Alaska Region Climate Change Response Strategy 2010-2014

National Park Service
U.S. Department of the Interior

Alaska Region

National Park Service. Alaska Region climate change response strategy 2010-2014. National Park Service. Anchorage, Alaska.

Figure 1. (Cover) Calving ice at Margerie Glacier. Glacier Bay National Park and Preserve.

NPS photograph

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Figure 31. (Backcover) NPS has exceptional opportunities to interpret the local effects of climate change to visitors from other areas. Klondike Gold Rush National Historic Park.

NPS photograph by Josh Foreman

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Foreword

How this strategy is organized

This document is organized into four sections.

- Section I provides the context for the strategy, evidence of how climate change is already affecting national parks throughout the Alaska Region, and historic trends and forecasts.
- Section II presents four broad goals for thinking about climate change in Alaska and how to address the challenges and opportunities for park management. A set of general strategies are provided for accomplishing each goal.
- Section III outlines five initial steps towards implementation: identify assets and how they can be coordinated, coordinate with other climate change planning efforts, set priorities, identify costs and develop an approach to funding, and develop a timeline with milestones for early actions.
- The appendices include more detail about specific objectives and include reference materials, park-specific climate projections, etc.

How the NPS Alaska Region climate change response strategy was developed

An ad-hoc committee composed of approximately 30 senior park and regional management and other subject matter experts in multiple discipline areas (e.g., science and resources, facilities and operations, interpretation and education, policy and management) contributed information and ideas to this strategy. Committee members also served as points of contact for communications on issues and projects in their areas of knowledge and responsibility. The Alaska Region Science Advisor compiled and integrated contributions from the committee, coordinated broad review of the document both inside and outside the agency, and oversaw its editing, design, and production of the document.

Because the discipline of climate change is evolving rapidly, the committee recommends that the document be reviewed for any needed revisions every two years.

How development of the NPS Alaska Region climate change response strategy was coordinated with other federal, DOI, NPS, state, and non-government planning efforts

While this strategy focuses primarily on changes affecting NPS units in the Alaska Region, it also draws upon relevant information, goals, objectives, and action items suggested through other planning efforts, including NPS national efforts and DOI efforts (DOI 2008a, DOI 2010).

Considerable information was also shared through NPS participation in multiple workgroups with other federal, state, university, and non-governmental cooperators, many of whom are involved in Alaska-wide coordination efforts.

Many of the goals, objectives, and action items set out in this document are likely to be accomplished cooperatively in partnership with other agencies, institutions and non-government organizations. Several committee members and NPS representatives have followed, participated in, and led other planning efforts and are continuing to do so as opportunities allow.

Executive Summary

This National Park Service (NPS) *Alaska Region Climate Change Response Strategy* (Strategy) outlines current and expected impacts of climate change on park resources, assets and operations in the Alaska Region and recommendations for addressing those effects. It envisions a future where the NPS works effectively with numerous partners to preserve and restore park resources, assets, and opportunities for visitor enjoyment. The strategy explains why climate change matters for managing national parks and how it affects NPS operations and resources. While focusing primarily on NPS units in the Alaska Region, the Strategy also draws heavily on relevant information from cooperative planning efforts, especially U.S. Department of the Interior (DOI) and NPS national efforts, and from several inter-agency coordinating committees in Alaska.

The Alaska Region strategy is guided first and foremost by the NPS mission. The vision and four broad goals also reflect components of the NPS national Climate Change Response Strategy: Science, Adaptation, Mitigation, and Communication (2010). A number of general objectives have been identified to advance these goals, with specific actions identified and prioritized by representatives of parks, programs, and advisory groups in the Alaska Region.

The final section of the strategy identifies initial implementation steps; however, NPS responses to climate change did not begin with this strategy. Many were already well established through policies, management strategies, and programs. For example, climate change was factored into the conceptual models and vital sign indicators for the ongoing natural resource Inventory and Monitoring Program. Research, modeling, and assessments have already been initiated with cooperators on several important questions including: downscaled climate models, a cultural resource vulnerability assessment, wildland fire and wildlife habitat modeling. Highly sustainable construction practices and testing of innovative alternative energy systems have been employed in parks for several years. The NPS is also continually sharing what we learn with employees, cooperators, visitors, and the general public through development of interpretive products, training, and experiential learning programs.

Climate change will undoubtedly affect how NPS manages park resources and services in the Alaska Region. We know that Alaska is changing, as are other places, but we do not yet know how those changes will play out. Working with the best available information, and with others, will help NPS to protect and preserve America's natural and cultural heritage for current and future generations.

A Vision for the NPS Climate Change Program in Alaska (2010-2014)

The National Park Service adapts to climate changes and effectively preserves and restores park resources and opportunities for visitor enjoyment in Alaska. Through collaboration with our employees, partners, and the public, the NPS teaches, promotes climate change science, and uses the best management practices and sustainable behaviors that will help preserve park resources and provide for visitor enjoyment in the face of climate change.

Why climate change matters for managing national parks in Alaska

"Climate change is changing habitats, use of areas, accessibility, biotic communities, diseases and causing other effects that will change the characteristics of parks as well as the type of management action required to maintain park values and mission." (Marcy 2006)

A general trend towards global warming has been documented since about the mid-1800s. Indeed, glaciers in Alaska have been getting smaller for thousands of years. What is different about the late 20th century is the accelerated warming trend, to which scientists and world leaders are reacting with alarm, and the recognition that human activities, notably fossil fuel use, are accelerating the rate of change.

Until recently, most people assumed climate was relatively static. New information challenges that assumption. As time and documentation of trends continue, more people are coming to a consensus that changes in weather patterns and changes in other phenomenon can no longer be attributed to short- or long-term natural fluctuations and random circumstances, but are evidence of long-term climate changes and associated trends.

Analysts of climate change are increasingly able to attribute seemingly-unrelated events, such as the expansion of invasive species, shipping accidents, and even earthquakes, to direct or indirect effects of climate change. Temperatures are expected to continue to rise, whether or not greenhouse gas emissions are stabilized in the near future (*Saunders and Turekian 2007*). With climate warming other dramatic changes such as melting ice, rising sea level and increased coastal flooding also appear.

Park managers need information about how climate change will affect (directly and indirectly) park resources, facilities, operations, visitor experiences, subsistence, and other customary and traditional uses. They need this information to respond appropriately to reduce, mitigate, or otherwise manage these direct and indirect impacts of climate change affecting parks. A better understanding of probable rates of change and potential effects across Alaska and in specific park locations will facilitate informed decision making and consideration of alternative strategies and action items. There are actions that the NPS can and should take now to understand, communicate, mitigate and adapt to a changing climate. This strategy is intended to identify such actions for the Alaska Region.

Rationale for developing a climate change response strategy for the Alaska region

Alaska is different.

There is broad consensus in the scientific community that climate change is a global and national issue that will require national and international coordination to address. The need for national coordination is well recognized within the NPS. However, Alaska parks are dealing with many resource issues that are confined to Alaska (e.g., permafrost and subsistence). Other issues may be shared in common with parks nationwide, but in many cases the effects of climate change are occurring more quickly and with more severity in Alaska than at lower latitudes. The local effects of climate change on park resources, operations, visitor experience and uses are expected to increase in coming years. Identical responses will not be appropriate in all locations nationwide, or even across all Alaska parks.

This regional strategy identifies specific information needs, goals, objectives and actions for addressing the effects of climate change in Alaska, in a way that is intended to facilitate communication with the public, our partners, other agencies and others with a stake or interest in Alaska's national parklands.

Research and monitoring are already underway in national parks in Alaska and many other locations to better understand global, national, and regional climate change. These efforts will help the NPS anticipate effects on resources, infrastructure, economies, visitor experiences and customary and traditional park uses.

A future of uncertainty instead of stasis.

Climate change will challenge NPS in how it manages park resources because many of the policies that direct NPS management of public lands are premised on static or stable climate, and on our ability to

Examples of legislated purposes for NPS areas in Alaska (Public Law 96-487, 1980) likely to be affected by climate change

…assure the continuation of geological and biological processes unimpaired by adverse human activity

…protect habitat for seals and other marine mammals; to protect habitat for and populations of, birds, and other wildlife, and fish resources; and to protect the viability of subsistence resources

…maintain unimpaired the scenic beauty and quality of high mountain peaks, foothills, glacial systems, lakes, and streams, valleys, and coastal landscapes in their natural state

…maintain unimpaired the scenic and environmental integrity of the Harding Icefield, its outflowing glaciers, and coastal fjords and islands in their natural state; and to protect seals, sea lions, other marine mammals, and marine and other birds

….protect the watershed necessary for perpetuation of the red salmon fishery in Bristol Bay; to maintain unimpaired the scenic beauty and quality of portions of the Alaska Range and the Aleutian Range, including active volcanoes, glaciers, wild rivers, lakes, waterfalls, and alpine meadows in their natural state; and to protect habitat for and populations of fish and wildlife

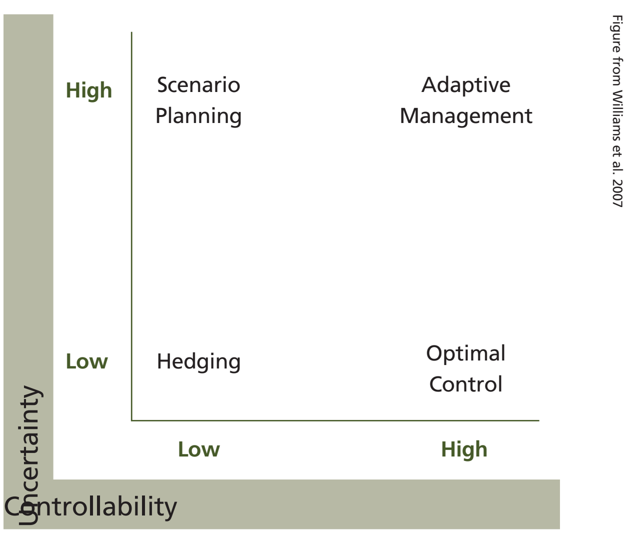


Figure 2a. Scenario planning, adaptive management, and hedging are alternative approaches for decision making. The appropriate choice depends largely on the level of uncertainty and risk, and the degree to which the situation can be controlled.

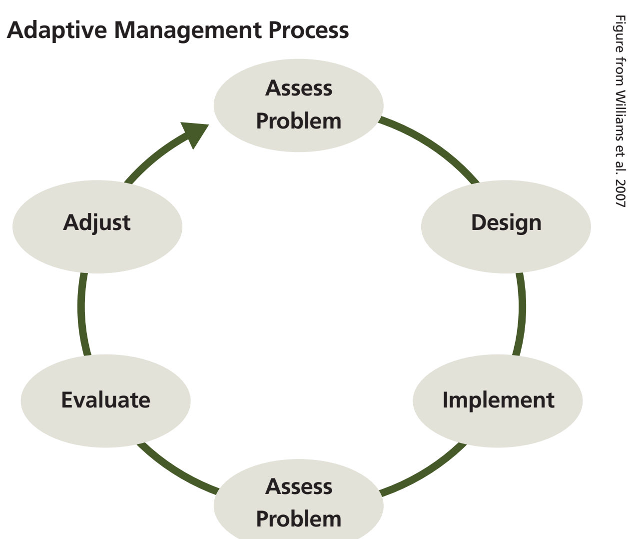


Figure 2b. Key elements of the adaptive management process include periodically reassessing the situation and adjusting decisions as needed, based on expected and observed outcomes and new information gained through monitoring and research.

determine desired conditions for the future. Climate change introduces great uncertainty about the future. While we can predict the direction of some climatic trends, the climate may also be less stable in many areas. Environmental planning will require deliberate consideration of site-specific effects of climate change, including ones that may yet be unknown or only partially known. Climate change effects should also be identified and evaluated as part of site selection and design of facilities, natural hazard mitigation, and to prioritize a variety of projects from resource surveys to restoration activities. Responding effectively to climate change challenges will not simply mean putting more money and blind faith into good causes. Even the mitigation efforts intended to minimize the effects of climate change need to be prioritized on the basis of urgency, probability of success, and cost/benefit considerations.

Assembling information and tools for response.

Just as there is no single answer for addressing the effects of climate change, there is also more than one way to think about and plan for them. Using a range of appropriate information and decision-support tools, including models and forecasts, scenario planning (for considering a range of plausible but uncertain future conditions), adaptive management (using science to adjust management decisions), and hedging (planning for the worst) will better equip park managers to make well-informed decisions (*Williams et al. 2007*) (*Figures 2a-b*).

The scope of the NPS Alaska Region climate change response strategy

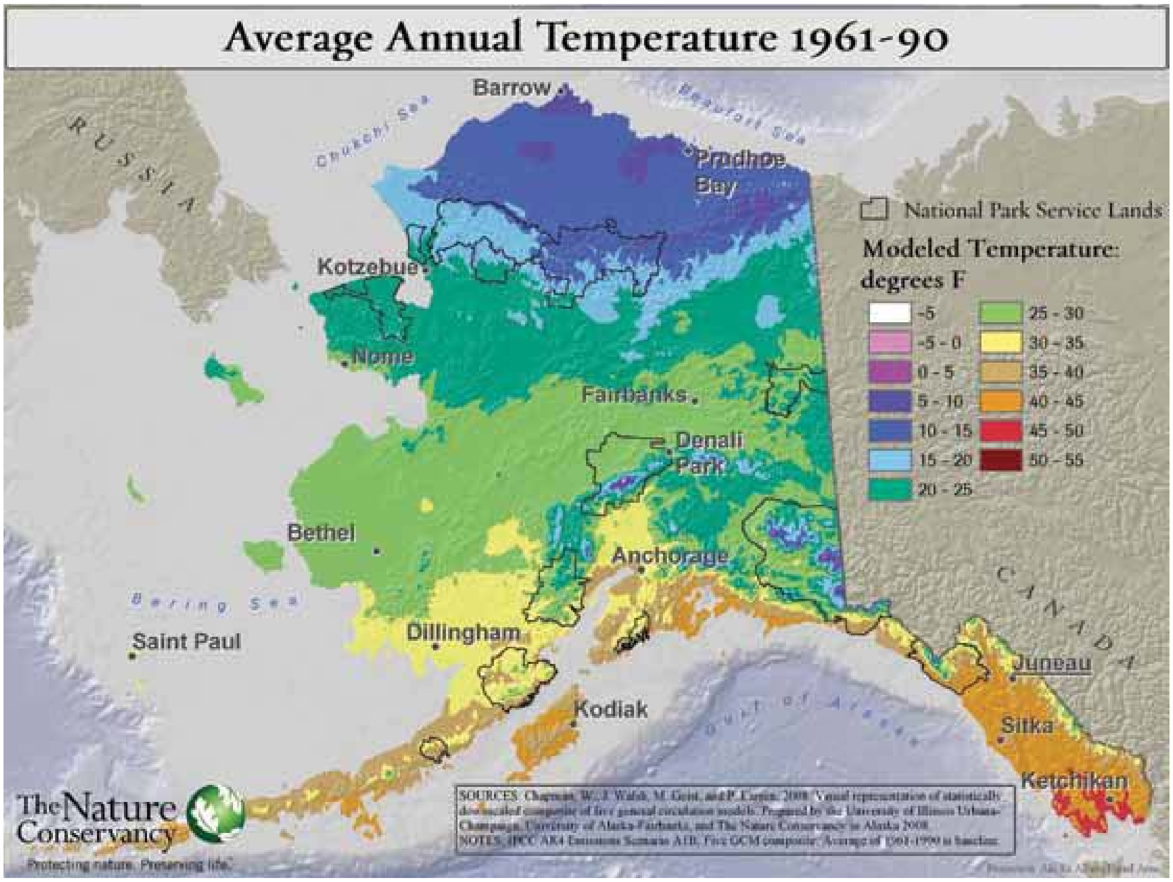
The NPS Alaska Region Climate Change Strategy summarizes current thinking and addresses challenges and opportunities in four broad areas: science, adaptation, mitigation, and communication. The strategy describes in general terms the range of probable effects of climate change on NPS units and programs in the Alaska Region, major questions and uncertainties about those effects. The vision, goals, objectives and actions are consistent with the NPS and DOI mission, policy, and guidance. They are intended to be used to guide development of project proposals, and management practices to better anticipate and understand the effects of climate change; to adapt to climate-related conditions that are currently beyond our control; to mitigate impacts to affected resources and to climate change itself that results from NPS activities (e.g., greenhouse gases); and to communicate information among ourselves and to others. The strategy also begins to identify law, regulations, and policies that do not have the flexibility to adapt to climate related conditions beyond our control. Climate change is expected to exacerbate challenges for many NPS programs, such as maintenance, invasive species, natural and cultural resources, subsistence management and others. NPS responses will also often require taking actions through existing programs. While not specifically mentioned with each recommendation (to reduce redundancy), it should be noted that the actions recommended in this strategy are intended to address challenges and issues that are directly or indirectly related to climate change, including, but not limited to, effects to existing programs.

What we know about climate change in and near Alaska national park system units, and how it affects NPS operations and resources

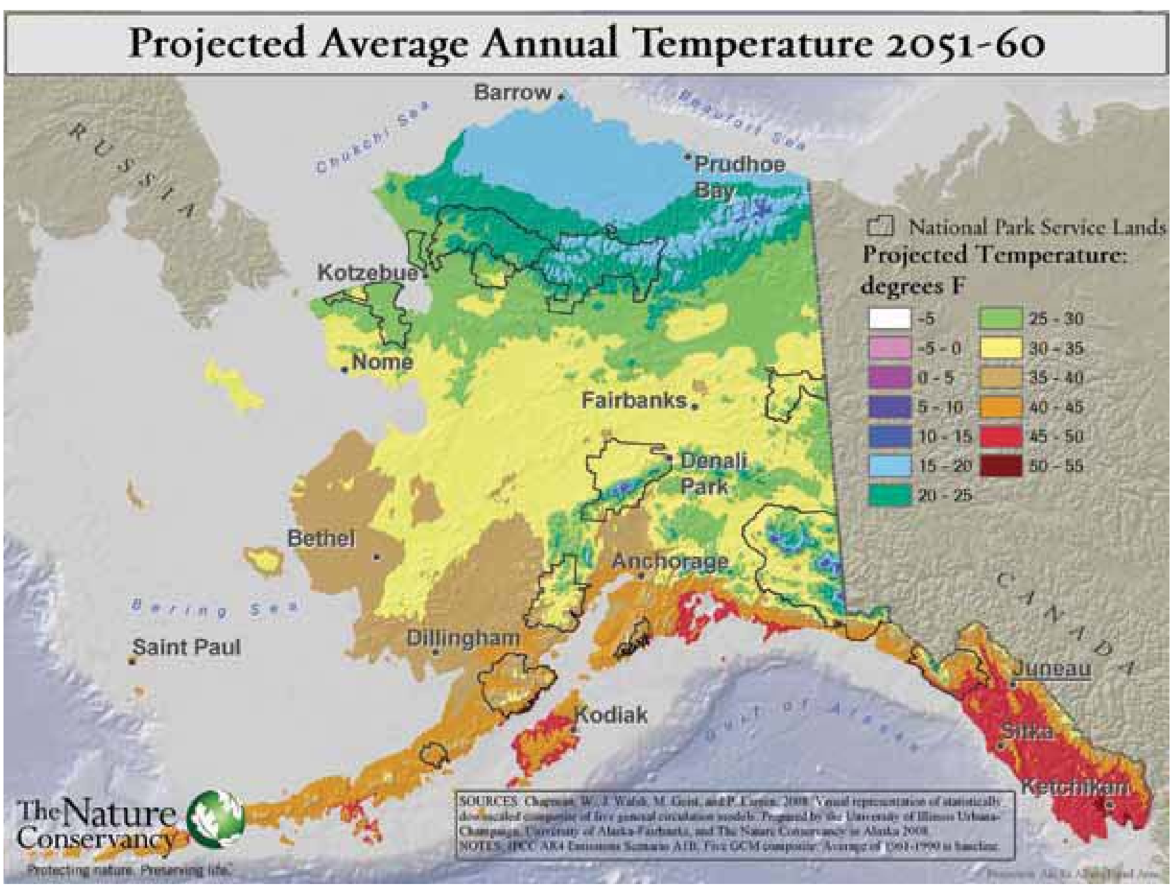
The evidence of climate change is abundant and varied in Alaska. Climate influences weather patterns (atmosphere), snow, ice, frozen ground (cryosphere), freshwater and seawater (hydrosphere), plant and animal life (biosphere), and remarkably even the stability of the ground we stand and build upon (lithosphere). However, the rates of change vary among resource types. While some changes, such as a landslide or debris flow, are obvious to even casual observers, other trends and causal factors may not be readily apparent without rigorous study. Nevertheless, the range of documented and probable climate change impacts is large and increasing, as the following observations indicate.

Ecological change is rarely simple, as nature is interrelated and interdependent. The effects of climate change are also likely to be complex. It may be helpful to visualize the effects of climate change as a cascading series of events, where changes at one level flow and spread into other levels. For example, temperature strongly affects melting of ice and snow, evaporation, and precipitation, which in turn affect water supplies, flooding, and soil stability. Temperature and moisture both affect vegetation growth and fire hazards, which influence wildlife populations, and thus subsistence and recreational opportunities. Community economics and human welfare

From ACRC 2008



3a



3b

Figures 3a-3b. Average annual temperatures during the late 20th century and future projections.

are affected by many factors. Several examples of documented and probable effects of climate change in Alaska's national parks follow.

Alaska is warming.

Climate, which determines the temperature and precipitation regimes for any ecosystem, is widely recognized as one of the most fundamental drivers of ecological condition. The physical characteristics of a region provide a foundation that defines fundamental parameters of that ecosystem. Changes in the physical environment, caused either by climate change or normal physical processes, can have significant impacts on the entire ecosystem (*Sousanes 2006*). Data from climate normals (30 year averages, 1971 to 2000) indicate that average annual and seasonal temperatures are increasing across the state. State-wide analysis indicates the average annual temperature increased by 3.40 F between 1949 and 2007 (*ACRC 2008*). Modeling by Rupp and Loya (*2008*) (Appendix C) indicates that air temperatures could increase at an average rate of 10 F per decade in national parks in Alaska during the 21st century. Recent trends and projected warming are especially pronounced for our northernmost parks and during the historically coldest times of the year (*Figures 3a-b*).

Changes to snow and ice.

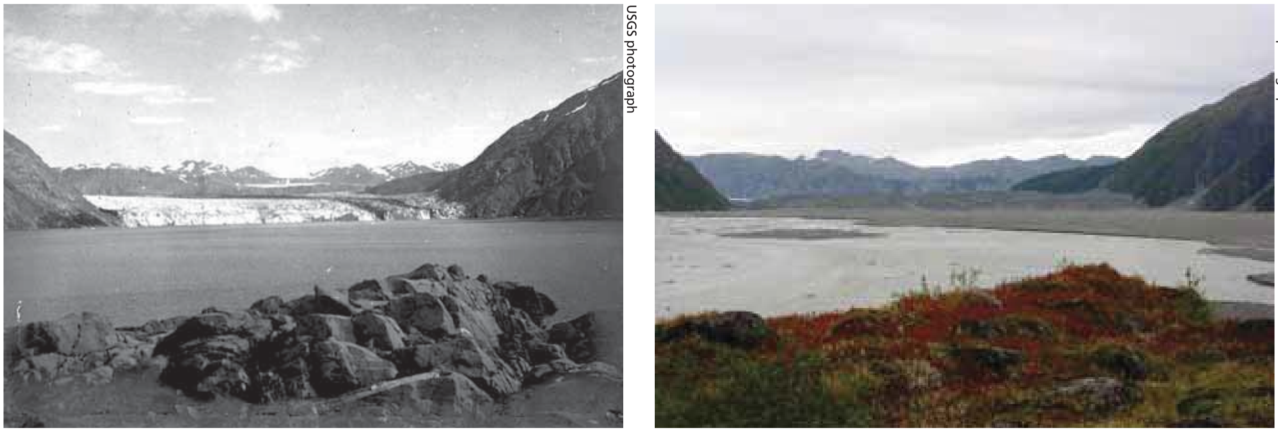
A predominant feature of climate in high latitude regions is the presence of a seasonal snowpack. Snowpack has a major influence on hydrology, vegetation, and faunal communities (*Jones et al. 2001*). Changes in snowpack and the hydrologic regime affect timing of peak discharge and duration and degree of low flow events. Spring breakup has been clocked on the Nenana River for 91 years, through the Nenana Ice Classic (NIC), an annual competition to predict the time of ice breakup on the river (*NIC 2009*). A review of published breakup dates suggests a trend towards earlier river breakup, a likely indicator of warmer river conditions. If we use 1963 as the midpoint in the history of the NIC, the records show that about 70% of the latest breakup dates (May 10-20) occurred before 1963. In contrast about 70% of the earliest breakup dates (April 20-29) happened after 1963. If the dates of breakup were random, we'd expect to see about equal numbers of early and late breakup dates. Precipitation is also expected to increase through the mid- to late-21st century (see Appendix C) (*Rupp and Loya 2008*). The relative proportions of moisture deposited as snow, ice or rain are likely to change as temperatures increase.

Changes to snow and ice can affect park operations in the following ways:

- Reduced sea, lake and river ice strength affect wave action, coastal and shore erosion, and travel hazards. Developmental pressures are likely to increase as a direct or indirect effect of reduced snow and ice cover. These include expanded global and regional transportation systems and their associated infrastructure (e.g. opening of the Northwest Passage due to reduced sea ice, permanent roads to replace ice roads), increased demand for natural resource development (construction materials – especially gravel and rock, energy and minerals for infrastructure repair, replacement, and expansion), shifting agricultural production zones, community resettlement and other population shifts.
- Data from the Southwest Alaska Inventory and Monitoring Network (*SWANa*) and other glacier-bearing parks in Alaska indicates that glacial coverage is decreasing in extent and glaciers are thinning, the length of ice cover on lakes is shortening, and evaporation from water and land surfaces is increasing. This appears to be changing surface hydrology which, in turn, will also influence water chemistry, availability of aquatic habitats to fish and wildlife populations, and access and opportunities for recreational and subsistence users (*Spencer et al. 2008*).
- Some effects of rising precipitation and rising winter temperatures are uncertain, but could include greater or lesser avalanche hazards in different areas. More freezing rain events could affect foraging success and survival of wildlife, travel safety, and utility transmission.

Increased risk of shipping accidents in Arctic waters.

Increasing commercial ship traffic through the Bering and Beaufort Seas, and across the Northwest Passage, will increase the risk and potentially the environmental damage from accidents – oil and cargo spills (*ACIA 2005*). Marine tourism is also increasing in polar regions, and some of the ships were not designed for icy waters. Cruise ships already carry upwards of 45,000 passengers a year to Antarctica (*IAATO 2008*), where one ship sank in 2007 after puncturing its hull (*Reel 2007*). The Northwest Passage was traversed by 23 cruise ships between 1984 and 2004, and seven in 2008 alone *(Arctic Council 2009)*. Passenger cruises on Russian icebreakers are also already available to the North Pole. Opportunities and demand are expected



Figures 4a-4b. Paired photographs of Carroll Glacier (GLBA) in 1906 and 2003 demonstrate the rapid glacial retreat and expansion of terrestrial vegetation.

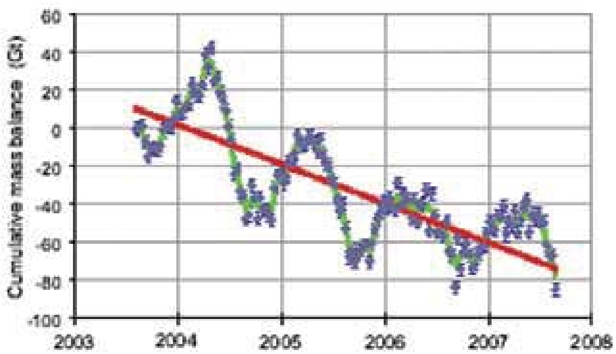


Figure 5. The GRACE (Gravity Recovery and Climate Experiment) satellite mass-balance estimates confirmed altimetry observations of rapid reductions in glacier mass in the St. Elias Mountains between 2003-2007.

to increase as sea ice diminishes. As passenger and cargo traffic increases, the potential for accidents and the risk of spills contaminating NPS coastal resources will also increase. Clean-up options in arctic climates are severely limited by ice and weather conditions, and by a lack of proven technology.

Glaciers are retreating, thinning and shrinking in overall volume.

Repeat photography at intervals of several decades or more by Molnia, Jorgenson, Nolan and others has documented glacial retreat in most glaciated parks throughout the region (*Figures 4a-b*). In fact, Alaska's glaciers are changing faster than an where else in the world (*S. O'Neel, personal communication*). The Southwest Alaska Network (SWAN) has measured 2.3-7.7 % reduction in glacier extent in Kenai Fjord's (KEFJ) Harding Icefield and Katmai (KATM) over a 14-year period (1986-2000). Glaciers are not only receding but are thinning. Thinning of glacier ice is well documented in repeat photography, laser altimetry, LiDAR surveys, and satellite mass-balance studies conducted throughout Alaska. Mass balance measurements of selected glaciers in Denali (DENA) and Wrangell-St. Elias (WRST) also show evidence of reduction over many years (*Figure 5*) (*Arendt et al. 2008, C. Larsen et al. 2007, NSIDC, SWANb, SWANc*). The ending of the Little Ice Age (ca. 1200-1850 AD) is believed to have hastened Glacier Bay's (GLBA) rapid 60+ mile retreat since 1700 AD (*Akasofu 2008*). Glacial melting can affect park operations in several ways:

- Glacial outburst floods occur when ice dams fail below glacial lakes, as has happened during the last few years in Klondike Goldrush (KLGO) (*Figure 6*), KEFJ (*Figures 8a-b*), GLBA, and WRST. Some glaciers are also known to "surge" or move forward rapidly under certain conditions, probably related to lubrication from water collecting at the ice/ground interface. When a surging glacier blocks an existing drainage basin, it can result in potentially dangerous overflow and flooding events. Hubbard and Tweedsmuir Glaciers (*Figure 7*), near WRST and GLBA, are among those recognized for severe flood hazards.
- Glaciers act as enormous reservoirs of freshwater, gaining snow and ice during cold seasons and releasing freshwater through the warm season. Worldwide glaciers serve as major sources of fresh water for humans and ecosystems. As glaciers are diminished in extent, the quantity of water they store is greatly reduced. Even if annual precipitation remains constant, seasonal flows are likely to change substantially. Other water storage options (e.g., reservoirs, ponds) may be required where consistent supplies are essential.
- Rapid glacial retreat can leave unstable sediments perched high on steep slopes that are subject to sudden collapse (*Figure 9*). The USGS has researched such a perched landslide in Tidal Inlet in

Photograph by TEMSCO Helicopters, Inc. Used with permission

Figure 6. In July 2002 this glacial moraine and outwash failure discharged an estimated ten million cubic yards (8 million cubic meters) of mud and sediment into West Creek, a tributary of the Taiya River in KLGO. The release caused a large flood downstream in KLGO, endangering human life and damaging property and park resources.

Photograph by Chris Larsen. Used with permission

Figure 7. Surging of the Tweedsmuir Glacier in Canada (to left of the river) could block the Alsek River, a popular recreational river that flows into Dry Bay in GLBA. Subsequent failure of the resulting ice dam could result in severe downstream flooding.

NPS photograph

NPS photograph

Figures 8a-8b. Paired photographs of Breakout Lake along Bear Glacier (2005 and 2008) in KEFJ. The 2005 image shows significant accumulation of water being dammed by the Bear Glacier. The 2008 image shows the same area after the lake has drained. Flood waters could pose a threat to park visitors.

USGS photograph from Fuis and Wald (2003)

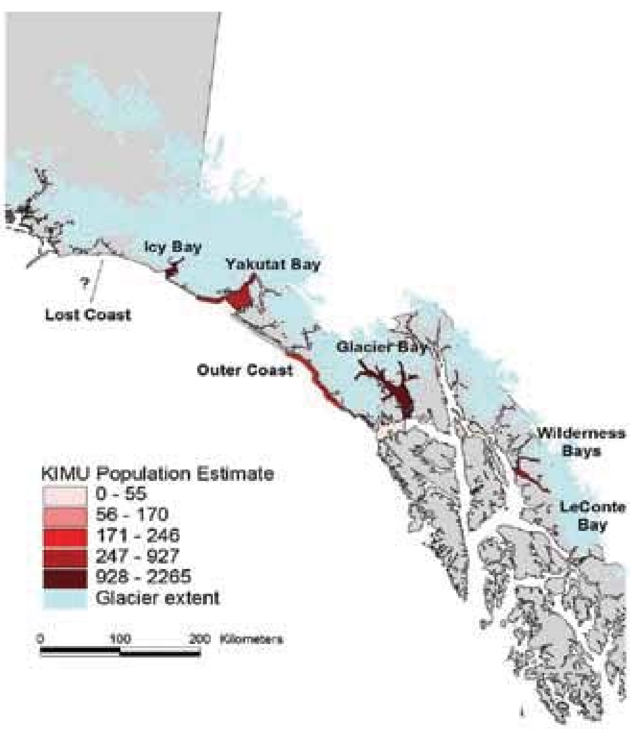
Figure 9. This huge landslide on Black Rapids Glacier in the Alaska Range was triggered by the 2002 Denali Fault earthquake. The snow line approximates the former surface elevation of the glacier. It is not clear whether climate change (e.g., freeze/thaw fracturing, glacier wasting) was a contributing factor in this massive collapse. However, geologists note that there are numerous unstable slopes and increased tectonic activity in other areas of rapid glacial retreat, particularly in the southeastern part of the state. Some may be hazardous to human life, safety and property, but their scope remain largely undetermined.

NPS photograph by Robert Winfree

Figure 10. An unstable slope resulting from rapid glacial retreat in Tidal Inlet, GLBA. Research by USGS indicates that rapid collapse of a large perched rock mass could generate a giant wave (tsunami) in Tidal Inlet and the adjacent West Arm of Glacier Bay.

NPS photograph

Figure 11. This cruise ship reportedly grounded on uncharted glacial outwash, then became stranded on an outgoing tide in Glacier Bay in July 2008.



Courtesy of Scott Gende

Figure 12. Kittlitz's murrelets habitat use around Glacier Bay.

GLBA (*GLBAa*) (*Figure 10*). Rapid slope failure into deep water, whether triggered by seismic activity, rapid and heavy precipitation, or stress failure, has demonstrated potential to produce giant waves capable of sinking ships and producing severe on-shore damage (e.g., Lituya Bay). Much of the damage caused by the great Alaska earthquake of 1964 was, in fact, due to tsunamis that resulted from landslides above and below water (*Sokolowski, no date*).

- Normal glacial activity produces dissolved and suspended mineral matter (glacial flour) that affects aquatic productivity in both positive and negative ways, through nutrient enrichment, sedimentation, and light extinction. Glacial retreat may change productivity and species composition in adjacent waters. Changing sedimentation rates can also affect navigation hazards, as evidenced by the grounding of a small cruise ship on a sandbar in Glacier Bay in 2008 (*Figure 11*).
- Kittlitz's murrelets are small seabirds that are experiencing precipitous population declines.

NASA/USGS images

Figure 13. Earthquakes between magnitude 2 and 6 that have occurred in southern Alaska since 1993. In this image series the size of the ring around each earthquake represents its relative magnitude.

NPS photograph by Whitney Rapp

Figure 14. Common dandelion (a European invasive species) has colonized "new" land created by post glacial rebound in the Beardslee Islands of GLBA.

NPS photograph by Whitney Rapp

Figure 15. The valley left by the retreating Scidmore Glacier in GLBA is already being invaded by common dandelions.

Existing data suggest that about 25% of their global population is found in and adjacent to national parks in Alaska. They nest in recently de-glaciated rocky areas and moraine deposits near their feeding areas (*Figure 12*). Their preferred unvegetated shore habitat appears to be declining as glaciers retreat upslope. Rapid vegetation of recently de-glaciated areas also favors predators of the Kittlitz's murrelets. Finally, the murrelets forage near glacial stream outwashes which disappear as glaciers recede and contract.

Rebound of land elevation.

Post glacial (isostatic) rebound is the rising of land masses previously deformed by the weight of overlying glaciers. Clear evidence of rebound is found at GLBA and KEFJ, as well as other locations in Alaska (*Kelley et al. 2007*).

- High water line can change with rebound. Water edges may shift away from property boundaries based on fixed survey points, while properties with flexible boundaries (e.g., owned to high water line) may expand with rising land.
- Rebound is also associated with increased tectonic activity, as rocks gradually respond to changing pressures and stress patterns. NASA and USGS researchers have reported that the 1979 St. Elias earthquake (Ricter magnitude 7.2) was likely caused by the changing mass of wasting glaciers (*NASA 2004*). Rapid glacial retreat can leave unstable hillsides that are susceptible to collapse, and can increase the likelihood of tectonic activity capable of triggering such movement (*Figure 13*).
- Isostatic rebound is creating new coastal meadows in GLBA that are vulnerable to invasive species invasion (*Figure 14*). Shrinking glaciers across

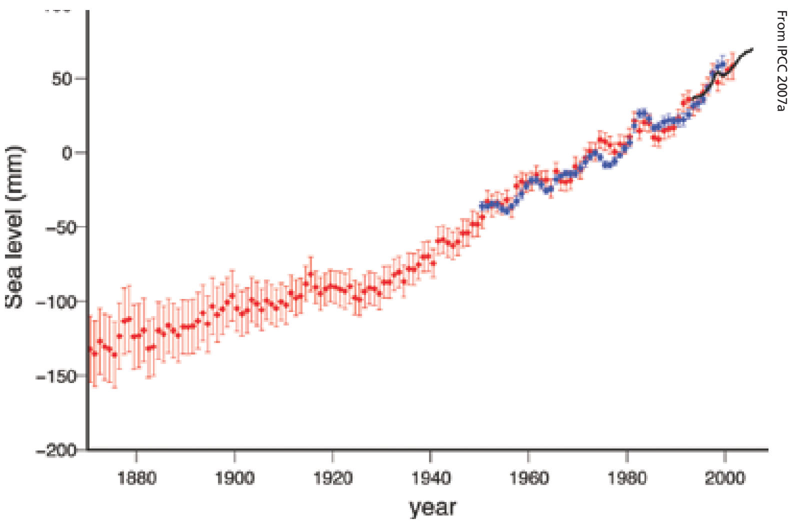


Figure 16. Global mean sea level (mm) rise since 1870, based on reconstructed data (red), tide gauges (blue) and satellite altimetry (black) with 90% confidence intervals. A 50 mm rise equals approximately two inches.

Figure 17. Coastal bluff erosion in CAKR.

Figure 18. Rapid erosion during fall storm events has resulted in collapse of several structures in the coastal community of Shismaref, near BELA.

Alaska are also exposing new land surfaces which maybe vulnerable to invasive species invasion. Common dandelions have proven to be adapted for colonizing early successional Dryas mats in glacial habitats, such as near Scidmore Glacier (*Figure 15*). As native species become increasingly stressed by changing conditions such as rising temperature and declining soil moisture, it will become easier for invasive species that are already adapted to such conditions, to survive, reproduce and expand into available habitat.

Sea level is rising.

Geologic records indicate that about 125,000 years ago sea level was about 13-20 feet (4-6 meters) higher than present-day levels. Sea level fell to about 400 ft (120 m) below current levels 20,000 years ago during the last glacial maximum, when much of the world's water was trapped on land as snow and ice. Sea level change has been very slow during the last several thousand years, at least until the mid to late 19th century when the rate of rise accelerated (*Gornitz 2007*) (*Figure 16*). IPCC models based on thermal expansion predict 7-23 inches of additional sea level rise by the end of the 21st century (*IPCC 2007a, 2007b*), but may underestimate the risks due to global warming. More recent modeling efforts that incorporate estimates of land-based ice thaw (in Antarctica, Greenland, and Alaska) indicate a likelihood of even more rapid sea level rise (*Meier et al. 2007*). A current estimate of the "worst case" scenario predicts a 30-75 inch (75-190 cm) rise during the 21st century (*Vermeer and Rahmstorf 2009*). Such rapid sea level rise would increase the frequency of flooding and eventually submerge many coastal areas, overtop protective sandbars (e.g., Bering Land Bridge, BELA), replace freshwater coastal lagoons and marshes with salt water (e.g., Cape Krusenstern, CAKR), and infiltrate shallow freshwater aquifers with salt.

Coastal erosion has accelerated dramatically.

Coastal erosion is proceeding at an average of 20 inches (0.5 m)/year in some areas of CAKR and BELA. Such erosion is likely caused by a combination of events, including storm surges resulting from reduced sea ice cover and sea level rise. Erosion affects even high bluffs, as exposed permafrost is especially subject to block failure during high water events (*Figure 17*).

Photograph by William Manley

Figure 19. Archeological surveys in WRST and other sites in Alaska and the Yukon Territory have yielded remarkably well preserved (frozen) artifacts and animal remains that are hundreds or thousands of years old.

Damage and loss to coastal facilities and resources.

Land-fast sea ice protects shorelines from severe coastal storms, while a lack of sea ice leaves the coast open to storm damage. As sea ice freezes later in the fall and thins overall, offshore storms are more likely to produce high storm surges and wave action, resulting in severe erosion of elevated coastal bluffs through undercutting and block failure, overtopping of barrier islands, flooding of coastal environments, seawater breaching of freshwater lagoons and ponds, and shoreline scouring by wind-propelled loose sea ice. Coastal erosion is recognized as a serious threat to historic, prehistoric, and modern settlements in Alaska (*Figure 18*). Several present-day settlements that are built on barrier islands or low coastal ground are at high risk. Recent costs estimates for relocating the small communities of Shismaref, Kivalina and Newtok have ranged up to $450 million (*CIER 2007*).

- Preservation of cultural resources is affected by increased exposure, decomposition, site erosion or collapse and wildland fires, and expanding vegetation that can hide sites from discovery. Many scientists feel that the paucity of very old human sites in Alaska may be, in part, due to the submergence of ancient coastal habitation sites by rising sea level. Large areas of Alaska's coastal parks lack needed surveys for archaeological sites (Appendix D). Melting of perennial snow patches can also expose rare organic artifacts and animal remains to decay (*Figure 19*).

NPS photograph by Robert Winfree

Figure 20. Extensive thermokarst landscape near BELA (polygonal patterned ground, beaded streams, and thaw ponds). Note shadow of helicopter in lower left corner for scale.

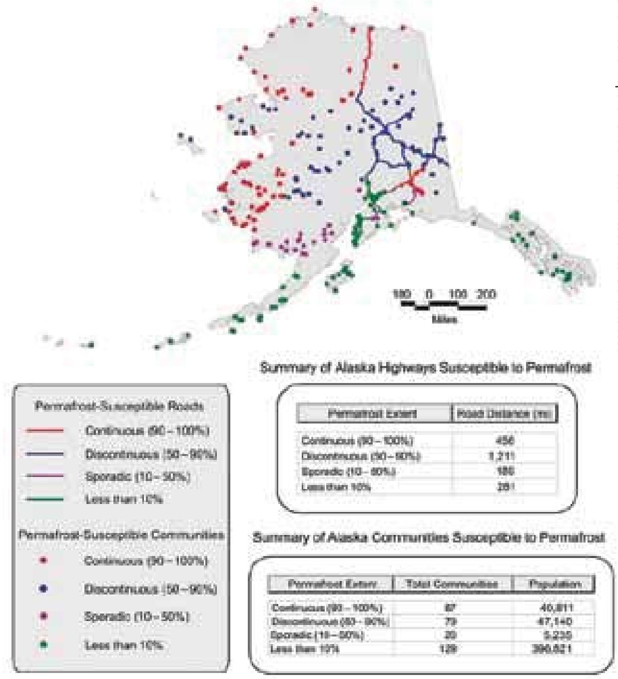
From Balser et al. 2007

Figure 21. Massive hill slope collapse resulting from permafrost thaw near Okoklik Lake (NOAT). Note helicopter at left and the person in the center (small red box) to gauge the scale of this event. The red box with the person is also enlarged at right.

Permafrost thawing and subsidence.

Much of Alaska is underlain by continuous or discontinuous areas of permafrost, ground that has been frozen continuously for more than a year (often for thousands of years). Monitoring conducted through a network of shallow and deep boreholes has documented warming and thawing of permafrost across Alaska. Nearly all of these monitoring sites show warming trends, while none show evidence of permafrost becoming colder (Sergei Marchenko, personal communication). Modeling indicates that average annual temperatures in several more parks could approach or exceed freezing during the 21st century (*Rupp and Loya 2008*). According to modeling simulations reported by the IPCC, the projected warming during the 21st century would be associated with increased thaw depth (30-40% increase in active layer thickness) for most of the permafrost areas in the Northern Hemisphere (*IPCC 2007b*). The US Global Change Research Program projects as much as 30 to 35 feet (10 meters) of surface thawing in discontinuous permafrost in Alaska by 2100 (*NAT 2000*). Increasing thaw depth has profound consequences for permafrost and soil stability over the long term.

- Thermokarst is a landscape phenomenon characterized by irregular or patterned depressions, pools and beaded streams caused by subsidence from melting ice blocks or wedges below the ground surface (*Figure 20*). Thermokarst landscapes are dramatic evidence of permafrost thaw in many areas. Arctic Network (ARCN) studies show a much larger number of thermokarst features (e.g., thawed patterned ground) in the Noatak drainage than had previously been known from aerial photography. The ARCN has identified 650 thermokarst features in one small survey area in Noatak National Preserve (*Jim Lawler and Andrew Balser, personal communications*).
- Shallow lakes are shrinking in some situations (*Riordan et al. 2006*). For example during the last 27 years, 25% of small shallow lakes in a portion of Denali underlain by wind-blown deposits have shrunk markedly. Jorgenson has suggested that pond formation and drainage are early and later



From U.S. ARC 2003, source data: U.S. Geological Survey, International Permafrost Association, and Alaska Department of Natural Resources GIS database.

Figure 22. Exposure of communities and major roads in Alaska to permafrost.

NPS photograph by Robert Winfree

Figure 23. Thermokarst formation and road collapse on the Nome to Taylor Highway, outside of Bering Land Bridge (BELA). The pond resulted from thawing and collapse of ground ice.

NPS photograph

Figure 24. Quick responses were necessary when active layer thaw and collapse resulted in mudflows blocking the Denali Park Road.

NPS photograph

Figure 25. Processing salmon at a subsistence fishcamp. Subsistence users may experience severe changes to quantity and location of resources.

stages of permafrost thaw, respectively. Pools can form as ground ice thaws and ground surface subsides. Drainage can occur through surface or subsurface discharge as thaw depth increases (*personal communication*). Thermokarst processes may be progressing across arctic landscapes (to higher altitude and higher latitude), with frozen landscapes initially becoming wetter, and then drier over time. This can have profound consequences for aquatic species and waterbirds that depend upon wetland habitats for survival as well as for subsistence users who rely on these and other potentially-affected species.

- Active layer depth (soil depth to frozen ground) is increasing. Ground that freezes and thaws seasonally is referred to as the active layer. Ground subsidence and deepening of the active layer are inter-related consequences of permafrost thaw. Active layer depth (maximum thaw depth over permafrost) is also increasing. Snowdrifts, whether natural or human caused (e.g., behind snow fences or road berms), can also influence permafrost thaw and thermokarsting. Snow accumulations in early winter can delay seasonal freezing of the active layer, while persistent late-winter drifts can insulate hard-frozen ground from summer thaw. Shifts in vegetation patterns (open tundra to low shrub) can effect snow accumulation across broad areas.
- Severe mud and debris flows can occur without warning. Solifluction is a slow down slope movement of the saturated active layer during the summer months, often resulting in characteristic lobed or terraced slopes. However, even minor precipitation events can result in sudden failure on such slopes. Mass movement of soils and debris has been observed by several park staff over the course of the past few years. For example, a debris flow that resulted from permafrost degradation in Gates of the Arctic (GAAR) covered an archaeological site of about 3 acres at Kurupa Lake. A slope failure of unprecedented size, about 2 miles (3 km) in length, deposited enormous quantities of sediment and rock into important fish habitats in Noatak (NOAT) (*Figure 21*). Several mudflows and massive hill slope collapse have occurred along and over the Denali park road in recent years.
- Constructed assets are failing prematurely. Many locations in Alaska that are underlain by permafrost are susceptible to thaw damage (*Figure 22*) (*Smith and Levasseur 2003, U.S. ARC 2003*). Even on relatively flat ground, thawing and subsidence of ice-rich permafrost can lead to premature failure or require expensive retrofitting or replacement of buildings, utility infrastructure and other constructed assets. Modeling by University of Alaska researchers suggests that projected climate changes could raise future infrastructure costs about 10% above the costs of normal wear and tear (*P. Larsen et al. 2007*).
  Fractured road surfaces, adjacent thaw ponds, and damaged structures are already relatively common in some areas (*Figure 23*). The slope failures mentioned above have also damaged and blocked park roads in DENA (*Figure 24*).

Altered water and air quality.

Water and air quality are affected by greenhouse gas emissions, and contaminant distribution, thaw and seepage, wildland fire, erosion, vegetation and organic soil decay. Drainage from thawing permafrost also contains elevated levels of organic carbon and nitrogen as compared to rain and snow melt, which can also affect water quality. As previously mentioned, slope failures can deposit enormous quantities of sediment into streams and rivers, seriously altering these habitats for long periods. Climate-related hydrologic changes can result in thawing, flooding and erosion of dump sites, increasing the prevalence of diarrhea, hepatitis, and other water-borne diseases in affected communities. Warming and wetter climates could accelerate oxidation of airborne contaminants from regional mining operations (i.e., metal sulfide mineral dusts) into more soluble, bio-available, and toxic forms. Warming climates in industrialized and agricultural regions outside of Alaska and agricultural expansion in a warming Alaska could increase volatilization of organic compounds, notably pesticides and herbicides that are transported by global circulation and deposited as persistent organic pollutants (POPS) in the Arctic.

- Surface water drainage from waste dumps is already a serious health hazard in many remote Alaska villages, including park-affiliated communities. Two-thirds of Alaska's village residents do not have access to sanitary means of sewage disposal or adequate supplies of safe water (*Magee 2006*). High water tables and permafrost preclude use of outhouses or septic tanks, so human wastes are generally collected in buckets for disposal in designated lagoons (*SNRAS 2005*). Ground seepage and flooding can contaminate drinking water supplies.
- Increasing temperature and moisture can accelerate

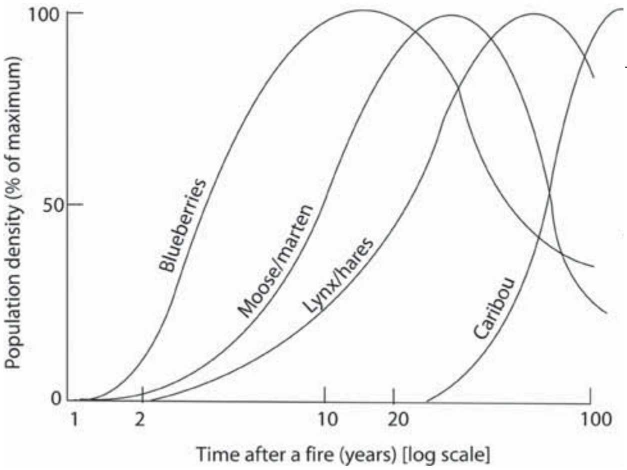


Figure 26. Estimated time for recovery of subsistence species following fire, based on local knowledge.

BLM photograph

Figure 27. The 2007 Anaktuvuk River fire burned 260,000 acres, making it the largest tundra fire ever recorded on the North Slope. It started in June/July and burned until extinguished by fall snows.

NPS photograph by Peter Neitlich

Figure 28. A lichen mat in BELA. According to vegetation models, up to 70% of Alaska's tundra will turn to some form of forested ecosystem. Barren-ground lichen mats will become increasingly rare along with large arctic caribou herds, which rely on lichen for forage.

alteration of metal contaminants into more toxic and bioavailable forms. Fugitive dust releases from mining operations near NOAT and transportation of ore concentrates through CAKR have resulted in elevated lead, cadmium, and zinc levels in plants and small animals in CAKR and in plants in the NOAT. Increased bioavailability of zinc dust with changing climatic conditions could markedly alter vegetation communities over large areas, and affect other species, subsistence use patterns and public health (*Ford and Hasselbach 2001, Hasselbach et al. 2005, Brumbaugh et al. 2008*).

- Changing global patterns of atmospheric distribution and deposition can spread contaminants to even the most remote areas. Dieldrin, p,p'-DDE, and mercury concentrations in some NPS areas in Alaska already exceed established human health thresholds for humans, fish and mammals (*Landers et al. 2008*). Consumption advisories may be warranted to reduce or curtail consumption of affected species and age/size classes, especially for children and women of child bearing age. Many species and areas have not yet been tested to determine the full scope of the problem.

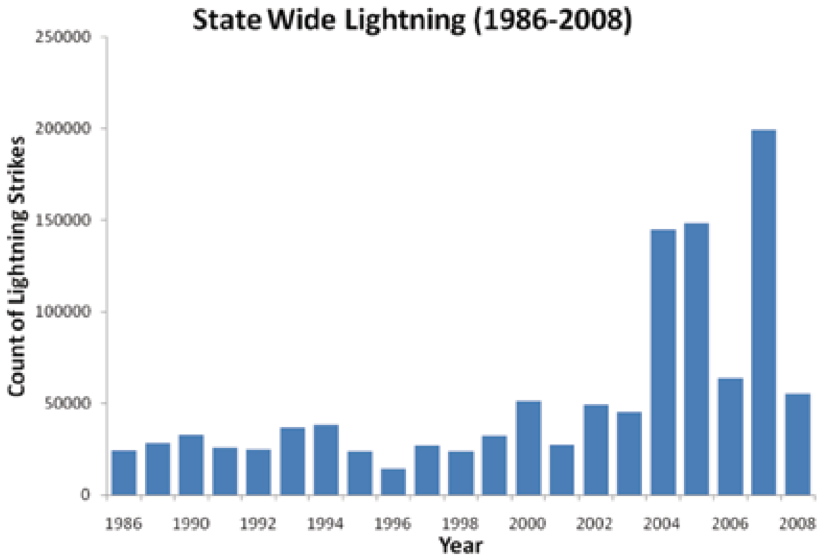
Wildlife, fisheries, and subsistence.

"Present climate change already poses serious harms to subsistence livelihoods" (*NAT 2004*). Climate change affects the habitat, seasonal movements, and populations of fish and wildlife species from pica to polar bear, sand lance to salmon, in ways yet to be revealed through monitoring and research. Wildlife and fisheries, and their availability and suitability for subsistence uses, are affected by terrestrial, aquatic, and marine habitat shifting and loss, population and range shifts, heat stress, pests and disease organisms, and invasive species—all of which may be affected by climate change (*Figure 25*). Changes to the environment may be abrupt and dramatic. We may need to focus on something that is not boundary specific and manage for that issue, such as biodiversity or ecological function as opposed to species or their dependant habitats (*Chapin 2007*). Effects on park resources could include plant and animal distribution shifts, changing species, and population densities, with consequent effects on subsistence opportunities and patterns of use.

- Habitat for ice-dependant wildlife species is shrinking. Rapid melting of critical sea-ice resulted in the USFWS listing polar bears as a threatened species in 2008 (*DOI 2008b*). Other ice-dependant species are under consideration for listing. Retreating tidewater glaciers affect floating ice fields used as rearing habitat for seal pups. An expedition to DENA in 2008 sought to confirm the presence of iceworms, a uniquely ice-dependent invertebrate species. They discovered no iceworms, and instead found that the glaciers had receded well beyond the locations where the species was reported to have been present about 20 years ago (*Shain 2009*).

- Lack of snow cover for subnivean species such as voles exposes them to increased predation and cold stress. The absence of snow cover in winter of 2002-03 led to lack of insulating cover for vegetation, wind desiccation, frost damage, and changes in small and large mammal predator-prey relationships.
- Increased frequency, extent, and intensity of wildland fires will alter habitats to the detriment of some wildlife species and plant communities, while benefitting some early-succession species. Large areas of coniferous forest in Alaska could be replaced by deciduous forests, and some by grasslands, during the next century (*Chapin et al. 2008*). Predator-prey relationships may change in unexpected ways. Subsistence users may need to travel further from their communities to harvest traditional foods. Harvest timing, means of access, and other subsistence patterns of use may also change (*Figure 26*).
- Shrubs have dramatically expanded both range and coverage on the North Slope and in previously barren-ground habitats in the Arctic parks (as indicated in photograph comparisons from the 1930s and 1950s). Shrub encroachment and treeline advance have been documented with repeat photography in Denali (*C. Roland, personal communication*), Arctic Network parks (*Tape 2010*), and Southwest Alaska Network parks (*T. Jorgenson, personal communication*). In addition to changes in plant species composition, landcover changes influence snow cover, habitat, forage availability, wildland fire, and travel routes. Warming and drying trends are expected to result in major vegetation changes in Alaska. However, further model development, research, and monitoring are needed for development of projections and timescales.

  Some terrestrial vegetation models based on global climate models (GCMs) have indicated potential for large-scale conversion of tundra to coniferous forests (*Bachelet et al. 2005*). However, other research found that increased fire frequency would lead to conditions more favorable for deciduous trees (*Rupp et al. 2001*). Some scientists have privately speculated that more frequent fires could eventually lead to an "aspen parkland" biome in parts of Interior Alaska. (Aspen parklands are a transitional biome between prairie and boreal forests and are presently found in Canada, northern Russia and Europe.) However, more data is needed to evaluate this hypothesis (*S. Rupp, personal communication*).
- Wildland fires in Alaska have increased in size, frequency and severity. In addition, large fires are occurring later in the season, when the greatest extent of drying has occurred in the duff layers, and are therefore burning deeper leading to shifts from coniferous to deciduous forest types (*S. Rupp and others, personal communication*). The 2007 Anaktuvuk River tundra fire on the North Slope appears to be rare for this area according to preliminary results from lake coring study, although fires in tundra regions of the Noatak and Seward Peninsula have a higher frequency (*Higuera et al. 2009, Hu and Higuera, unpublished data*) (*Figures 27-28*). Increased fire frequency and severity reduces the quantity of lichen forage available for periods of 50 – 160 years after a fire (*Black and Bliss 1978, Holt et al. 2006, 2007*). Shortly after a fire, tundra ecosystems are typically simplified into homogeneous cottongrass *Eriophorum* meadows lacking the diversity and complexity of former dwarf shrub systems; however, within 10-30 years increases in shrubs have been detected in tundra areas of Noatak and the Seward Peninsula (*Racine et. al. 2004, 2006*)
- Lightning and lightning-ignited fires are on the increase. An assessment of lightning activity on the Alaska's North Slope indicates a significant increase beginning in 2002 (*Savage 2008*) (*Figure 29*). During the 2004 and 2005 fire seasons, when 11 million acres burned in Alaska, statewide lightning activity reached several thousand per day as early as May. Typically, high daily counts numbers (several thousand) would not begin until late June or early July. There has not yet been an increase in the average numbers of fires per year, but lightning activity levels have increased. There were a record number of lightning strikes in June 2005 in Interior Alaska. The second largest (acres burned) fire season on record was 2005, when 4 million acres burned with widespread smoke during June and July.



From Weatherby 2007

Figure 29. Recorded number of strikes per year in Alaska. Improved detection capability is thought to be partly responsible for the apparent upward trend in strike numbers. The lightning detection/recording system in Alaska has received multiple upgrades to sensors and recording equipment since 1987. Two new sensors, Port Alsworth and Cordova, were added and contributed to the lightning dataset.

From Weatherby 2007

Figure 30. Beetle-killed forest above Tuxedni Bay in Lake Clark (LACL). Warming air temperatures have increased the severity of insect pest outbreaks in Alaska, including spruce bark beetles, with devastating ecological and economic effects.

Acres burned and greater burn severity.

The annual acres burned due to wildland fire exhibits a large variance. The majority of burned acres recorded are the result of relatively few large fire years indicating an episodic distribution. For the Alaska boreal forest region, 55% of the total area that burned between 1961 and 2000 did so in just six years. In addition, according to the statewide large fire geospatial dataset, the average fire size for large fire years was approximately 2.6 times larger than the average fire size for low fire years. More large fire years have occurred between 1981 and 2000 than in the preceding 20 years (1961 and 1980). The length of the data record for Alaska is insufficient to determine whether the increase in frequency of large fire years is due to climate change or part of the natural variability (*Kasischke et al. 2003*). Fire statistics in DENA show an increase in fire size over the last seven years. The Moose Lake Fire in 2002 was the largest single fire on record for DENA (117,920 acres) and the Highpower Creek Fire (2005) lasted 81 days – well beyond the average of 24 days.

Duffy et al. (*2007*) completed analysis of the linear regression of average Normalized Burn Ratio, a remotely sensed measure of burn severity, on the natural logarithm of area burned on 24 fires from across Interior Alaska. The results suggest there is a moderately strong relationship between the natural logarithm of the size of a fire and the average burn severity. Large fires are more likely to contain areas that are more severely burned than smaller fires as opposed to a uniform increase in overall burn severity. In Alaska two of the three largest fire years on record occurred in 2004 and 2005. Given the two large fire years in Alaska and given that the average fire size is greater in large fire years than small fire years and that the average burn severity is greater for large fires than small fires it is reasonable to conclude that Alaska will have more acres that burn in the future with the likelihood of increased burn severity. Looking at the Canadian and Hadley Centre GCMs with the Canadian fire weather index (FWI), Flannigan et al. (*2005*) anticipate that more acres will burn in Canada in the future.

- Longer and more intense fire seasons can result in seasonal and locally-severe smoke events, with respiratory and other associated health risks to populations.

Invasive species.

Temperature and moisture changes affect vegetation growth rate, vitality, succession patterns, fire effects, decomposition rates, and the potential for establishment of invasive species. The extent of invasive species, and of new introductions, is increasing across Alaska. Carlson and Shephard (*2007*) showed on average that one new invasive plant species was added each year between 1941 and 1968, and between 1968 and 2006 nearly three species were added annually. Today, 14% of Alaska's floral species are non-native. It is important to recognize that the vast majority of species introductions (natural, accidental, and intentional) have failed because the species was unsuited to the conditions that it experienced during vulnerable life stages. While the percentage of species have characteristics that favor "invasiveness" may be relatively small, their proliferation can overwhelm local species to the detriment of park values, such as naturalness. Such
invasive species may also not provide comparable ecological and human benefits (e.g., subsistence) as the native species that they displaced. Hellman et al. (*2008*) outlined the management characteristics of native and invasive species.

- Atypical outbreaks of forest pests and plant diseases are increasing. Native and exotic forest pests, such as spruce bark beetles and budworms have expanded following warm winters, with severe consequences (*Figure 30*). The extent of spruce mortality from bark beetles in Southcentral Alaska is one of the largest ever documented from an insect outbreak in North America (*Juday 1998*).
- Exotic insects and plant diseases are likely to continue to expand into heat and moisture stressed forests. Climate change could affect all stages of invasive species establishment, including 1) transport, 2) colonization, 3) establishment, and 4) landscape spread. As native plant communities become more stressed due to climate change, the likelihood of seed dispersal and establishment increases. Additionally, other habitat such as marine intertidal environments may become more susceptible to exotic species, including green crabs. Poor salmon runs and spreading of *Ichthyophonus* (a serious fish parasite) in the Yukon River are correlated with rising water temperatures. In Emmonak, Alaska, water temperatures rose from 52 °F in June of 1975 to 59°F in June of 2002 (*Kocan 2004, Cullenberg 2008*). Warming aquatic habitats stress

cold-water adapted species and favor introductions of warm-water adapted species, including sportfish like smallmouth bass (*Sharma et al. 2007*). The interaction between invasive species and climate change may also change management effectiveness. Currently, mechanical removal methods can be very effective. However, mechanical removal may become ineffective as growth rates change or overwintering success shifts. Chemical controls may be inhibited if plants become more tolerant to herbicides with increased atmospheric carbon dioxide. Finally, biocontrol may be less effective as changes occur to the tight interspecific interactions between host and agent (*Hellman et al. 2008*).

- Phenology, the relative timing of physical and biological events is changing with uncertain plants and animal effects. While data remains limited, scientists hypothesize that a de-sequencing of strongly dependent events (such as flowering of plants and availability of their pollinators, migration and nesting of birds and the availability of their insect prey) could put serious adaptive pressures on species. BLM scientists report that nesting dates for some bird populations on the North Slope have advanced two weeks earlier over the last 20 years (*Zack and Liebezeit 2009, cited by Winfree 2009*). Landscape level processes such as the phenology of ice, snow and vegetation parameters are being studied across the I&M networks.

National Park Service Mission

The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations, and cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

Goals

Goal 1. Science: Support resource inventories, monitoring and research to better understand the current and potential impact of changing climate on park resources.

Objectives:

1.1. Acquire basic datasets required for accurate assessments, forecasting, planning and decision making.

1.2. Acquire or develop and use modeling, forecasts, and other decision support tools.

1.3. Continue development and implementation of natural resource and other monitoring. Enhance or expand monitoring where needed, to determine status and trends of environmental and indicators of climate change, including information needed to evaluate modeled projections.

1.4. Expand research on climate change topics needed to better understand, manage, and be able to communicate trends, processes, and effects on ecosystems and people.

1.5. Foster partnerships with other agencies, organizations, tribes, adjacent land managers/owners, park affiliate communities, and international partners to address common needs relative to resource stewardship and science.

1.6. Expand and improve response capabilities to known and expected climate change impacts to park resources (e.g., freshwater and marine resources, invasive species).

Goal 2. Adaptation: Modify management practices to manage parks in an era of climate change.

Objectives:

2.1. Identify and prioritize risks to parks resulting from climate changes, and identify response options and capacities.

2.2. Identify park assets, resources, visitor services, and activities that are likely to be affected by climate change and determine what management actions are needed to prepare.

2.3. Engage in scenario planning to develop and evaluate alternatives and options for managing a range of probable changes. Use trend data, models, and forecasts to support scenario planning to identify probable changes and potential impacts that will occur due to climate change.

2.4. Develop adaptive management as a tool for assessing situations, designing, implementing, monitoring, evaluating, and adjusting management decisions.

2.5. Enhance collaborative management, with federal, state, and other land managers in Alaska in order to coordinate climate change response strategies on a landscape scale.

2.6. Develop guidelines consistent with current law and policy for park stewardship in a rapidly changing environment.

2.7. Conduct analyses to identify legal and policy issues affecting an agency's ability to respond to climate change. Recommend changes as necessary.

2.8. Incorporate consideration of climate change in planning, compliance and mitigation processes.

2.9. Convene interdisciplinary groups to review, update, and identify high priority actions under goals as needed.

Goal 3. Mitigation: Through innovation, demonstration projects, and new business practices become a model of environmentally sustainable operation at all locations.

Objectives:

3.1. Develop programs to encourage and facilitate the adoption of sustainable energy practices and reduce carbon footprints in Alaska parks.

3.2. Track energy use at the park level relative to reduction goals and provide for accountability.

3.3. Develop and implement Best Management Practices for sustainable operations and ensure capacity to continue sustainable practices and maintain new technologies.

3.4. Consider sustainability in planning new or replacement facilities and infrastructure.

3.5. Learn and participate in local sustainable operations by coordinating with other government entities, non-profits, municipalities, boroughs rather than just looking inward.

3.6. Encourage innovation in employee transportation to and from work.

3.7. Develop and interpret one sustainability demonstration project at each park.

Goal 4. Communication: Increase public and employee awareness and understanding of the causes and effects of climate change, and the measures that will reduce or mitigate these effects.

Objectives:

4.1. Using contemporary interpretive and education methods, provide educational materials and programs for internal and external audiences to understand what is happening and how we're going to respond.

4.2. Incorporate climate change as a key interpretive message at each park, and at NPS Public Land Information Centers (AAPLIC, and FAPLIC). Develop messages, programs and products relative to the intersection of park resources and climate change.

4.3. Communicate the implications of changing climate through life-long learning opportunities in every park, and encourage individuals to take appropriate actions to maintain sustainability for future generations.

4.4. Communicate internally about our successes and failures with regards to environmentally sustainable practices.

4.5. Support efforts to collaborate and utilize parks as centers of continuous learning and as indicators of climate changes in Alaska, in order to communicate trends and changes in natural systems. (Requires collaboration with I&M networks, Research Learning Centers, Natural Resource Advisory Committee (NRAC), researchers, and others.)

Section III. Implementation Steps (Initial Actions)

Implementation plans outline the "means" by which goals can be achieved. Implementation of this NPS Alaska Region Climate Change Response Strategy includes focusing and coordinating of existing assets (including workforce and funding streams), cultivating existing and new partnerships, establishing priorities, securing additional resources necessary to implement priority actions (funding, staff, etc.), and establishing a timetable and milestones for early actions.

1. Identify and coordinate existing assets for strategy implementation

Accomplishing the priorities identified in this strategy will require coordinated efforts, identification and clarification of roles and responsibilities among many individuals, workgroups, teams, and advisory groups at park, regional, network, national levels (*Table 1*).

2. Coordinate NPS Alaska Region involvement with other climate change planning efforts (federal, state, international, NGO)

The NPS cooperates with other federal, state, and local agencies, institutions, non-government organizations and individuals. Many cooperators have contributed and reviewed information for this strategy. Sustained and expanded participation in cooperative programs will be important for timely and effective implementation of this strategy.

a) Engage in broader dialog with potential cooperators. Climate change issues affect large regions and areas, and collaboration with others outside park borders is critical to understand indicators and trends, and to develop effective mitigation/adaptation strategies. To that end, the NPS Alaska Region has engaged in coordinated climate change communication and coordination at multiple levels, including interagency groups such as the Alaska Climate Change Executive Roundtable, Landscape Conservation Cooperatives, DOI Climate Science Center, DOI Arctic Coordination Committee, and many others. These and other high priority partnerships will be identified through development of an up-to-date list of notable interagency science and resource partnerships and workgroups relevant to NPS in Alaska. NPS regional advisory committees, teams, and knowledgeable individuals will be invited to

Table 1. Existing Assets for Implementation (listed in alphabetical order):

- **Administration Program staff support project and program implementation through budget management, procurement of needed services and supplies, workforce management, and development of policies and regulations.**
- **Advisory Groups and Committees identify and develop actionable project statements, review and make recommendations for funding individual projects in natural resources, cultural resources, subsistence, maintenance, education, wilderness, and more.**
- **Communications Program staff disseminate information to the public through press releases, interviews, the internet, etc.**
- **Cooperative Ecosystem Studies Units assist park and regional office staff in finding institutional and academic partners to address research, education, and technical assistance needs.**
- **Cultural Resources Program staff work to preserve cultural (historic, archaeological, ethnographic) information and resources, and to recover data and specimens from locations that are at risk of loss. In 2008 the NPS (Cultural Resources and GIS) completed an assessment of un-surveyed park acreage in Alaska that is presumed to be vulnerable to impacts of global climate change resulting from coastal erosion, ice patch degradation, development and access (see Appendix D).**
- **Environmental Planning and Compliance Program staff incorporate scientific and scholarly information into analyses of the effects of proposed actions, through NEPA, ESA, NHPA, etc. Climate change adds a new level of complexity to future planning, and will affect implementation of**

Table 1 continues on next page.

Table 1 continued.

numerous plans already in place, some of which also specifically relate to how the Alaska Region can and should address the issues, uncertainties, and effects of climate change. Existing strategy documents that specifically relate to this strategy include:

- **Ocean Park Strategy. Development of an Alaska Region Ocean and Coastal program is underway, to coordinate efforts and offer technical assistance to ocean and coastal parks to address their needs. There will be many overlapping issues between climate change and ocean stewardship; close coordination will be essential.**
- **NPS Alaska Region Science Strategy identified a framework for establishing and addressing scientific questions and issues in the Alaska Region. Climate change is listed first among five major issues identified in that document (Marcy 2006).**

- **Fire Program staff coordinate with other agencies to develop and implement fire management plans, conduct fire-related research and monitoring, and to preserve assets that are at risk of damage from wildfire and structural fire.**
- **GIS Program staff provide GIS and GPS support and services to parks and programs. The program manages and distributes spatial data related to cultural and natural resources, park assets, as well as base cartographic data such as imagery, hydrography, and digital elevation models. The program also provides technical assistance and develops cartographic products in support of park management activities.**
- **Interpretation and Education staff communicate messages and issues in the context of on-going duties (interpreters, education specialists, public affairs officers, etc).**
- **Inventory and Monitoring Program staff conduct extensive inventory and monitoring in Alaska national park units with four organized networks:**
  - **Arctic Network (ARCN), headquarters stationed in Fairbanks**
  - **Central Alaska Network (CAKN), headquarters stationed in Fairbanks**

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make recommendations regarding appropriate levels of NPS participation.

b) Engage local communities and non-government organizations. NPS also engages on many issues at the park/cluster level to identify opportunities for cooperation in planning solutions, including with adjacent land management units, and Native and park-affiliated communities. Several non-government organizations have demonstrated capacity and interest in providing assistance through development of information products, conservation initiatives, and other means. Some recent initiatives are highly relevant to NPS needs related to climate change. For example, the National Parks Conservation Association contributed staff to assist NPS with organization of subsistence-related wildlife research data provided by state and federal biologists. The Wilderness Society worked with the University of Alaska to produce downscaled climate-change data and maps that are included in this document. The Nature Conservancy has been actively involved in ecosystem mapping and conservation planning on Alaska's North Slope, coastal areas, and across broad landscapes. The passage of S. 2739 (Consolidated Natural Resources Act of 2008, May 8, 2008) enables the NPS to seek out and develop extensive partnerships with stakeholders, tribal entities, state and federal agencies, academics, and other NGO's.

c) Develop a communications plan. A communications plan is appropriate to reach internal audiences, media, and others in order to raise awareness of climate change issues and actions. Programs and agency representatives should incorporate means to communicate back to individual agencies and organizations through appropriate and effective means, such as email, newsletters, briefings, reports, web sites, workshops, etc.

3. Establish priorities and determine the sequence of new actions (short-, medium- and long-Term)

This Strategy outlines a suite of goals, objectives, and actions (Appendix B) for helping parks to understand, address, and adapt to the effects of climate change on park resources, assets, and operations. Prioritization was accomplished through the participation of members of six advisory groups (NRAC, CRAC, SAC, MAG, EAG, BWAG) and I&M and were accepted by the ALC in 2009. Annual review will be important to identify which actions have been completed, are underway, likely to be completed by others or require direct support or involvement by NPS. The list should be adjusted periodically, as current priorities are accomplished and new priorities identified.

4. Identify funding requirements and approach

New personnel, projects, and program funding will be required, in addition to existing resources already mentioned, to accomplish the goals outlined in this strategy. The Alaska Region's list of prioritized actions (Appendix B) has already been used successfully in responding to the annual Servicewide Comprehensive Call for funding proposals. A new competitive fund source was established for climate change response by the NPS Natural Resource Program Center (NRPC) in FY2010. Additional funding sources, partnerships, and approaches will be identified through further review.

5. Establish timetable and implement short-term actions

A number of immediate and short-term actions have been implemented during internal and external review of this strategy. Those actions and others proposed for 2010 are listed below.

Actions initiated in 2009:

- Advisory groups developed and prioritized actions
- Advisory groups developed and successfully completed proposals for high priority actions
- An NPS Alaska "Green Team" was established to share mitigation strategies
- A draft of this strategy was broadly distributed inside and outside of NPS for review

Actions to initiate in 2010:

- Approval of this strategy by the Alaska Leadership Council and distribution to staffs and cooperators
- Identification of key individuals, workgroups, roles and responsibilities for strategy implementation
- Identification of key interagency partnerships and workgroups for NPS participation

Table 1 continued.

- **Southeast Alaska Network (SEAN), headquarters stationed in Juneau**
- **Southwest Alaska Network (SWAN), headquarters stationed in Anchorage**

These four I&M networks are collectively developing and implementing scientific protocols to determine status and trends of selected environmental and resource "vital signs" (e.g., climate, glaciers, wildland fire, water, wildlife, fisheries, vegetation) across 55 million acres (Appendix E) (NPS and AKGEO 2010).

The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. Data for this program is collected, analyzed and shared by NPS, other federal and state agencies, academic institutions, and nongovernment entities.

- **Natural Resources Program staff manage natural resources, design and conduct studies, and provide information to managers and the public through reports, presentations, and other means. Natural resource staff also engage in cooperative management of wildlife and fisheries populations to ensure sustainable harvests, where harvests are allowed by law and regulation. Most of the NPS biological and physical scientists work in the natural resource programs.**
- **Exotic Plant Management Team (EPMT) in Alaska is one of 16 teams in the NPS system addressing invasive plant management. The Alaska EPMT services all Alaska NPS units through prevention, education, inventory, control, and restoration work.**
- **Planning, Design, and Maintenance Program staff develop and implement plans for new, replacement, and retrofitted facilities and maintain built assets including recent and historic structures, utilities infrastructure, roads, trails, etc. They operate electrical, heating, water and fuel systems; collect, separates, and treat park waste. Uniformed maintenance staffs also interact regularly with the public and can be a major source of information for the public.**
- **Protection rangers work to protect park visitors, employees, and resources through law enforcement and emergency services, including incident command. They are often the first to respond and**

Table 1 continues on next page.

Table 1 continued.

take a major coordinating role during emergency incidents, such as floods, landslides, etc.

- **Research Learning Centers (RLC) facilitate research in parks by external scientists and scholars, and provide learning opportunities and experiences for the public. RLCs are among our strongest assets for sharing scientific information with elements of the public that are both knowledgeable and highly receptive to such information.**
- **Subsistence Program staff work to ensure sustainable harvests of natural resources (e.g., wildlife, fisheries, firewood) in locations where subsistence harvests are allowed by law and regulation.**

- Training and initiation of Climate Change Scenario Planning for all NPS areas in Alaska
- Expanded NPS participation in Alaska Landscape Conservation Cooperatives
- Expanded NPS participation in the DOI Alaska Climate Change Science Center
- Expanded NPS participation in marine and coastal work groups in Alaska
- Expanded resource monitoring and research relative to climate change in Alaska
- Further development of action items and timetables for priority actions with advisory committees

Appendix A.
Secretarial Order 3289 Amended

THE SECRETARY OF THE INTERIOR

WASHINGTON

ORDER NO. 3289, Amendment No. 1 (*Amended material italicized*)

SIGNATURE DATE: February 22, 2010

Subject: Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources

Sec. 1 **Purpose and Background**. Secretarial Order No. 3285, issued on March 11, 2009, made production and transmission of renewable energy on public lands a priority for the Department. This Order establishes a Department-wide approach for applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts on tribes and on the land, water, ocean, fish and wildlife, and cultural heritage resources that the Department manages. This Order replaces Secretarial Order No. 3226, Amendment No. 1, issued on January 16, 2009, and reinstates the provisions of Secretarial Order No. 3226, issued on January 19, 2001.

To fulfill our nation's vision for a clean energy economy, Interior is now managing America's public lands and oceans not just for balanced oil, natural gas, and coal development, but also—for the first time ever—to promote environmentally responsible renewable energy development. Sun, wind, biomass, and geothermal energy from our public and tribal lands is creating new jobs and will power millions of American homes and electric vehicles.

The Department is also taking the lead in protecting our country's water, land, fish and wildlife, and cultural heritage and tribal lands and resources from the dramatic effects of climate change that are already occurring—from the Arctic to the Everglades. The realities of climate change require us to change how we manage the land, water, fish and wildlife, and cultural heritage and tribal lands and resources we oversee. For example:

- New water management imperatives associated with climate change may require restoration of natural systems and construction of new infrastructure to reduce new flood risks or to capture early run-off.
- Strategies to address sea level rise may require acquisition of upland habitat and creation of wetlands and other natural filters and barriers to protect against sea level rise and storm surges. It may be necessary to relocate certain iconic and culturally historic structures.
- Shifting wildlife and habitat populations may require investments in new wildlife corridors.
- New invasions of exotic species and new wildland fire threats due to longer fire seasons and more severe droughts will require innovation and more effective ways of managing the Department's resources.

The Department of the Interior, with its 67,000 employees and scientific and resource management expertise, is responsible for helping protect the nation from the impacts of climate change. In particular the Department must:

- Adapt its water management strategies to address the possibility of shrinking water supplies and more frequent and extended droughts to continue to supply drinking water to more than 31 million people and irrigation water to 140,000 farmers.
- Wisely manage millions of acres of parks, refuges and other public lands, and prudently exercise its shared responsibility for managing the 1.7 billion acres of the U.S. outer continental shelf.
- Conserve and manage fish and wildlife resources, including over 800 native migratory bird species and nearly 2,000 federally listed threatened and endangered species.
- Protect cultural and archaeological resources and iconic structures that may be affected by climate change.
- Address the impacts of climate change on American Indians and Alaska Natives, for whom the Department holds trust responsibilities on behalf of the Federal government.
- Continue to provide state-of-the art science to better understand the impacts of climate change and to develop science-based adaptive management strategies for natural and cultural resource managers.
- Continue its work to quantify the amount of carbon stored in our forests, wetlands, and grasslands, identifying areas where carbon dioxide can be safely stored underground, and ways to reduce the Department's carbon footprint.

Sec. 2 **Authority.** This Order is issued under the authority of Section 2 of Reorganization Plan No. 3 of 1950 (64 Stat. 1262), as amended.

Sec. 3 **Coordinating the Department's Response to Climate Change Impacts on Our Resources.** ***The Climate Change Response Council within the Office of the Secretary is renamed the Energy and Climate Change Council (Council). The Council*** will execute a coordinated Department-wide strategy to address ***renewable energy efforts*** and to increase scientific understanding of and development of effective adaptive management tools ***to address*** the impacts of climate change on our natural and cultural resources. The ***Energy and Climate Change Council*** will be composed of the Secretary (Chair), Deputy Secretary (Vice-Chair), Counselor to the Secretary (Vice-Chair), Assistant Secretaries, Bureau Directors and the Solicitor. The Council will help coordinate activities within and among the Department's agencies and bureaus to develop and implement an integrated strategy for responding to ***renewable energy efforts and*** climate change impacts involving the resources managed by the Department. The Department's ***Energy and Climate Change Council*** will also coordinate its ***energy and*** climate change activities with all relevant Federal Departments and agencies including, but not limited to, the Council on Environmental Quality, the Office of Energy and Climate Change, the Office of Science and Technology Policy, the National Science and Technology Council, the Department of Agriculture, the Department of Commerce, the Department of Defense, and the Environmental Protection Agency.

The ***Energy and Climate Change Council*** will implement Department-specific ***energy activities as described in Secretarial Order # 3285 (Amendment No. 1), and implement*** climate change activities through the following mechanisms:

a) Climate Change Planning Requirements. Each bureau and office of the Department must consider and analyze potential climate change impacts when undertaking long-range planning exercises, setting priorities for scientific research and investigations, developing multi-year management plans, and making major decisions regarding potential use of resources under the Department's purview. These requirements were set forth in Secretary's Orders No. 3226 and 3285, and remain in effect. The organizational changes made by this Order will enable the bureaus and agencies to fulfill these planning requirements.

b) *DOI Climate Science Centers*. Management decisions made in response to climate change impacts must be informed by science and require that scientists work in tandem with those managers who are confronting climate change impacts and evaluating options to respond to such impacts. Pursuant to P.L. 110-161, the United States Geological Survey (USGS) has been developing regional science centers to provide climate change impact data and analysis geared to the needs of fish and wildlife managers as they develop adaptation strategies in response to climate change. These centers are currently known as "regional hubs" of the National Climate Change and Wildlife Science Center, and are being developed in close collaboration with Interior agencies and other federal, state, university, and non-governmental partners.

The ***Energy and Climate Change Council*** will work with USGS and other Department bureaus to rename these regional science centers as ***DOI Climate Science Centers (Centers)*** and broaden their mandate to encompass other climate-change-related impacts on Departmental resources. These eight Centers will synthesize and integrate climate change impact data and develop tools that the Department's managers and partners can use when managing the Department's land, water, fish and wildlife, and cultural heritage resources.

c) <u>Landscape Conservation Cooperatives</u>. Given the broad impacts of climate change, management responses to such impacts must be coordinated on a landscape-level basis. For example, wildlife migration and related needs for new wildlife corridors, the spread of invasive species and wildfire risks, typically will extend beyond the borders of National Wildlife Refuges, BLM lands, or National Parks. Additionally, some bureau responsibilities (e.g., Fish and Wildlife Service migratory bird and threatened and endangered species responsibilities) extend nationally and globally. Because of the unprecedented scope of affected landscapes, Interior bureaus and agencies must work together, and with other federal, state, tribal and local governments, and private landowner partners, to develop landscape-level strategies for understanding and responding
to climate change impacts. Interior bureaus and agencies, guided by the ***Energy and Climate Change Council***, will work to stimulate the development of a network of collaborative "Landscape Conservation Cooperatives." These cooperatives, which already have been formed in some regions, will work interactively with the relevant ***DOI Climate Science Center(s)*** and help coordinate adaptation efforts in the region.

Sec. 4 **Additional Departmental Action to Mitigate Climate Change**. In accordance with Secretarial Order No. 3285, the Department has prioritized development of renewable energy on public lands and offshore waters to reduce our dependence on foreign oil and to reduce greenhouse gas pollution. This Order establishes two additional projects to mitigate climate change: the DOI Carbon Storage Project, and the DOI Carbon Footprint Project. Additional mitigation projects will be encouraged and supported by the ***Energy and Climate Change Council***.

a) <u>The DOI Carbon Storage Project</u>. This project is being implemented under P.L. 110-140, "The Energy Independence and Security Act of 2007," which gives the Department statutory responsibility to develop carbon sequestration methodologies for geological (i.e., underground) and biological (e.g., forests and rangelands) carbon storage. The USGS has the lead in administering the Carbon Storage Project, but will work closely with other bureaus and agencies in the Department and external partners to enhance carbon storage in geologic formations and in plants and soils in a manner consistent with the Department's responsibility to provide comprehensive, long-term stewardship of its resources. The DOI Carbon Storage Project is vital for successful domestic and global geological and biological carbon sequestration efforts.

a) <u>The DOI Carbon Footprint Project</u>. The project will develop a unified greenhouse gas emission reduction program, including setting a baseline and reduction goal for the Department's greenhouse gas emissions and energy use. The Assistant Secretary for Policy, Management and Budget will have the lead in administering the DOI Carbon Footprint Project, with the cooperation of all of the Department's agencies and bureaus.

Sec. 5 **American Indians and Alaska Natives**. Climate change may disproportionately affect tribes and their lands because they are heavily dependent on their natural resources for economic and cultural identity. As the Department has the primary trust responsibility for the Federal government for American Indians, Alaska Natives, and tribal lands and resources, the Department will ensure consistent and in-depth government-to-government consultation with tribes and Alaska Natives on the Department's climate change initiatives. Tribal values are critical to determining what is to be protected, why, and how to protect the interests of their communities. The Department will support the use of the best available science, including traditional ecological knowledge, in formulating policy pertaining to climate change. The Department will also support substantive participation by tribes in deliberations on climate-related mechanisms, agreements, rules, and regulations.

Sec. 6 **Implementation**. The Deputy Secretary is responsible for ensuring implementation of all aspects of this Order. This responsibility may be delegated as appropriate. This Order does not alter or affect any existing duty or authority of individual bureaus.

Sec. 7 **Effective Date**. This Order is effective immediately and will remain in effect until its provisions are converted to the Departmental Manual or until it is amended, superseded, or revoked, whichever occurs first.

SO#3289A1 2/22/10 /s/ Ken Salazar Secretary of the Interior

Appendix B. Recommended Actions for the NPS Alaska Region Climate Change Response Strategy (organized by goal and objective)

Goals and objectives shown in bold text were not prioritized, as all are considered important to achieving the vision. The actions (a, b, c, etc.) shown **underlined and in bold text** were identified as high priority by representatives of six advisory committees (NRAC, CRAC, SAC, MAG, EAG, BWAG) and the I&M program. Actions shown only in **bold text** and without underlining were identified as medium priority. Actions shown in plain text were identified as lower priority. The elements listed below actions, shown in plain text, are provided for information, and were also not prioritized.

Goal 1. Science: Support resource inventories, monitoring and research to better understand the current and potential impact of changing climate on park resources.

Objectives and Actions:

1.1. Acquire basic datasets required for accurate assessments, forecasting, planning and decision making.

a) **<u>Improve statewide digital datasets</u>**, to ensure an adequate base map is available for other resource mapping and analysis. Develop and update GIS datasets that accurately portray coastlines. Develop and update a GIS dataset that accurately portrays the shorelines of Alaska coastal parks.

i. Continue to acquire high quality Digital Elevation Models (DEM) over glacier areas of Alaska parks to establish a baseline dataset to assess volumetric changes to glaciers in Alaska national parks.

ii. Improve the currently available National Hydrograph Dataset (NHD) so that accurate modeling can be accomplished.

b) **Ensure completion of the NPS Inventory and Monitoring program's Phase 1 inventories**. In Alaska, this includes land cover for 4 parks, soils for 14 parks, and orthoimagery for all parks by 2020.

c) **Continue to acquire GIS datasets of historic extents for critical indicators** as early as possible for use in baseline comparisons, including:

i. permafrost extents
ii. species distributions
iii. snow and ice cover
iv. climate data
v. fire history extent and occurrence
vi. land use history
vii. hydrography

d) **Sustain and expand climate monitoring**. Continue to support NPS efforts to deploy and maintain Remote Automated Weather Stations (RAWS) throughout Alaska national parks in an effort to establish long-term climate datasets in remote areas not currently monitored.

1.2. Acquire or develop and use modeling, forecasts, and other decision support tools.

a) **<u>Terrestrial, aquatic, and marine flora and fauna</u>**. Use decision support and modeling tools at various scales to better understand and predict the effects of climate change on species and their habitat. Simulate changes using bioclimatic models.

i. Identify most vulnerable species at edge of ranges with no likely migration corridor or adaptation strategy.

ii. Identify hotspots for climate change impacts in terms of biological diversity and habitat to produce statewide ecological climate risk map.

iii. Identify potential impacts to habitat for endangered, threatened and endemic species in parks.

iv. Model the effects of climate and fire on wildlife habitat and subsistence resources.

v. Model the effects of climate and fire on hydrologic systems and their biota (macroinvertebrates and fisheries), water chemistry and sedimentation.

vi. Develop habitat suitability models for species of concern and analyze possible changes to habitat under changing climate scenarios.

vii. Develop list of at-risk taxa.

viii. Model prey species and assemblages shifts in distribution and abundance with an acceptable level of precision.

viii. Monitor and model the spread of terrestrial, aquatic, and marine invasive plants, animals and pathogens.

ix. Identify freshwater and marine aquatic species that are vulnerable to changes in habitat, such as primary freshwater fish, and assess the potential for management strategies to assist in their conservation. Identify aquatic habitats subject to large-scale changes as a result of climate change, as well as the nature of those habitat changes. Model seasonal lake over turn as a function of precipitation and ambient temperature to improve forecasting of climate effects on large lake habitats.

x. Identify current uses of subsistence resources by community, changes that have already occurred in migration or home ranges, and changes that have been made by local users to access or harvest resources. Model projected changes and community needs.

b) **Sea level, marine and coastal processes.**

i. Project effects of sea level rise, rebound, and coastal inundation in all NPS areas in Alaska.

ii. Project changes in near shore habitats and physical characteristics in and adjacent to all NPS areas in Alaska.

c) **Climate.** Obtain and use downscaled global climate model projections (GIS layers and maps of future mean and extreme temperatures and precipitation in all Alaska NPS areas. Utilize down-scaled models of regional climate to project probable future changes affecting local park areas. PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate models should be updated regularly, beginning in 10 years, including reanalysis in light of potential shift from positive to negative PDO phase.

d) **Cultural Resources.** Utilize geographic cultural resource impact projections (e.g., coastal and riverine erosion, thaw zones, soil stability and deflation, animal disturbance, and changes in the water table) to target specific areas for expanded cultural resource inventories (archeological and historic), stabilization or data recovery. A few preliminary GIS models have been developed; however, there are still limitations with coastal DEMs and other base imagery. Further refinements could include coastal erosion risk estimates, based on substrate type (rock, permafrost) and other factors.

e) **Wildland Fire.**

i. Evaluate the needs for wildfire prediction models to better understand the scope of wildland fire in coming decades, as well as the vegetation types where prescribed natural fire will be most beneficial.

ii. Develop Alaska-specific fuels models using newly available land cover and other data.

iii. Determine fire size, frequency, duration, and fire return intervals prior to 1950 by vegetation type and geographical area to enable fire managers and resource managers to make more informed decisions about fire management activities. Incorporate traditional knowledge of forest management and intentional, anthropogenic burning.

iv. Determine the natural range of hazy conditions in each park caused by wildfire smoke.

v. Using pre- and post-fire Landsat imagery, develop a robust mapping methodology and consistent data products to evaluate and compare burn severity within individual wildland fires and among fires across different ecosystems. Analyze burn severity every five years.

vi. Gather historical weather data, verify its accuracy, and establish good weather predictors associated with fire development, fire behavior, and the end date of the fire season. Examine historical weather data for commonality and rarity of significant weather events to determine the probability of such events. Compare fire behavior outputs using the Canadian FBP software using Canadian Forest Fire Danger Rating System (CFFDRS) indices versus actual fire behavior. Evaluate the Fire Weather Indices within CFFDRS to predict large fire growth. Determine the utility of moisture probes to model CFFDRS indices, and evaluate whether alternative drought indices would be useful in Alaska.

vii. Analyze fuel characteristics (e.g., vegetation type, fuel load, moisture, and tree age) that allow previously burned areas to act as fuel breaks for new fires.

viii. Continue to document wildland fires with GIS coverage of fire perimeters, on-site fire observations, and photography. Compare observed fire behavior with results from existing fire behavior models.

f) Hydrology. Develop forecasts to anticipate changing surface water bodies, surface and subsurface flow (volume, timing, and locations), composition (nutrients, sediment) in priority areas.

g) Permafrost. Develop mapping products of current permafrost extent, and depth to frozen ground for all Alaska NPS areas, and projections through the 21st century.

h) Ocean acidification. Identify likely impacts of ocean acidification on coastal park biological resources. Identify species and process most vulnerable to acidification.

i) Ocean circulation. Identify likely changes to ocean currents, upwelling patterns, and related offshore productivity on coastal park resources.

j) Visitor experience, use, and perceptions. Analyze projected changes in human use with respect to resources, e.g. increased visitation, changes in access, and habitat susceptibility to impacts.

1.3. **Continue development and implementation of natural resource and other monitoring.** Enhance or expand monitoring where needed, to determine status and trends of environmental and indicators of climate change, including information needed to evaluate modeled projections.

a) **Characterize and monitor coastlines** (geomorphology, tectonic uplift and subsidence, biology, cultural sites) to enable coastal impact forecasting, scenario planning, monitoring, trend analysis, and spill response following shipping accidents.

i. Expand coordination with NOAA ShoreZone program towards a goal of completing statewide mapping with consistent information and delivery.

b) **Continue to map glacier extent** on a decadal scale in Alaska park units.

c) **Monitor marine habitats for invasive species.**

i. Continue marine invasive species monitoring at GLBA and KEFJ.

ii. Create an alert system to make park managers aware of new marine invasive species. Draw information from already established and expanding Alaska Early Detection Rapid Response (EDRR) networks for European green crabs, tunicates, Atlantic salmon, and other species.

iii. Develop monitoring program for Arctic marine species shifting ranges in BELA and CAKR. Increased shipping through Arctic is a new invasive species pathway (*Hellmann et al. 2008, Pyke et al. 2008*); warming temperatures and resumption of northward spread of Pacific species to Arctic and Atlantic systems (*Vermeij and Roopnarine 2009.*)

d) **Document changes in vegetation patterns in terrestrial and marine environments**, especially those relevant to biodiversity, rare plants, and wildlife forage. Use ground-based measurements in tandem with remote sensing imagery and landcover mapping to produce landscape-level estimates of change.

e) **Include a broad suite of phenological indicators in monitoring program**s, including migration and breeding of birds, mammals and amphibians, leaf-out and flowering dates of plants. Sound monitoring instrumentation may be an effective means of monitoring avian and amphibian species through vocalization.

f) **Cooperate in development of uniform, scientific, peer-reviewed fish and wildlife monitoring** protocols for federal, state, and community land management agencies to use for adaptive management.

g) **Monitor freshwater aquatic habitats** for invasive plant and animal species, pests, and diseases.

h) Permafrost.

i. Identify trends and trajectories in active layer depth and permafrost distribution as a cooperator on studies of permafrost degradation.

ii. Retrieve and analyze geotechnical site data on permafrost. Over the past 20 to 30 years most all parks have had new buildings constructed. Soils investigations were normally done before construction. This information needs to be retrieved from park files and consolidated as a first step towards understanding the threats that warming temperatures will have on local soils.

iii. NRCS Order 2 soil survey provides permafrost data. Will need additional funding to inventory soils at this level of detail.

i) Monitor species changing latitudinal and altitudinal ranges. Determine if rate of species range change is keeping pace with climatic changes in habitat.

j) Conduct retrospective analyses using lake cores for example to increase information about prehistoric soil, landcover, and fire conditions.

k) Conduct land cover (including fire) and near-shore studies to determine trends and to forecast future habitat suitability for native, migrant and invasive species.

l) Monitor insect herbivore/forest pest densities and phenologies throughout growing season.

m) Expand climate change inventory and monitoring.

i. Increase the number of existing vital signs monitoring sites, and enhance the design parameters with which they are selected to ensure robust inference.
ii. Expand active monitoring to include vital signs that have been identified as high priority but that are currently unfunded or underfunded.

n) Monitor phenology of invasive species to identify shifting patterns throughout growing season.

o) Monitor changing water chemistry, particularly pH and concentrations of aragonite, calcite, and other minerals essential to calcifying organisms

1.4. Expand research on climate change topics needed to better understand, manage, and be able to communicate trends, processes, and effects on ecosystems and people.

a) **Conduct archaeological resource surveys,** research, and data recovery in areas where coastal erosion is occurring or expected and at other vulnerable sites, such as ice patches and stream margins.

b) **Expand the analyses currently underway at park or network scales to encompass a more regional view**. For example, consider vegetation changes across broad landscapes, changes in timing, sequence, and linkages between seasonal biological events (phenology) such as spring green-up and animal migration.

c) **Native and Traditional Cultures**. Determine impact of climate change on the larger cultural landscape. How is traditional ecological knowledge impacted? How is use of resources by indigenous populations impacted?

i. Appropriately obtain, incorporate and effectively use traditional ecological knowledge.

d) **Develop criteria for investigating unexpected changes to wildlife, fish, and vegetation** that seem likely to have been triggered by climate change.

e) Increase social science research relative to climate change

i. Model and measure the influence of climate change on visitor experiences and choices.
ii. Determine economic impacts of climate change on NPS visitor operations and communities.
iii. Determine relationships between physical impacts of visitor use and climate change.
iv. Assess public perception of climate change impacts to parks, NPS role and responses.
v. Query the various audiences we serve, both internal and external, to determine the best means and techniques for communicating with them about climate change and its effects.

f) Identify mechanisms of dispersal of invasive plants and animals to better monitor and facilitate management decisions about spread and control. Determine potential and extent of hybridization between native and invasive species.

g) Expand research on contaminants. Includes persistent organic pollutants (POPS) deposited from global air circulation, fugitive dusts from ore concentrates, mercury and other heavy metals, etc.

h) Include studies of the effects of climate change on at-risk fish and wildlife species, populations, and habitats in the Nation's Climate Change Science Program (CCSP).

i) Estimate carbon flux and net AKR contribution to greenhouse gases (+ or -) from NPS areas, to determine where NPS lands function as carbon sinks (e.g., expanding vegetation) or carbon sources (e.g., permafrost thaw, wildfire), a likely national priority for federal lands.

j) Identify species and habitat conservation refugia.

k) Prioritize critical migration, spawning, and rearing habitats of aquatic species deemed vulnerable, particularly Copper and Yukon Rivers adjacent to NPS areas.

1.5. Foster partnerships with other agencies, organizations, tribes, adjacent land managers/owners, park affiliate communities, and international partners to address common needs relative to resource stewardship and science.

a) **Continue to engage in interagency efforts** to share information, identify, and address common issues.

i. Actively participate in Alaska's DOI Climate Change Science Centers and Landscape Conservation Cooperatives

ii. Support interagency efforts to ensure data sharing and interoperability of appropriate datasets collected and managed by other agencies and institutions (e.g., Alaska Climate Change Executive Roundtable data workgroup).

iii. Encourage preservation and sharing of legacy data through data mining and rescue activities for hardcopy (printed) data.

iv. Partner with other agencies (USDA Forest Service, Alaska Department of Fish and Game, Alaska Division of Forestry, Cooperative Extension Service, Alaska Sea Grant Marine Advisory Program, and the USDA Animal and Plant Health Inspection Service (APHIS)) to detect invasive insects, pathogens, etc.

b) **Leverage and facilitate the research interests of other institutions** by ensuring NPS is welcoming to science while maintaining our unique role as stewards of unimpaired landscapes.

1.6. **Expand and improve response capabilities** to known and expected climate change impacts to park resources (e.g., freshwater and marine resources, invasive species).

a) **Monitor front country and backcountry locations for invasive plant** establishment and apply best management practices to prevent invasive species from expanding into vacant niches and displacing native species stressed by climate change.

b) **Develop regional capacity for an oceans coastal program** that would assist parks with specific needs and have the ability to represent the agency in regional interagency efforts such as the Alaska Marine Ecosystem Forum, North Slope Science Initiative, Alaska Ocean Observing System, North Pacific Fisheries Management Council, and North Pacific Research Board, etc.

Goal 2. Adaptation: Modify management practices to manage parks in an era of climate change.

Objectives and Actions:

2.1 Identify and prioritize *risks* to parks resulting from climate changes, and identify NPS response options and capacities.

a) **Geo-hazards** from glacial outbursts and river flooding, surging glaciers, avalanches, landslides, coastal hazards, coastal erosion, submergence, salinization, etc. Consider locations of campgrounds, field camps, ranger stations, etc.

b) **Wildland Fire**. Document the pre-and post-treatment condition of the vegetation in all hazard fuels treatment areas; monitor the effects of the treatment on vegetation; and evaluate the original prescription. Model fire risk associated with different types of fuel treatments. Determine maximum efficiency in hazard fuels reduction techniques for application at all Alaska park units. Address fire hazard in areas within full suppression zones that are untreated in order to prioritize fuel treatments.

c) **Invasive plant, animal, pest and disease** species expansion in terrestrial, aquatic, and marine park ecosystems. Create prioritized invasive species treatment plans. Consider need for strategies for phasing out treatment efforts on some invasive species as they become naturalized.

d) **Hydrologic changes**: water quality, quantity, timing, and salinization.

e) Permafrost Thaw Hazards.

i. Contaminants resulting from permafrost thaw or changes to surface or groundwater hydrology in historically contaminated areas in parks or adjacent lands.

ii. Ground failures through solifluction, erosion, inundation, subsidence.

f) Species habitat loss and fragmentation. Assess risks to seasonal migration and natural range shifts of species by climate change.

2.2 Identify park assets, resources, visitor services, and activities that are likely to be affected by climate change and determine what management actions are needed to prepare.

a) **Natural Resources likely to be affected**: Flora, fauna, view shed, physical resources, and water resources.

b) **Cultural resources**.

c) **Subsistence and sport hunting and fishing**. Seasons may need to be adjusted to changing species availability, and traditional modes of access may not be sufficient or safe to reach animals or water bodies, as frozen ground, vegetation, habitat, and migratory patterns change.

d) **Infrastructure**.

i. Utilities. Soil inventories (including active layer depth) need to be performed to identify buried and above-ground utilities that will fail as permafrost thaws (e.g., power, water, and wastewater lines).

ii. Building foundations. Soils inventories need to be performed to identify which building foundations are likely to fail when the permafrost melts. Treatment strategies will need to be developed, which could range from installing equipment to keep the soils frozen (not very sustainable) to moving the buildings (very expensive). (UAF has developed a network of very low cost monitoring stations for active layer depth and temperature monitoring and is seeking increased NPS participation.)

e) **Access**.

i. Road Structure. Soil inventories need to be performed to identify roads which will fail when permafrost melts. Treatment strategies will need to be developed. Insulation is not a permanent solution. Treatments could range from filling failed areas with gravel to relocating entire roads. In some instances new modes of transportation may need to be considered.

ii. Air strips used to access remote areas in parks may be washed out by changing river flows.

iii. Trails. Soil inventories need to be performed to identify trails which will fail when permafrost melts. Treatment strategies will need to be developed. Many trails may need to be relocated.

f) Vegetation and Hazard Fuels

i. Vegetation. Expanding vegetation is changing the viewscape and visitor viewing opportunities in some locations. Increased brushing efforts will be required due to the increased length of growing season. Changes in vegetation will require new brushing techniques.

ii. Hazard Fuels Treatments. Increased fire clearing and continual brushing efforts will be needed due to the longer growing season (3-week increase in past 20 years has already occurred) and expanding vegetation. Tree line is expected to rise, which will increase number of developed areas needing Firewise treatment.

g) Fire protection. Identify areas and/or habitats that may need modifications to fire suppression protection levels (fire management options) due to potential increases in fire frequency, extent, or severity.

h) Wildlife viewing may change because of encroaching vegetation or changes in habitat that cause animals to move away or not be readily visible.

i) Glaciers. Visitors may not be able to get close to glaciers because they have receded to points inaccessible by water. (A small cruise ship grounded during an outgoing tide on glacial outwash in GLBA during 2008.) Glacier landings may not be possible by air taxis due to changing conditions on air strips located on ice fields. In 2009, air taxis attempted to use snowmobiles to groom a glacier airstrip in Denali, due to increased snow melt and rough conditions.

2.3 Engage in scenario planning to develop and evaluate alternatives and options for managing a range of probable changes. Use trend data, models, and forecasts to support scenario planning to identify probable changes and potential impacts that will occur due to climate change.

a) **Develop and implement scenario planning workshops** in Alaska on a rotating park, network, or cluster level.

b) Utilize scenario planning in training for NPS and the cooperators to understand the issues. For example, vessel management and spill response plans may be needed for coastal parks in northwestern Alaska as sea ice retreats and ship traffic increases through the Northwest Passage and Northern Sea Route.

2.4 Develop adaptive management as a tool for assessing situations, designing, implementing, monitoring, evaluating, and adjusting management decisions.

2.5 Enhance collaborative management, with federal, state, and other land managers in Alaska in order to coordinate climate change response strategies on a landscape scale.

a) **Identify NPS leads, desired roles and functions, and identify the most important climate change partnerships** for NPS to develop and maintain with other agencies, organizations, etc. (e.g., multi-agency invasive species planning.)

2.6 Develop guidelines consistent with current law and policy for park stewardship in a rapidly changing environment.

2.7 Conduct analyses to identify legal and policy issues affecting an agency's ability to respond to climate change. Recommend changes as necessary.

a) **Establish regional coordination with the Service-wide law and policy working group**. Examples of questions that should be addressed include:

i. How much flexibility does the NPS have to protect or not protect species and landscapes under its jurisdiction?

ii. How does the NPS reconcile the current definition of "natural" (absence of human dominance over the landscape) with the impacts to resources resulting from the changing climate? Specifically, how do managers comply with mandates and policies for conservation and maintenance of natural conditions?

iii. Clarify how the impairment standard applies under climate change? Envision and capture through park planning and processes what will be the metric of successful management in the future.

iv. Is active manipulation/intervention desirable (e.g. assisted migration or colonization) or warranted to save a species?

v. How much should NPS minimize, prevent or reduce greenhouse gas emissions produced by park operations and activities?

vi. Should parks be able to sell carbon credits through various sequestration methods (underground, harvesting, land/forest management)?

b) **Assess and develop policies and criteria regarding natural and assisted migration of native species** as natural climate zone shifts (e.g., Hoegh-Guldberg et al. 2008). Identify any obstacles to natural migration of native species, such as east-west mountain ranges, rivers, islands, ice fields, etc. Develop strategy for acceptance of assisted migration taxa from more southerly regions. Assess invasibility of species in new range. Weigh concerns of reduced risk of extinction vs. potential to inadvertently create new invasive species and introduce new parasites and disease into previously-isolated areas. Intracontinental invasive species are less common (<15% of species), but those that are invasive are just as likely to have severe effects; fish and crustaceans are particularly high threat (>30% of species) (Mueller and Hellmann 2008).

c) **Evaluate the need to modify existing regulations that are based on set calendar dates.** As climate change alters migrations, glacier melt, etc, park managers will need more flexibility to address public use closures. This would reverse the State of Alaska's current trend to reduce park manager's discretion, and would affect the Federal Subsistence Program.

d) Address jurisdictional issues that will arise as a result of migrating coastal boundaries and existing park boundaries that may change significantly due to climate change, such as those described by features such as rivers. Work towards changing the legal description to a fixed location (e.g., Kantishna River in Denali near Lake Chilchukabena).

e) Evaluate inconsistencies in existing Alaska park-specific plans and policies affecting the Alaska Region relative to actions needed to address potential climate change impacts. Include evaluation of Alaska National Interest Lands Conservation Act (ANILCA) and Alaska Native Claims Settlement Act (ANCSA) provisions which are based upon a static and not dynamic climate situation. Lack of flexibility to adapt to climate change may make it difficult to protect resources, and cultural and subsistence practices that the laws were established to protect.

2.8 Incorporate consideration of climate change in planning, compliance and mitigation processes.

a) **Plan how NPS will "preserve park's unique and special values"** identified in enabling legislation and foundation documents and perceived by the public in the face of climate change. Managing a protected area in an era of climate change is a very different task.

i. What are the unique and special values established in foundation documents?
ii. What does the public see as the unique and special values?
iii. Are these unique and special values being impacted by climate change?
iv. What is needed to preserve and enhance park values in a time of rapid change?

b) **Create landscape-level assessment standards and protocols** for impacts to adequately evaluate potential environmental of climate change and energy development (e.g., NEPA and HPA 106).

c) Focus management on something that is not boundary specific. Changes to the environment may be abrupt and dramatic. NPS may have to manage for biodiversity or ecological function rather than maintain species or specific habitats in their current locations.

d) Envision and capture through park planning and processes what will be the metric of successful management in the future.

e) Identify mitigation strategies involving federal, state, and private partners in terms of management activities.

f) Develop adaptation strategies for biota pertaining to natural climate zone shifts and identify any obstacles to natural migration of wildlife, fish, and vegetation.

2.9 Convene interdisciplinary groups to review, update, and identify high priority actions under goals as needed.

Goal 3. Mitigation: Through innovation, demonstration projects, and new business practices become a model of environmentally sustainable operation at all locations.

Objectives and Actions:

3.1. Develop programs to encourage and facilitate the adoption of sustainable energy practices and reduce carbon footprints in Alaska parks.

a) **Establish energy and carbon baselines**. Track use, set specific goals and targets, and provide incentives to succeed in sustainable energy.

b) **Investigate ways to utilize wasted power.**

i. Charge electric vehicles with interruptible power.
ii. Use IT server room air handling to augment the heating and air conditioning for the rest of the facility. For each park and regional office that has server rooms and telecommunications rooms with heat generating communications equipment, have the air handling redirected into the facilities main air handling system. During the winter months, the heat would help heat the whole facility.
iii. Conduct energy audits of NPS-owned structures and utility systems to identify opportunities to reduce energy consumption and reduce greenhouse gas emissions linked to climate change.
iv. Invest in high efficiency boilers, generators, and water heaters when these units are replaced.
v. Evaluate our fleets and replace with hybrids or less consumptive, more efficient vehicles, boat engines and equipment where feasible.
vi. Winterize vacant residences and other buildings so that they will not require heating during winter seasons.

c) **Evaluate and test alternative, renewable and highly efficient energy technologies** to determine what is most appropriate to specific locations (electricity, lighting, fuels, heating, transportation, etc.).

i. Invest in smart outlets for block heaters on vehicles that limit "on" time based on outside temperatures.

d) **Meter all possible uses of energy at the building level** or other low level so that losses or wasting of resources can be more easily found.

e) **Consider cogeneration of energy and heat production** in all cases. Look at the washaterias in the villages as one model of cogeneration – most are also coincident with power production. Look at models such as Denali's Toklat power generation system, where waste heat from generators is used to heat the Auto Shop.

f) **Move up to a cleaner fuel** where opportunities exist, even if it is not the final answer. Propane is less polluting than diesel, for instance, and any spills are much easier on the environment and to clean up. Denali has significant experience and success with propane, the lessons learned can be applied at other parks. Recognize that switching to cleaner fuels is a multi-year commitment.

g) **Look for opportunities to utilize potential energy**. Your water line may be able to support a hydro system – Eielson and Kennecott are examples of this.

h) **Evaluate and implement practices towards carbon neutral operations** in collaboration with EPA and other national programs (e.g., Climate Friendly Parks, Federal Green Challenge).

i. Encourage participation in the Climate Friendly Parks program by all NPS units in Alaska.
ii. Participate in carbon tracking activities where measurements can occur, such as Climate Friendly Parks, Federal Green Challenge.
iii. Complete their Climate Leadership in Parks (CLIP) inventories for all Alaska NPS units (in the Climate Friendly Park initiative) to document energy use and areas for conservation.

i) **Take a chance on a demonstration project on sustainable practices/energy**. Use our ability to educate and outreach to show transferable technologies – even if they do not initially show a dollar cost savings.

j) **Know your heating loads and work on their efficiency**. Alaska, including the National Park Service, uses more diesel fuel for heating and electricity than in transportation.

k) Understand energy and waste streams. Know where your electricity comes from and where your solid waste goes and how it gets there. For example, heating water with electricity produced by generators is only 35% efficient, whereas heating water directly with fuel is 90% efficient.

l) Evaluate options to offset both energy used in travel and operations by purchase of carbon offset credits (investments in alternative energy production either in Alaska or elsewhere) including verification and quality assurance provisions (General Accounting Office 2008). (As an example, Yosemite has offset some of its emissions by buying into photovoltaic arrays in the Mojave Desert.)

m) Ensure that any biofuels and biolubricants used are sourced from non-invasive and sustainably managed sources. Fuel production from food products (grain, sugar, etc.) has, in some cases, resulted in severe ecological and social consequences and has not always reduced net petroleum consumption. Likely candidates for newer biofuels include invasive perennial grasses. Current pace of policy leaves little time for research and adaptive management (*Pyke et al. 2008*).

3.2. Track energy use at the park level relative to reduction goals and provide for accountability.

3.3. Develop and implement Best Management Practices for sustainable operations and ensure capacity to continue sustainable practices and maintain new technologies.

a) **Ensure that the "sustainable" practice is really sustainable locally.** An electric vehicle that requires on site diesel generation, for charging, is less sustainable than a diesel vehicle. Look for opportunities to change practices. Can that diesel generator be shut down at night or go to a hybrid with batteries or other hybrids and operate less hours? When two generators are used in a power generation system consider sizing one smaller than the other so that it can be run when system loads are lower. Look to install load shedding equipment to allow for system operation with smaller generators.

b) **Utilize natural products for cleaning**. Increase the use of citric based cleaners. Household chemicals are now the major contamination source for hazardous materials in solid waste in the United States, so it isn't just in workplace.

c) **Reduce, reuse, recycle, and locally source products** to minimize impacts over the products' entire life cycle (i.e., including manufacture, transportation, use, and disposal). Include shipping and packaging as considerations in green purchasing of materials.

d) **Bring in only certified weed-free or otherwise pre-inspected materials** (soil, gravel, fill, plant material, straw/hay, firewood, woodchips, etc) to avoid introducing invasive species into a park.

e) **Use vegetable based lubricants and hydraulic fluids**. They are readily available and work in most instances.

f) **Identify local gravel sources** that can be used for repairs when they are needed. Most all repairs to roads, trails, foundations and utility systems will require gravel. This will take significant investigation and compliance efforts ahead of the repairs.

g) **Bring only pre-cleaned and inspected equipment into a park** to avoid introduction of invasive species.

h) **Pursue subsequent funding through additional project components for follow-up landscape restoration and initial maintenance** where such activities are consistent with park planning and development goals. Restore with native plant species and remove invasive plants as appropriate.

i) **Develop locally sourced native seed banks for restoration** at all parks, following protocols similar to Densmore et al. 2000 or Alaska Plant Materials Center (APMC).

j) **Salvage native plants and soils prior to beginning projects**. Denali has had great success in transplanting tundra mats and other native plants prior to ground disturbance. These soils and plant materials are moved back after the project is complete. This practice significantly reduces the need for importing soils and plant materials and speeds up the reclamation of disturbed areas.

k) **Ensure mechanisms are in place to continue sustainable elements of projects** after the initial project funding has expired.

l) Investigate claims of sustainability – there are less than truthful claims made on many products.

3.4. Consider sustainability in planning new or replacement facilities and infrastructure.

a) **<u>Implement highly sustainable construction practices and to insure parks have capacity and incentive to utilize and maintain new technologies</u>**. Use Leadership in Energy and Environmental Design (LEED) as a construction check list of things that can be done to make new and remodeled construction more sustainable.

i. Include efficient lighting in any remodeling or new construction. Include changing incandescent lamps to compact fluorescents and changing tube fluorescents to T-8 or T-5 technology with electronic ballasts. We should also be pushing for LED lighting where appropriate to reduce the levels of mercury in our waste stream.

ii. Include occupancy sensors and programmable thermostats in any remodeling or new construction.

b) **<u>Reconsider need for new or replacement facilities</u>**. An existing building, or no building at all, is often the most sustainable option. Use Park Asset Management Plans to evaluate what is really needed.

3.5. Learn and participate in local sustainable operations by coordinating with other government entities, non-profits, municipalities, boroughs rather than just looking inward.

3.6. Encourage innovation in employee transportation to and from work.

a) **<u>Support and expand</u>** use of NPS telecommuting program.

b) **<u>Utilize video conferencing</u>** and related technologies to reduce travel.

3.7. Develop and interpret one sustainability demonstration project at each park.

Goal 4. Communication: Increase public and employee awareness and understanding of the causes and effects of climate change, and the measures that will reduce or mitigate these effects.

Objectives and Actions:

4.1 **Using contemporary interpretive and education methods, provide educational materials and programs** for internal and external audiences to understand what is happening and how we're going to respond.

a) **Identify key messages about national parks and climate change.**

i. Incorporate results from various national and regional working groups (e.g., Science and Resources Stewardship, Sustainable Operations, Adaptation) to effectively communicate the issue.

ii. Develop a set of statements of knowledge regarding climate change specific to geographic regions in Alaska. (Bio-regional "talking points" are already being developed nationally.)

b) **Provide training for NPS employees**, recognizing their differing levels of understanding on what climate change will mean for parks and programs and what we can do about it.

i. Conduct a survey of workforce to determine current levels of knowledge about the issue.

c) **Conduct a climate change workshop** to educate interpreters, public affairs officers, and other employees on issues and the means to communicate climate change in an understandable way; include communication goals and messages.

d) Create an annual report summarizing the preceding Fiscal Year's progress on implementing the AKR Climate change response strategy and enumerate a work plan with measurable (SMART) actions for the current Fiscal Year. This report will be organized in keeping with the AKR strategy vision and goals (which may be restructured with Directorate approval), as well as address broader Federal Government climate change adaptation and mitigation responsibilities.

4.2 Incorporate climate change as a key interpretive message at each park, and NPS Public Land Information Center (AAPLIC, and FAPLIC). Develop messages, programs and products relative to the intersection of park resources and climate change.

a) **Identify the effects on fish and wildlife and their habitat, and on dependent recreation and subsistence activities** through multiple media and to multiple audiences.

b) **Develop and provide interpretive materials, programs and products** to inform park visitors and stakeholders about the evidence of climate change and its impacts on local park units and encourage individuals to take appropriate actions to maintain sustainability for future generations. Possibilities include:

i. Create and deploy a suite of interpretive products including exhibits, publications, podcasts, web pages, and other means of delivering messages.

ii. Develop digital atlas of climate change effects from past, present and future scenarios impacting park resources.

iii. Develop interpretive displays that illustrate potential results of climate change in Alaska Parks for comparison with current conditions (maps, interactive kiosks, web pages).

iv. Utilize digital media and television as communication tools.

c) **Demonstrate and explain environmentally sustainable "Climate Friendly" practices** in parks (construction, energy, restoration, etc.) including the Climate Friendly Parks program, and wherever opportunities exist.

d) Communicate ongoing NPS efforts taking place on climate change in the monitoring/research, education, mitigation, and adaptation realms. Put this information into appropriate media including a comprehensive synthesis document, links on park websites, or highlights in AK2Day, for internal and external audiences.

e) Evaluate impacts of messages on visitor experience to ensure understanding, appreciation, and enjoyment of parks.

f) Connect the issues of climate change and invasive species as leading driver of ecological issues in messages, programs, and displays.

4.3 Communicate the implications of changing climate through life-long learning opportunities in every park, and encourage individuals to take appropriate actions to maintain sustainability for future generations.

a) **Develop a thematic curriculum-based resource** guide aimed at teachers and non-formal education partners; incorporate climate change messages into existing curricula where feasible.

b) Create and deploy distance learning modules and opportunities for high school and middle school students.

c) Host Science-based Education Seminars for specific audiences such as "Fire in Alaska Workshop" or the current Murie Science and Learning Center (MSLC) Field Seminars

4.4 Communicate internally about our successes and failures with regards to environmentally sustainable practices.

a) **Develop an Alaska Region website/SharePoint site**.

b) **Ensure that Interpretation and Education are represented in the NPS National Climate Change Steering Committee.**

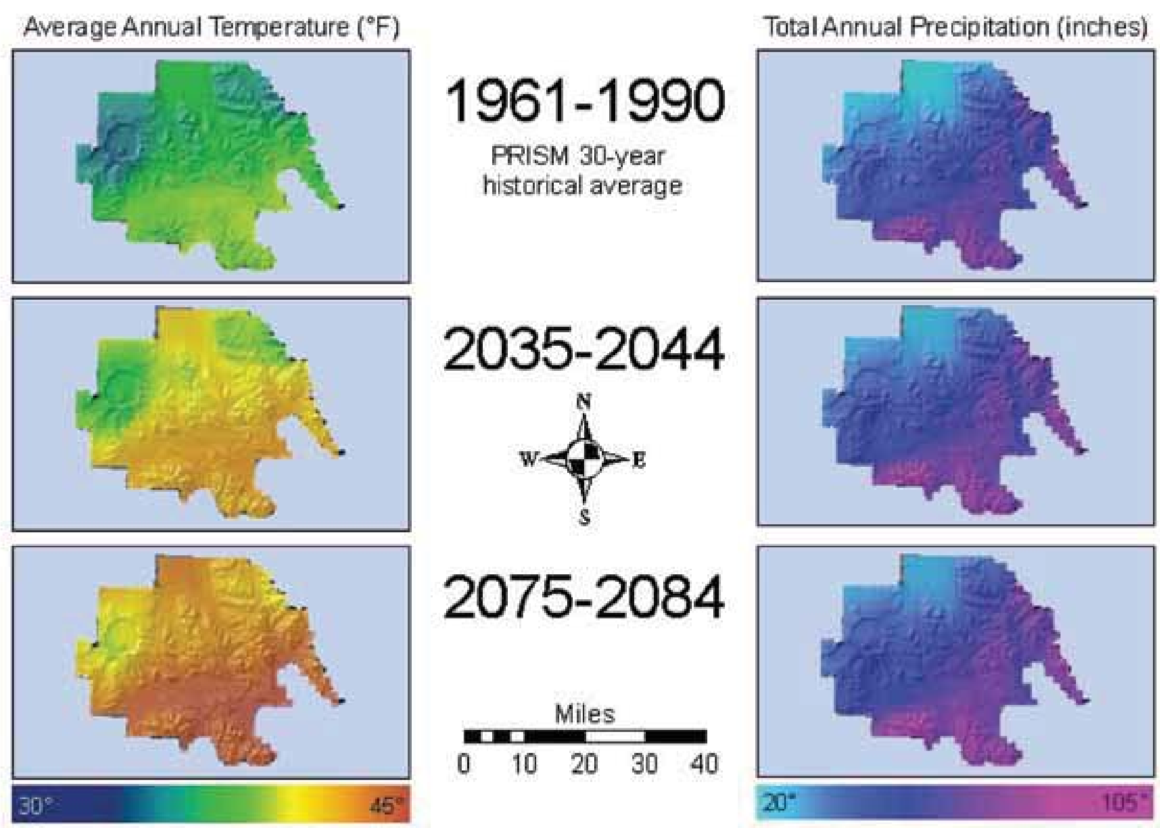
c) **Provide representation on the National Education Council**, in order to encourage parallel activities Service-wide (and to incorporate/use others good ideas).

4.5 Support efforts to collaborate and utilize parks as centers of continuous learning and as indicators of climate changes in Alaska, in order to communicate trends and changes in natural systems. (Requires collaboration with I&M networks, Research Learning Centers, Natural Resource Advisory Committee (NRAC), researchers, and others.)

Appendix C.
Climate Forecasts for National Parks in Alaska

Aniakchak National Monument and Preserve

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	35.9 ± 0.6	NA	**Annual**	Hist	53.5 ± 5.4	NA	NA
	2040	40.1 ± 0.6	4.3		2040	59.1 ± 5.4	5.6	10%
	2080	43.1 ± 0.6	7.2		2080	61.8 ± 5.4	8.4	16%
Summer	Hist	47.5 ± 0.5	NA	**Summer**	Hist	21.4 ± 1.9	NA	NA
	2040	50.0 ± 0.5	2.5		2040	23.1 ± 1.9	1.6	8%
	2080	52.5 ± 0.5	5.0		2080	23.7 ± 1.9	2.2	10%
Winter	Hist	27.6 ± 0.7	NA	**Winter**	Hist	32.0 ± 3.5	NA	NA
	2040	33.1 ± 0.6	5.5		2040	36.0 ± 3.5	3.9	12%
	2080	36.3 ± 0.6	8.8		2080	38.2 ± 3.5	6.1	19%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

For more information:

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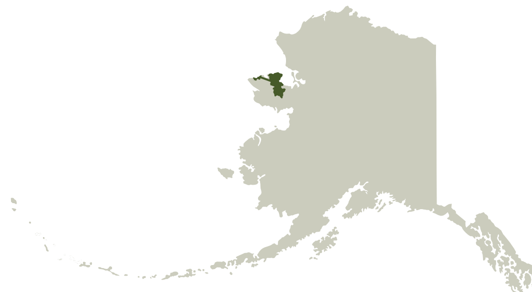
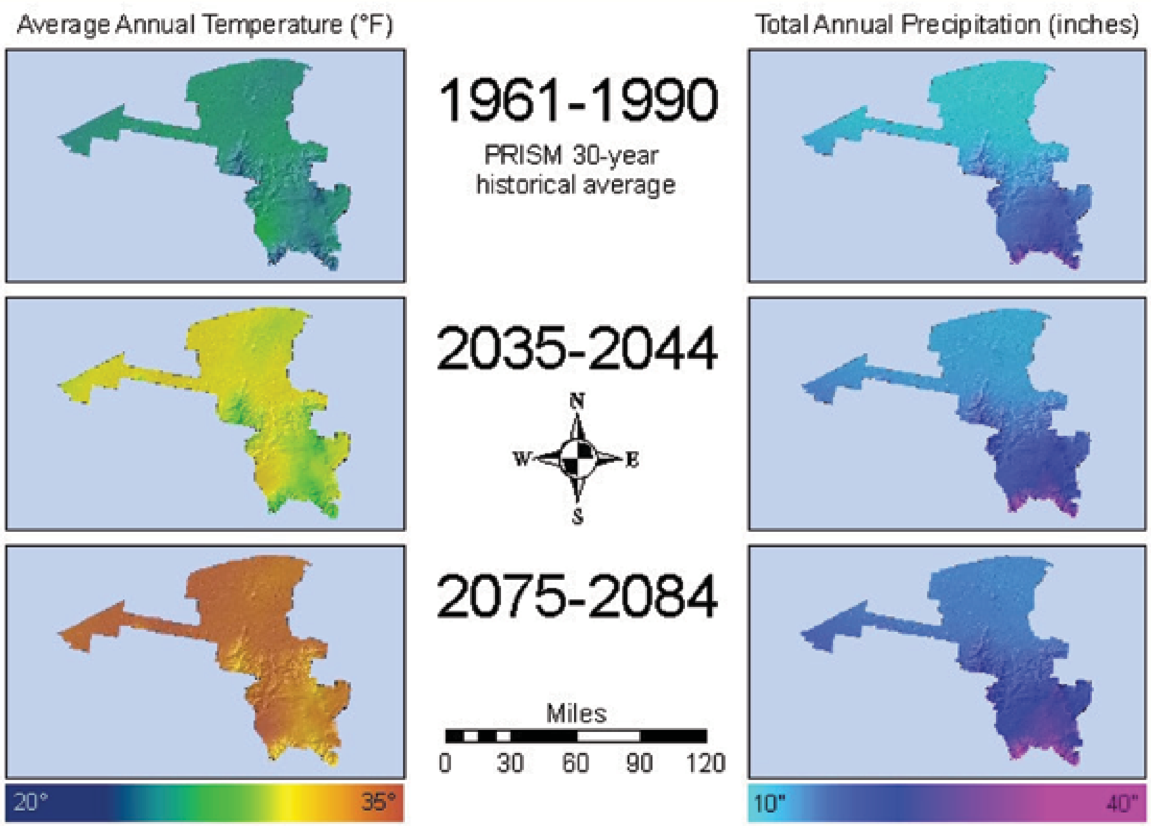
02/08

Bering Land Bridge National Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	21.6 ± 0.2	NA	**Annual**	Hist	12.4 ± 1.5	NA	NA
	2040	27.2 ± 0.2	5.6		2040	15.4 ± 1.5	3.0	24%
	2080	31.9 ± 0.3	10.3		2080	18.1 ± 1.5	5.7	46%
Summer	Hist	43.6 ± 0.4	NA	**Summer**	Hist	7.4 ± 0.9	NA	NA
	2040	46.0 ± 0.4	2.4		2040	8.8 ± 0.9	1.5	20%
	2080	48.5 ± 0.4	4.8		2080	9.8 ± 0.9	2.4	33%
Winter	Hist	5.9 ± 0.4	NA	**Winter**	Hist	5.1 ± 0.6	NA	NA
	2040	13.8 ± 0.5	7.9		2040	6.6 ± 0.6	1.5	31%
	2080	20.1 ± 0.6	14.3		2080	8.3 ± 0.6	3.3	65%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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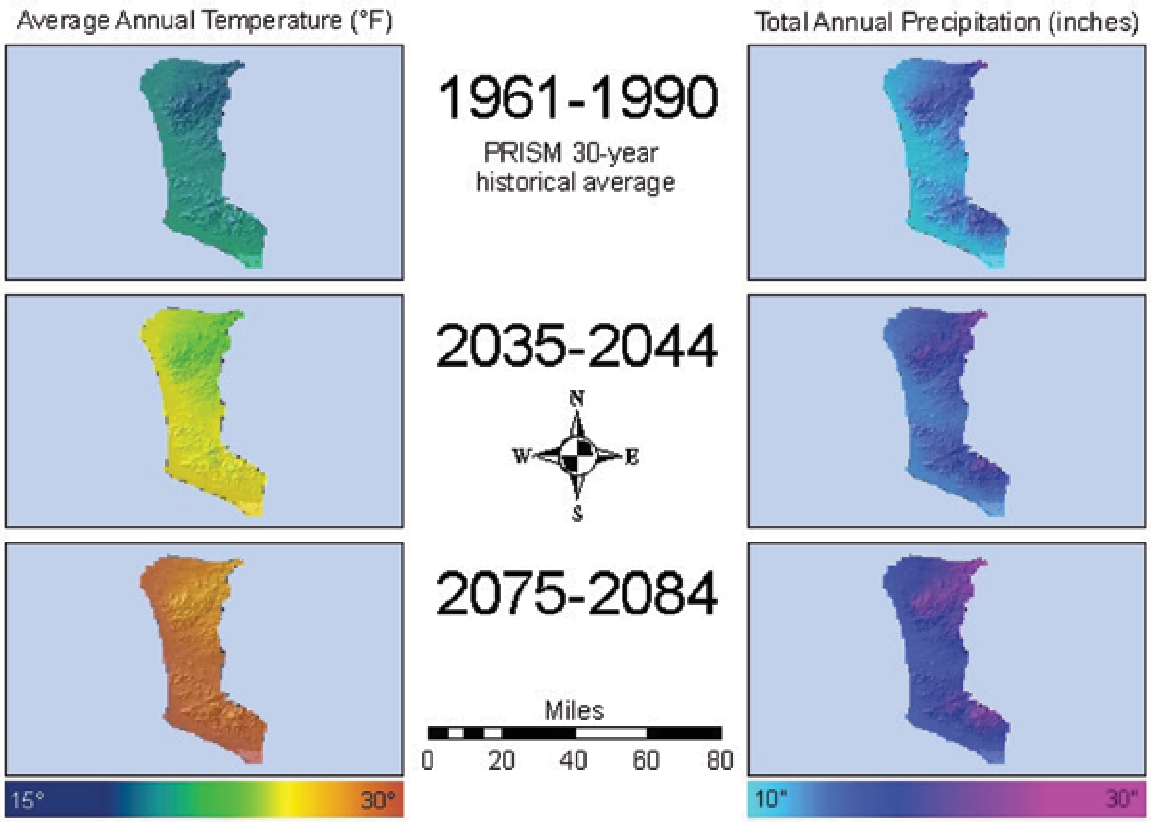
12/08

Cape Krusenstern National Monument

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	19.8 ± 0.3	NA	**Annual**	Hist	13.1 ± 0.7	NA	NA
	2040	25.6 ± 0.2	5.8		2040	15.8 ± 0.7	2.7	20%
	2080	30.3 ± 0.2	10.5		2080	18.2 ± 0.6	5.0	38%
Summer	Hist	45.0 ± 0.2	NA	**Summer**	Hist	7.6 ± 0.4	NA	NA
	2040	47.4 ± 0.2	2.4		2040	8.9 ± 0.4	1.3	16%
	2080	49.9 ± 0.2	4.8		2080	9.7 ± 0.4	2.1	28%
Winter	Hist	1.8 ± 0.4	NA	**Winter**	Hist	5.5 ± 0.3	NA	NA
	2040	10.0 ± 0.4	8.2		2040	6.9 ± 0.3	1.4	26%
	2080	16.4 ± 0.4	14.6		2080	8.4 ± 0.3	2.9	53%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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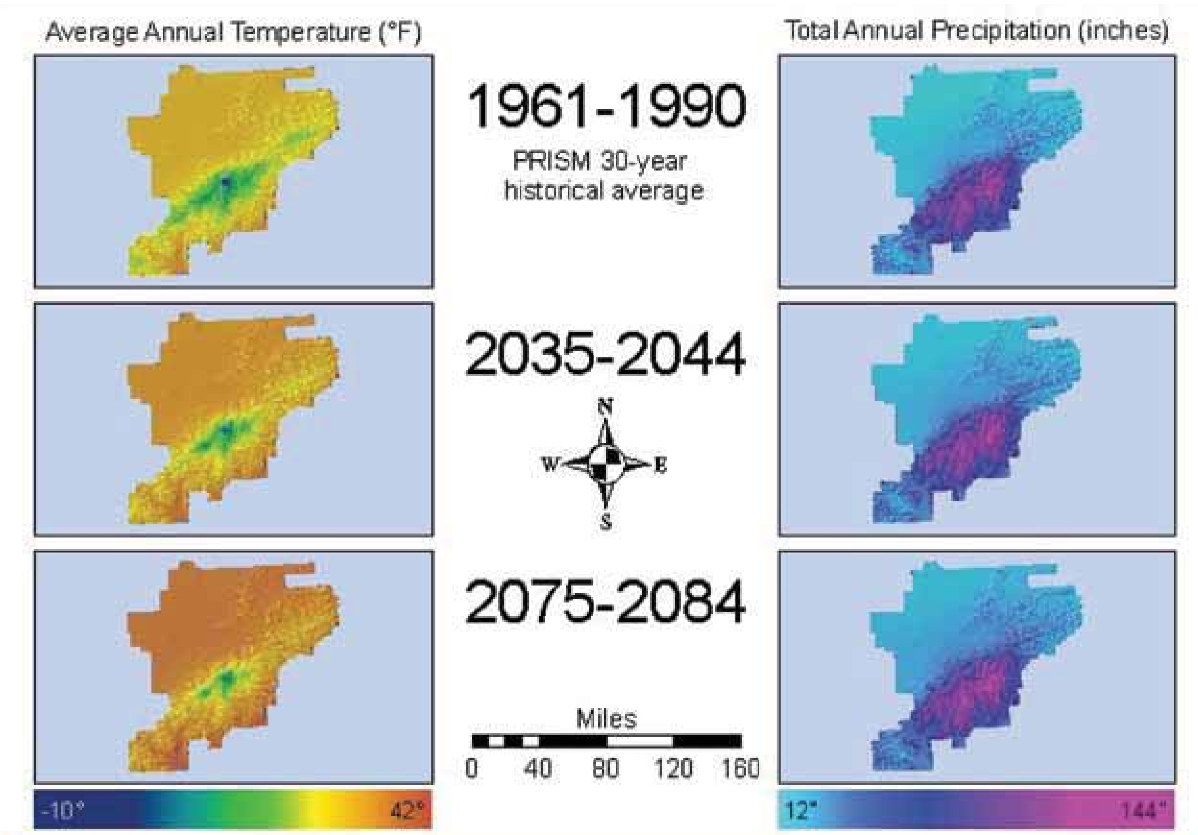
12/08

Denali National Park and Preserve

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	24.0 ± 1.6	NA	**Annual**	Hist	40.9 ± 9.7	NA	NA
	2040	28.6 ± 1.6	4.6		2040	45.2 ± 9.8	4.3	11%
	2080	32.3 ± 1.6	8.3		2080	48.1 ± 9.9	7.2	17%
Summer	Hist	44.6 ± 2.4	NA	**Summer**	Hist	23.6 ± 4.9	NA	NA
	2040	47.1 ± 2.4	2.5		2040	25.7 ± 4.9	2.1	9%
	2080	50.2 ± 2.4	5.6		2080	26.4 ± 4.9	2.8	12%
Winter	Hist	9.2 ± 1.2	NA	**Winter**	Hist	17.3 ± 4.9	NA	NA
	2040	15.3 ± 1.2	6.1		2040	19.5 ± 4.9	2.2	13%
	2080	19.4 ± 1.2	10.2		2080	21.6 ± 5.0	4.3	25%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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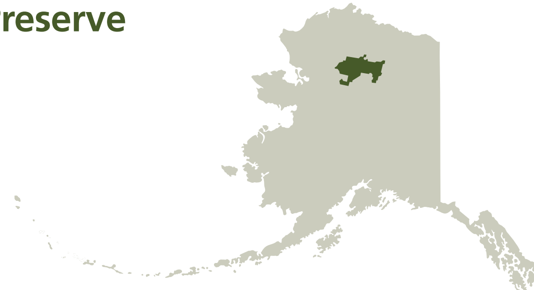
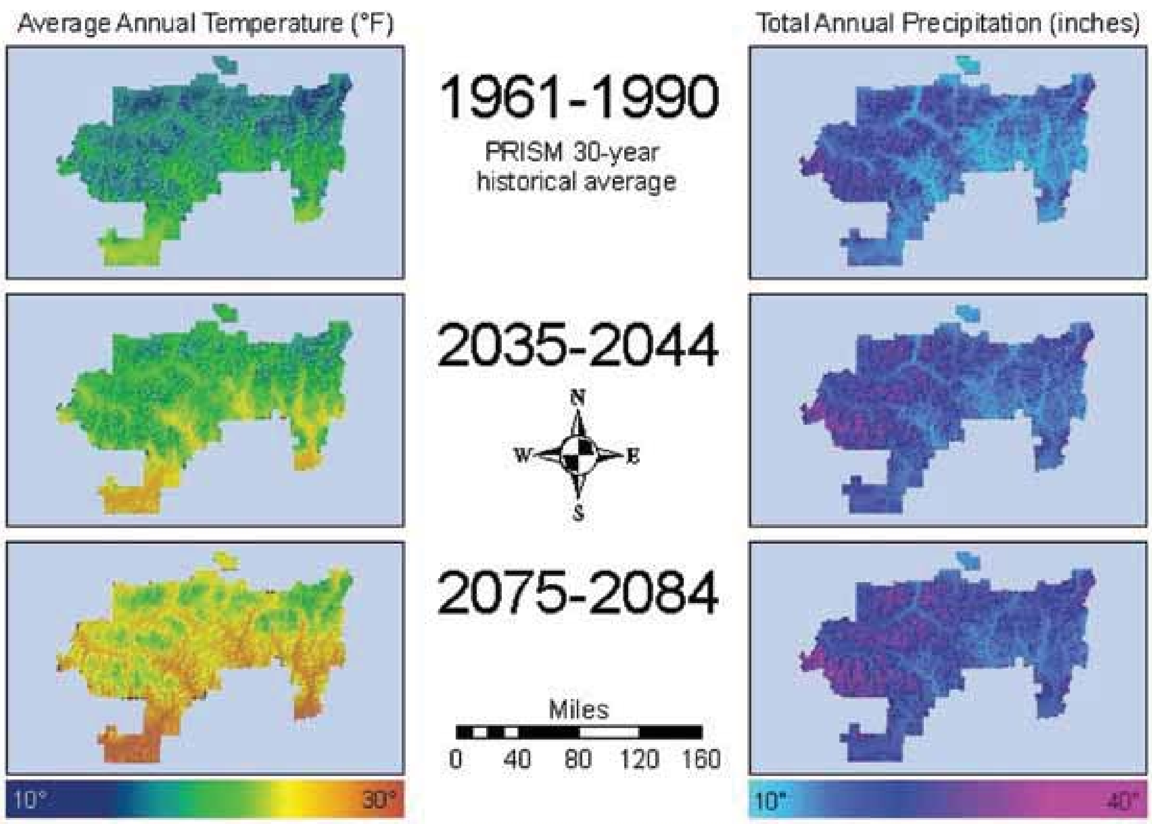
12/08

Gates of the Arctic National Park and Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	14.1 ± 0.9	NA	**Annual**	Hist	19.2 ± 1.5	NA	NA
	2040	19.6 ± 0.9	5.5		2040	22.1 ± 1.5	2.9	15%
	2080	24.1 ± 0.8	10.0		2080	23.9 ± 1.5	4.7	24%
Summer	Hist	41.5 ± 1.2	NA	**Summer**	Hist	11.0 ± 0.9	NA	NA
	2040	44.0 ± 1.2	2.5		2040	12.3 ± 0.9	1.3	12%
	2080	47.0 ± 1.2	5.5		2080	12.9 ± 0.9	1.9	18%
Winter	Hist	-5.4 ± 0.7	NA	**Winter**	Hist	8.2 ± 0.7	NA	NA
	2040	2.2 ± 0.6	7.6		2040	9.8 ± 0.7	1.6	19%
	2080	7.7 ± 0.6	13.1		2080	11.0 ± 0.7	2.7	33%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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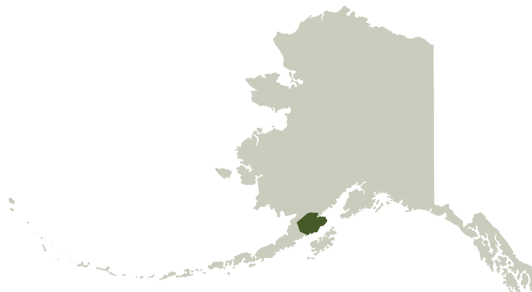
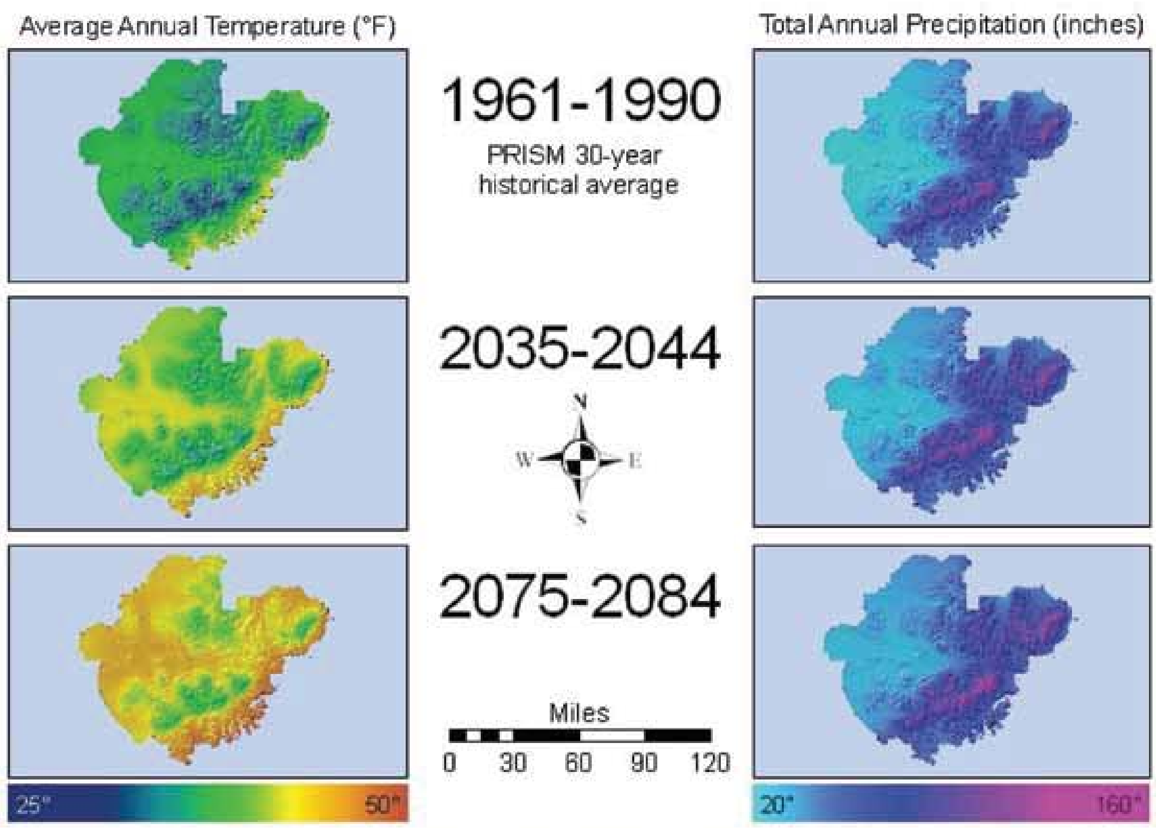
12/08

Katmai National Park and Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist.	33.5 ± 0.8	NA	Annual	Hist.	52.8 ± 8.4	NA	NA
	2040	38.1 ± 0.8	4.6		2040	59.3 ± 8.4	6.5	12%
	2080	41.5 ± 0.8	8.0		2080	63.1 ± 8.4	10.3	19%
Summer	Hist.	47.7 ± 0.8	NA	Summer	Hist.	23.6 ± 3.0	NA	NA
	2040	50.2 ± 0.8	2.5		2040	25.9 ± 3.0	2.3	10%
	2080	53.2 ± 0.8	5.4		2080	26.4 ± 3.0	2.8	12%
Winter	Hist.	23.3 ± 1.0	NA	Winter	Hist.	29.2 ± 5.6	NA	NA
	2040	29.4 ± 1.0	6.1		2040	33.4 ± 5.6	4.2	14%
	2080	33.2 ± 1.0	9.9		2080	36.6 ± 5.6	7.5	26%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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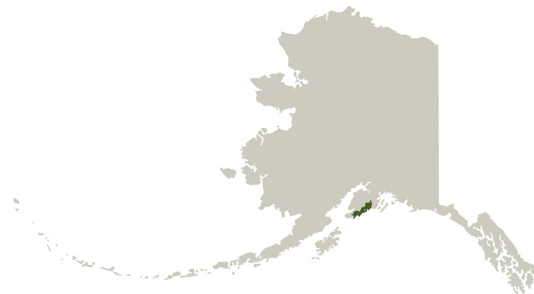
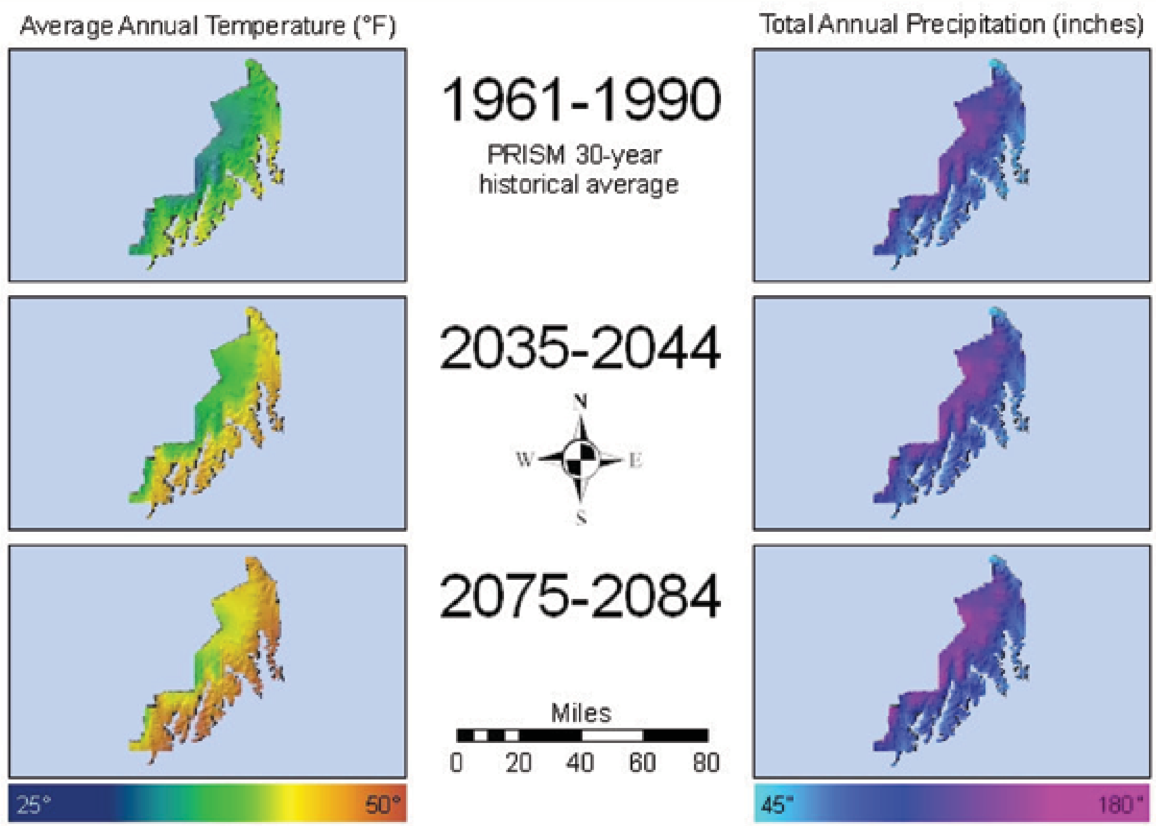
12/08

Kenai Fjords National Park

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist.	34.5 ± 0.9	NA	Annual	Hist.	103.7 ± 8.0	NA	NA
	2040	38.6 ± 0.9	4.1		2040	110.8 ± 8.0	7.0	7%
	2080	41.8 ± 0.9	7.3		2080	114.6 ± 8.0	10.8	10%
Summer	Hist.	47.6 ± 0.8	NA	Summer	Hist.	36.4 ± 2.9	NA	NA
	2040	50.1 ± 0.8	2.5		2040	39.0 ± 2.9	2.6	7%
	2080	53.1 ± 0.8	5.5		2080	39.9 ± 2.9	3.5	10%
Winter	Hist.	25.1 ± 1.0	NA	Winter	Hist.	67.4 ± 5.1	NA	NA
	2040	30.4 ± 1.0	5.2		2040	71.8 ± 5.1	4.4	7%
	2080	33.7 ± 0.9	8.6		2080	74.7 ± 5.1	7.3	11%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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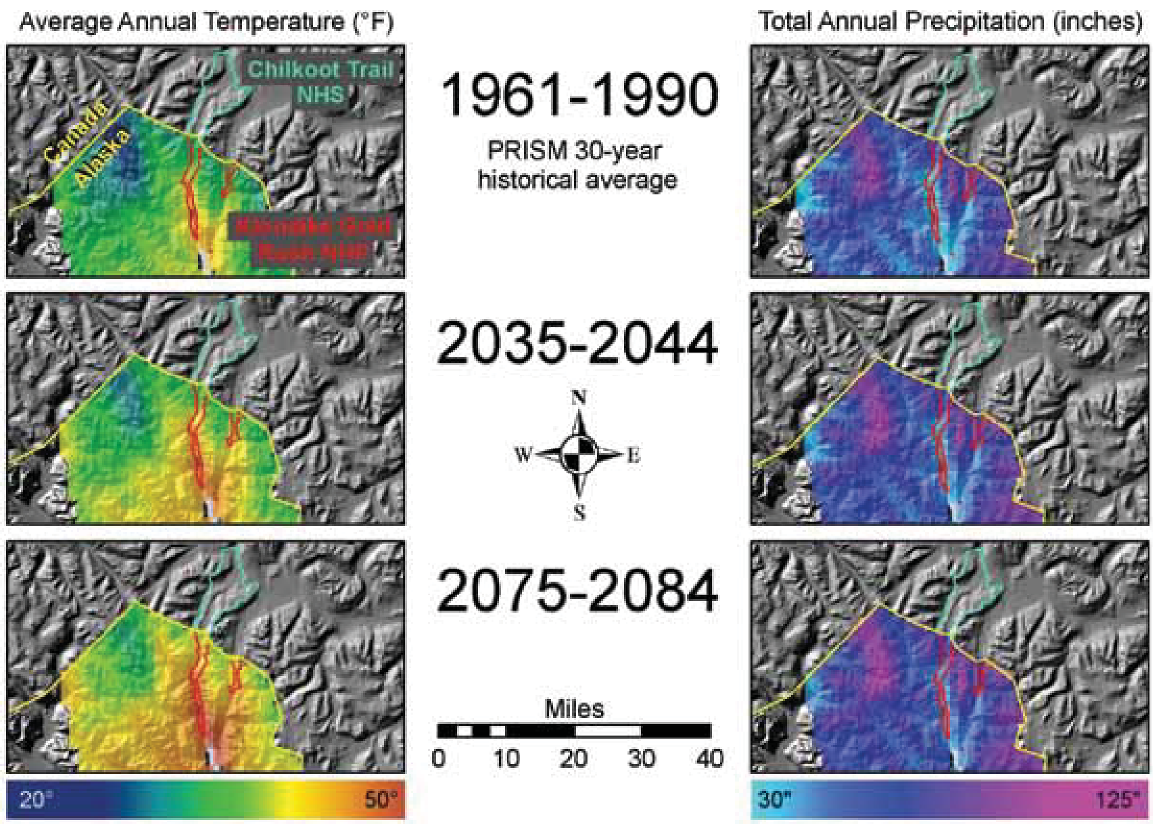
Klondike Gold Rush National Historic Park & surrounding area

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist.	33.9 ± 1.2	NA	**Annual**	Hist.	65.2 ± 5.0	NA	NA
	2040	37.3 ± 1.2	3.5		2040	71.2 ± 5.0	6.0	9%
	2080	40.4 ± 1.2	6.5		2080	74.9 ± 5.0	9.7	15%
Summer	Hist.	47.6 ± 1.2	NA	**Summer**	Hist.	22.9 ± 2.1	NA	NA
	2040	50.2 ± 1.1	2.6		2040	25.2 ± 2.1	2.3	10%
	2080	52.9 ± 1.1	5.4		2080	25.9 ± 2.1	3.1	13%
Winter	Hist.	24.0 ± 1.3	NA	**Winter**	Hist.	42.3 ± 3.4	NA	NA
	2040	28.1 ± 1.3	4.1		2040	46.0 ± 3.4	3.7	9%
	2080	31.4 ± 1.2	7.4		2080	48.9 ± 3.4	6.6	16%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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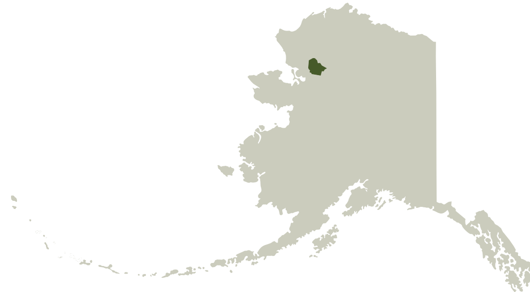
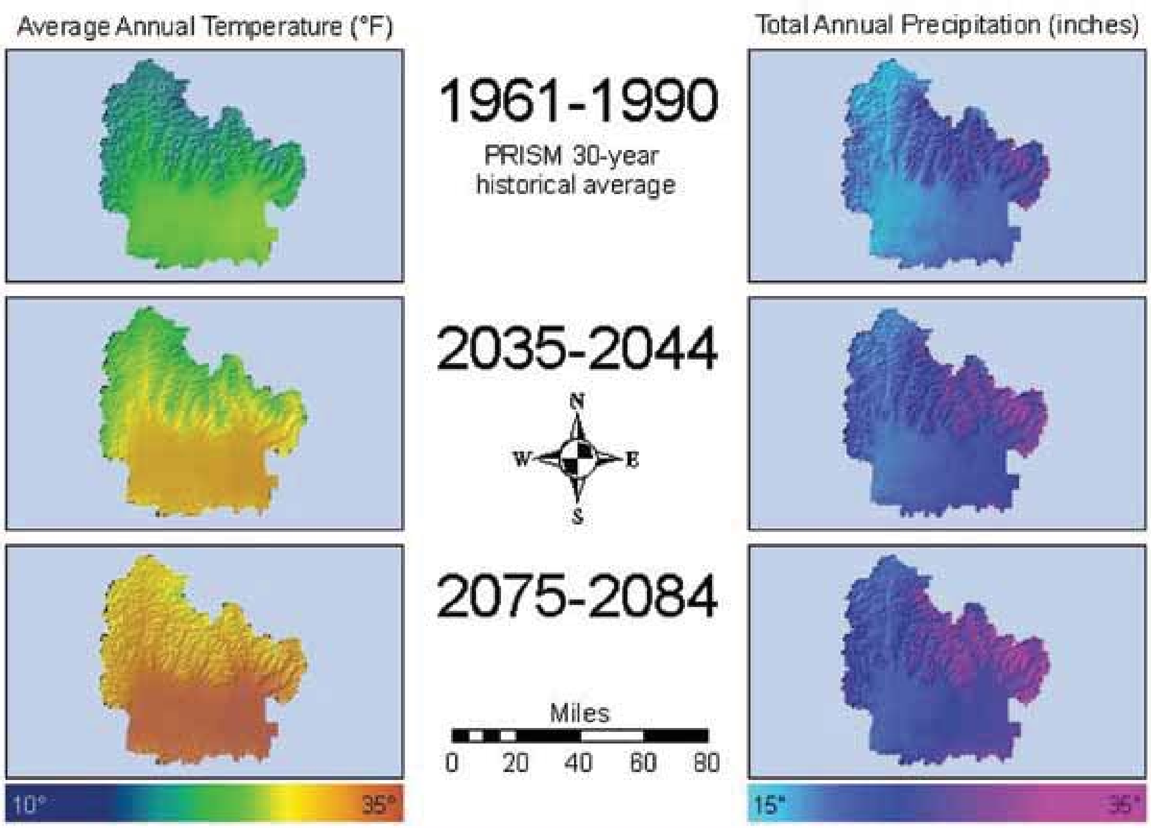
01/09

Kobuk Valley National Park

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	19.8 ± 0.8	NA	**Annual**	Hist	21.2 ± 1.1	NA	NA
	2040	25.5 ± 0.8	5.7		2040	24.2 ± 1.1	3.0	14%
	2080	29.9 ± 0.8	10.1		2080	26.2 ± 1.1	5.0	24%
Summer	Hist	47.3 ± 0.7	NA	**Summer**	Hist	13.2 ± 0.7	NA	NA
	2040	49.9 ± 0.7	2.5		2040	14.6 ± 0.7	1.5	11%
	2080	52.7 ± 0.7	5.4		2080	15.3 ± 0.7	2.1	16%
Winter	Hist	0.1 ± 0.9	NA	**Winter**	Hist	8.0 ± 0.4	NA	NA
	2040	8.1 ± 0.9	8.0		2040	9.6 ± 0.4	1.5	19%
	2080	13.6 ± 0.9	13.5		2080	10.9 ± 0.4	2.9	36%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

For more information:
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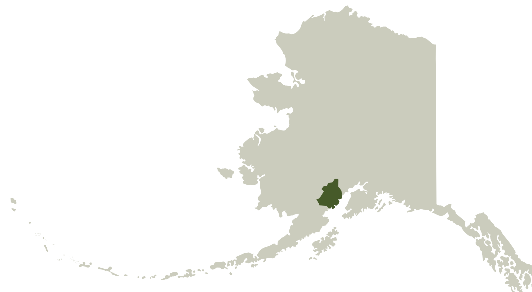
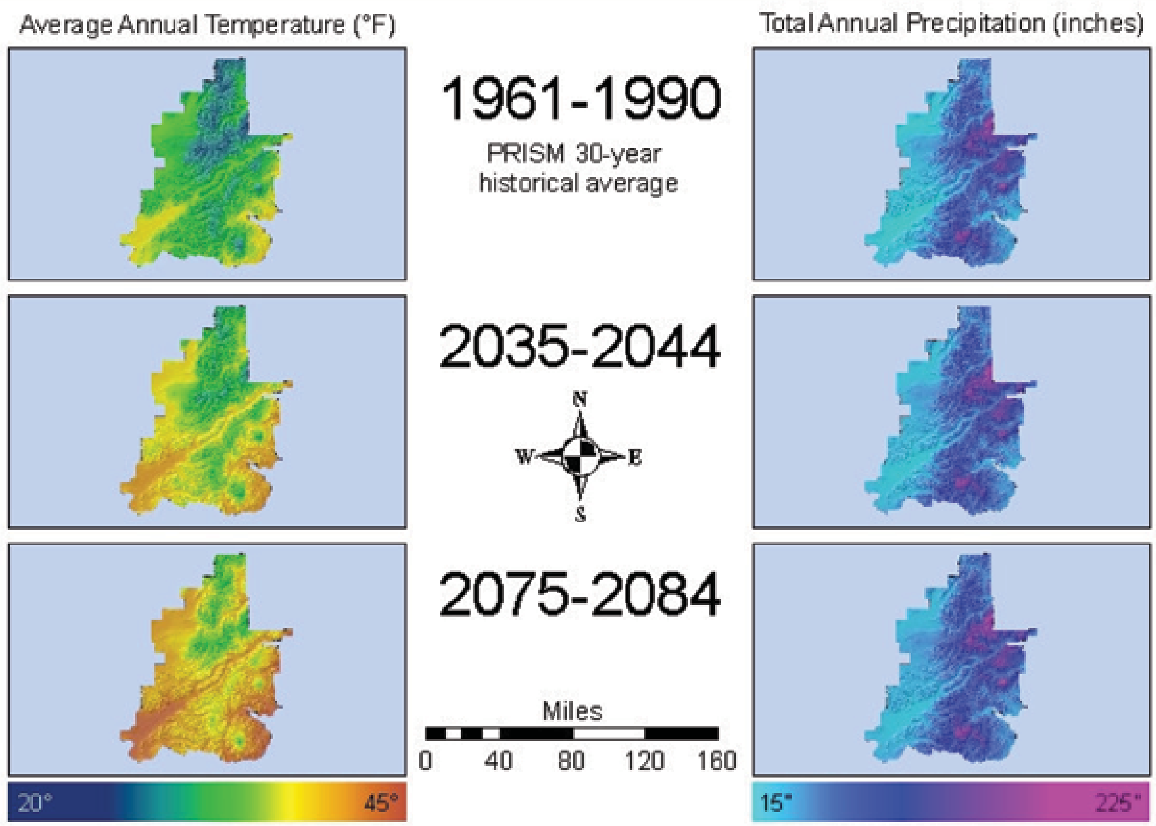
12/08

Lake Clark National Park and Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist.	28.0 ± 1.1	NA	**Annual**	Hist.	65.1 ± 11.9	NA	NA
	2040	32.5 ± 1.1	4.6		2040	71.2 ± 12.0	6.1	9%
	2080	36.0 ± 1.1	8.1		2080	114.6 ± 12.0	49.5	76%
Summer	Hist.	45.4 ± 1.1	NA	**Summer**	Hist.	30.9 ± 5.4	NA	NA
	2040	47.9 ± 1.1	2.5		2040	33.5 ± 5.4	2.6	8%
	2080	51.0 ± 1.1	5.6		2080	34.2 ± 5.5	3.3	11%
Winter	Hist.	15.5 ± 1.4	NA	**Winter**	Hist.	34.2 ± 6.7	NA	NA
	2040	21.6 ± 1.4	6.1		2040	37.7 ± 6.7	3.6	10%
	2080	25.3 ± 1.4	9.8		2080	40.9 ± 6.7	6.7	20%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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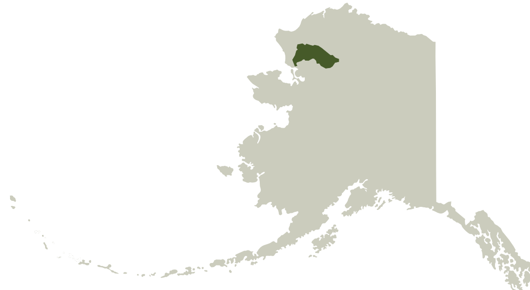
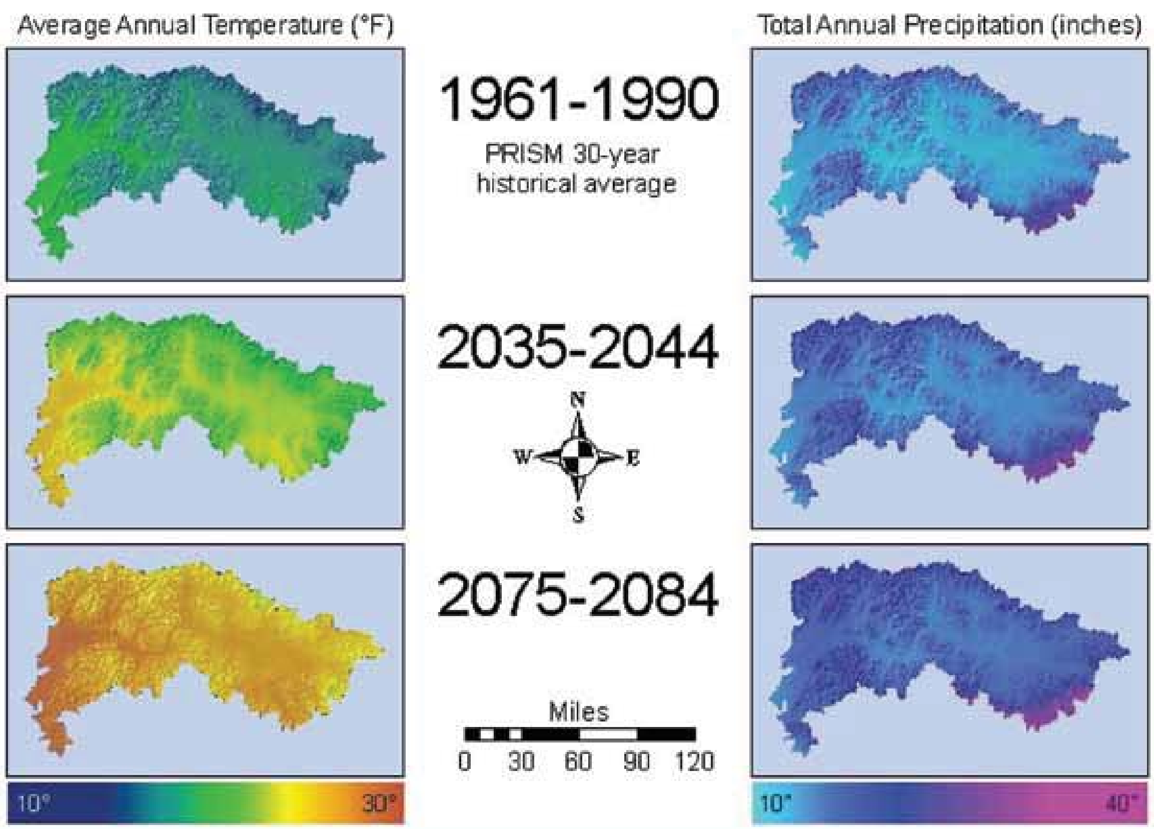
12/08

Noatak National Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	16.6 ± 0.5	NA	**Annual**	Hist	17.4 ± 1.0	NA	NA
	2040	22.4 ± 0.5	5.8		2040	20.1 ± 1.0	2.6	15%
	2080	26.9 ± 0.5	10.3		2080	21.9 ± 1.1	4.4	25%
Summer	Hist	44.6 ± 0.4	NA	**Summer**	Hist	10.6 ± 0.7	NA	NA
	2040	47.0 ± 0.4	2.4		2040	11.8 ± 0.7	1.3	12%
	2080	49.7 ± 0.4	5.1		2080	12.4 ± 0.7	1.9	18%
Winter	Hist	-3.4 ± 0.6	NA	**Winter**	Hist	6.8 ± 0.4	NA	NA
	2040	4.8 ± 0.6	8.2		2040	8.2 ± 0.4	1.4	20%
	2080	10.6 ± 0.6	14.0		2080	9.4 ± 0.4	2.6	38%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

For more information:

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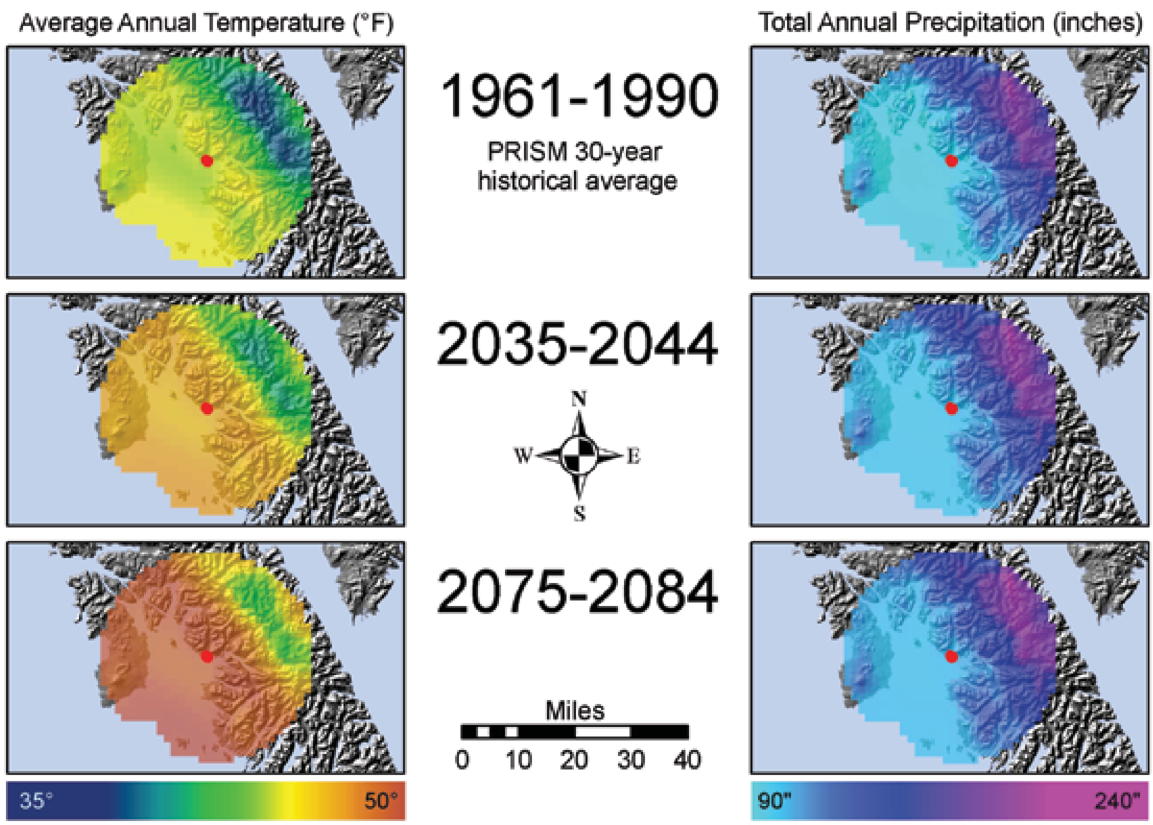
12/08

Sitka National Historic Site & surrounding area

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist.	42.2 ± 0.8	NA	**Annual**	Hist.	122.6 ± 10.8	NA	NA
	2040	45.1 ± 0.7	2.9		2040	130.1 ± 10.8	7.4	6%
	2080	47.8 ± 0.7	5.6		2080	133.7 ± 10.8	11.1	9%
Summer	Hist.	50.9 ± 0.6	NA	**Summer**	Hist.	37.9 ± 2.7	NA	NA
	2040	53.3 ± 0.6	2.3		2040	40.1 ± 2.7	2.1	6%
	2080	55.6 ± 0.6	4.7		2080	41.0 ± 2.7	3.0	8%
Winter	Hist.	35.9 ± 0.9	NA	**Winter**	Hist.	84.7 ± 8.3	NA	NA
	2040	39.2 ± 0.9	3.3		2040	90.0 ± 8.3	5.3	6%
	2080	42.2 ± 0.9	6.3		2080	92.8 ± 8.3	8.1	10%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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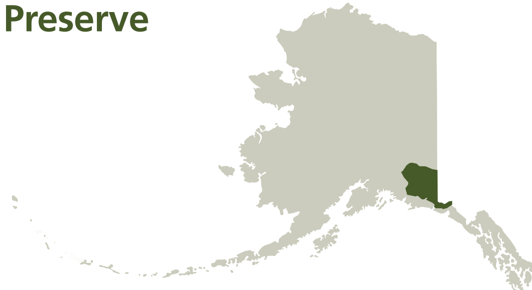
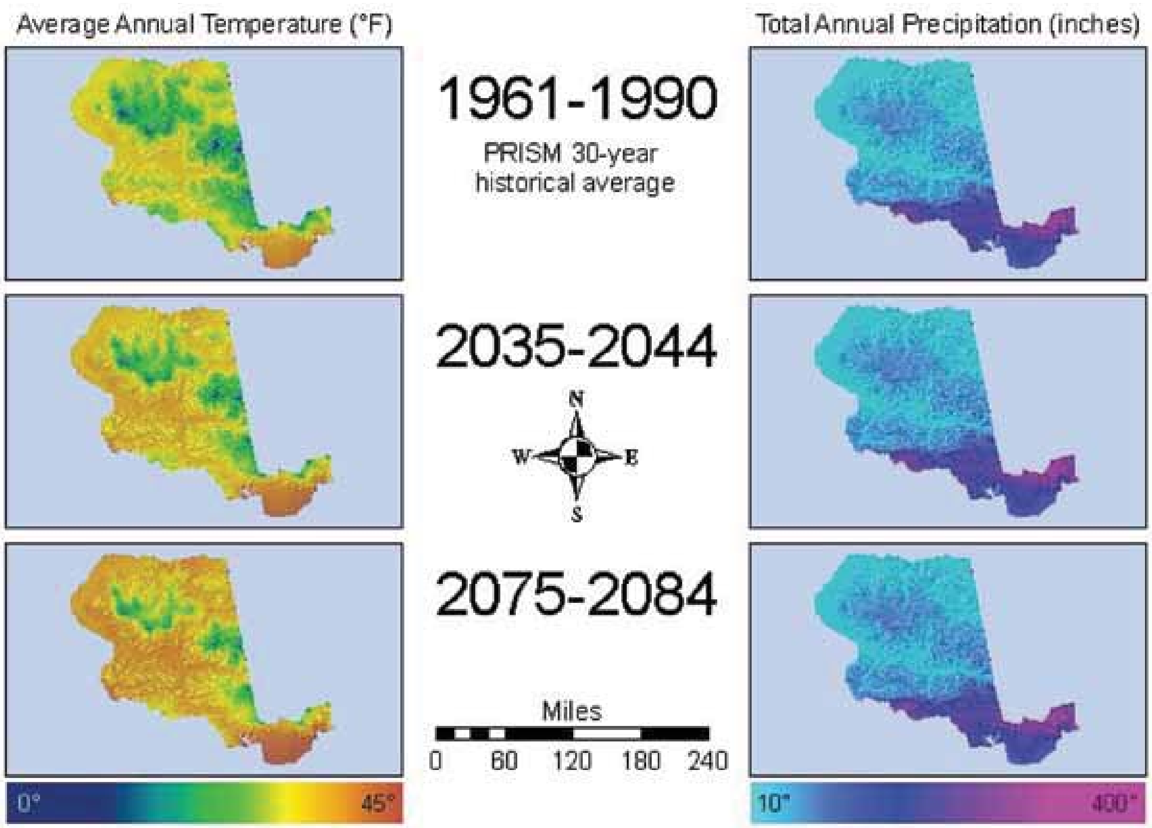
01/09

Wrangell-Saint Elias National Park and Preserve

Projected Climate Change Scenarios





Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	**Time**	**Avg. TEMP**	**Δ TEMP***	**Season**	**Time**	**Total PRCP**	**Δ PRCP***	**% Δ PRCP***
Annual	Hist.	23.6 ± 2.0	NA	**Annual**	Hist.	85.2 ± 25.8	NA	NA
	2040	27.5 ± 2.0	3.8		2040	90.5 ± 26.0	5.3	6%
	2080	30.7 ± 1.9	7.1		2080	93.6 ± 26.0	8.4	10%
Summer	Hist.	41.6 ± 2.4	NA	**Summer**	Hist.	36.2 ± 8.9	NA	NA
	2040	44.1 ± 2.5	2.5		2040	38.7 ± 9.0	2.5	7%
	2080	47.2 ± 2.4	5.5		2080	39.6 ± 9.0	3.4	9%
Winter	Hist.	10.8 ± 1.9	NA	**Winter**	Hist.	48.9 ± 17.1	NA	NA
	2040	15.6 ± 1.9	4.8		2040	51.8 ± 17.2	2.9	6%
	2080	18.9 ± 1.9	8.2		2080	54.0 ± 17.3	5.1	10%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

For more information:

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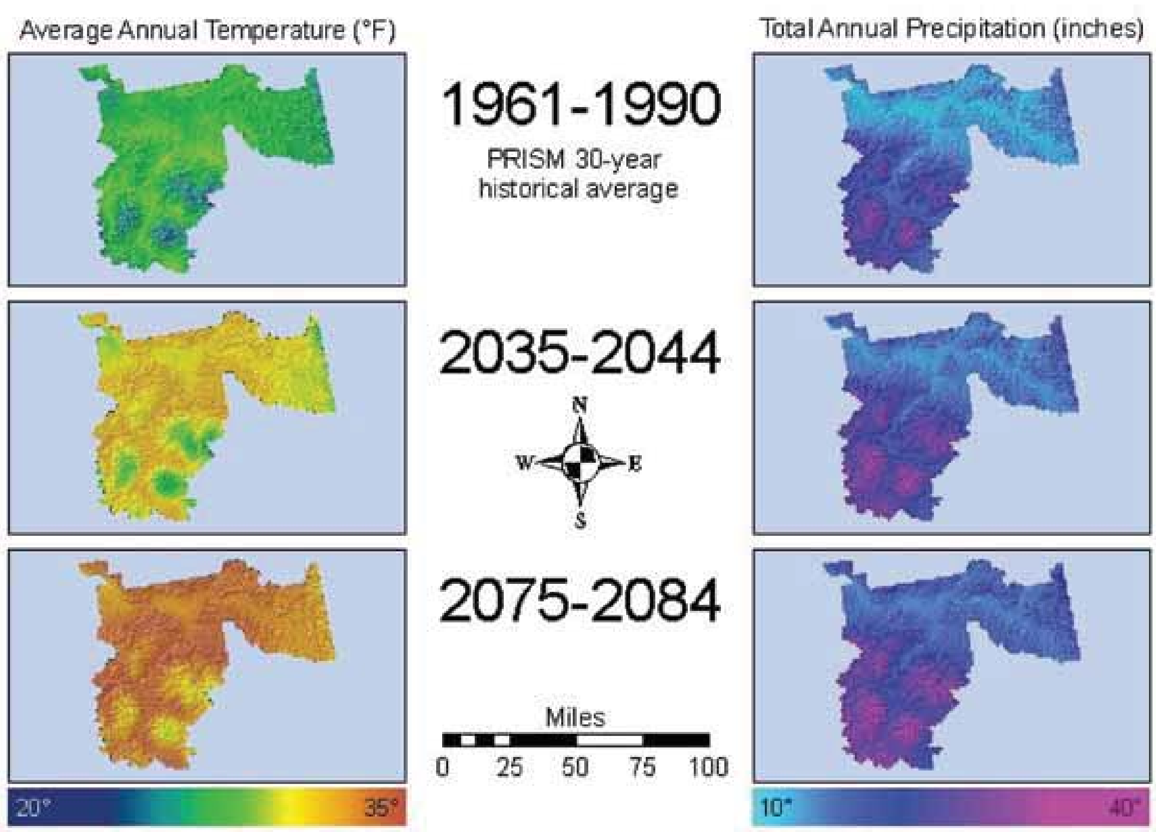
12/08

Yukon-Charley Rivers National Preserve

Projected Climate Change Scenarios



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	24.7 ± 0.4	NA	**Annual**	Hist	17.0 ± 1.7	NA	NA
	2040	29.4 ± 0.4	4.6		2040	19.9 ± 1.7	2.9	17%
	2080	33.2 ± 0.4	8.4		2080	21.6 ± 1.7	4.6	27%
Summer	Hist	49.2 ± 1.2	NA	**Summer**	Hist	10.9 ± 1.1	NA	NA
	2040	51.8 ± 1.2	2.5		2040	12.4 ± 1.1	1.5	14%
	2080	54.9 ± 1.2	5.6		2080	13.1 ± 1.1	2.2	20%
Winter	Hist	7.3 ± 0.8	NA	**Winter**	Hist	6.1 ± 0.6	NA	NA
	2040	13.4 ± 0.8	6.2		2040	7.5 ± 0.6	1.4	23%
	2080	17.6 ± 0.8	10.4		2080	8.6 ± 0.6	2.5	40%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

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12/08

Appendix D. Estimated Park Acreage and Coastline Miles Vulnerable to Impacts of Climate Change and Without Cultural Resource Surveys

There are a wide range of GIS datasets that can provide help in the analysis of cultural resource conditions in the Alaska region. These datasets will be helpful in modeling potentially at risk cultural resources due to climate change. In addition, GIS can be used with existing cultural resource information to determine areas requiring further cultural resource surveys, preservation strategies and damage/loss estimates.

As part of this 2009 exercise, many park and regional staff indicated the need to include the highly vulnerable ice patch resources that have proven in several parts of the world to yield rich cultural information and artifacts. In addition to work done in Canada over the last decade, at least two Alaska archeologists are currently studying ice patches in Alaska. Their work has helped refine the approaches that are most efficacious. Brian Wygal's report "The Risk of Global Climate Change to Cultural Resources in Denali National Park and Preserve: A Report on Current Efforts and Future Needs in Archeological Monitoring and Inventory" summarizes the need to address ice patch inventory and monitoring in DENA, but is applicable to all Alaska NPS parks with similar resources.

Park	GIS Coastal Miles	GIS Coastal Acres <=5m	Coastal Acres Not Surveyed	% Coastal Acres Not Surveyed	Coastal Miles Not Surveyed	Unsurveyed Acreage Vulnerable to Development or Visitor Impacts	Acreage Vulnerable to Snow/Ice Patch Melt
TOTAL	2,679	70,623	47,983	~65% avg	1,748	43,547	2,177,742

Table 2. Estimate of un-surveyed NPS areas (coastal miles and acreage) in Alaska reported to be vulnerable to climate change impacts due to coastal erosion, increased visitor access, or ice patch melt.

Appendix E.
Alaska Inventory and Monitoring Program

The Inventory and Monitoring Program is now established in the Alaska Region. Vital Signs Monitoring Plans have been developed and approved, and **monitoring protocols for a suite of "vital signs"** are in development or have been implemented macross the region. Each of the four Alaska networks is monitoring important indicators ("vital signs") of park ecological condition in collaboration with NPS staff and partners from academic institutions, government agencies, and private organizations. Virtually all vital signs are directly or indirectly related to climate change, and data will provide a long term perspective on climate and its direct and indirect effects on park ecosystems (Table 3). The scoping, conceptual modeling, and prioritizing over a period of several years has been summarized in workshop reports, monitoring plans, and other **summary documents** available on network websites (NPSa). This information has proven valuable for a host of additional purposes, from park planning and condition assessment to interagency collaborations.

Each network is **staffed** with a Network Coordinator and Data Manager. Most networks have additional staff (total of 21 in the Alaska Region). This staff is primarily responsible for implementation of the vital signs monitoring program, but also provides expertise to parks in evaluating information about how changing climate is affecting park resources. Network **organizational structures** that include superintendents and natural resource managers provide program oversight and are venues for prioritization of the most critical information needs. Network programs provide a core staff to accomplish a subset of the park needs, but in design and implementation these programs have assembled a suite of **partnerships and collaborators** that leverages the program's relatively modest means to accomplish far more than would otherwise be possible.

Clear, articulated procedures and sophisticated infrastructures for data collection and management are a hallmark of the I&M program, and are available for use by all NPS. Examples include database standards, peer review requirements, data storage and delivery mechanisms, and reporting requirements. Enterprise databases such as NatureBib (bibliography), NPSpecies (species database), and the NPS Data Store (datasets and metadata) are available and have been populated with current and legacy information. The I&M program routinely reports the results of the vital signs monitoring activities, through annual and other synthesis reporting available on network websites and delivered to park managers and other audiences through regular symposia and workshop venues. Many of these reports are published in the NPS Natural Resource Report Series (NPSb) or are available on network web pages. Outreach products are developed such as resource briefs and educational materials that summarize the status and trend of vital signs and can thus be evaluated in light of climate change and its myriad influences on park environments.

The I&M program has added 20 weather stations to the existing climate monitoring networks in the region. These stations were sited following careful evaluation and compliance procedures so as to represent a range of climatic zones. NPS climate data is stored and served by the NWS Western Regional Climate Center where users can access data from multiple sources (WRCC).

Analyzed together these vital signs will likely show evidence of changing climate, whereas if only one were analyzed the causal agent of any observed trend is more difficult to determine. Indeed, the framework for vital signs selection was to detect status and trend of important resources whatever the cause.

The breadth of vital signs currently monitored by the Alaskan networks as well as a brief description of their relevance to climate change is provided in Table 3.

Table 3. (Right) Climate Change and I&M in Alaska. Examples of existing Vital Signs in the four Alaska Inventory and Monitoring Networks and their relationship to NPS detection capacity for Climate Change. Those with an * are existing programs that other agencies are leading.

Project	Vital Sign	Relevance to Climate Change detection
Weather and Climate	Visibility and Particulate Matter*	Provides trend information regarding S, N and particulates that impact visibility.
	Weather and Climate	Will provide higher resolution precipitation & temperature data; will enable more accurate climate modeling in the future; we are updating PRISM models; provides insight into growing seasons
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	Using images from 1970s to present; provides a solid understanding of the retreat of glaciers in last 30 years
	Volcanic and Earthquake Activity*	Not applicable
	Invasive/Exotic Species*	Increasing temperature will provide more opportunities for invasive exotics to become established
	Insect Outbreaks*	AK entomologists predict outbreaks may intensify with longer/warmer summers and warmer winters
	Sensitive Vegetation Communities	Two plant community types chosen– Nunataks and Salt marshes – are very prone to changes with changing climate; increasing temperature – may lose alpine species that are poor competitors etc.
	Vegetation Composition and Structure	Vegetation is expected to respond directly to changes in ppt and temp, as well as indirectly to increases in nutrient availability (expected with increasing decomposition, nutrient turnover w/ increasing temperature, changes in disturbance regime, etc.); Veg viewed as an integrator of environmental drivers; largest tundra fire ever this summer near Toolik (burning where it did not before)
	Land Cover/Land Use	Tree line advance north, shrub encroachment
	Landscape Processes	Tracking long-term trends in lake freeze-up, and extent, snow cover duration, and the normalized difference vegetation index (NDVI)
Marine Nearshore	Geomorphic Coastal Change	Subject to direct alteration as a result of changing storm pattern, intensity, frequency
	Permafrost	Arctic Network has already created detailed images of change based on IKONOS and Alaska High Altitude Program photography
	Marine Water Chemistry	Subject to direct alteration due to shifts in precipitation, glacial melting, and weather (wind?) patterns
	Kelp and Eelgrass	Together, all the marine nearshore components provide valuable context for potential climate related changes due to changing temperature, chemistry and abundance of species
	Marine Intertidal Invertebrates	Ditto
	Black Oystercatcher	Ditto
	Seabirds	Ditto

Table 3 continues on next page.

Table 3 continued.

Project	Vital Sign	Relevance to Climate Change detection
Marine Nearshore	Sea Otter	Ditto
	Harbor Seal*	Ditto
Lakes, Rivers, and Fish	Surface Hydrology	Climate warming is decreasing glacial coverage, increasing evaporation and possible changing precipitation patterns thus networks are monitoring changes in lake levels, discharge, and water budget
	Freshwater Chemistry	Directly linked to surface hydrology. Shifts in water quality alter habitat conditions for aquatic biota
	Resident Lake Fish	Shifts in species abundance/composition as a result of changes to water quality & quantity
	Salmon*	Same as resident fish with direct ties to subsistence use/harvest
Animals	All: Bald Eagles, Brown Bears, Wolf, Wolverine, Moose, Caribou	Assist parks and cooperating agencies to further define methods and improve data storage; Will facilitate seeing changes in populations that may be linked to climate changes; Eelgrass moving north; Migratory patterns influence subsistence uses; Kittlitz's Murrlet habitat rapidly shrinking; Program structured to cut across elevation and latitudinal gradients (eg CAKN mammals)
Human Activities	Resource Harvest for Subsistence and Sport*	Subsistence patterns of use may change (inability to travel across certain lands or waters in customary ways or changes in travel patterns); changes in the types and mix of species, amounts harvested and possibly the manner of handling and sharing; changes could amount to a significant cultural change, including significant adverse effects on the social structure of rural life in Alaska
	Visitor Use*	Visitor experiences will change, and the duration of the summer season, and locations may also change

Appendix F.
List of Abbreviations

Alaska National Parks, Preserves and Monuments

ALWR	Alagnak Wild River
ANIA	Aniakchak National Monument and Preserve
BELA	Bering Land Bridge National Preserve
CAKR	Cape Krusenstern National Monument
DENA	Denali National Park and Preserve
GAAR	Gates of the Arctic National Park and Preserve
GLBA	Glacier Bay National Park and Preserve
KATM	Katmai National Park and Preserve
KEFJ	Kenai Fjords National Park
KLGO	Klondike Gold Rush National Historical Park
KOVA	Kobuk Valley National Park
LACL	Lake Clark National Park and Preserve
NOAT	Noatak National Preserve
SITK	Sitka National Historical Park
WRST	Wrangell-St. Elias National Park and Preserve
YUCH	Yukon Charlie National Park and Preserve

Other Abbreviations

ACIA	Arctic Climate Impact Assessment
ACRC	Alaska Climate Research Center
AK	Alaska
AKGEO	Alaska Geographic Association
AKNHP	Alaska Natural Heritage Program
AKR	Alaska Region of the NPS
ALC	National Park Service Alaska Leadership Council
ANILCA	Alaska National Interest Lands Conservation Act
APMC	Alaska Plant Materials Center
AAPLIC	Anchorage Alaska Public Lands Information Center
ARCN	NPS Arctic Inventory and Monitoring Network
BLM	Bureau of Land Management
BWAG	Backcountry Wilderness Advisory Group
CAKN	NPS Central Alaska Inventory and Monitoring Network
CFFDRS	Canadian Forest Fire Danger Rating System
CCSP	U.S. Climate Change Science Program
CESU	Cooperative Ecosystem Studies Units
CIER	Center for Integrative Environmental Research
CRAC	Cultural Resources Advisory Council
DOI	U.S. Department of Interior
EAG	Educational Advisory Group
EPMT	Exotic Plant Management Team
ESA	Endangered Species Act
FAPLIC	Fairbanks Alaska Public Lands Information Center
FWI	Fire Weather Index
GCM	Global Climate Model
GAO	General Accounting Office

GEM	Gulf Ecosystem Monitoring Program
GIS	Geographic Information System
GRACE	Gravity Recovery and Climate Experiment
I&M	NPS Inventory and Monitoring Program
IAATO	International Association of Antarctica Tour Operators
IPCC	Intergovernmental Panel on Climate Change.
LiDar	Light, Imaging, Detection and Ranging
MAG	Maintenance Advisory Group
MSLC	Murie Science and Learning Center
NEPA	National Environmental Protection Act
NASA	National Aeronautics and Space Administration
NHPA	National Historic Preservation Act
NIC	Nenana Ice Classic.
NGO	Non-governmental organization
NPS	National Park Service
NRAC	Natural Resources Advisory Council
NRCS	Natural Resource Conservation Service
NRPC	NPS Natural Resource Program Center
NSIDC	National Snow and Ice Data Center
ORV	Off Road Vehicle
POPS	Persistent Organic Pollutants
RLC	Science and Research Learning Centers
SAC	Subsistence Advisory Council
SCC	Service-Wide Comprehensive Call
SEAN	NPS Southeast Alaska Inventory and Monitoring Network
SWAN	NPS Southwest Alaska Inventory and Monitoring Network
UAF	University of Alaska Fairbanks
USARC	U.S. Arctic Research Commission
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WRCC	Western Regional Climate Center

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Alaska Region

Alaska Region Climate Change Response Strategy 2010-2014