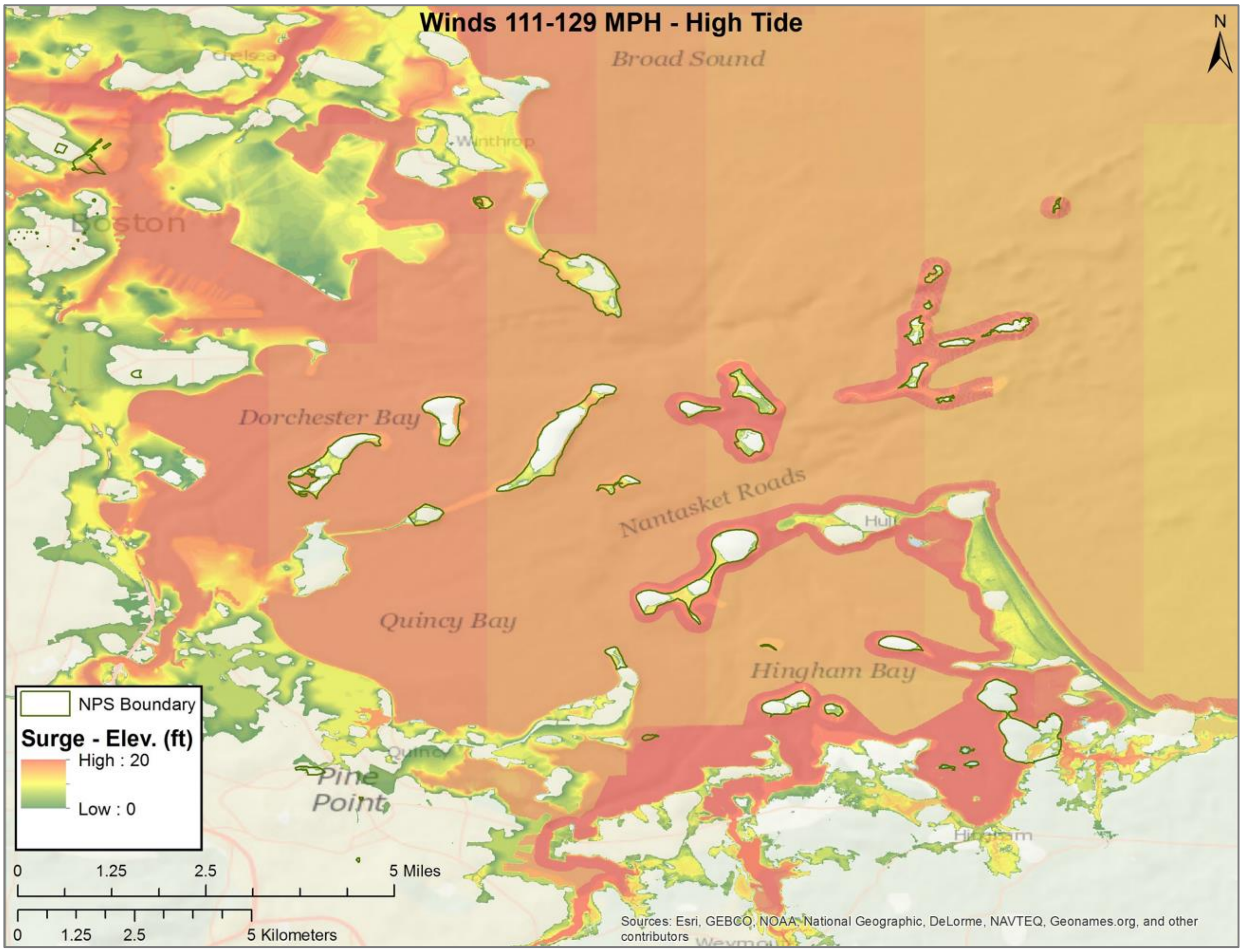

Figure 8. Estimated storm surge created by Saffir-Simpson category 3 hurricane occurring at high tide near Boston Harbor Islands National Recreation Area. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

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 parks in the Outer Banks Group, including 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).

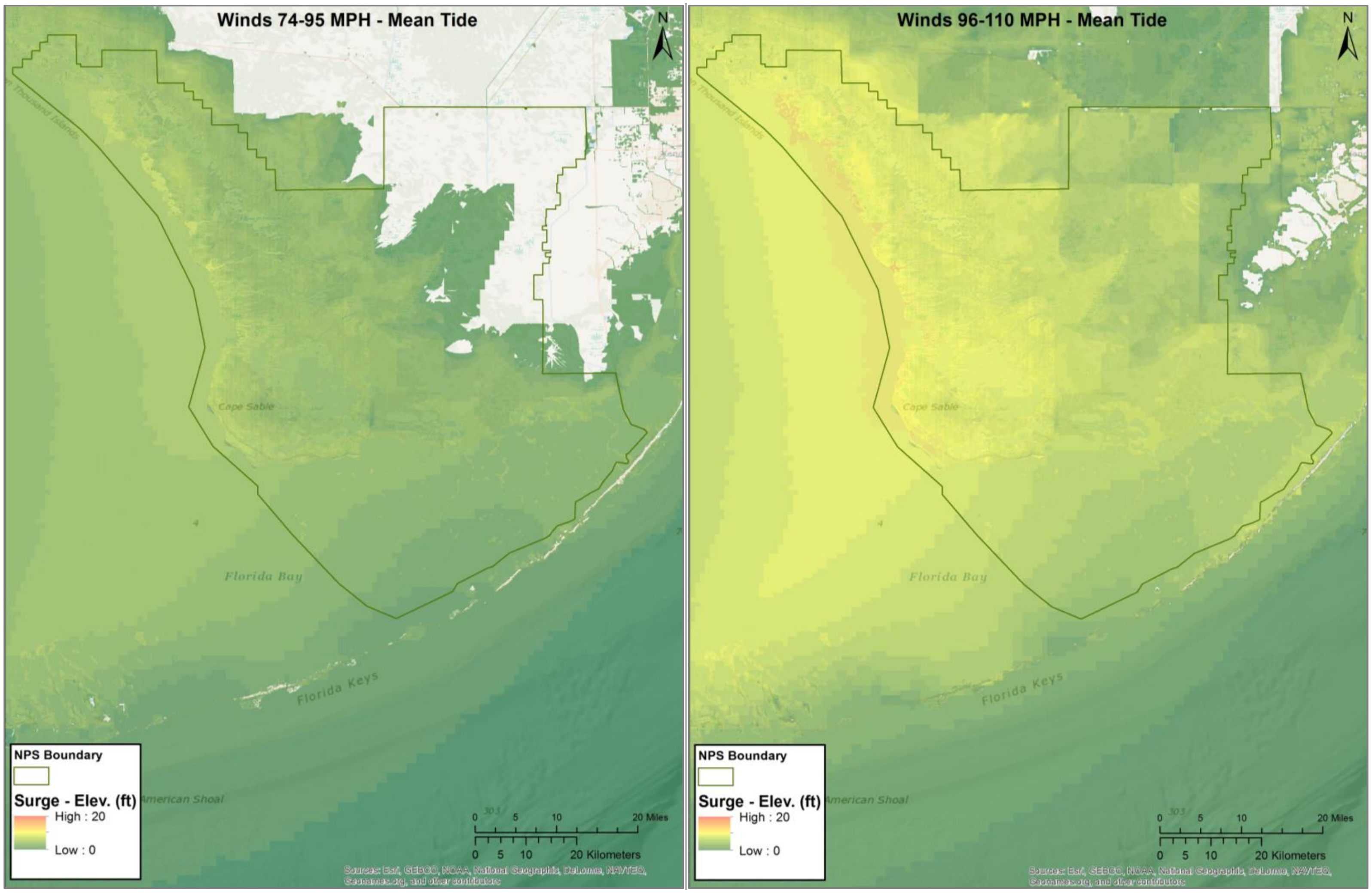

Figure 9. SLOSH MOM storm surge maps for a Saffir-Simpson category 1 (left) versus category 2 hurricane striking Everglades National Park at mean tide (right). Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated range).

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.

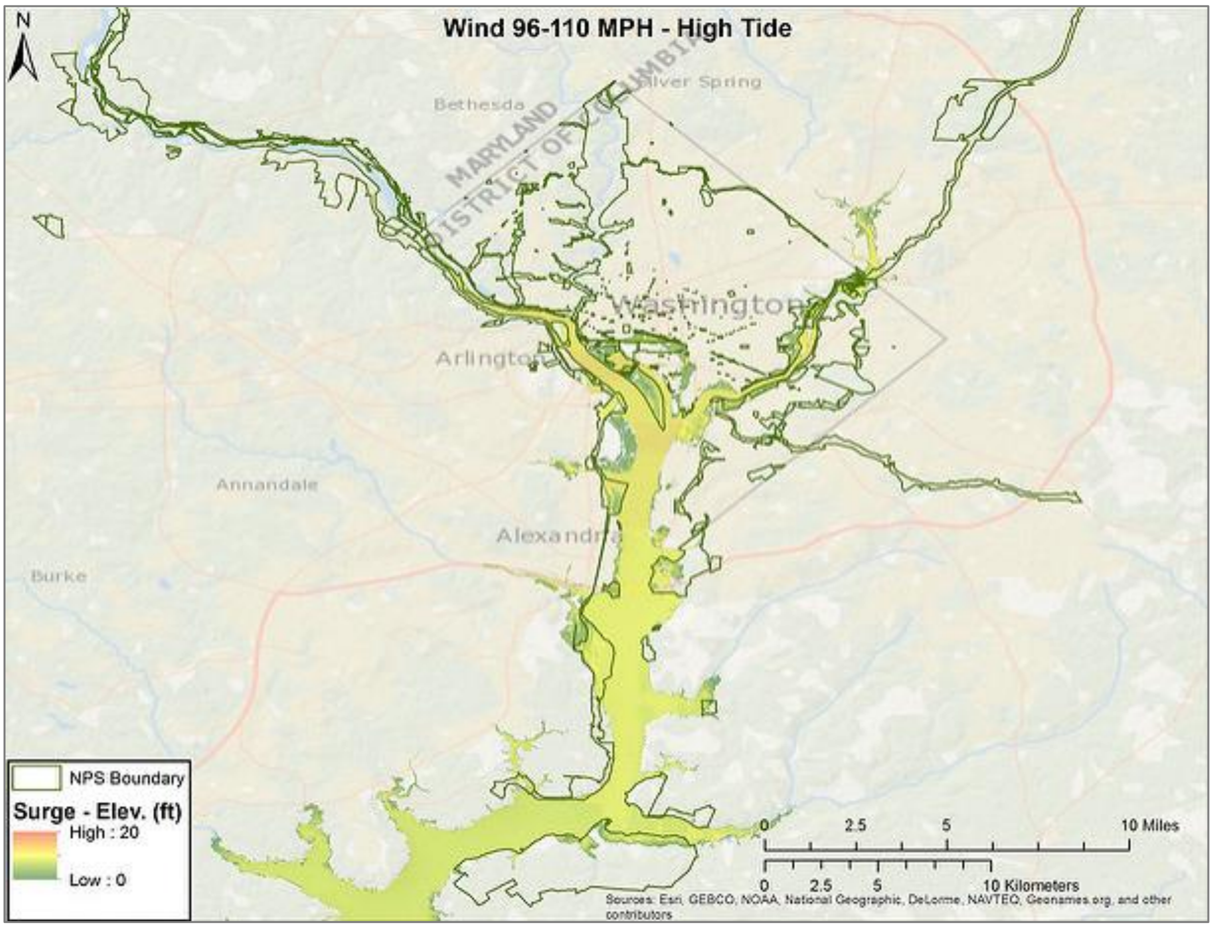

Figure 10. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 2 hurricane striking the Washington D.C. region at high tide. Colored areas represent areas of flooding. Colors from green to red show estimated height of a storm surge (see inset legend for estimated 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.

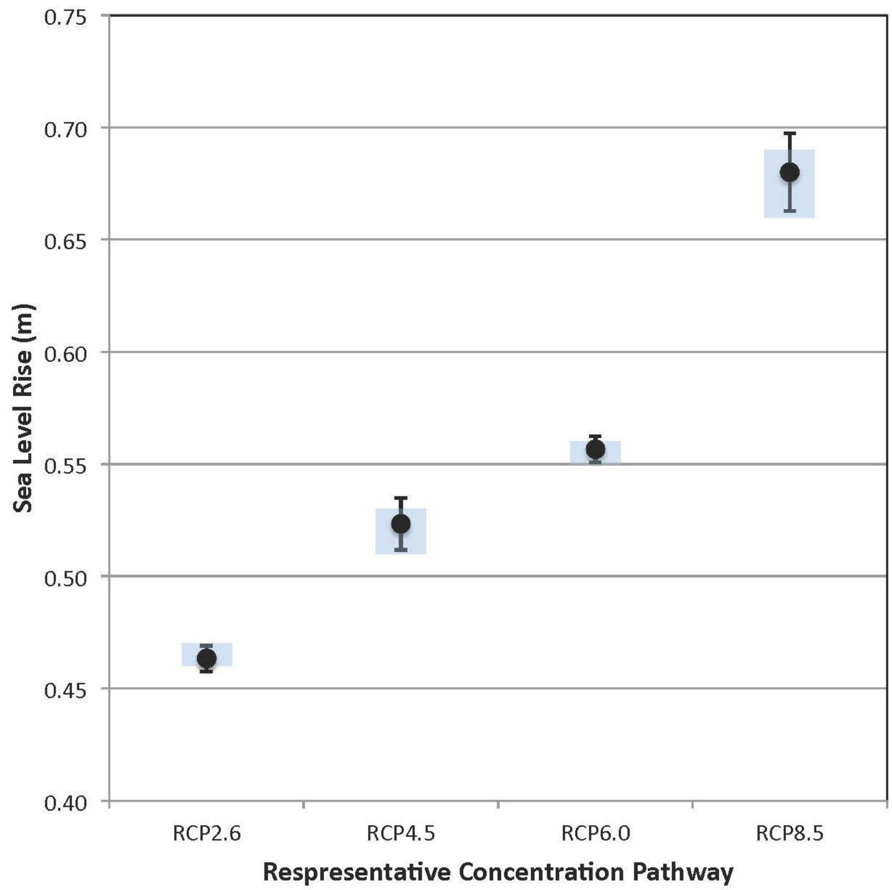

Figure 11. Projected future sea level rise by 2100 for the NPS Intermountain Region under all of the representative concentration pathways. Black dots indicate the average sea level rise (m) for all units within the respective regions. Black bars represent the standard deviation from each mean. Blue bars mark the full range of sea level estimates for each category.

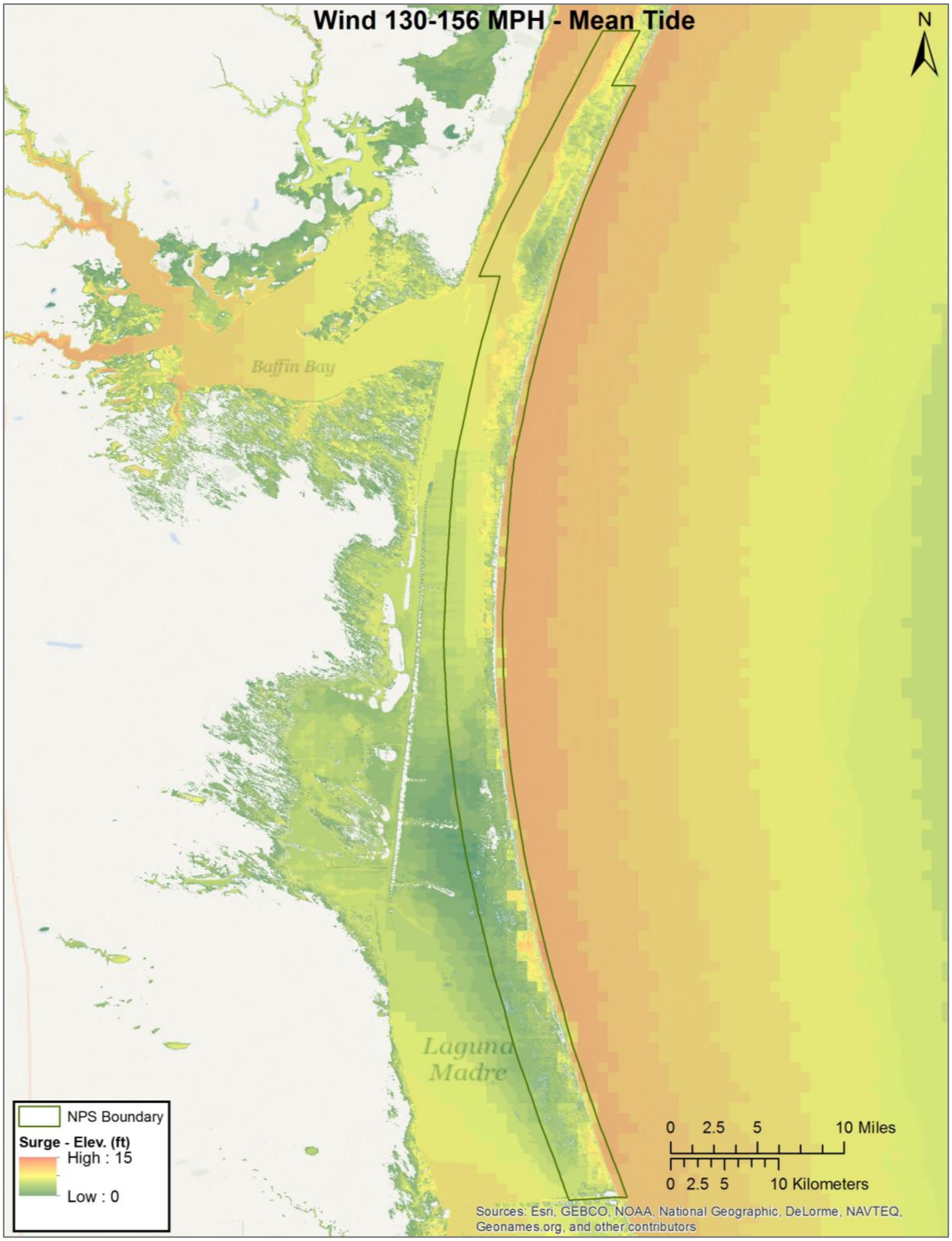

Figure 12. A SLOSH MOM map showing storm surge height and extent created by a Saffir-Simspon category 4 hurricane striking the southwestern Texas region at mean tide. The dark green line around the island represents the boundary of Padre Island National Seashore. Colored areas represent areas of flooding. 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, Saipan, 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, Saipan, 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. Slangen 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.

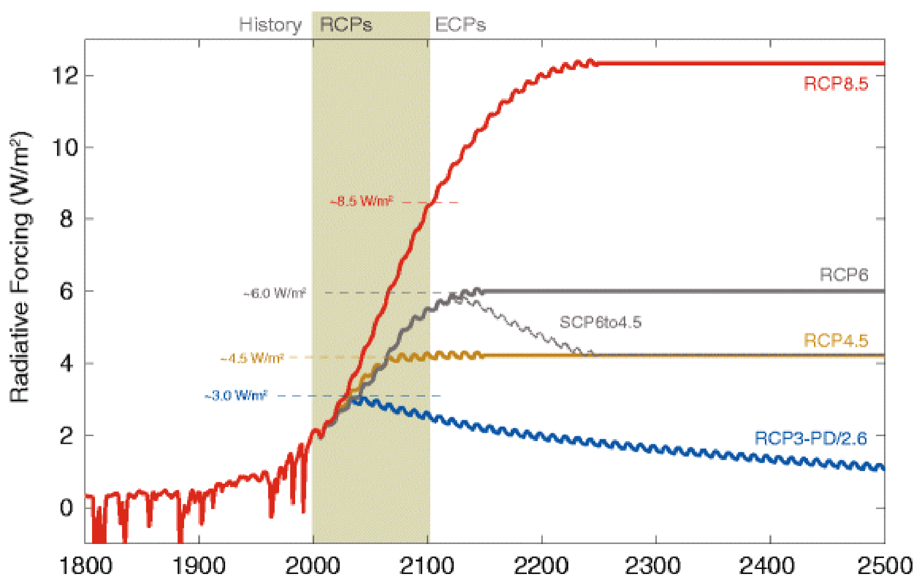

Figure 13. Radiative forcing (see list of terms) for each of the Representative Concentration Pathways (RCPs). An increase in radiative forcing (due to the loading of anthropogenic gases into the atmosphere) will result in higher global average temperatures. RCPs replace the IPCC SRES scenarios. Note 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 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, Padre Island National Seashore, 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 https://irma.nps.gov/Portal

Storm surge maps are also available on https://irma.nps.gov/Portal 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. What was the process and timeline of this project?

A. This is the culmination of a multi-year project that was initiated in 2013. Collaboration between the National Park Service and the University of Colorado Boulder led to development of the report, associated data, and GIS files. External peer review of this report was conducted in late 2016 and early 2017. Management review extended into early 2018. A data visualization viewer is still in development.

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 https://irma.nps.gov/Portal. 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

Data Tables

Table C1. 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

†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 C1 (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 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

†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 C1 (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)	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

†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 C1 (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)	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

†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 C1 (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 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 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

†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 C1 (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)	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

†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 C1 (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)	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 Scenic Trail	Washington, DC (8594900)	N	83	1.340
	President's Park (White House)	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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*The park boundary stretches over either large or multiple areas. More than one tide gauge record is appropriate for this park.

Table C1 (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)	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	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

†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 C1 (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)	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

†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 C1 (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)	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
	Cape Krusenstern National Monument‡	No data	No data	No data	No data
	Glacier Bay National Park*‡	Juneau, AK (9452210)	N	71	-14.620

†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 C1 (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)	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 C2a. Sea level rise numbers by NPS unit for the Northeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

[*]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 C2a (continued). Sea level rise numbers by NPS unit for the Northeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2a (continued). Sea level rise numbers by NPS unit for the Northeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2a (continued). Sea level rise numbers by NPS unit for the Northeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2a (continued). Sea level rise numbers by NPS unit for the Northeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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

*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 C2b. Sea level rise numbers by NPS unit for the Southeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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	0.2	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 C2b (continued). Sea level rise numbers by NPS unit for the Southeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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 C2b (continued). Sea level rise numbers by NPS unit for the Southeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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 C2b (continued). Sea level rise numbers by NPS unit for the Southeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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 C2b (continued). Sea level rise numbers by NPS unit for the Southeast Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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	0.7
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

*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 C2c. Sea level rise numbers by NPS unit for the National Capital Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2c (continued). Sea level rise numbers by NPS unit for the National Capital Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2c (continued). Sea level rise numbers by NPS unit for the National Capital Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2c (continued). Sea level rise numbers by NPS unit for the National Capital Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2d. Sea level rise numbers by NPS unit for the Intermountain Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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

[*]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 C2e. Sea level rise numbers by NPS unit for the Pacific West Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2e (continued). Sea level rise numbers by NPS unit for the Pacific West Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2e (continued). Sea level rise numbers by NPS unit for the Pacific West Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2e (continued). Sea level rise numbers by NPS unit for the Pacific West Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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

*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 C2f. Sea level rise numbers by NPS unit for the Alaska Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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
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 C2f (continued). Sea level rise numbers by NPS unit for the Alaska Region. Values are reported in meters. See table footnotes for further details.

Park Unit	Year	RCP2.6	RCP4.5	RCP6.0	RCP8.5
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 C3. 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 C3 (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 C3 (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	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

Table C3 (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)	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

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