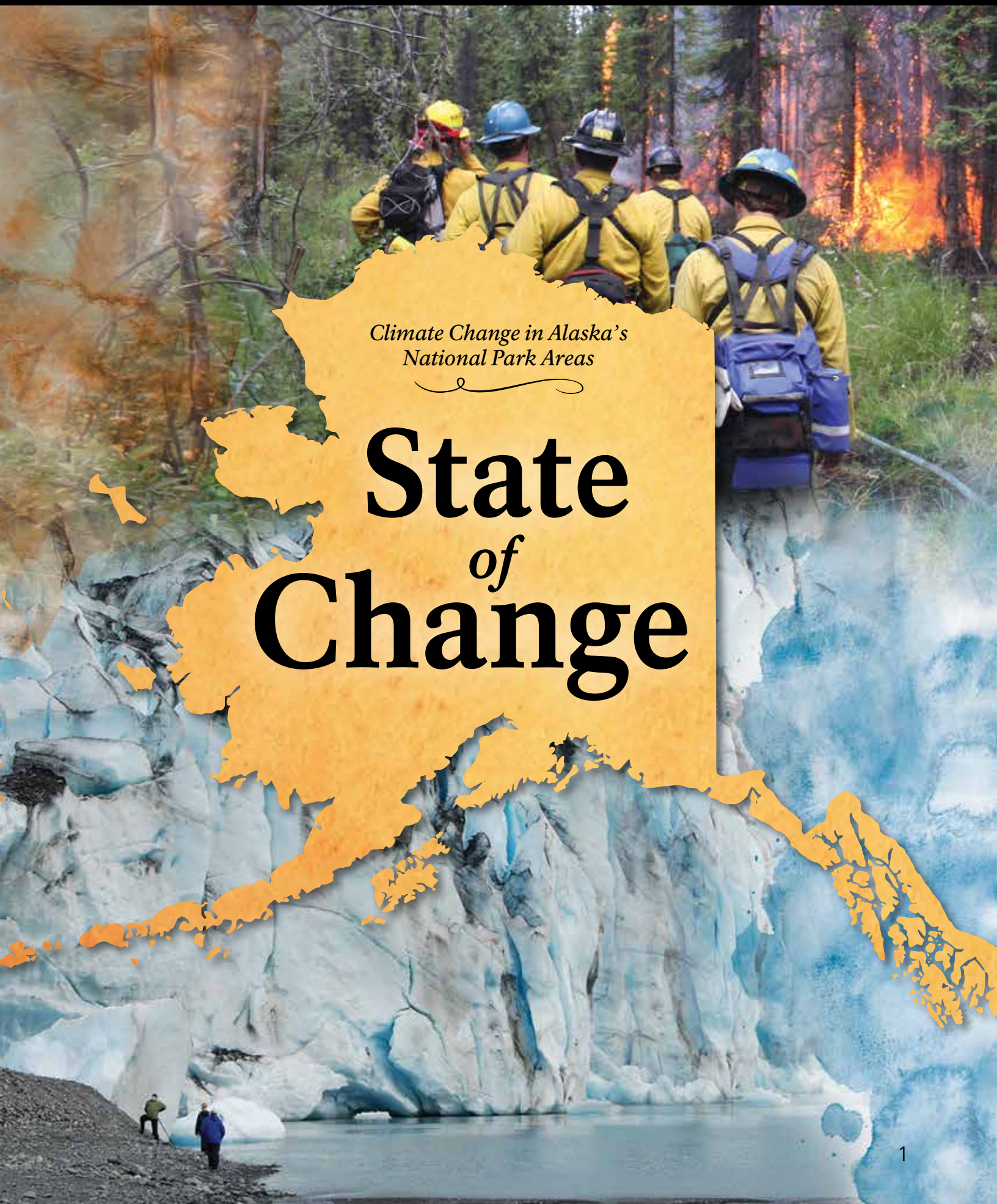


Climate Change in Alaska's National Park Areas

State *of* Change

Stories of Change from Alaska's National Parks

WHAT HAPPENS IN ALASKA DOESN'T STAY IN ALASKA

Whether you live in Alaska or are visiting the state, we invite you to join the conversation about climate change in Alaska's national parks. This guide is one way for all stakeholders to engage.

From the coastal rainforests of Southeast Alaska to the treeless tundra north of the Arctic Circle, Alaska's national parks embody a diversity of climates and living landscapes. Alaskans and visitors alike are uncertain about how a changing climate will impact their lives, but they recognize that becoming more self-reliant and prepared will provide clear benefits. By planning for, rather than reacting to, climate change, park users can improve their health, protect their livelihoods, save money, and create more resilient communities.

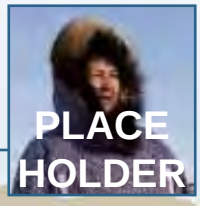
Explore the following stories about the impacts of climate change and the innovative ways in which Alaskans—and all of us—can learn, respond, and adapt in a changing world.

HOW DO WE KNOW ALASKA IS WARMING?

While weather can change from day to day and even minute to minute, climate is a measure of long-term patterns and trends. Climate change refers to changes in long-term averages of daily weather. "Climate is what you expect, weather is what you get."

We know that our planet is warming because multiple lines of evidence all come to the same conclusion. In Alaska, average annual temperatures have increased by as much as 5 degrees F since 1949. It is difficult to determine whether a flooding event, a melting glacier, or an animal's change in diet is a response to a change in climate. To do so, it is important to understand the role of each part of a regional system and whether a change has been occurring over a long period of time. The more we understand those connections, the more certain we can be that what we're observing is attributable to a changing climate. Climate cycles are driven by variations in both human-induced and naturally occurring phenomena.

The current rapid warming trend is linked to greenhouse gases that human activities add to the atmosphere. Throughout most of Earth's history, global temperature and greenhouse gases have fluctuated but remained in balance. Over recent decades, however, the burning of fossil fuels has added a disproportionate amount of carbon to our atmosphere, which results in higher temperatures. Warming trends are exaggerated in Alaska and other Arctic regions because as ice and snow melt, the darker ground cover left behind absorbs yet more heat. Current warming trends are very likely to continue.



BERING LAND BRIDGE NATIONAL PRESERVE

"Every year, until the protective winter pack ice returns, we agonize that the next storm will be the one that wipes us out."

Luci Eningowuk, Shishmaref Erosion and Location Coalition

NOATAK NATIONAL PRESERVE

"Communities out here depend on a healthy environment for food, and if there are changes in the environment, that's going to create changes in our eating and our harvesting of animals."

John Chase, Northwest Arctic Borough

YUKON-CHARLEY RIVERS NATIONAL PRESERVE

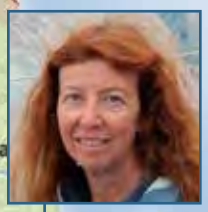
"In the 25 years I have worked as a meteorologist in Alaska, I have seen background conditions that are much different than when I was a young man just getting into forecasting."

Rick Thoman, National Weather Service

DENALI NATIONAL PARK

"I have worked on glaciers in Alaska for over 10 years, and within the time I have been here I have seen the changes in a noticeable way."

Anthony Arendt, University of Alaska



GLACIER BAY NATIONAL PARK

"We can see some of the impacts of climate change in California, but it was really evident throughout our trip to Alaska."

Blair P., California

Iñupiat Heritage Center
Barrow
Gates of the Arctic
Anaktuvuk Pass
Bettles
Alaska Public Lands Information Center
Fairbanks
Yukon-Charley Rivers
Eagle
McKinley Park
Alaska Public Lands Information Center
Denali
Wrangell-Saint Elias
Gulkana
APLIC Anchorage
Anchorage
Valdez
Cordova
Lake Clark
Kenai
Seward
Kenai Fjords
Iliamna
Homer
COOK INLET
GULF OF ALASKA
King Salmon
Katmai
Kodiak
PACIFIC OCEAN
Klondike Gold Rush
Skagway
Haines
Yakutat
Glacier Bay
Gustavus
Juneau
Hoonah
Sitka
Petersburg
Wrangell

QUICK INDEX:

Changing Attractions

Why are Alaska's glaciers disappearing so fast?

What was on the top of your list of things to see and do during your visit to Alaska? If you are like many other visitors to the state, you wanted to see a glacier. Glaciers are a special resource for the National Park Service. Each year, millions of people visit one or more of Alaska's nine glaciated parks

GROWING OR SHRINKING?

Each winter, snow accumulates high in Alaska's mountain ranges. Not all of this snow melts during the summer months, and some eventually becomes blue glacier ice. Like rivers, glaciers flow downslope from the mountains. At lower elevations, glaciers lose mass to melting or to calving. Like a bank account, glaciers can have a positive or negative net balance in a year. A glacier with a negative balance tends to thin or recede. In order to see if long-term climate trends are causing glaciers to lose mass, scientists use satellites to detect overall changes in glacier mass over large regions and several glaciers.

WHAT'S DOWNSTREAM?

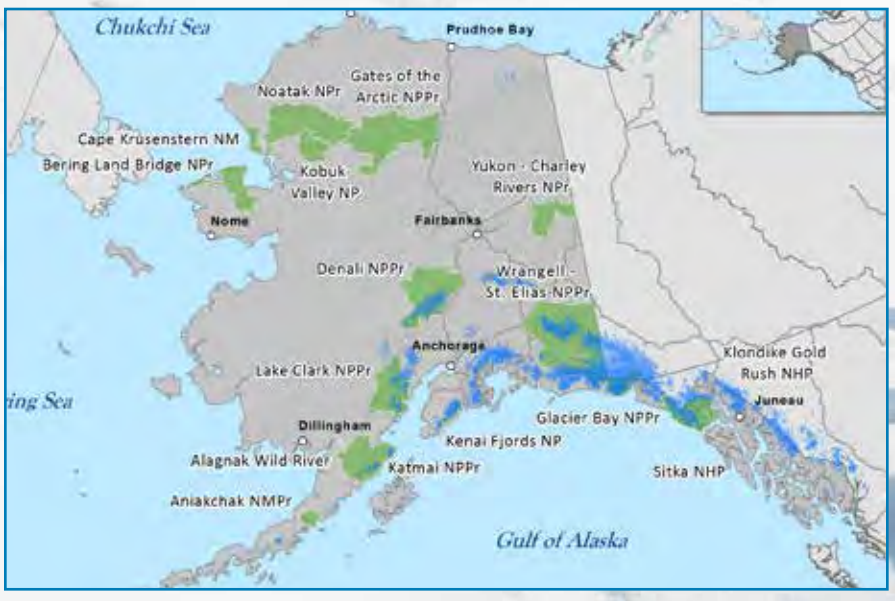
It is very likely that Alaska's glaciers will continue to lose more mass than they are able to gain. This will cause sea level to continue to rise, and may also impact the physical and biological systems that are closely connected to glaciers. In inland parks, glacial meltwater affects the shape of streams, as well as the plants and animal habitats that border streams. In coastal parks such as Glacier Bay National Park, runoff from tidewater glaciers adds cold water, nutrients, and sediments to the ocean. Seabirds, fish, and marine mammals rely on the unique water conditions created by glaciers.

20 YEARS TRACKING ICE

In the past 10 years, Gulf of Alaska glaciers have lost hundreds of billions of tons of ice. The amount of freshwater added to the ocean as a result is equal to completely draining the five Great Lakes each month for a decade. As glaciers melt, the freshwater they release changes the ecology and chemistry of the rivers downstream. Glaciologist Anthony Arendt at the University of Alaska Fairbanks is working with the National Park Service to document changes in glaciers so that the National Park Service, commercial operators, and others can plan for and adapt to the continued loss of glacier ice.

PARKS TAKE ACTION

In order to understand how glaciers are changing, NPS undertook a multi-year study in six of Alaska's park areas. Results of this study showed glacial loss and thinning in many areas. For example, ice cover in Gates of the Arctic diminished 43% between the 1970s and the 2000s; ice cover in areas surrounding Klondike diminished 18% between 1948 and 2011; and all but two Denali glaciers showed loss of mass. Variable results in some parks can be attributed to historical mapping errors or fragmentation of glaciers.



▲ Many of Alaska's National Parks (green) have glaciers (blue). Glaciers cover about 5% of the state of Alaska.

"Glaciers in Alaska probably won't disappear in the next 100 years, but they are likely to change a lot and make large contributions to rising sea levels."

Anthony Arendt, Glaciologist
University of Alaska Fairbanks

"I have been studying glaciers for over 20 years now, and I find it fascinating because it brings together so many elements of science. I always wanted to do something that would allow me to spend time outside and study how the earth was responding to climate, and this was a great avenue for that.

In one project, we are trying to create an inventory of all the glaciers and icefields in Alaska's national parks. We started by looking at glaciers on the USGS maps of Alaska created in the 1950s. Then we compared this with satellite imagery from 2010. We have also set up temperature and precipitation monitors so that we can explore the ways that glaciers may respond to climate change in the future.

Anthony Arendt, Glaciologist
University of Alaska Fairbanks

SCIENCE NOTES: AIR IN THE ICE

While glaciers form, tiny bubbles of air are trapped in the ice, preserving small samples of air from the time period. Scientists are able to analyze air samples from very deep ice cores in Antarctica and Greenland dating back as far as 800,000 years. They can also identify how much carbon in the bubble came from burning fossil fuels because it has an atomic signature that differentiates it from other atmospheric carbon. By studying ice, we have confirmed that not only are humans adding carbon dioxide to the atmosphere in disproportionate amounts, but that the source of this extra carbon dioxide is the burning of fossil fuels.

▶ Anthony and Joanna conduct research on the Kahiltna Glacier in Denali National Park.

Thawing Permafrost

Are we losing stability?

Many of Alaska's parks have a secret underground world of ice and permanently frozen ground known as permafrost. The depth and extent of permafrost varies around the state depending on average air temperatures, soil type, and topography, as well as the types of trees and plants that grow on the surface.

UNCERTAIN FOOTING

Frozen ground is stable, making it possible to build roads and buildings on solid permafrost. As temperatures increase, however, permafrost thaws. Major investments in infrastructure can be lost when soils become unstable. Thawing permafrost leads to drier landscapes, more frequent wildfires, and increased maintenance costs. Thawing soils also release additional greenhouse gases.

GOING WITH THE FLOW

When permafrost thaws, wetlands and lakes drain and flow in new ways, creating slumps, holes, and bank erosion. Maintenance of roads, bridges, trails, and buildings can become difficult and expensive, within and outside of parklands. Denali National Park has one of the most extensive road systems of any park in Alaska. Managing roads in a time of change poses many challenges.

DOWN THE ROAD

Tim Taylor has been working on the road crew in Denali for 31 years. He has seen a range of climate change impacts, including landform slips, slumping ground, earlier springs, milder winters, and more rapid vegetation growth along roadsides. Permafrost thaw is at the core of many of the engineering challenges faced by Tim and his partners with the Department of Transportation.

◀ Permafrost is frozen ground—sometimes with areas of pure ice—that does not thaw even in summer. Insulated below the surface, permafrost acts as a barrier and keeps water from draining deep into the soil. As soils thaw, however, whole lakes can drain and disappear, like this lake in one of Alaska's arctic parks.

▼ Nearly 400,00 people visit Denali National Park each year. Many visitors explore the park via bus which travels the 92-mile park road over 5000 times every summer.

"It seems like thawing is more exaggerated because of climate change. Everything is constantly moving, but you can only throw so much money at it."

Tim Taylor, Road Manager
Denali National Park

PARKS TAKE ACTION

When permafrost thaw undermines road structures, NPS must be ready to take action. Predicting and planning for such change helps prevent accidents and reduce costs.

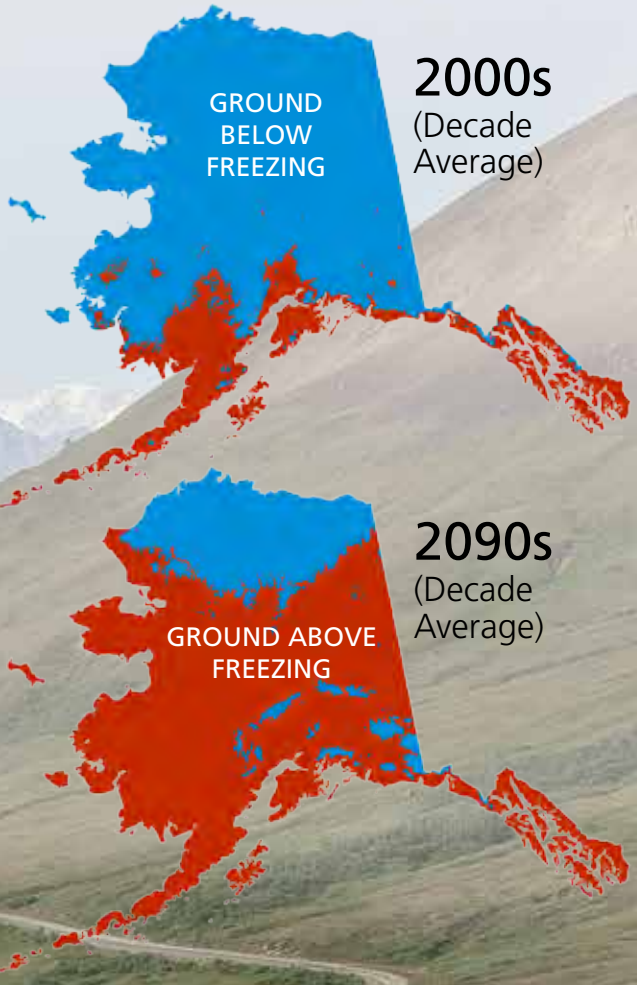
"We all see a lot of changes as far as climate goes, or at least that's what we think. I've got a project going on right now, out at mile 25, and it's a sliding hillside, and we think it has been induced by a thaw, permafrost thawing, and all the tundra is sliding down the hill toward the road, and plugging our ditches and plugging our culverts...

We have a contractor out right now out there who's putting in big rocks and trying to stabilize its slope so it doesn't continue its sliding; and that hasn't always been a problem, that's probably been in the last 15 years…and every time we go to do a repair we have to look at… where it is thawing and try to design it accordingly so it's structurally sound in the future, which is a challenge…

You have to stand back and just do the best you can, because there's just not enough money in the world to attack all these issues."

Tim Taylor, Road Manager
Denali National Park

▼ Combined models of climate and permafrost show that large areas of thawing ground (shown in red) are expected during this century. Thawing soils are likely to affect our roads, buildings, and ecosystems.



Sparked by Lightning

Are natural fire cycles are changing?

Wildfire is an important natural component of boreal forest and tundra ecosystems. Sparked by lightning during hot, dry summers, older vegetation is burned and replaced by new growth. The changing climate has resulted in hotter, drier conditions, as well as more frequent and intense fires.

PART OF THE INTERIOR

Most fires in the state occur in the boreal forests of Interior Alaska. Parks in this region include Denali National Park and Preserve, Gates of the Arctic National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. Historically, tundra fires have been smaller and rarer than forest fires, but they may have a greater impact on the landscape as the Arctic becomes warmer and drier.

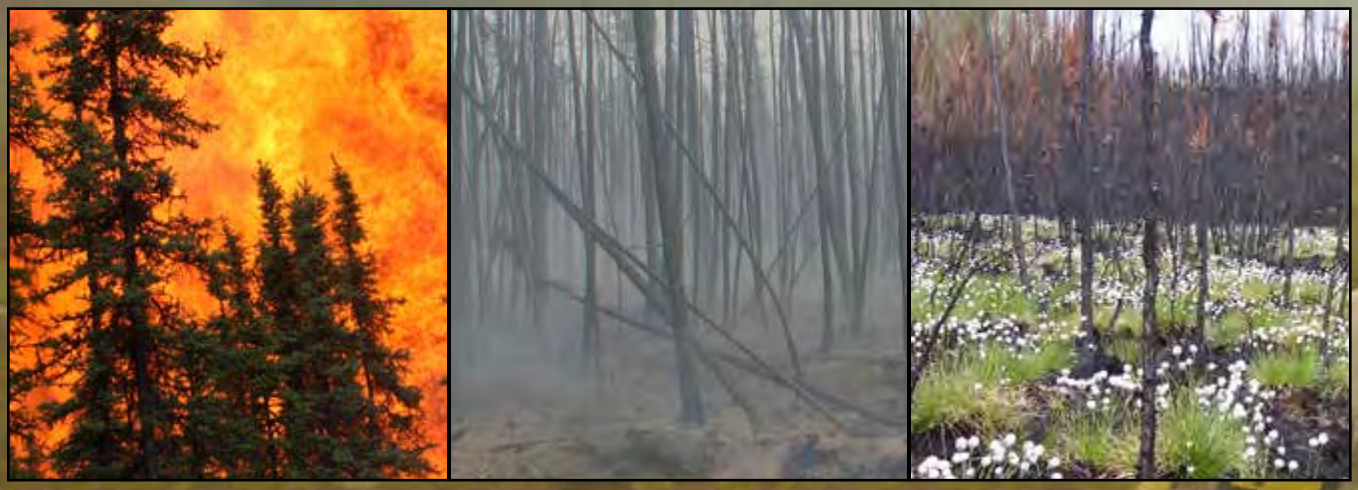
WINNERS AND LOSERS

The area burned per year in Alaska ranges from a few hundred thousand to several million acres. As more acres burn, the landscape changes. Ashes left by fire are rich in minerals such as calcium, phosphorus, and potassium. Grasses and shrubs benefit from the enriched soil left after a burn, while lichens, moss, and algae do not. Some plant and animal species may have a harder time returning after more frequent, hotter, and longer fires.

MILLIONS OF ACRES

John Lyons has worked as a firefighter in Alaska for 26 years. He understands that higher average air temperatures may affect fire. "If the climate pattern results in longer summers and longer active burning periods, we're going to see a lot more fire on the landscape and we're going to see big landscape burns." In the last decade (2000-2009), the area burned in Alaska was twice as large as in any decade in the previous 40 years.

▼ Fire is a natural part of the boreal forest. The spruce trees are adapted to withstand frequent, low intensity fires. Cottongrass, fireweed, and other plants are the first plants to come up after a fire. Fires that are more intense may threaten this time-tested cycle by killing more trees, creating better conditions for invasive species, or affecting the ability of plants to colonize the burned soil.



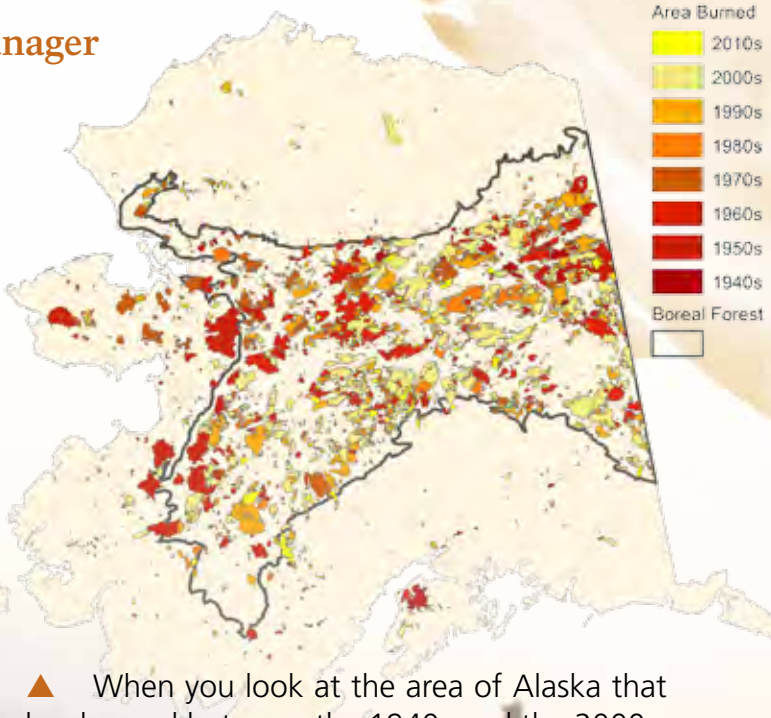
"The big [fire] seasons are where you really wonder, what's this landscape going to look like in 50 years if this keeps up?"

John Lyons, Fire Manager
Denali National Park

PARKS TAKE ACTION

The primary focus of the Alaska National Park Service Fire Ecology Program is to understand the effects of fire on the landscape. Fire ecologists collect and analyze information about fire behavior and the effects of fire on vegetation, fuels, soil, and wildlife habitat. The results inform fire management planning, objectives, and decisions.

One long-term monitoring effort looked at tundra fires and other changes in Noatak National Park from 1981 to 2005, a remarkable period of warming in the North American Arctic. This study found that shrubs were expanding into tundra areas where they did not grow before.



▲ When you look at the area of Alaska that has burned between the 1940s and the 2000s, you can see how prevelant fire is in the boreal forest region of Interior Alaska.

▲ John Lyons and his team discuss their strategy for addressing a forest fire.

Finding the Wildlife

Will there be food on the table or not?

Many Alaskans depend on moose, caribou, salmon, ducks, and other animals for food. Changes in snow cover or the timing of river freeze-up can affect the ability of people to reach the animals they use for food. Changes in wildfire or extreme weather events also influence hunting success and animal health.

A LIFE ON THE LAND

There are almost 300 small communities in Alaska that cannot be reached by roads. These communities are largely inhabited by Alaska Native people who have centuries-long traditions of relying on the land for the foods needed to survive and thrive. In such communities, many necessities—from building supplies to fuel to groceries—must be brought to town by airplane or boat. As a result, such commodities are very expensive.

PROTECTING TRADITIONS

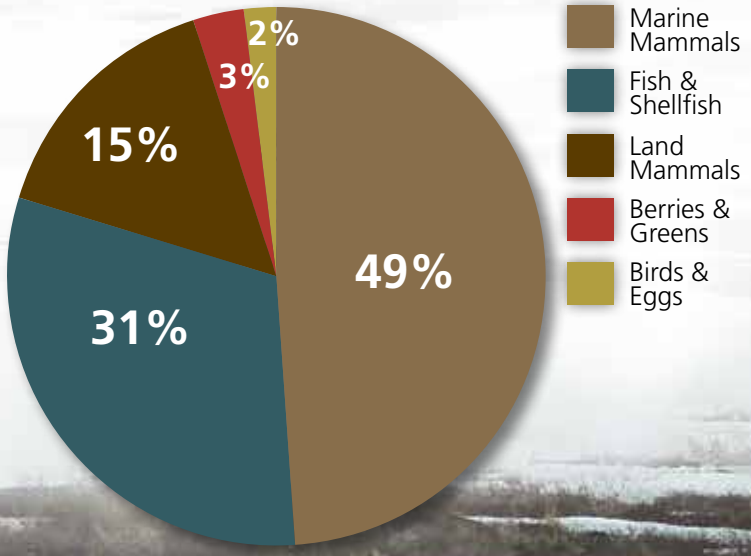
In Alaska, the national parks have unique relationships with local communities. Subsistence activities—including hunting, fishing, and gathering traditional foods—are not only essential to Native culture, but are also a necessity for many families, given the high cost of food that is flown in. This traditional way of life is protected by Federal law as part of the Alaska National Interest Lands Conservation Act (ANILCA).

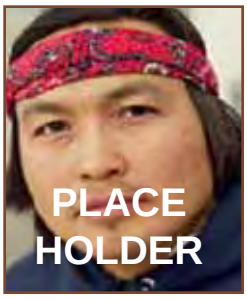
SEASONS OUT OF SYNC

John Chase is an Alaska Native who grew up hunting and fishing near the village of Bethel. He now works for the Northwest Arctic Borough and lives with his wife,son, and daughter in Kotzebue, a community of about 3200 people with no road access to the rest of the state. Growing up and hunting in Alaska, John has observed seasonal changes that are affecting the resources that local people rely on.

▲ Depending on the region of Alaska, different wild foods make up different portions of people's diets. Many foods, like seal (left) and salmon (right), can be dried and frozen so they can be eaten all year.

▼ In 2007, an average citizen in the arctic coastal community of Kivalina consumed nearly 600 pounds of wild foods in one year. About 50% of that total came from marine mammals like seals and whales. About 30% came from fish and shellfish, and another 15% came from land mammals, such as caribou.





"Communities out here depend on a healthy environment to harvest food, and if there are changes in the environment, that's going to create changes in how we harvest that food."

John Chase, Community Development & Flood Program Specialist, Northwest Arctic Borough

"It will rain or snow when it's not supposed to….when you get rain on a winter day it's never good, because ice will cover the plants that caribou forage on….i've even heard of ice trapping ptarmigan underneath….if the caribou aren't able to forage and feed because of that layer of ice, there are going to be hungry and unhealthy caribou….i'd like to let folks know that we have a spiritual connection to the land, and that we depend on a healthy environment for survival. If there are changes to the land, we're going to have to and we will adapt to those changes."

"I've heard stories of folks who have seen change, and I have experienced it myself. But we're a people that are always adapting. If you put some changes out there, we are always going to adapt to those changes. I can't say how that is going to happen because I can't predict the future, but we are a people who are always adapting to our environment."

"For us, the important question is whether there is food on the table or not?"

John Chase
Kotzebue, Alaska

PARKS TAKE ACTION

One of the efforts of the National Park Service, in collaboration with many other partners, is to monitor the Western Arctic Caribou Herd. This effort is to better understand an extremely important subsistence species found in all of the park units in the Arctic Network: Gates of the Arctic, Kobuk Valley and Noatak National Parks, as well as reindeer in Bering Land Bridge National Preserve, and to better understand caribou ecology across the Arctic region. Successful monitoring of the Western Arctic Herd by NPS staff is combined with existing efforts by the Alaska Department of Fish and Game (ADF&G), US Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM).

Loading the dice

Is climate change taking our weather to the extremes?

Unusual weather events, like the winter rains John Chase observed in and around Kotzebue, are affecting other parts of Alaska too. It is not possible to link any one flood, storm, heat wave, or other weather event to climate change, but climate change may be "loading the dice" in favor of extreme storms, flooding, and fires.

HAZARD ZONES

In Alaska, extreme weather events frequently threaten people, wildlife, or infrastructure. Weather forecasts are very important for people traveling on remote highways, in small planes, or on boats. Understanding exactly how climate change will impact extreme events can be challenging because there is so much uncertainty about the future frequency, intensity, and even the types of events we see.

UNCERTAINTY

By examining climate data provided by the best available science and models, we can identify what thresholds may be crossed that can lead to sudden change. This information also allows us to examine a range of scenarios of the types of events that may unfold. Planning can then focus on ways to prepare for the full range of possible futures, emphasizing solutions that make sense across a wide range of outcomes.

THE PRICE TAG

Typically, climate change is described in terms of averages. Most of the social and economic costs associated with climate change will result from changes in the severity and frequency of extreme events. Such events are extremely hard to predict, but being prepared for floods, droughts, heat waves, or storms can help protect lives and preserve resources.

PARKS TAKE ACTION

▼ When the towns of Eagle and nearby Eagle Village were hit hard by flooding from the ice-jammed Yukon River in the spring of 2009, NPS already had an Incident Command team on site. The team's proactive assistance and hard work proved crucial. They helped calm rising panic among residents and rescued two people and a 24-dog mushing team from a home threatened by the flood. Although property damage and destruction were great, NPS action helped prevent even greater losses.

▲ Ice jams are very powerful and destructive. Ice chunks as big as houses and cars easily plowed over these full size spruce trees on the bank of the Yukon River near Eagle.

"Extreme events are—and always have been—a part of our weather and climate. However, climate change involves an observable shift in the severity and frequency of extreme events."

Rick Thoman, Weather Forecaster
National Weather Service Alaska

"All of the experience you gain as a weather forecaster is based on a set of assumptions, and they have a normal range. Extreme weather events often fall outside of this normal range, and forecasters in Alaska have already had to adjust to unprecedented events and learn to expect the unexpected.

In the 25 years I have worked as a meteorologist in Alaska, I have seen background conditions that are much different than when I was a young man. If our experience no longer serves us, then we have less information to help people and communities prepare for and cope with weather events."

Rick Thoman
Fairbanks, Alaska

▼ When the Yukon River flooded the community of Eagle in the spring of 2009, ice and water swept away homes. Historic buildings were destroyed, including the US Customs house (below) where Jack London and Wyatt Earp once signed the US Customs book. Before the flood of 2009, the US Customs house stood unharmed on the banks of the Yukon River for over 100 years.

Losing Ground

Are coastal communities at risk?

As permafrost disappears and sea ice forms later in the season, coastal communities become more susceptible to storms. Unprotected shorelines are hammered by waves and winds from autumn storms, resulting in unprecedented rates of coastal erosion. Some communities are trying to relocate to more inland locations.

SOFT SOIL, HARD CHOICES

One threatened community is located on a small barrier island off the coast of Alaska near the Arctic Circle. About 600 people call Shishmaref home. The seas that surround the island no longer freeze before the arrival of powerful fall and winter storms, as they had for centuries. Storm waves now batter the unprotected coastline, causing hundreds of feet of erosion and washing away buildings and other property.

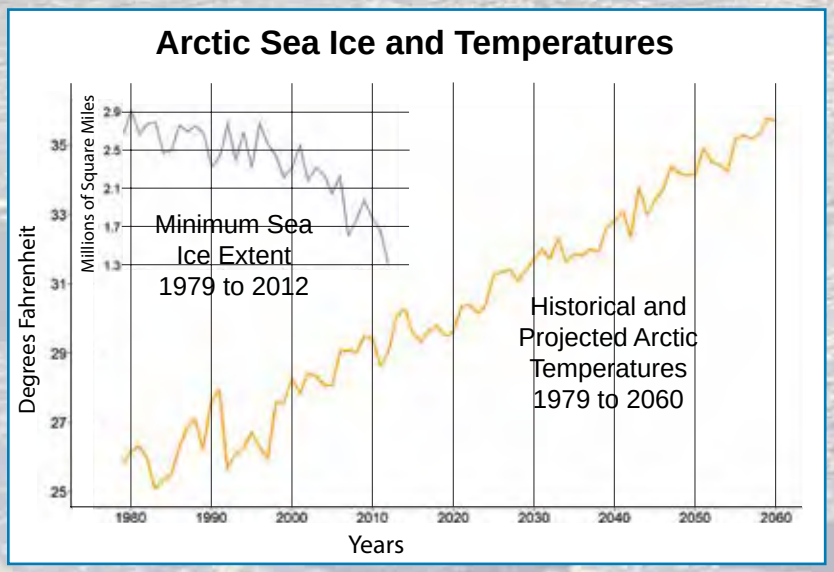
COMMUNITIES AT RISK

In 2004, Luci Eningowuk testified before the United States Senate. "To date, we have lost numerous storage buildings and boats, an ATV, two snowmachines, meat-drying racks, and buried food. Tragically, we have lost one home; so far we have been able to move 18 threatened homes. However, those of us living here know that it is merely a matter of time before we experience greater losses. We are quickly running out of space on our ever-shrinking island."

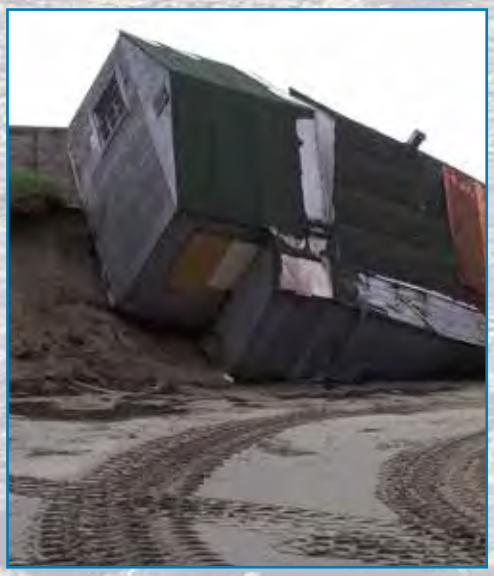
SEA ICE DECLINES

The average sea ice extent in September has decreased by 11.5% per decade over the past 30 years. This dramatic decline is, in part, a result of longer warm seasons. The change is also linked to the "Arctic Oscillation," an index defined by atmospheric pressure patterns in the polar region that affect the middle latitude jet stream. Satellite images and climate models show continued retreat and thinning of Arctic sea ice. By the 2040s, late summers could be nearly ice-free.

▼ Summer sea ice extent and overall ice thickness have been declining for at least 30 years, since satellite monitoring of sea-ice extent began. Recent projections for sea ice minimums indicate that a nearly ice-free Arctic Ocean will occur by mid-century, and perhaps before 2030.



▼ This house in Shishmaref is one of many across Alaska that have lost the battle with eroding shorelines.



"Every year, until the protective winter pack ice returns, we agonize that the next storm will be the one that wipes us out."

Luci Eningowuk, Former Chairperson
Shishmaref Erosion and Location Coalition

Born in Shishmaref, Fred Tocktoo now lives in Nome where he has worked at the Bering Land Bridge National Preserve since 1992. In his lifetime, he has seen major changes in weather patterns, particularly in their predictability.

"Everything changes in a minute… When we were growing up, we had sort of a weather pattern that was stable, but now you can't trust it. If you're going to plan for a long time, a two or three day trip, chances are that you're going to be storm-bound somewhere.

Fifty or sixty years ago, it was stable [enough] that you were almost guaranteed that if you were going to go from Shishmaref to Wales, you get there in 3 days by dog team. Now, with faster snowmachines, you get there in 3 hours, but within those 3 hours the weather can change two or three times. And, the ice conditions are so unstable that people don't venture out more than three or four miles from the mainland nowadays."

Fred Tocktoo
Nome, Alaska

Luci Eningowuk is an Iñupiat Eskimo and a resident of the coastal village of Shishmaref. She is the former Chairwoman of Shishmaref's Relocation Committee.

"Our community is heavily reliant on subsistence, as are most Alaska Native Communities. Our diet is based on the animals and plants found nearby. Relocation of our community away from our home territory would have a devastating impact on how we exist and who we are. Consolidation with another community is not acceptable, as it will cause extensive competition for subsistence foods, and depletion of natural resources. Our way of life is centered around subsistence; it is the driving force of our existence."

Luci Eningowuk
Shishmaref, Alaska

▶ Arctic sea ice has changed dramatically in the last 30 years. Native elders describe how the ice used to form much earlier in the fall. This ice protected coastal communities from the pounding waves of autumn storms. Now, without the ice, communities are more vulnerable to erosion.

The Acid Test

Will they adapt or are marine species in trouble?

Alaska has more coastline than any other US state, and the ocean is a major part of Alaska's economy and culture. Marine mammals and fish—particularly salmon—provide important resources for Alaska residents and for exports.

OCEAN ACIDITY

Over the past century, Earth's oceans have absorbed approximately 525 billion tons of carbon dioxide from the atmosphere—about one third of all carbon emissions released from fossil fuel burning, deforestation, and urbanization. This carbon dioxide absorption increases oceanic acidity (reduced pH). This in turn reduces the availability of carbonate ions that marine organisms such as corals, marine plankton, and shellfish need for shell formation.

SPECIES AT RISK

An increase in ocean acidity has ramifications felt across the food chain. Pteropods, which can make up more than 50% of the juvenile pink salmon diet, are particularly sensitive to changing acidity levels in the ocean. Since different species have different sensitivities to altered pH, there is no one-size-fits-all response. In addition to the potential effects of ocean acidification, species at risk also face threats from higher temperatures, pollution, or other factors.

PROBING THE DEPTHS

Claudine Hauri is a researcher at the University of Alaska. She has been studying ocean acidification using data she collects at sea, from varying depths and locations. Despite the breadth of her work, she urges that far more research is needed in order to understand not only what change is occurring, but also the connection between pH and species at risk. "Organisms react differently…but in Alaska, not many organisms have been studied."

PARKS TAKE ACTION

Researchers from the University of Alaska Fairbanks have been studying ocean acidification in Glacier Bay, a highly productive glacial fjord environment with few direct anthropogenic impacts. The environment at Glacier Bay has been shaped by a rapid loss of glaciers over the last 250 years, making it an ideal natural laboratory to study the role of glacier retreat in the ocean acidification process. As glaciers have retreated, the amount of freshwater entering Glacier Bay in the form of glacial meltwater has increased. Glacial meltwater has naturally low alkalinity, which is the principle measure of how well waters are buffered to protect against changes in pH or ocean acidification. By measuring seawater chemistry at sites with varying levels of glacial meltwater, researchers hope to relate their findings to the known history of glacial retreat and employ this understanding to better anticipate future changes in the acidity of Glacier Bay.

◀ Sea butterflies (left) have winglike lobes for swimming. They a type of pteropods or small sea snails. They may be sensitive to changes in the ocean pH, because the acidic water dissolves their shells.

These animals and other shelled animals may be small, but they are the base of the marine food web. Impacts to their populations could affect theanimals that rely on them for food.

"The biggest challenge we face, is multiple stressors that will get stronger and stronger...it's all very complex and interconnected."

Claudine Hauri, Scientist
University of Alaska Fairbanks

SCIENCE NOTES: ACIDIFICATION IN THE FAR NORTH

While many national parks are terrestrial, NPS also protects several special marine areas, where ocean acidification may become a pressing issue. Although this change in pH is occurring worldwide, the effects are more pronounced in Alaska for several reasons. Colder water absorbs more CO_2. The waters that circulate toward Alaska on prevailing ocean currents are already high in natural CO_2 due to the decomposition of organic matter from massive phytoplankton blooms further south. In addition, meltwater from glaciers tends to lower the water's pH.

"The biggest cruise I have done went from Dutch Harbor up to the Beaufort Sea and back, and that took about a month. We have 12 hour operations on the ship, and I analyzed samples for the whole time. We lower the instruments down to 4000 meters, and just one cast can take up to 4-5 hours.

In the ocean, the CO_2 is taken up by the water and acts as an acid, changing the chemistry of the water. The pH gets lower, and that means it acidifies the oceans. The global ocean surface pH used to be 8.2 and now it has dropped by 0.1 [about a 30% increase in acidity]. This is a big deal for some organisms because some are very sensitive to their chemical environment."

Claudine Hauri
Fairbanks, Alaska

▲ Oceanographers use instruments that are lowered into the ocean to collect water samples from different locations and depths. The samples can be analyzed on the ship or in the lab to determine the pH of the water.

Adapting to new Patterns

Is climate change shifting whole ecosystems?

The pronounced warming trend of the past several decades is driving change at a scale as vast as the landscapes of Alaska. Ecosystems are shifting as plants and animals move northwards or are replaced by new species. The ramifications of these changes are felt both locally and statewide.

A BIRD'S-EYE VIEW

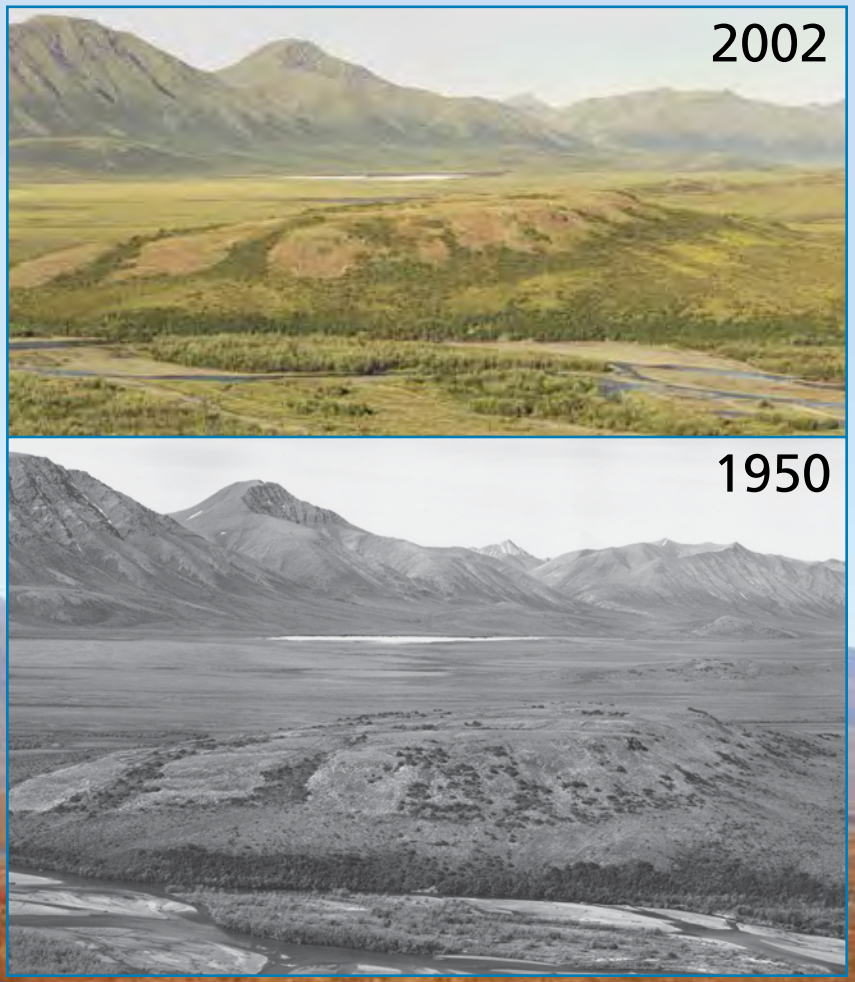
Ecosystem change is experienced at ground-level by Alaska residents or visitors who spend time on the land, but it can also be detected and measured by flying over the landscape or gathering satellite data. Observed changes in forests, lakes, shrublands and wetlands are predicted to continue, based on models that link climate with landscape changes across the state.

ANIMALS ON THE MOVE

Following a fire, vegetation changes affect different animal species differently. Moose tend to browse most heavily in recently burned areas, which are rich in birch, aspen, and willow. Caribou, on the other hand, tend to avoid recently-burned areas and prefer old growth lichen woodlands and tussock tundra - ecosystems that are less resilient to fire.

FOOD FROM THE LAND

Many Alaskans rely on moose and caribou for food. About 7,000 moose and 22,000 caribou are harvested in Alaska each year, amounting to about 6 million pounds of meat. Changes in fire cycles as a result of warmer and drier conditions may make it easier for some people to hunt the meat they rely on – and harder for others.



▶ This repeat photo pair shows the expansion of shrubby plants on the Nimiuktuk River, in the western Brooks Range. The old photo, from the Col photo collection, is from 1950, and the new photo is from 2002. Warmer temperatures create better conditions for shrubs. Notice how they have expanded. The white patch in the background of both photos is remnant aufeis (frozen overflow) from the previous winter.

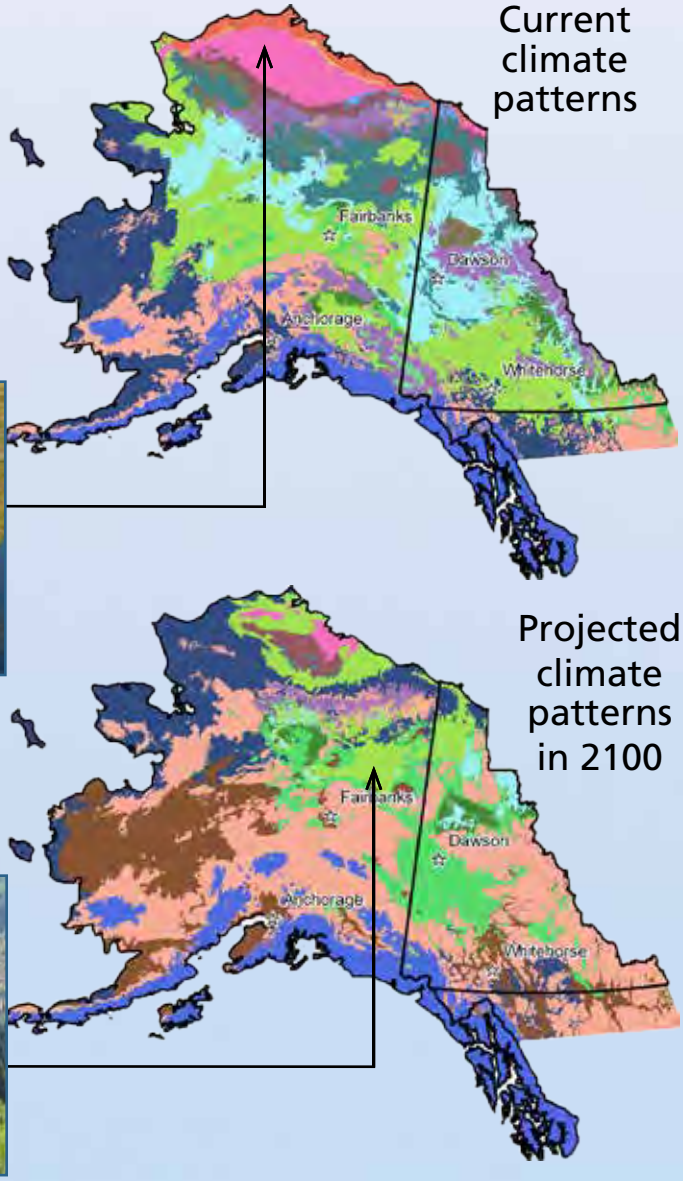
Photos courtesy of Ken Tape, from *The Changing Arctic Landscape*

SCIENCE NOTES: LANDSCAPE MODELING

Creating clusters of areas with similar climates allows researchers at the Scenarios Network for Alaska and Arctic Planning to project how ecosystems may respond as the climate changes. Current climate patterns (top) are likely to undergo radical changes by the end of this century (bottom). As a result, some plants and animals are likely to migrate northward, while others may become threatened or disappear.

▶ The arctic (pink and orange) currently experience very short summers and extremely cold winters. Permanently frozen ground lies just below the surface, and wetlands cannot easily drain. It is dominated by tundra—a mix of grass and low shrubs, with no tree cover (above). In the Arctic, current climate patterns are likely to all but disappear by the end of this century.

▶ The future climate of the arctic areas is predicted to be more similar to what is currently seen in the interior of the state (light green). Here, slightly longer, hotter summers allow dense spruce forests to dominate.



▲ Computer models look at changes in temperature and precipitation and historic conditions to make estimates about the future. Although plant and animal species cannot always migrate across the landscape as rapidly as the climate changes, models such as this one can provided hints as to what Alaska may look like in the future and help people plan for the future..

PARKS TAKE ACTION: CLIMATE MODELING

Climate is currently the most important factor influencing Alaska's ecosystems. Global climate models indicate that the changes will be greatest in the arctic. Climate monitoring is critical to understanding changing park ecosystems. NPS has invested substantial time and effort in developing the NPS Inventory and Monitoring Program. This intensive, landscape-scale program tackles critical questions about how trends in temperature and precipitation are changing in Alaska's national parks. Monitoring helps park managers detect changes in climatic conditions and quantify the ecological consequences of these changes. Climate trends are woven into a comprehensive picture of multiple possible futures. Inventory and Monitoring data will make a critical difference in our understanding of climate trends in Alaska over the next 50 years, and will help managers select appropriate and effective actions.

Impressions to Last a Lifetime

How do visitors respond to climate change impacts?

Alaska is famous for capturing the hearts and minds of people around the world. Alaska national parks are home to some of our nation's greatest natural treasures, but these places and settings could be very different for future park visitors.

NATURAL REFLECTIONS

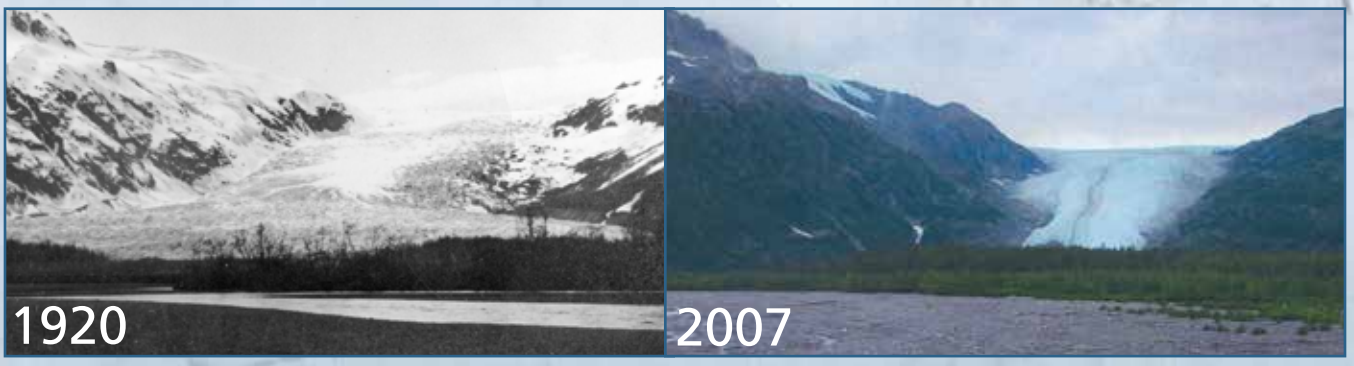
Alaska's national parks have the power to inspire and transform. As visitors learn about themselves and explore their connection to the natural world, they also recognize that changes are occurring around the state. In the future, the effects of climate change will increasingly become part of this learning experience and part of the story that both enriches and challenges park visitors.

REACHING OUT

The National Park Service strives to increase awareness about specific impacts to park areas and current strategies for addressing these impacts. Educational products such as this booklet explain what we understand about climate change in the parks. Keeping rangers and tour guides up-to-date on climate research helps keep visitors and residents informed and engaged in planning for a changing future.

MIXED EMOTIONS

Sometimes visitors feel a sense of internal conflict about the changes to park resources that are being driven by climate change. One guest described her tour to a tidewater glacier in Kenai Fjords National Park. She was thrilled that her tour boat was able to get so close to a calving glacier, but the glacier's rapid recession and lack of icebergs were what made the close approach possible.



▲ Exit Glacier, in Kenai Fjords National Park, has significantly thinned and receded in the past century. These photos show the glacier in 1920 (left) and 2007 (right). Exit Glacier is visited by several thousand people each year, and access to the shrinking glacier will become more challenging as it continues to recede.

▲ Blair, California

"Because of its beauty, Alaska is a place I had always wanted to go. One of the highlights of our trip was walking in the tundra at Denali. It was so cool—just soft, spongy carpet. It was so gorgeous and there was no one around.

We can see some of the impacts of climate change in California, but it was really evident throughout our trip to Alaska. It's just obvious that it's happening. Every time we went to a glacier, there were pictures and signs of what the glacier used to look like and what it looks like now. It really brought it home. We talked with many of the rangers and tour guides, and they all acknowledge that it is happening.

We need more people to get out there—to say this is going on and we need to do something about it. We need to know what individuals can do about this problem."

▲ Timothy, Arkansas

"It wasn't ever hard to convince my wife to take a trip to Alaska—she was just as excited as I!

We visited the Mendenhall Glacier, and it was really interesting how the glacier was in a radically different spot just 80-90 years ago. It was an "oh my goodness" moment for me. I like to be able to see things before I buy in. Climate change is such an abstraction; it's hard for people to grasp what it means. You can't see carbon, but when you see how much a glacier like Mendenhall has receded, it's really crystallized.

I used to go to the grocery store and get a plastic bag every time. I stopped doing that after my Alaska trip. I used to think, what difference does one person make? I felt a personal responsibility to do things differently after my trip to Alaska—I want to do something about climate change."

▲ Christine, Oregon

"I try to get back to Alaska every few years. We still have a cabin there—it is on a lake and we have to fly in to get to it. In 2004 we came up to visit and go to the cabin, but we couldn't get there because massive forest fires had caused so much smoke that visibility was reduced.

During that trip, we landed in Anchorage at about 10 o'clock at night and it was really warm. I mentioned this to the taxi driver and was really surprised when he started telling me all about the ways that climate change is impacting Alaska.

We started asking the people that we met about climate change, and everyone would describe how it was happening and start giving examples."

The Future is Now

Alaska's National Parks lead by example

Because carbon dioxide remains in the atmosphere for several decades, we can expect that temperatures will continue to rise until we dramatically reduces our emissions. The National Park Service is working to minimize its carbon footprint. With impacts already being felt in parks and nearby communities, park managers and local residents must continue to find ways to respond and adapt.

LEADING BY EXAMPLE

The Alaska NPS uses climate change scenario planning to explore different ways the future may unfold and identify how climate change may impact them. Jeff Mow participated in several scenarios planning workshops. He admits that climate change is "a massive thing that can make your head hurt", but he believes that scenario planning has improved the conversation by breaking the issue into manageable bits.

BUILDING KNOWLEDGE

Parks use a variety of studies to guide adaptation to changing conditions, despite the uncertainties. Glacier monitoring studies investigate how the park and its resources may be vulnerable in the future. Social science research has helped innovate climate change communication by examining climate change perceptions of visitors and local business operators.

RETHINKING PROCESSES

National parks provide a means to think about what is possible in our communities and in our everyday lives. In what ways can we change? Learning to do things differently will not be easy. NPS areas have traditionally been managed to preserve unique habitats, special features, important systems, or remnants of our past; however, as the climate changes, preserving certain values may be impossible.

▲ Climate change is adding challenges to NPS management, such as road damage and flooding. NPS is responding by increasing education efforts and making proactive changes. Recent innovations in Alaska's parks include new energy systems, electric and hybrid vehicle fleets, and higher standards for recycling waste. With these efforts, NPS is making a difference and saving money at the same time.

"The past will not be our guide to a future with climate change."

Jeff Mow, Former Park Superintendent
Kenai Fjords National Park

▼ At Denali National Park and Preserve, Eielsen Visitor Center recently received Leadership in Energy and Environmental design (LEED) Platinum Certification. The LEED program sets global standards for high performance in buildings that are efficient, cost-effective, and better for occupants and the environment. By using materials from the existing building, and recycling them into a renewed and more efficient replacement, NPS is demonstrating what shaping the future is all about.

SCIENCE NOTES: IT ALL COMES BACK TO CARBON

Carbon is one of the building blocks of life. We exhale carbon dioxide and plants absorb it. The oceans also absorb carbon dioxide. Carbon is added to soil each time a living thing dies, slowly accumulating over millions of years. When people take this carbon out of the ground in the form of coal and oil and burn it, they rapidly add ancient stores of carbon back into the atmosphere. There is more carbon dioxide in the atmosphere now compared to any other time in earth's history. Since 1950, CO_2 concentrations in the atmosphere have grown from 285 to over 400 parts per million. Based on estimates from ice cores, that level is higher than it's been in 3 million years.

A Shared Journey

What will our grandchildren's parks look like?

We are in the early steps of a long journey towards adapting to Earth's changing climate. This journey that will take decades to fully achieve, and will likely result in a significantly different way of life for most of us, regardless of where we live. Alaska's National Park System areas are living laboratories and communities for understanding, appreciating, and protecting a continually changing environment and invaluable natural heritage. We invite you to join the conversation and to share the experience.

This publication represents a joint effort from the US National Park Service (NPS), Alaska Region and the Scenarios Network for Alaska and Arctic Planning (SNAP), University of Alaska.

We welcome you to explore the expanded digital version of the book, available here: [website] or by scanning the QR code (left).

www.nps.gov/akso www.snap.uaf.edu