LOREM IPSUM

Climate Change info for Interpreters at Katmai National Park

KATMAI NATIONAL PARK AND PRESERVE

Climate Change

Climate Change and Interpreters

Climate change is one of the greatest challenges humanity faces in the 21st century. Climate change impacts they way national parks are used and managed and the ecosystems within them. It alters weather patterns and ocean temperatures, increases the risk of drought, can exacerbate habitat loss and extinction, causes sea level rise, and affects our ability to grow and access food across the globe.

The scientific consensus on human-caused climate change is overwhelming: humans, primarily through the burning of fossil fuels like oil and coal, are forcing earth's climate to warm. There is no scientifically plausible alternative theory that explains the changes to Earth's climate we are experiencing today.

In this chapter, you'll find basic information about the physics of climate change, how it may impact Katmai's resources, visitor surveys regarding opinions on climate change, and techniques to help you interpret climate change.

Consider weaving relevant climate change messages into your programs, social media posts, and roving contacts. With so much misunderstanding and misinformation about climate change and the potential consequences of no action, we have a duty to interpret this topic.

Climate Change and the Role of Interpreters

NPS Director Jon Jarvis and others explain why interpreters in the National Park Service have a chance to make a big difference helping the public understand and care about climate change.

Climate Change Basics

In This Section

The information in this section is gleaned from a variety of sources, especially climate.nasa.gov. Other sources are linked to within the text.

What is the greenhouse effect?

The greenhouse effect is a natural phenomenon whereby heat-trapping gases in the atmosphere, primarily water vapor, keep the Earth's surface warm. Without the greenhouse effect, our planet could not support life as we know it. Human activities, primarily by burning fossil fuels and changing land cover patterns, are increasing the concentrations of some of these gases, like carbon dioxide, amplifying the natural greenhouse effect.

Certain gases in the atmosphere block heat from escaping. Long-lived gases that remain semi-permanently in the atmosphere and do not respond physically or chemically to changes in temperature are described as "forcing" climate change. Gases, such as water vapor, which respond physically or chemically to changes in temperature are seen as "feedbacks."

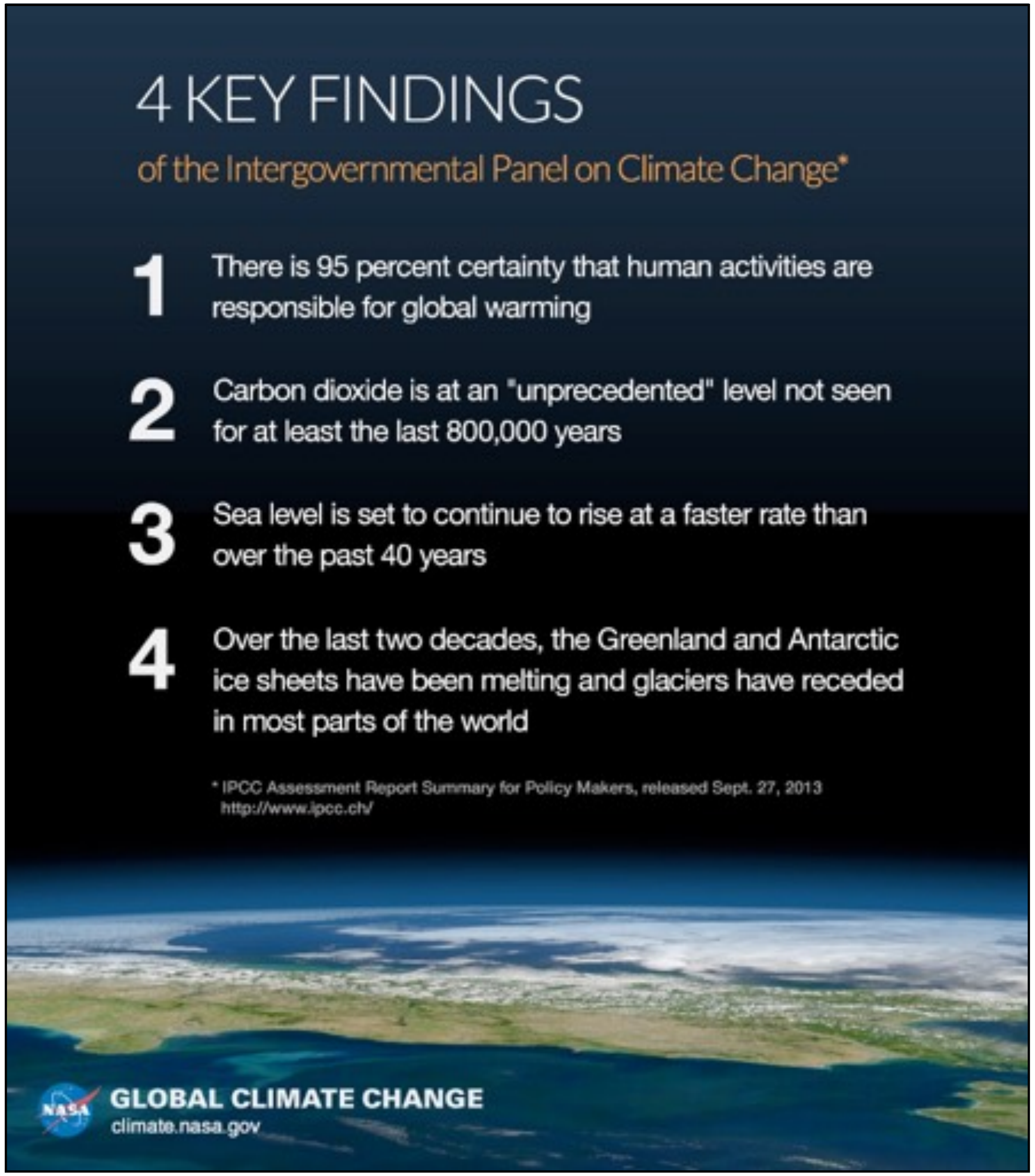
Are You Climate Literate?

This PDF contains the basics on earth's climate. Source: http://pmm.nasa.gov/education/articles/climate-literacy-essential-principles-climate-sciences

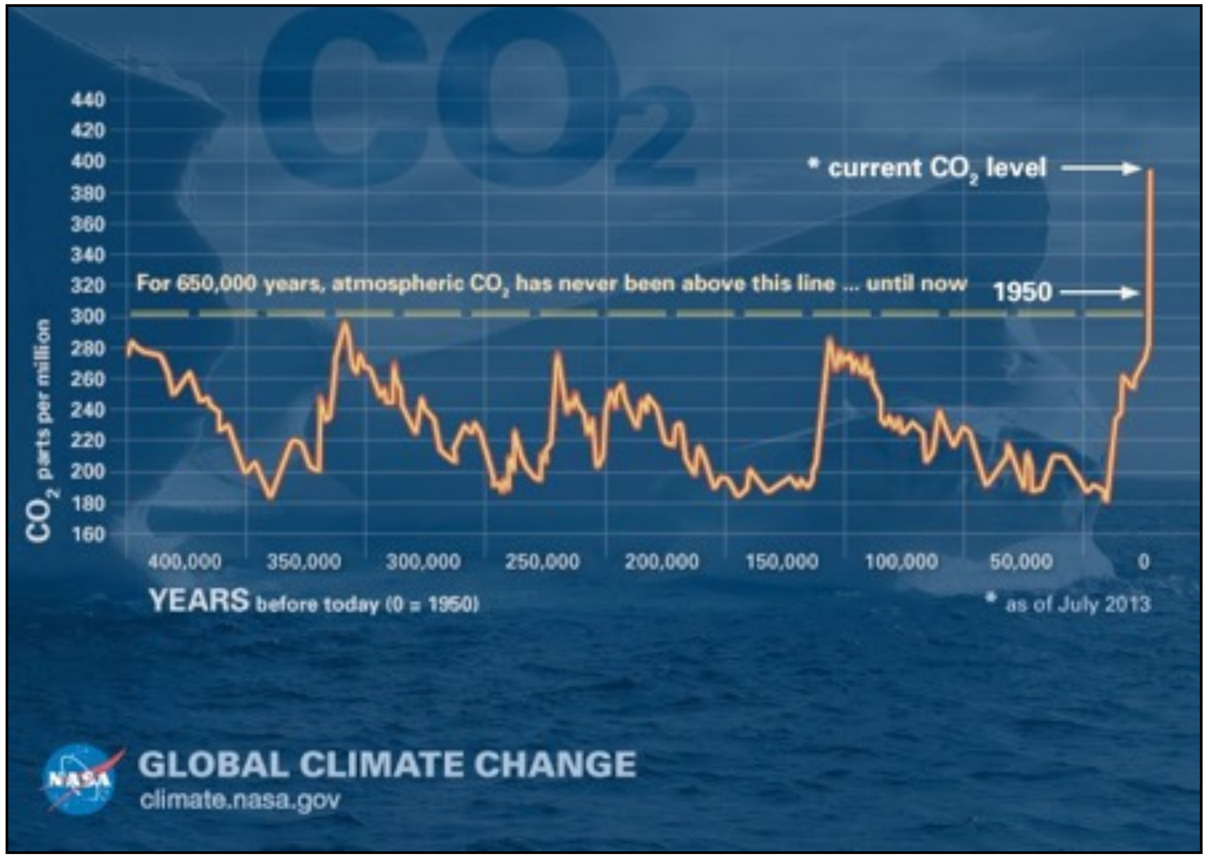
How does CO_2 trap heat?

Carbon dioxide (CO_2) is a minor but very important component of the atmosphere. Carbon dioxide is released through natural processes such as biological respiration, volcano eruptions, and through human activities such as deforestation, land use changes, and burning fossil fuels. The coal or oil burning process combines carbon with oxygen in the air to make CO_2. Humans have increased atmospheric CO_2 concentration by a third since the Industrial Revolution began. This is the most important long-lived forcing of climate change.

By burning fossil fuels, humans have essentially thickened the insulating blanket around Earth. CO_2 is transparent to visible light, but not infrared energy. Sunlight reaching earth heats the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet. Infrared energy, radiating towards space from Earth's surface and atmosphere is trapped and reemitted by CO_2. Therefore, an increase in



The above graphic lists four highlights from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report Summary for Policy Makers, released September 27, 2013, which more than 25 NASA scientists helped author and review. The report is the work of 209 lead authors and 50 review editors from 39 countries, and over 600 contributing authors from 32 countries. Source: http://climate.nasa.gov/climate_resources/26/



Ancient air bubbles trapped in ice enable us to step back in time and see what Earth's atmosphere, and climate, were like in the distant past. They tell us that levels of carbon dioxide (CO_2) in the atmosphere are higher than they have been at any time in the past 400,000 years. During ice ages, CO_2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm. In 2013, CO_2 levels surpassed 400 ppm for the first time in recorded history. This recent relentless rise in CO_2 shows a remarkably constant relationship with fossil-fuel burning, and can be well accounted for based on the simple premise that about 60 percent of fossil-fuel emissions stay in the air. Today, we stand on the threshold of a new geologic era, which some term the Anthropocene, one where the climate is very different to the one our ancestors knew.

If fossil-fuel burning continues at a business-as-usual rate, such that humanity exhausts the reserves over the next few centuries, CO_2 will continue to rise to levels of order of 1500 ppm. The atmosphere would then not return to pre-industrial levels even tens of thousands of years into the future. This graph not only conveys the scientific measurements, but it also underscores the fact that humans have a great capacity to change the climate and planet. Source: http://climate.nasa.gov/climate_resources/24/

CO_2 increases the atmosphere's ability to absorb and retain heat.

The consequences of changing the natural atmospheric greenhouse are difficult to predict, but certain effects seem likely:

- On average, Earth will become warmer. People in some regions may welcome warmer temperatures, but others may not.
- Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer.
- A stronger greenhouse effect will warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing further to sea level rise.
- Meanwhile, some crops and other plants may respond favorably to increased atmospheric CO_2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities.

Evidence for Human-Caused Climate Change

Many lines of evidence lead scientists to conclude that humans, primarily through burning of fossil fuels, are changing Earth's climate.

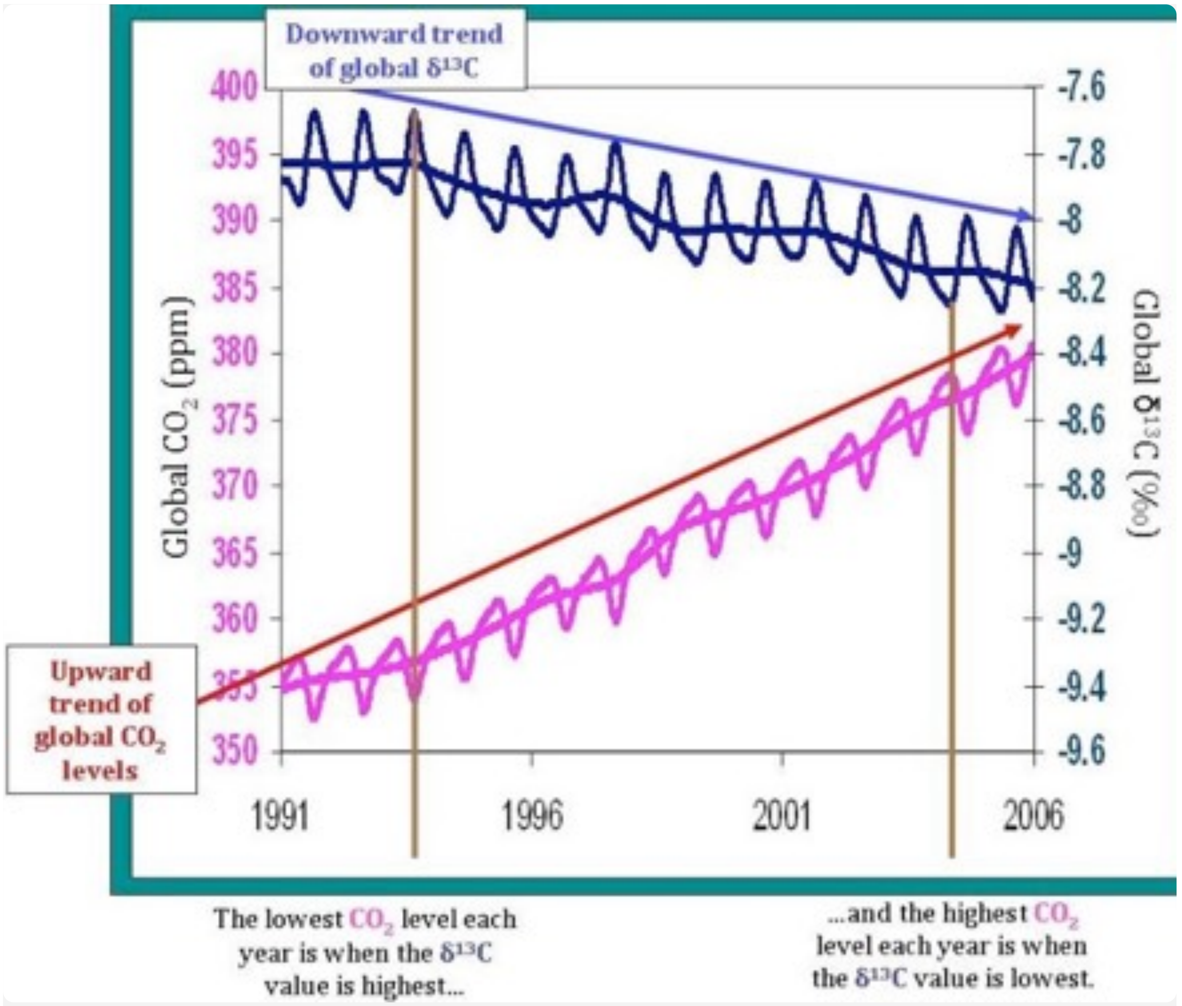
Atmospheric CO_2 Levels are Increasing: CO_2 levels in the atmosphere have climbed rapidly since the Industrial Revolution. In late January 2016, the level of CO_2 in the mid-troposphere was 402 ppm.

CO_2 Increase is From Fossil Fuels: By measuring the changing ratios of different carbon isotopes in the atmosphere, scientists can trace how much carbon is from fossil fuels. Isotope signatures are a smoking gun that directly connects the rise in atmospheric CO_2 directly to humanity's emissions.

Carbon has three isotopes—^{12}C, ^{13}C, and ^{14}C. Two of these, ^{12}C and ^{13}C, are stable. They are not radioactive and do not decay into another element or isotope. ^{14}C is radioactive and has a half life of 5,730 years. Since fossil fuels are millions of years old and ^{14}C half life is so short, fossil fuels do not contain ^{14}C.

By studying how the ratio of these isotopes have changed in the atmosphere, scientists have determined that the atmospheric increase in carbon dioxide is dominated by fossil fuel emissions. During photosynthesis, plants prefer to take in ^{12}C over ^{13}C. Simply put, plants have less ^{13}C compared to ^{12}C than the atmosphere. Fossil fuels also have less ^{13}C relative to ^{12}C than the atmosphere. Why? Fossil fuels are ancient plants.

Therefore, when CO_2 from fossil fuels enter the atmosphere, the amount of ^{14}C and ^{13}C in the atmosphere goes down. This is precisely what has been measured.

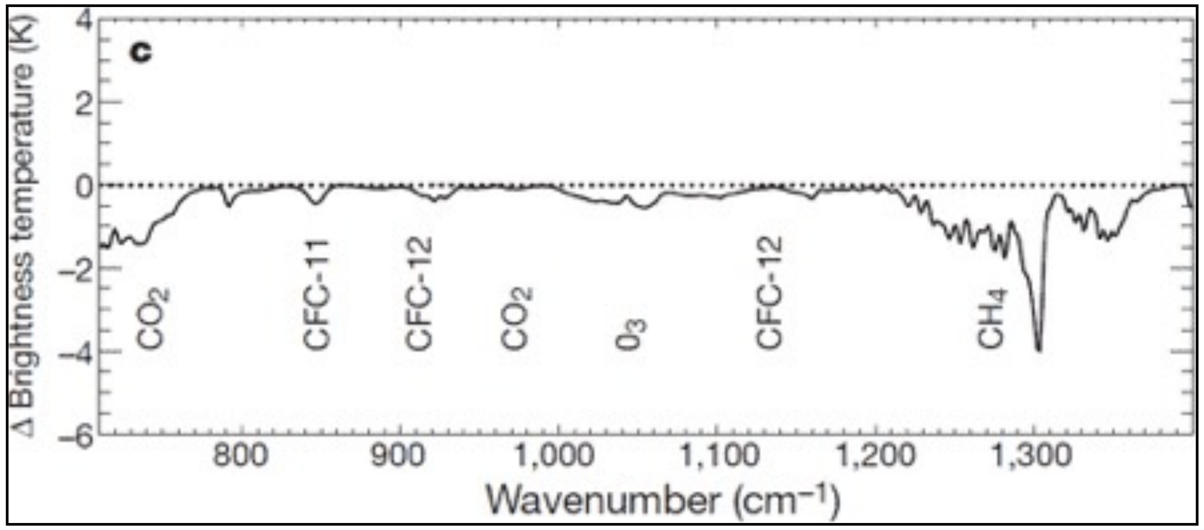


While global CO2 levels in the atmosphere have risen, the levels of certain elements of carbon in the atmosphere, like 13C and 14C, have decreased.

The relative proportion of ^{13}C in our atmosphere is steadily decreasing over time. Most fossil fuels, which are ancient plant and animal material, have the same ^{13}C isotopic fingerprint as other plants. The annual trend–the overall decrease in atmospheric ^{13}C–is explained by the addition of carbon dioxide to the atmosphere that must come from the terrestrial biosphere and/or fossil fuels. Since the amount of ^{14}C in the atmosphere is not going up either—it's going down too—then the increase in carbon (i.e. CO_2) in the atmosphere can only be from fossil fuels. Read more in-depth information at http://www.esrl.noaa.gov/gmd/outreach/isotopes/.

CO_2 Absorbs Infrared Energy: Carbon dioxide's ability to absorb infrared energy has been known since the 19th century. Now, satellite technology allows us to measure warming from CO_2 and other greenhouse gases in the upper atmosphere.

CO_2 and other gases absorb infrared energy along certain wavelengths and the amount of radiation of these wavelengths outgoing into space

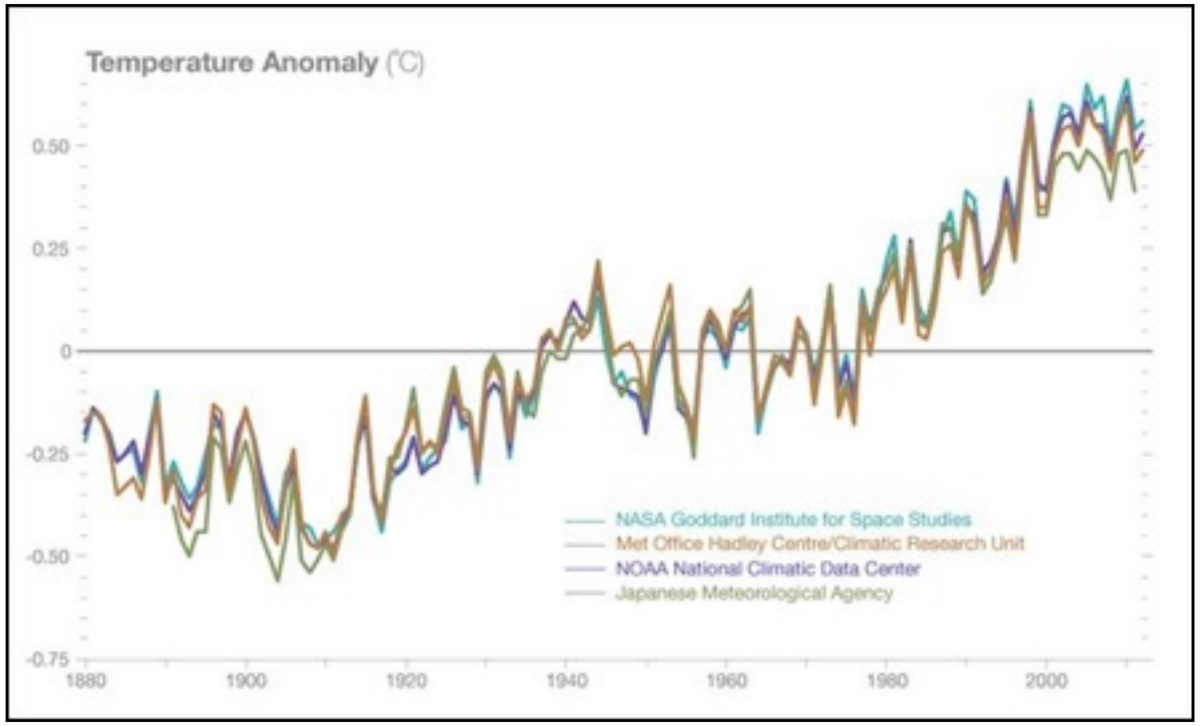


Less infrared energy is reaching space from Earth because CO2 and other greenhouse gases are absorbing it. (Harries, 2001)

can be measured. Doing this demonstrates CO_2 is adding considerable warming along with ozone (O_3) and methane (CH_4).

In 2001, John Harries and others published a paper in Nature documenting direct experimental evidence for a significant increase in the Earth's greenhouse effect that is consistent with greenhouse gases. Emissions infrared radiation into space have decreased at exactly the same wavelengths that CO_2 is best at absorbing. Less infrared radiation is reaching space because there is more CO_2 in the atmosphere to absorb it. Find more information at https://www.skepticalscience.com/empirical-evidence-for-CO2-enhanced-greenhouse-effect-basic.htm.

Global Temperatures have Increased: All four major global surface temperature reconstructions show that Earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years. Even though solar output declined in the



Temperature data from four international science institutions. All show rapid warming in the past few decades and that the last decade has been the warmest on record. Data sources: NASA's Goddard Institute for Space Studies, NOAA National Climatic Data Center, Met Office Hadley Centre/Climatic Research Unit and the Japanese Meteorological Agency.

2000s, resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continued to increase.

In sum, we know that CO_2 absorbs and reemits infrared energy. We know that CO_2 levels in the atmosphere are increasing. We know that the increase comes from humans burning fossils fuels. We know that temperatures in the ocean and atmosphere are increasing. All lines of evidence point towards humans as the cause for the climate change we experience today.

Other Evidence and Impacts

1. **Warming Oceans and More Acidic Oceans:** The oceans have absorbed much of the earth's increased heat, with the top 700 meters

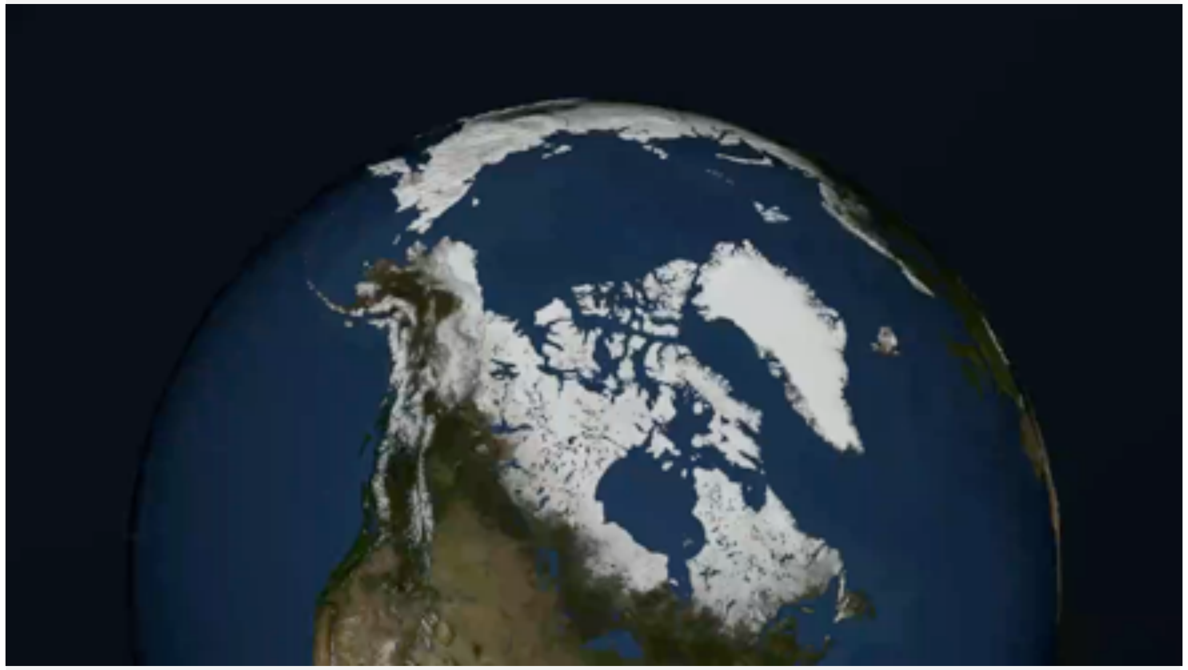
(about 2,300 feet) of ocean showing warming of 0.302 degrees Fahrenheit since 1969 (NASA, http://climate.nasa.gov/evidence/). When water absorbs CO_2, it can form a weak, but important acid called carbonic acid (H_2CO_3). Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH units. Since the pH scale, like the Richter scale, is logarithmic, this change represents approximately a 30 percent increase in acidity. Source: http://www.pmel.noaa.gov/CO2/story/What+is+Ocean+Acidification%3F.

2. **Sea Levels are Rising:** Global sea level rose about 17 centimeters (6.7 inches) in the last century. The rate in the last decade, however, is nearly double that of the last century.

3. **Extreme Events are More Frequent:** The number of record high temperature events in the United States has been increasing, while the number of record low temperature events has been decreasing, since 1950. The U.S. has also witnessed increasing numbers of intense rainfall events.

4. **Glaciers, Ice Caps, and Sea Ice are Shrinking:** The Greenland and Antarctic ice sheets have decreased in mass. Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska, and Africa. Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades.

5. **Decreased Snow Cover:** Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier.



Arctic Sea Ice Minimum: Arctic sea ice reaches its minimum each September. September Arctic sea ice is now declining at a rate of 13.4 percent per decade, relative to the 1981 to 2010 average. This animation shows the difference in the area, volume and depth of the average September Arctic sea ice between 1979 and 2013. Each grid cell of the ground plane is 1,000 kilometers in width, or one million square kilometers per cell. The depth of the sea ice is measured in meters. Source: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4206

Climate Change Impacts on Alaska and Katmai

In This Section

Alaska and the Arctic are warming more rapidly than much of the rest of the planet. At first glance, this temperature change could be welcomed. However, climate change will fundamentally alter the state's ecology and potentially the way of life for people all across the state. Since Alaska is so varied geographically, ecologically, and climatologically, changes will happen in different ways and at different rates across the state.

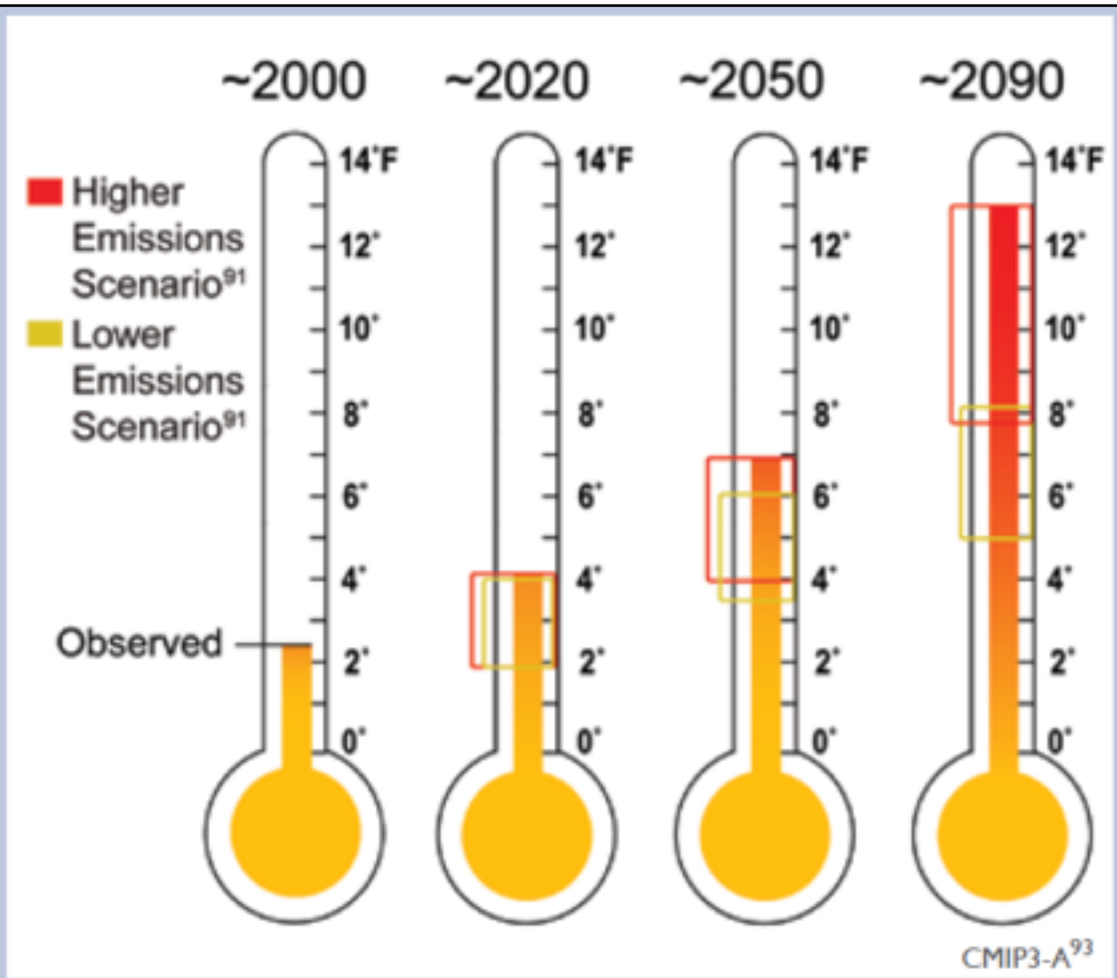
Because of its cold-adapted features and rapid warming, climate change impacts on Alaska are already pronounced, including earlier spring snowmelt, reduced sea ice, widespread glacier retreat, warmer permafrost, drier landscapes, and more extensive insect outbreaks and wildfire.

This section outlines some of the changes observed and modeled for Alaska and the Katmai region.

The information in this section is derived primarily from Ch. 22 Alaska in the 2014 Climate Change Impacts in the United States, National Climate Assessment available at http://nca2014.globalchange.gov/report/regions/alaska. Tap on the image to read the PDF. The website also has expanded content and is well worth visiting. Both the PDF and website include citations. Other information specific to the Katmai area is included and cited when necessary.

Projected Climate Change in Alaska

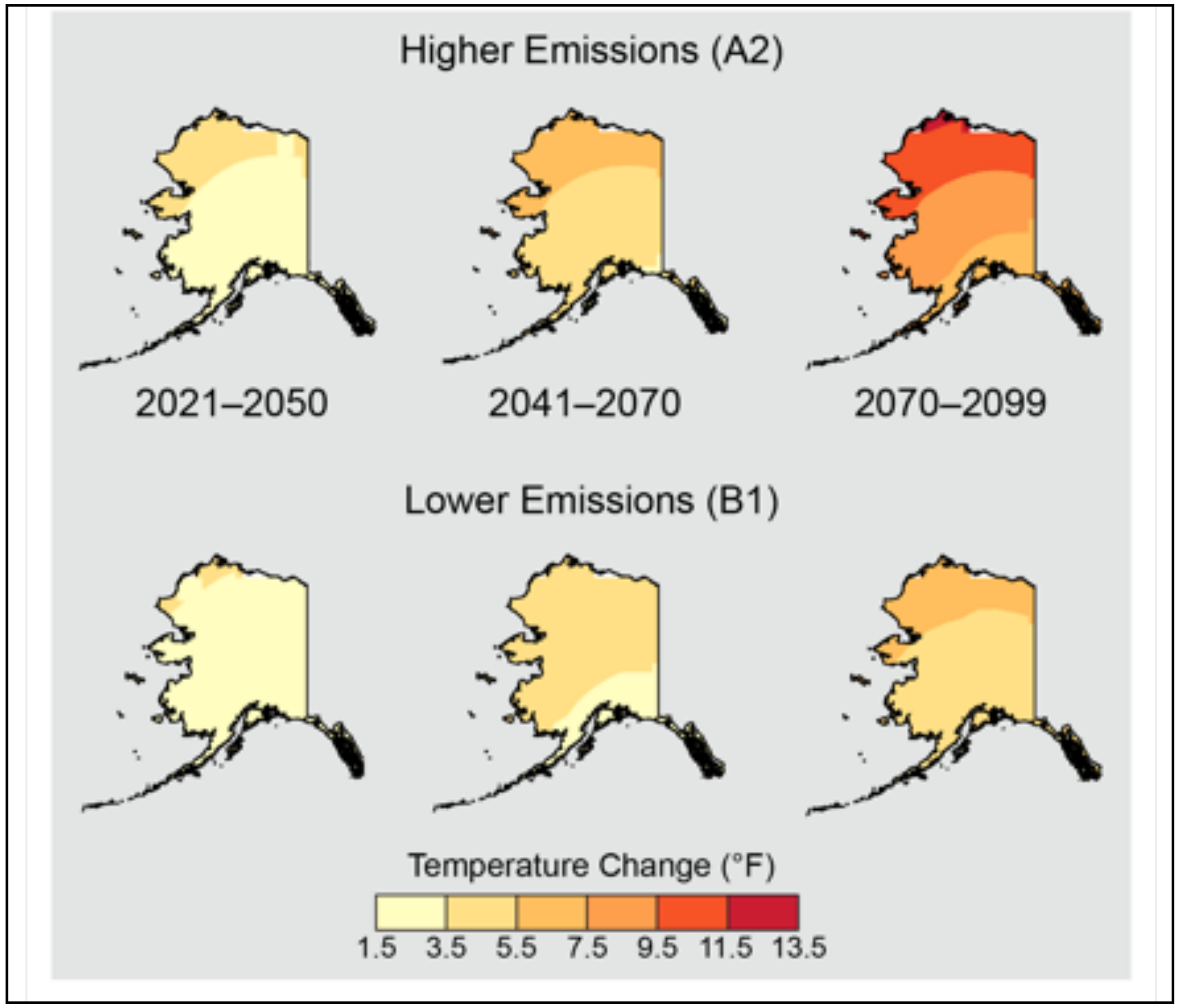
Average annual temperatures in Alaska are projected to rise by an additional 2°F to 4°F by 2050. If global emissions continue to increase during this century, temperatures can be expected to rise 10°F to 12°F in the north, 8°F to 10°F in the Interior Alaska, and 6°F to 8°F in the rest of the state. Even with substantial emissions reductions, Alaska is projected to warm by 6°F to 8°F in the north and 4°F to 6°F in the rest of the state by the end of the century.



Alaska's annual average temperature has increased 3.4°F over the past 50 years. The observed increase shown above compares the average temperature of 1993-2007 with a 1960s-1970s baseline, an increase of over 2°F. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. By the end of this century, the average temperature is projected to rise by 5 to 13°F above the 1960s-1970s baseline.

Annual precipitation is projected to increase, especially in northwestern Alaska, as part of the broad pattern of increases projected for high northern latitudes. Annual precipitation increases of about 15% to 30%

Alaska Will Continue to Warm Rapidly



Northern latitudes are warming faster than more temperate regions, and Alaska has already warmed much faster than the rest of the country. Maps show changes in temperature, relative to 1971-1999, projected for Alaska in the early, middle, and late parts of this century, if greenhouse gas emissions continue to increase (higher emissions, A2), or are substantially reduced (lower emissions, B1).

are projected for the region by late this century if global emissions continue to increase. All models project increases in all four seasons. However, increases in evaporation due to higher air temperatures and longer growing seasons are expected to reduce water availability in most of the state.

The length of the growing season in interior Alaska has increased 45% over the last century and that trend is projected to continue. This could improve conditions for agriculture where moisture is adequate, but will reduce water storage and increase the risks of more extensive wildfire and insect outbreaks across much of Alaska. Changes in dates of snowmelt and freeze-up would influence seasonal migration of birds and other animals, increase the likelihood and rate of northerly range expansion of native and non-native species, alter the habitats of both ecologically important and endangered species, and affect ocean currents.

Shrinking Glaciers

Most glaciers in Alaska and British Columbia are shrinking substantially. This trend is expected to continue and has implications for hydropower production, ocean circulation patterns, fisheries, and global sea level rise.

Alaska is home to some of the largest glaciers and fastest loss of glacier ice on Earth. This rapid ice loss is primarily a result of rising temperatures. Loss of glacial volume in Alaska and neighboring British Columbia, Canada, currently contributes 20% to 30% as much surplus freshwater to the oceans as does the Greenland Ice Sheet – about 40 to 70 gigatons per year, comparable to 10% of the annual discharge of the Mississippi River. Alaska is home to 11% Earth's mountain glaciers, but

Fourpeaked Glacier: Then and Now

Fourpeaked Mountain area seen from Cape Douglas in 1904 (R. Stone) and 2005 (M. Jorgenson). Comparison with Stone's 1904 image shows dramatic retreat of Fourpeaked Glacier (left) and an unnamed glacier (right). In 1904, both glaciers were near their maximal extent after the Little Ice Age. 1904 photo courtesy USGS. Tap on the icon to see the before and after photos.

Mount Douglas: Then and Now

Unnamed glacier south of Cape Douglas seen in 1895 (C. Purington) and 2005 (M. Jorgenson). Purington's photograph shows the glacier's terminus at or near its maximal extent following the Little Ice Age. By 2005, it had retreated out of the field of view. Tall scrub has established widely on morainal surfaces, but not on the continually disturbed floodplain of the glacial stream. 1895 photo courtesy USGS. Tap on the icon to see the before and after photos.

25% of mountain glacier's total contribution to sea level rise. In Alaska, most glacial retreat is due to warmer temperatures, not a reduction in precipitation (Shad O'Neel, USGS glaciologist in a presentation to Earth to Sky participants, Oct. 14, 2015).

Glaciers continue to respond to climate warming for years to decades after warming ceases, so ice loss is expected to continue, even if air temperatures were to remain at current levels. The global decline in glacial and ice-sheet volume is predicted to be one of the largest contributors to global sea level rise during this century.

Spotted Glacier: Then and Now

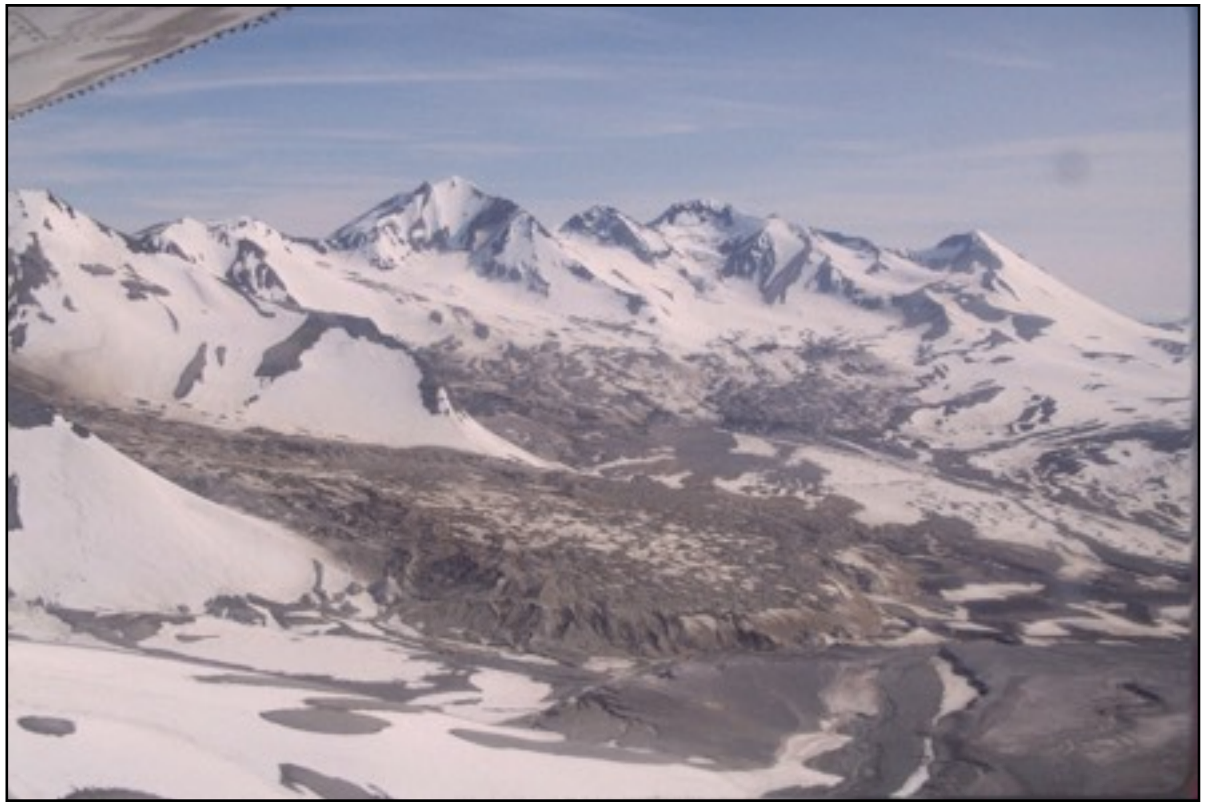
Spotted Glacier area looking west in 1904 (T. Stanton) and 2005 (M. Jorgenson). In 1904 the glacier was near its maximal extent following the Little Ice Age, but in the last century the glacier has retreated about 6 km. The young morainal surface has been colonized by alders and scattered trees, while the center of the valley is occupied by a moraine-dammed lake. Thaw of ice-cored moraine has formed several kettle ponds. 1904 photo courtesy USGS. Tap on the icon to see the before and after photos.

Glacial Change on Mount Mageik

On Mount Mageik, all glaciers have retreated since they were first photographed. Ash fall on Mageik thins from 50 cm on its northeast to 5 cm on its southeast and nearly all of it was removed within a few decades. National Geographic Society photo from 1919 and 2010 photo from M. Fitz. Tap on the photo to see the before and after photos.

Glaciers supply about half of the total freshwater input to the Gulf of Alaska. Water from glacial landscapes is also recognized as an important source of organic carbon, phosphorus, and iron that contribute to high productivity in coastal waters, so changes in these inputs could alter critical nearshore fisheries.

Katmai's glaciers cover around 915 km² (350 mi²) based on 2009 satellite imagery around 2009, including glaciers wholly or partly inside of the park boundary. In Katmai the number of glaciers counted on 1950s



Debris covered glaciers respond to climate change differently than bare ice. The lower portions of the Knife Creek Glaciers are covered with a heavy mantle of ice and pumice from the 1912 Novarupta-Katmai eruption which insulates the glaciers and slows melting. As much as 12 meters of fallout remain on parts of the Knife Creek Glaciers on Trident. As a result, the Knife Creek Glaciers have advanced over top of the 1912 ash flow.

USGS topographic maps was 255 glaciers, and 298 glaciers in satellite imagery, an increase of 17%. However, the glacial area decreased from 1,060 km² to 915 km² (410 mi² to 350 mi²), or -14%.

Most glaciers in the Katmai area are receding, like most glaciers in Alaska, but glaciers that were covered by thick deposits of 1912 ash are not receding and some have advanced. Terminus retreat was the response seen in most individual glaciers, including notable retreats by glaciers on Fourpeaked and Douglas mountains in the northeast section of the park and Hallo Glacier and others on Kukak Volcano. (Information on Katmai's glaciers in the last two paragraphs are from a draft Katmai Geologic Report. The final report should be available in 2016).

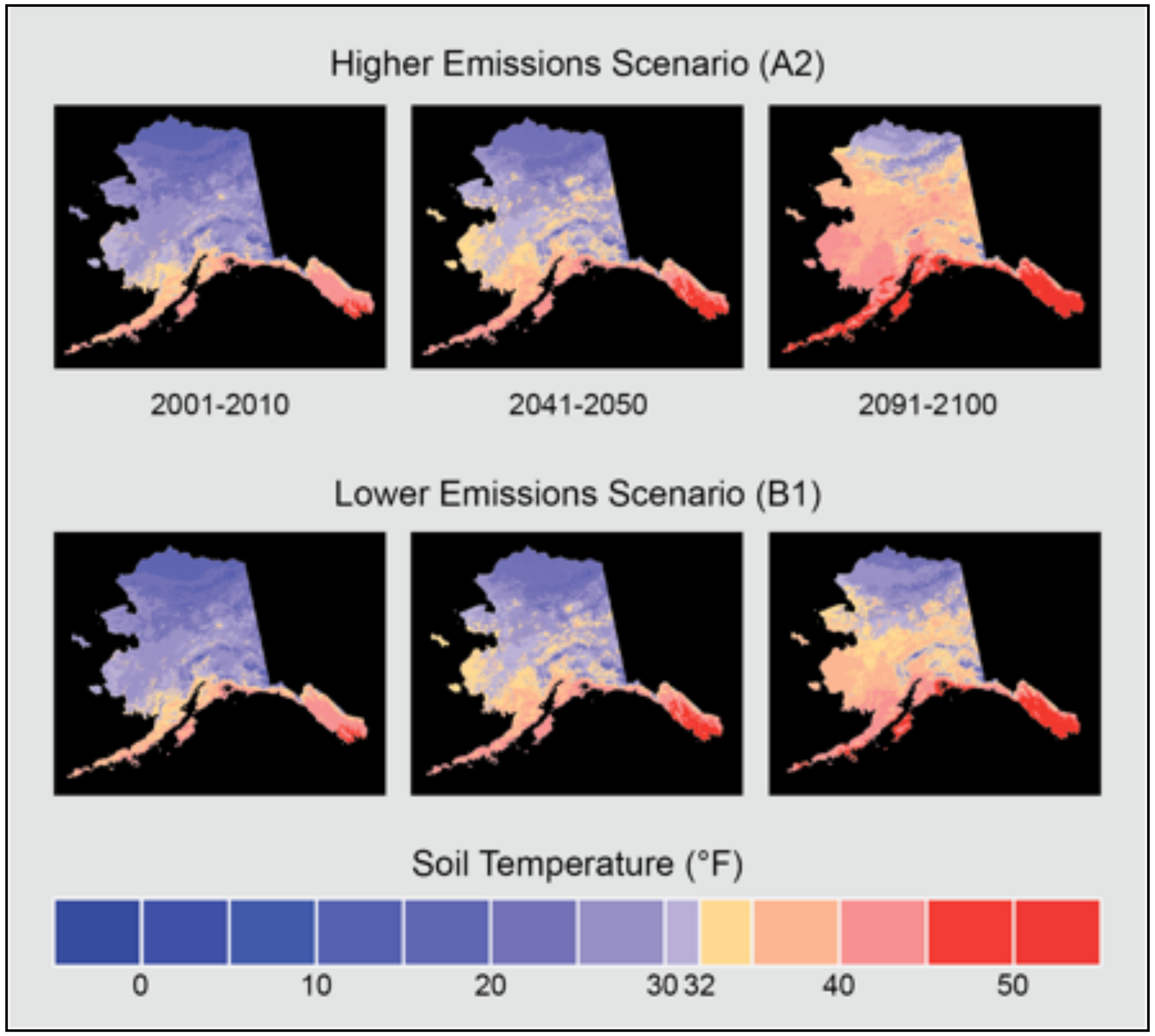
Thawing Permafrost

Alaska differs from most of the rest of the U.S. in having permafrost – frozen ground that restricts water drainage and therefore strongly influences landscape water balance and the design and maintenance of infrastructure. Permafrost near the Alaskan arctic coast has warmed 4°F to 5°F at 65 foot depth, since the late 1970s and 6°F to 8°F at 3.3 foot depth since the mid-1980s. In Alaska, 80% of land is underlain by permafrost, and of this, more than 70% is vulnerable to subsidence upon thawing because of ice content that is either variable, moderate, or high. Thaw is already occurring in interior and southern Alaska and in northern Canada, where permafrost temperatures are near the thaw point. Models project that permafrost in Alaska will continue to thaw and some models project that near-surface permafrost will be lost entirely from large parts of Alaska by the end of the century.

Although the average annual temperature at King Salmon is above freezing, isolated permafrost is present in the western portion of Katmai on the coastal plain under areas insulated by peat and thick vegetation mats. The presence of the permafrost is possibly due to the insulating properties of overlying peat, or remnants of the Pleistocene glaciations. Frost-wedge crack nets are present at higher elevations on a pass near Kaguyak caldera (Hults, Chad. Draft Katmai Geologic Report. 2016).

Changes in terrestrial ecosystems in Alaska and the Arctic may be influencing the global climate system. Permafrost soils throughout the entire Arctic contain almost twice as much carbon as the atmosphere. Warming and thawing of these soils increases the release of carbon

The Big Thaw



Projections for average annual ground temperature at a depth of 3.3 feet over time if emissions of heat-trapping gases continue to grow (higher emissions scenario, A2), and if they are substantially reduced (lower emissions scenario, B1). Blue shades represent areas below freezing at a depth of 3.3 feet, and yellow and red shades represent areas above freezing at that depth, based on the GIPL 1.0 model. (Figure source: Permafrost Lab, Geophysical Institute, University of Alaska Fairbanks).

dioxide and methane through increased decomposition. Thawing permafrost also delivers organic-rich soils to lake bottoms, where decomposition in the absence of oxygen releases additional methane. Extensive wildfires also release carbon that contributes to climate warming.The capacity of the Yukon River Basin in Alaska and adjacent Canada to store carbon has been substantially weakened since the 1960s by the combination of warming and thawing of permafrost and by increased wildfire. Expansion of tall shrubs and trees into tundra (which is happening in Katmai too, not just in the arctic) makes the surface darker and rougher, increasing absorption of the sun's energy and further contributing to warming. This warming is likely stronger than the potential cooling effects of increased carbon dioxide uptake associated with tree and shrub expansion. The shorter snow-covered seasons in Alaska further increase energy absorption by the land surface, an effect only slightly offset by the reduced energy absorption of highly reflective post-fire snow-covered landscapes. This spectrum of changes in Alaskan and other high-latitude terrestrial ecosystems jeopardizes efforts by society to use ecosystem carbon management to offset fossil fuel emissions.

Changing Oceans and Ocean Acidification

Ocean acidification, rising ocean temperatures, declining sea ice, and other environmental changes interact to affect the location and abundance of marine fish, including those that are commercially important, those used as food by other species, and those used for subsistence. Overall habitat extent is expected to change as well, though the degree of the range migration will depend upon the life history of particular species.

Ocean waters globally have become 30% more acidic due to absorption of large amounts of human-produced carbon dioxide (CO_2) from the atmosphere. This CO_2 interacts with ocean water to form carbonic acid that lowers the ocean's pH (ocean acidification). The polar ocean is particularly prone to acidification because of low temperatures, and low salt content, the latter resulting from the large freshwater input from melting sea ice and large rivers. Acidity reduces the capacity of key plankton species and shelled animals to form and maintain shells and other hard parts, and therefore alters the food available to important fish species. A lower pH will have particularly strong societal effects on the Bering Sea on Alaska's west coast because of its high-productivity commercial and subsistence fisheries.

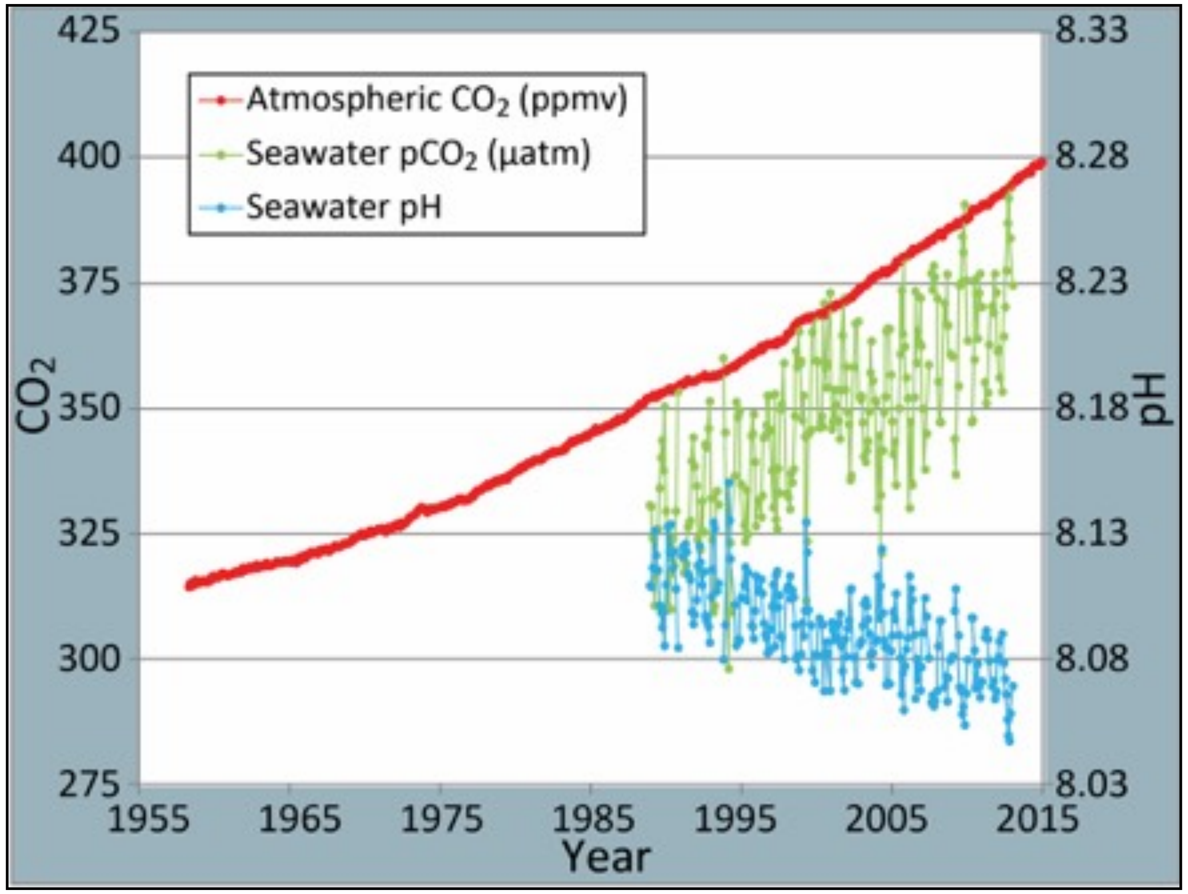
At some times of year, acidification has already reached a critical threshold for organisms living on Alaska's continental shelves. Certain algae and animals that form shells (such as clams, oysters, and crab) use carbonate minerals (aragonite and calcite) that dissolve below that threshold. These organisms form a crucial component of the marine food web that sustains life in the rich waters off Alaska's coasts. It is not difficult to connect the dots and see that changes in ocean chemistry can

How Does Ocean Acidification Work?

Ocean acidification occurs when CO_2 is absorbed into water at a high rate. It reacts with water molecules (H_2O) to form carbonic acid (HCO_3). This compound then breaks down into a hydrogen ion (H+) and carbonate (HCO_3). The presence of all these hydrogen ions is what decreases the pH, or acidifies the ocean. This can be summed up with a nifty chemical equation: $CO_2 + H_2O \rightarrow H + HCO_3$.

The saga does not end here, unfortunately. That carbonate molecule (HCO_3) is going to go on to cause trouble for marine organisms. Once

Scroll though this window to learn more about how ocean acidification happens. Based on information from http://climateinterpreter.org/content/ocean-acidification.



This graph shows the correlation between rising CO2 in the atmosphere measured at Mauna Loa with rising CO2 levels in the nearby ocean at Station Aloha in Hawaii. As more CO2 accumulates in the ocean, the pH of the ocean decrease.
http://www.pmel.noaa.gov/CO2/file/Hawaii+Carbon+Dioxide+Time-Series

have large impacts on fish like salmon and the animals (including humans) that depend on salmon.

Native Communities

With the exception of oil-producing regions in the north, rural Alaska is one of the most extensive areas of poverty in the U.S. in terms of household income, yet residents pay the highest prices for food and fuel. Alaska Native Peoples, who are the most numerous residents of this region, depend economically, nutritionally, and culturally on hunting and fishing for their livelihoods.

Hunters speak of thinning sea and river ice that makes harvest of wild foods more dangerous, changes to permafrost that alter spring run-off patterns, a northward shift in seal and fish species, and rising sea levels with more extreme tidal fluctuations. Responses to these changes are often constrained by regulations. Coastal erosion is destroying infrastructure. Impacts of climate change on river ice dynamics and spring flooding are threats to river communities but are complex, and trends have not yet been well documented. Major food sources are under stress due to many factors, including lack of sea ice for marine mammals.

Terrestrial Changes

Climate change is causing dramatic shifts in Alaska's terrestrial ecosystems.

Biome Shifts: Between 1970 and 2000, the snow-free season increased by approximately 10 days across Alaska, primarily due to earlier snowmelt in the spring. A longer growing season has potential economic benefits, providing a longer period of outdoor and commercial activity such as tourism. However, there are also downsides.

Winter extreme low temperatures have increased and mean annual and warm season temperatures have increased. More extensive and severe wildfires could shift the forests of Interior Alaska during this century from dominance by spruce to broadleaf trees for the first time in the past 4,000 to 6,000 years.

White spruce forests in Alaska's interior are experiencing declining growth due to drought stress and continued warming could lead to widespread death of trees. In Interior Alaska, aspen and spruce trees have shown a negative response to warm summer temperatures. This indicates that conditions for optimal growth may be surpassed by a warming climate in that region.

The opposite is true in western and southwestern Alaska, where conditions for tree growth have been historically suboptimal. Tree growth is increasing in western Alaska (where trees are sparse and growing conditions are suboptimal) and declining to near survival limits in the Interior.

In Lake Clark National Park, white spruce reacted variably to warmer temperatures since 1950. Trees in plots that did not experience drought stress increased growth, while drought stressed trees did not. (*Driscoll, et al (2005). Divergent tree growth response to recent climatic warming, Lake Clark National Park and Preserve, Alaska. Geophys. Res. Lett., 32, L20703, doi:10.1029/2005GL024258*)

Shrub and Tree Advance in King Salmon, Alaska

Naknek River from crest of bluff above "River Camp" public access site southeast of King Salmon, in 1918 (J. Sayre) and 2005 (G. Frost). Kenai birch and balsam poplar trees have become so dense on the bluff that it is now impossible to locate Sayre's precise 1918 vantage point. Although it is possible that the clearing in the 1918 image was created by human disturbance, repeated photographs elsewhere in the area confirm that trees have become much more abundant in the King Salmon area over the last century. 1918 photo courtesy National Geographic Society. Tap on the icon to see the before and after photos.

Overall, it is likely that spruce and other forest trees will expand their range in western and southwestern Alaska. Interior Alaska may see a significant biome shift to an ecosystem better adapted to seasonal drought. More locally, Katmai and the King Salmon area will no longer be the southwestern extent of spruce in Alaska. Spruce will continue to expand into southward along the Alaska Peninsula. Katmai and western Alaska may soon have optimal growing conditions for white spruce.

Forest Fires: Could wildfire become a part of Katmai's ecosystem? Natural fires in Katmai are very rare, and almost unheard of. However, in 2015 one natural fire burned just a few miles outside of the park's northwest boundary. Under changing climate conditions, the average area burned per year in Alaska is projected to double by the middle of this century. Any increase in wildfire in Katmai would be a significant increase.

Wildfire has mixed effects on habitat. It generally improves habitat for berries, mushrooms, and moose, but reduces winter habitat for caribou because lichens, a key winter food source for caribou, require 50 to 100 years to recover after wildfire.

Insects Outbreaks: Climate plays a key role in determining the extent and severity of insect outbreaks. Recent spruce bark beetle outbreaks in south-central Alaska and in Katmai have been tied to milder winter time conditions and warm spring and summer temperatures. See sidebar: Little Monsters on the next page.

INTERACTIVE 1.1 **Little Monsters**

Prior to 2006, Katmai's spruce forests appeared healthy. Under the dense canopy of needles, little light filtered through to the forest floor where mosses and shade tolerant shrubs held a dominant foothold. Reaching toward the sky were many spires of green-needled spruces that intercepted much of the incoming light.

Katmaï's spruce forest appeared healthy less than a decade ago. (NPS Photo)

Today, however, even the casual observer walking through those same forests will find something amiss. The standing spruce are now dead skeletons of their former selves. Light easily reaches the forest floor. Mosses are being overtaken by vigorous grasses and tall

The impacts of insect outbreaks are easy to observe at Brooks River. This was originally posted on the Katmai Terrane Blog in 2014 (http://www.nps.gov/katm/blogs/Little-Monsters.htm). While the post does a good job interpreting the interaction between bark beetles and spruce trees, it does not incorporate climate change info. How could it be rewritten to also interpret climate change?

Visitor Survey Information on Climate Change

In This Section

Before reading further, answer these questions and record your answers in the widget on this page.

- What percentage of the public believe that humans are changing the climate?
- How concerned do you think Katmai's visitors are about climate change?
- Do you think Katmai's visitors want more or less information about climate change?

This section presents survey information regarding climate change. Some surveys were national and other were more local. No Katmai-specific survey has attempted to measure attitudes and beliefs concerning climate change, but we can glean much insight from other surveys. Keep your answers in mind as you read further. Do your assumptions correlate with the survey data?

Knowledge of the Audience: Climate Change

What do you think the public thinks about climate change? Record your thoughts in this widget.

Six Americas

This survey found that Americans fall along a spectrum of attitudes towards global warming. Two-thirds of people surveyed were either cautious (23%), concerned (31%), or alarmed (13%) about climate change. Only 13% were dismissive of it. .

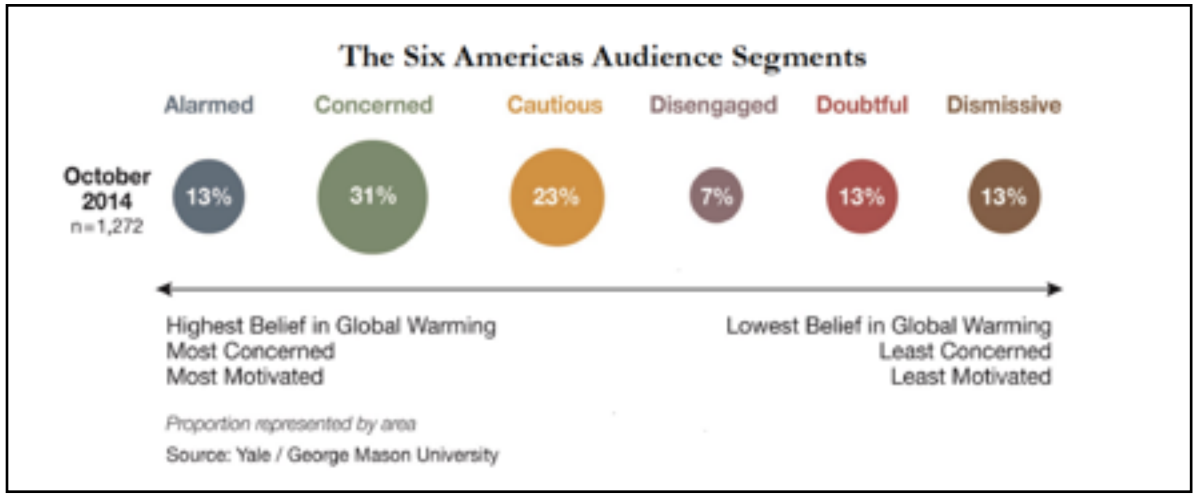
In-Depth Information on the Six Americas Survey

This in-depth information is from http://climatecommunication.yale.edu/wp-content/uploads/2016/02/2009_05_Global-Warmings-Six-Americas.pdf.

The Alarmed are the segment most convinced that global warming is happening. Global warming is very important to them and they are very worried about it. The Alarmed have thought a lot about the issue, believe they are well informed about the causes, consequences, and potential solutions, and are highly unlikely to change their minds. The Alarmed believe there is a scientific consensus that global warming is happening, and overwhelmingly believe that human activities are the primary cause. Compared to the other five segments, they are the most likely to view it as a threat to them personally and to future generations, and as already harming people in the United States, rather than in the distant future.

The Concerned are also convinced that global warming is happening, although they are less certain than the Alarmed. The issue is also less important to them than the Alarmed, yet they are relatively worried about it . The Concerned have thought some about global warming, believe they are somewhat informed about the causes, consequences

How do each of the Americas view global warming? Scroll through the window above to read more or go to http://climatecommunication.yale.edu/about/projects/global-warmings-six-americas/.



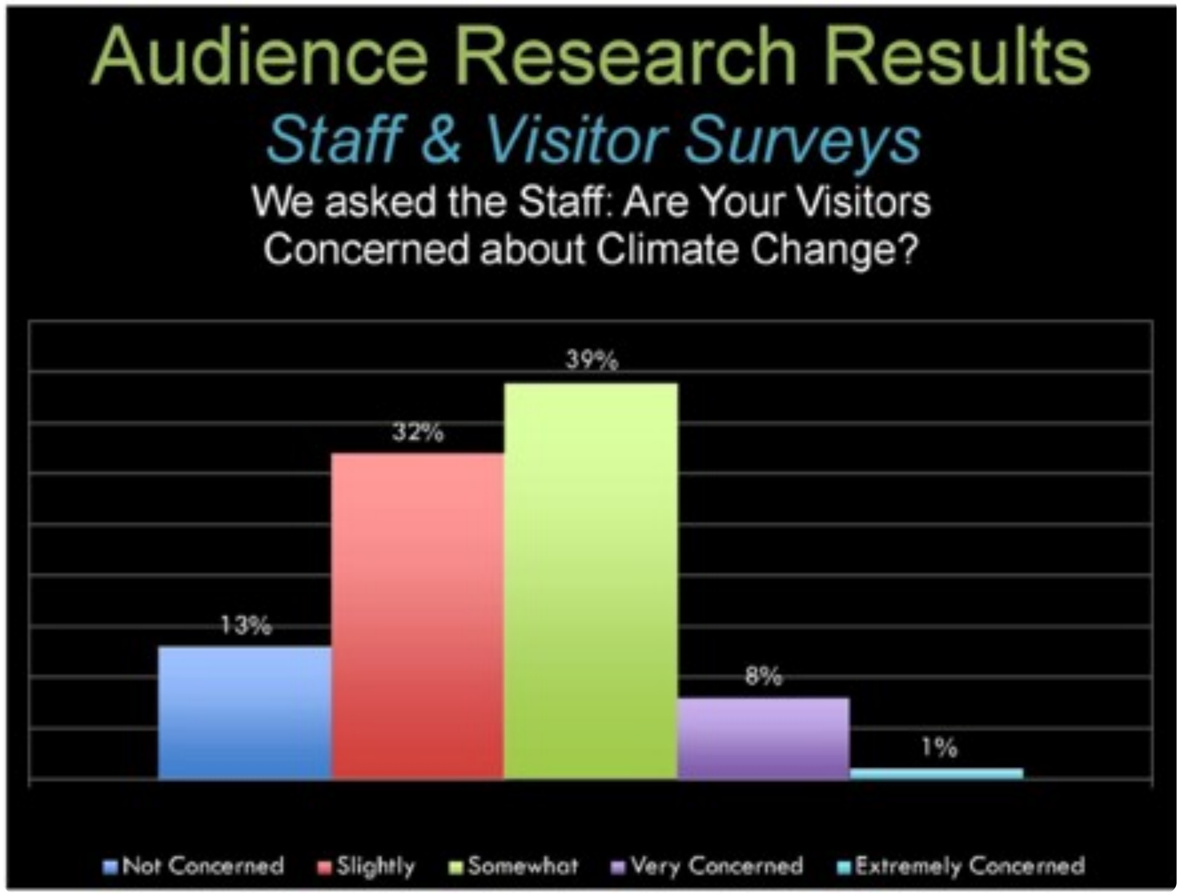
Climate Change Education Partnership Visitor Survey

How do visitors to national parks and wildlife refuges view climate change? Do they want to learn more or less about it?

In this survey, which includes results from Kenai National Park and Kenai National Wildlife Refuge, results reveal that visitors care deeply about these natural landscapes and differ significantly from the broader American public in regards to their knowledge and opinions on climate change, willingness to take mitigating actions, perceptions of climate change impacts, and desire for climate change education.

Most respondents stated that the national parks and national wildlife refuge system is extremely or very important to themselves and their family (95%) and were equally concerned about the future of the national parks and national wildlife refuges (74%). Most visitors surveyed indicated that they think climate change will harm the national park/wildlife refuge they visited a great deal (42%) and that it is being harmed now (32%).

Staff and Visitor Attitudes Towards Climate Change at Kenai National Wildlife Refuge



At Kenai National Wildlife Refuge, both visitors and employees were surveyed about climate change. Staff underestimated the concern the refuge's visitors had for the climate change. The vast majority of visitors wanted more information on climate change.

When asked about their perceptions of climate change, many visitors surveyed were sure that climate change is happening (77%). Most visitors stated that the issue is important (84%), indicating the salience of the issue. In addition, many respondents asserted that they feel responsible for contributing to climate change (54%).

The majority of survey respondents believe they can already see the effects of climate change at national parks and wildlife refuges (70%) and most visitors would like to learn more about climate change at these places (67%). Many visitors indicated that they have not received any information on the subject at the park or refuge they visited (66%) but would prefer to receive this information via trailside exhibits (42%) or online (46%). According to most respondents, actions visitors can take to reduce climate change is the most important topic for parks/refuges to address (78%). Additionally, most visitors are willing (91%) to change their behaviors in the park or refuge they visited to mitigate climate change.

Climate Change Education Partnership Executive Summary

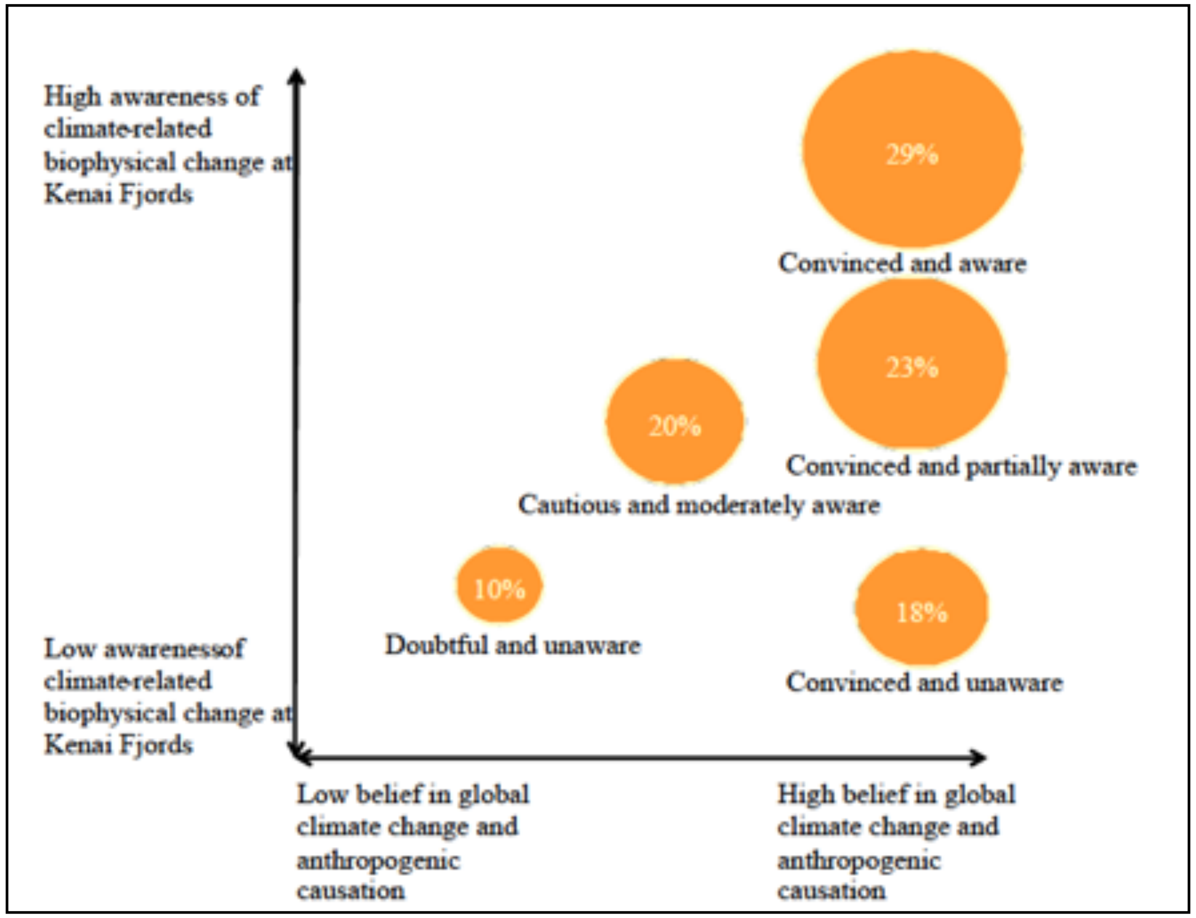
PDF

Read the executive summary of the Climate Change Education Partnership Visitor Survey Summary report.

Based on this research, it is apparent that the visitors to national parks and wildlife refuges care deeply for this protected land, see how climate change is affecting it, and want to be engaged in protecting these parks and refuges themselves. This audience wants to learn more about climate change and the actions they can take to mitigate its effects on these treasured landscapes. With proper education, visitors can become important advocates in the need to respond to climate change, both within the parks and refuges, and their communities.

Visitor Perceptions of Climate Change at Kenai Fjords National Park

Results from this survey indicate that five distinct groups of Kenai Fjords visitors exist, who differ statistically and conceptually regarding their levels of beliefs in 1) the occurrence of global climate change, 2) the influence of humans on global climate change, and their self-perceived awareness of 3) climate-related biophysical change at Kenai Fjords National Park. Only 10% of people survey were doubtful and unaware of human-caused climate change. More in-depth information from this survey can be read in the scrolling window below or at http://www.nps.gov/akso/nature/science/ak_park_science/PDF/2011Vol10-2/climate-change-segmentation-groups-at-kefj.pdf.



In the Kenai Fjords National Park survey, the size of each bubble is an approximate representation of each groups' percent of the overall study sample. Twenty-nine percent of people were convinced and aware, 23% were convinced and partially aware, 20% were cautious and moderately aware, 18% were convinced and unaware, and 10% were doubtful and unaware.

The researchers for the climate change survey at Kenia Fjords National Park made these recommendations to Kenai Fjords' staff. Consider how you can adapt these for Katmai. Could links between bears, salmon, and oceans be your hook?

- Considering the Kenai Fjords National Park (KEFJ) segmentation groups, 3 of the 5 groups agree or completely agree that global climate change is happening, and that global climate change is at least partially caused by human actions. However, 4 of the 5 groups are only partially aware or unaware of climate-related biophysical change at the park. Therefore, communication and interpretation with visitors should perhaps highlight biophysical change at the park to increase visitors' awareness of park-specific biophysical change. Consequently, limited attention and time should perhaps be spent on informing visitors about the occurrence and anthropogenic influences on climate change.
- Communication about park-specific change should perhaps start with discussions about glaciers (since a majority of visitors are aware of glacial related change at KEFJ, and since glaciers rank highly important to visitors). Next, communication can transition into topics such as increased vegetation and a decrease in Steller sea lions, since visitors are less aware of these two elements.
- When interpreting global climate change for visitors, KEFJ staff may benefit from discussing values related to the environment,

Interpreting Climate Change

In This Section

Interpreting this topic may seem daunting, but not when you consider that the evidence for it is very strong, the vast majority of people want to know more about it, and park visitors care about the impacts of climate change on national parks. Please consider this boiler plate advice on how to successfully craft climate messages into your programs and informal visitor contacts.

Techniques

Children: Kids have a wide sphere of influence among their families. If children care about a topic, then their parents are likely to care too. Encourage kids to be leaders and stewards. As you do so, avoid presenting doom and gloom scenarios to them.

Focus on hope: Avoiding framing climate change as a crisis only. That tends to shut down thinking. It also promotes common tropes in public conversation as the dueling viewpoint which invites skepticism and rhetorical tone which incites distrust.

Ask the right questions: Not "Do you believe in climate change?" But,

- Do you understand the realities of climate change?
- What climate change impacts do you see?

Psychology of Climate Change Communication

This document provides excellent advice about communication climate change information, especially concerning framing.

Frame your message effectively: Make it relevant to the audience. This is a tenet of interpretation.

Framing sets an issue within an appropriate context to achieve a desired interpretation or perspective. The intention is not to deceive or manipulate people, but to make credible climate science more accessible. Indeed, since it is impossible not to frame an issue, climate change communicators need to ensure they consciously select a frame that will resonate with their audience.

For example, most people visit Katmai to view bears or go fishing. If climate change impacts salmon, then bears, bear-watching, trout fishing and many other activities that people come here for will change. Can you frame climate change information around their experience or the resources they care about protecting?

Along those lines, also keep messages place based. People show greater interest and engagement when climate change messages focus on the park or refuge they visited.

If you are interpreting to people from Alaska Native communities, use stories from elders when discussing climate change to tell personal, local stories about our changing landscape.

Keep it simple: Global warming can be explained fairly simply when you understand how it happens and how we know it is happening.

Climate Change Metaphors

These metaphors from the Frameworks Institute's Getting to the Heart of the Matter (http://www.frameworksinstitute.org/). They are easy to remember, understand, and offer a starting point to explain several aspects of climate change and its impacts.

Climate's Heart: This explanatory metaphor enables people to think and talk more productively about the role of the ocean with the climate system. The metaphor is as follows.

"The oceans regulate the climate system the way your heart regulates the flow of blood throughout your body. The heart sustains the body by controlling the circulation of blood, making sure the right amount gets to all parts of the body — not too much and not too little. The oceans act as the climate's heart, sustaining the climate by controlling the circulation of things like heat and humidity.

"The oceans are the heart of a circulatory system that moves heat and moisture through all parts of the climate system, including oceans, land and atmosphere. As the heart of this circulatory system, the oceans regulate the climate by helping to control the earth's temperature. By absorbing heat from the sun and emitting it back into the atmosphere, the oceans maintain a regular flow of heat and stabilize the earth's temperature. And ocean currents and winds move heat and moisture to different parts of the world, which keeps the climate stable.

"Burning fossil fuels damages the oceans' ability to maintain good circulation of heat and moisture. When we burn fossil fuels, we put a lot of stress on the oceans, which damages their ability to keep the climate stable — so sometimes the oceans pump too much heat and moisture through the system, sometimes too little. Burning fossil fuels weakens the oceans' ability to regulate the climate system."

Regular vs. Rampant Carbon Dioxide: This explanatory metaphor helps people understand the role of carbon dioxide in climate and ocean change. The metaphor is as follows.

"Some carbon dioxide, or CO_2, is needed for life processes. We can call this Regular CO_2. But CO_2 is not just something that plants breathe in or that we breathe out. It's also something that gets put into the air when we drive cars or burn any kind of fossil fuel. And these things are putting a lot of CO_2 into the atmosphere and oceans. We can call this Rampant CO_2 because there's too much of it and it's getting out of control. Rampant CO_2 accumulates in the wrong places, like the oceans, and causes a number of problems in the climate and ecosystems. We'll always need Regular Carbon Dioxide, but we need to start reducing Rampant Carbon Dioxide."

Osteoporosis of the Sea: This metaphor helps people understand the effects of ocean acidification. Here's the metaphor.

"Ocean acidification is causing 'osteoporosis of the sea.' Acidification is changing the chemistry of the ocean and, as a result, many types of shellfish have trouble building and maintaining their shells. This osteoporosis of the sea causes the protective shells of these animals to become thinner and more brittle, which makes it hard for them to grow and survive."

Explanatory Chain on Ocean Acidification: Explanatory chains on ocean acidification enable the public to understand the process of ocean acidification. The chain is:

"When we burn fossil fuels like coal and gas, we release carbon dioxide (CO_2) into the air. The oceans absorb a lot of this carbon dioxide, which changes the ocean's chemistry. This is called ocean acidification. One result of this change in chemistry is that it makes the ocean a less hospitable environment for many types of marine life. This more challenging environment means that these types of marine life often have to work harder to do basic tasks, like reproducing and building their skeletons and shells, and, as a result, they are less successful in achieving these tasks. By making it harder for some types of marine life to grow and survive, ocean acidification disrupts the food chain, which undermines the stability of the whole ecosystem."