Climate Change Response Strategy
Goal 1: Science

Photo: Josh Foreman/NPS

Twice Haired Butterweed (*Senecio fuscatus*), Great Kobuk Sand Dunes, Kobuk Valley National Park

Summary of Efforts by the Alaska Inventory and Monitoring Program: 2011

The following resource briefs summarize the efforts of the Alaska Inventory and Monitoring Program, including the regional program and the four Networks, to enhance existing monitoring efforts as part of the National Park Service and Alaska Region Climate Change Response Strategies. The package includes the following documents:

Regional Summaries

- Program Brief: Overview of the Alaska I&M Program
- Vital Signs: Summary of monitoring focus areas
- Climate Change Overview Brief
- Glaciers and Climate Change Brief
- Permafrost and Climate Change Brief
- Seasonal Patterns and Climate Change Brief
- Weather Monitoring brief

Network-Specific Summaries

- Arctic Network Climate Change Response Brief
- Central Network Alaska Climate Change Response Brief
- Southeast Alaska Network Climate Change Response Brief
- Southwest Alaska Network Climate Change Response Brief

Program Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Arctic Network *Central Alaska Network* *Southeast Alaska Network* *Southwest Alaska Network*

Background

The Inventory and Monitoring Program (I & M) was established in 1992 and was expanded in 2000 as part of the National Park Service's (NPS) Natural Resource Challenge, a nationwide effort to revitalize and expand the natural resource programs in NPS units. The goal of the I & M Program is to improve park management through greater reliance on scientific information. Its purpose is to provide consistent information about natural resources within national parks, including species diversity, distribution, and abundance; and to determine the current condition of our park resources and how they change over time. The primary objective of the I & M Program is to collect, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling.

The 270 national park units are organized into 32 I & M Networks based on ecoregions, and Alaska has four such networks: Arctic, Central Alaska, Southwest Alaska, and Southeast Alaska. Each network supports a core, professional staff who conduct the day-to-day activities of the network and who collaborate with staff from network parks and other programs and agencies to implement an integrated long-term program to monitor the highest-priority vital signs. Network staff are involved in numerous activities and functions, such as organizing and cataloging data; performing data analysis, synthesis, and modeling; and providing data and expertise to park planners. Network personnel are also occasionally called upon to provide data and expertise for resource assessments and resource stewardship strategies, and to contribute to performance reporting.

Inventories

Twelve baseline inventories have been identified as the minimum set of information needed to effectively manage and protect natural resources within national parks, and baseline natural resource information is being collected for each national park. The inventories include natural resource bibliographies, base cartographic data, geologic maps, soils maps, weather data, air quality, locations of air quality monitoring stations, water body locations and classification, water quality data, vegetation maps, species list of vertebrates and vascular plants, and species distribution and status of vertebrates and vascular plants of high priority to each park.

Methods for collecting and managing inventories are compatible throughout the National Park Service. In Alaska, a unique regional management approach is used for the base cartography, soils, and vegetation inventories. Due to the large area covered by national parks in Alaska, a higher level of efficiency is achieved by managing these three inventories regionally. The nine other inventories are managed through a combination of national, network, and park efforts.

Arctic Network

Bering Land Bridge National Preserve	2.7 million acres
Cape Krusenstern National Monument	650,000 acres
Gates of the Arctic National Park and Preserve	8.5 million acres
Kobuk Valley National Park	1.8 million acres
Noatak National Preserve	6.6 million acres

Central Alaska Network

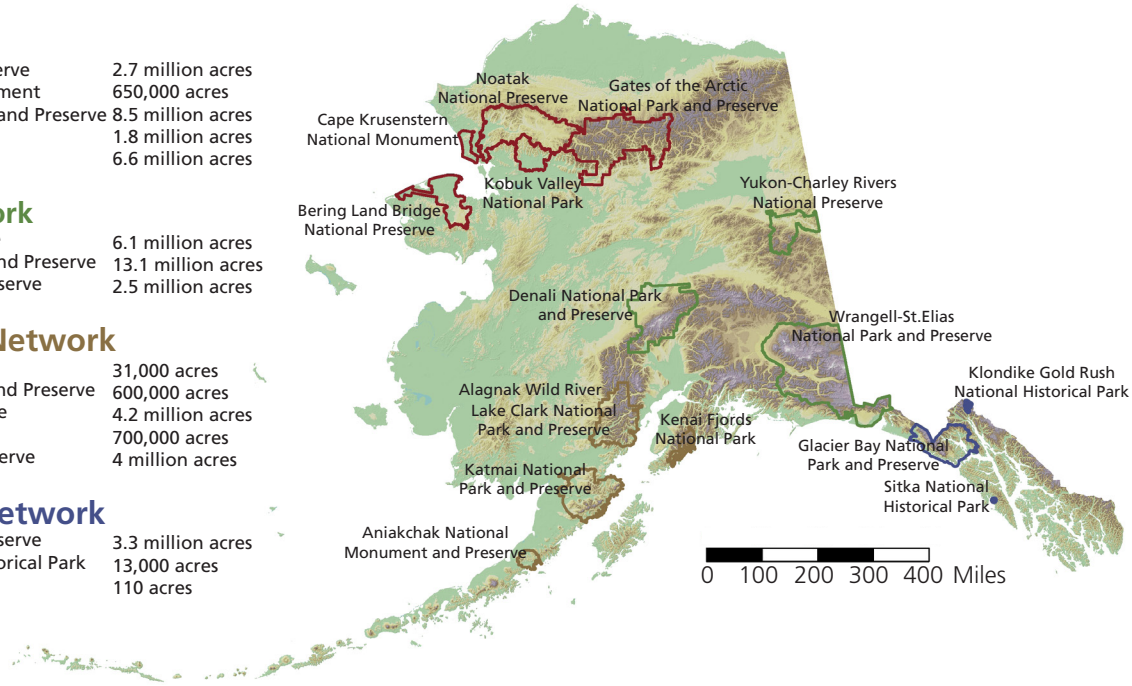
Denali National Park and Preserve	6.1 million acres
Wrangell-St. Elias National Park and Preserve	13.1 million acres
Yukon-Charlie Rivers National Preserve	2.5 million acres

Southwest Alaska Network

Alagnak Wild River	31,000 acres
Aniakchak National Monument and Preserve	600,000 acres
Katmai National Park and Preserve	4.2 million acres
Kenai Fjords National Park	700,000 acres
Lake Clark National Park and Preserve	4 million acres

Southeast Alaska Network

Glacier Bay National Park and Preserve	3.3 million acres
Klondike Gold Rush National Historical Park	13,000 acres
Sitka National Historical Park	110 acres



Monitoring

Parks are organized into networks based on ecologic and geologic regions. The networks share expertise across parks and other partners to monitor a small number of selected indicators, or "vital signs", of the condition of park resources over time. Network monitoring efforts are based on extensive and thorough planning and development processes that provide the foundations of each program. The intensive development phase is used to select vital signs and to develop the operational plans used to implement the monitoring over the long term. Each Vital Signs Monitoring Plan must be peer-reviewed and finalized before monitoring activities begin. In addition, each monitoring effort within a network adheres to strict guidelines for developing and following monitoring protocols. Protocols are peer reviewed and include monitoring objectives, rigorous sampling design, standard operating procedures, databases, and analysis and reporting procedures.

Vital signs monitoring networks are overseen by a Board of Directors consisting of the park superintendents and the Regional and Network I&M Coordinators. This ensures relevance to managers at the local level and enhances collaboration across program areas. Technical committees consisting of park resource managers and staff provide technical guidance, design and implementation. Strong accountability is maintained through annual reporting and work plan review and approval by the Board of Directors and national office. Details about the vital signs being monitored by each Network can be found on the Network web pages (see right box).

Pictured opposite page: Snow-cored dirt-cones, shown here in the caldera at Aniakchak National Monument, form when snow is unevenly covered by wind blown dirt. The dirt then insulates the snow and causes uneven melting patterns.

Alaska I & M Contacts

For more information about inventory and monitoring activities in Alaska, visit any on the following web pages:

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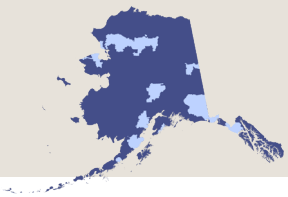

Inventory and Monitoring Program

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Vital Signs of Alaska

Artic Network *Central Alaska Network* *Southeast Alaska Network* *Southwest Alaska Network*

Each of the four Inventory and Monitoring networks within the Alaska Region monitor vital signs identified by each network as having the highest priority in documenting long-term trends in the composition, structure and function of park ecosystems. Among these vital signs, several vital common priorities exist throughout the region - ***water quality, climate change, contaminants, and wildlife populations.*** Activity level given for each vital sign reflects the highest level of activity within the network; it does not imply this level of activity for each park within the region.

- Air and Climate
- Geology and Soils
- Water
- Biological Integrity
- Human Use
- Landscapes (Ecosystem Patterns and Processes)

Arctic Network (ARCN)

Air Contaminants*
Weather & Climate*
Snowpack*

Coastal Erosion*
Sea Ice°
Permafrost*

Surface Water Dynamics†
Lagoon Communities*
Lake Communities*
Stream Communities*

Point Source Human Effects†
Subsistence/Harvest°

Invasive/Exotic Species†
Fish Assemblages†
Land Birds*
Yellow-billed Loons*
Small Mammal Assemblages†
Brown Bears*
Caribou°
Sheep*
Moose°
Muskox*
Terrestrial Vegetation*

Fire Extent & Severity°
Landscape Patterns & Dynamics*

Central Alaska Network (CAKN)

Air Quality°
Weather & Climate*
Snowpack*

Glacial Extent*
Disturbance: Volcanoes & Tectonics†
Permafrost*

Disturbance: Stream Flooding*
River/Stream Flow*
Water Quality*

Human Populations†
Consumptive Use°
Visitor Use†
Trails†

Disturbance: Fire Occurence & Extent°
Landcover, Use & Patterns*
Soundscape°
Plant Phenology°

Disturbance: Exotic Species†
Insect Damage†
Freshwater Fish*
Passerines*
Bald Eagles*
Golden Eagles*
Peregrine Falcons*
Ptarmigan†
Small Mammals*
Snowshoe Hare*
Arctic Ground Squirrel†
Caribou*
Moose*
Sheep*
Wolves*
Brown Bears†
Vegetation Structure & Composition*
Subarctic Steppe†

Southwest Alaska Network (SWAN)

Visibility & Particulate Matter*
Weather & Climate*

Glacial Extent*
Geomorphic Coastal Change*
Volcanic and Earthquake Activity°

Surface Hydrology*
Marine Water Chemistry*
Freshwater Chemistry*

Consumptive Use†
Visitor Use†

Landcover*
Land Use & Processes*

Invasive/Exotic Species°
Insect Outbreaks°
Kelp & Seagrasses*
Marine Intertidal Invertebrates*
Resident Lake Fish*
Salmon°
Black Oystercatchers*
Bald Eagles*
Marine Birds*
Caribou°
Moose*
Wolves*
Brown Bears*
Harbor Seal°
Sea Otter*
Vegetation Composition & Structure*
Sensitive Vegetation Communities*

Southeast Alaska Network (SEAN)

Air Contaminants*
Weather & Climate*
Visibility & Particulate Matter†

Glacial Extent*

Oceanography*
Stream Flow*
Freshwater Quality*
Freshwater Contaminants*
Marine Contaminants*

Consumptive Use°
Human Use & Modes of Access°

Landform & Landcover*
Underwater Sound°
Airborne Sound†

Invasive/Exotic Plants° & Animals†
Pests & Diseases†
Western Toads†
Freshwater Benthic Macroinvertebrates†
Intertidal Communities*
Forage Fishes†
Salmon†
Kittlitz's Murrelets*
Bald Eagles†
Bears†
Biodiversity of Select Groups†
Breeding Land Bird Assemblages†
Ungulates†
Humpback Whales°
Harbor Seals†
Stellar's Sea Lions†
Marine Predators*
Killer Whales†
Wetland† & Plant† Communities

* Vital signs for which the network is developing protocols and implementing monitoring efforts with funding from the vital signs or water quality monitoring program.
° Vital signs that are currently being monitored long-term by a network park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts where appropriate but will not use vital signs or water quality monitoring program funds.
† Vital signs for which monitoring will likely be done in the future but which cannot currently be implemented due to limited staff or funding.

Resource Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Arctic Network Central Alaska Network Southeast Alaska Network Southwest Alaska Network

Enhanced Monitoring in a Changing Climate

Background

The four Inventory and Monitoring networks in Alaska cover over 54 million acres of park lands, which include diverse ecosystems and some of the most remote and pristine natural and cultural resources in the country. All of the parks in Alaska include areas that have been identified by scientists as vulnerable to the effects of climate change. They include high latitude, coastal and high elevation areas or some combination of all of these features. *As part of the Climate Change Response Strategy developed by the National Park Service in September of 2010, the Alaska Region has been identified as one of the key areas within NPS to focus resources aimed at understanding, mitigating, applying adaptive science and communicating information related to climate change*. Specifically, Alaska is representing the high latitude environments in this effort.

The Alaska Region Inventory and Monitoring Program will obtain, analyze and communicate scientific information on variables related to climate change in an efficient and productive way by utilizing existing programs, established networks and enhanced partnerships. In particular, regional efforts will focus on enhanced monitoring of glaciers, permafrost, alpine plant communities and seasonal processes. Climate change science is complex and dynamic. Because of this, the regional areas of focus are subject to change as more information develops.

> I believe climate change is fundamentally the greatest threat to the integrity of our national parks that we have ever experienced. The current science confirms the planet is warming and the effects are here and now.
>
> Jonathan B. Jarvis
> Director, National Park Service
> Climate Change Response Strategy

Photo: Kent Miller

Dall's sheep depend on alpine plant communities for their survival. NPS is currently monitoring Dall's sheep in several Alaska parks.

Photo: Brendan Moynahan/NPS

Marjorie Glacier in Glacier Bay National Park is one glacier being monitored by the National Park Service in Alaska.

Enhanced Glacier Monitoring

Approximately 25% of Alaska's glaciers are located within national parks. Glaciers serve as major water reservoirs, and recent findings suggest that most glaciers are receding at an increasing rate. Receding glaciers may result in changes in hydrology, habitat and coastal and aquatic food webs that are not yet fully understood. Glacial monitoring efforts are being targeted in two key areas: extent mapping and change in glacial volume. Extent mapping using aerial photography and satellite imagery (Landsat) is being conducted to determine change between two time periods (1950s and current). Profiles detailing the physical characteristics of each glacier, such as length, width, slope, area and volume, will also be created. Volume change analysis is being conducted using existing altimetry data. The altimetry provides elevation profiles along the center flowline of glaciers, and elevation is projected across the surface of the glacier. Volume change will be calculated for glaciers with multiple elevation profiles.

Additionally, approximately 20 focus glaciers from national parks within Alaska will be selected and analyzed in greater detail to determine trends and variations throughout the region. An interpretive guide to Alaska's glaciers will be created using the detailed profiles, volume change analyses and historical information summarized in this project. Results will also be summarized in technical reports to be used by researchers and natural resource managers. Data collected and analyzed as part of this effort will be made available online for use by the scientific community.

Enhanced Permafrost Monitoring

Permafrost is ground that remains frozen for two or more consecutive years. It is the foundation of the Arctic and exists in 10 of the 16 national parks within Alaska. Thaw is a natural process, but recent data and forecasting models suggest that the rate of thawing has increased in recent decades and will continue to increase. The impacts of thawing range from changing landscapes and shifts in hydrology to potential impacts to wildlife. To monitor permafrost and to better prepare for responding to thaw-related impacts, ground temperatures and landform features are being measured. This multi-tiered approach builds on existing efforts by NPS and partner agencies. Temperature sensors are being installed at existing climate monitoring stations to measure near surface ground temperatures (0 to 2 m). The temperature data gathered is being incoporated into models that will result in maps of permafrost location and condition in the Arctic parks.

Rapid mapping of land features and cover currently experiencing active thaw will be conducted using satellite imagery. In areas likely to experience the greatest changes, three-dimensional models will be applied to track changes in landforms and vegetative cover over time. Data will be analyzed and summarized in technical and interpretive reports.

Developing Enhancements

In addition to enhanced glacier and permafrost monitoring efforts, protocols and plans are currently being developed to monitor seasonal processes using satellite imagery, remote cameras and on-site monitoring. Plans are also underway to enhance alpine vegetation monitoring efforts by joining the Global Alpine Research Initiative in Alpine Environments (GLORIA), an international program with established protocols for alpine vegetation monitoring.

Providing Decision Support

The data collected through monitoring efforts will be summarized and made available to the scientific community, park managers and the public. Park managers will have sound science to guide them on decisions related to managing natural and cultural resources in a rapidly changing climate. To support the expanded climate change monitoring effort in an efficient manner, remote sensing and science communications capabilities are being expanded at the regional headquarters.

Climate change response efforts for the Alaska Inventory and Monitoring Program focus on enhancing existing monitoring, partnerships and protocols as well as communicating summaries in ways that are useful to a wide range of audiences. For more details about each of the enhanced monitoring efforts, see all six resource briefs in the Enhanced Monitoring in a Changing Climate series. For more information on the Inventory and Monitoring programs in Alaska, refer to the Arctic, Central Alaska, Southeast Alaska and Southwest Alaska Networks' websites.

Photo: NPS

Climate monitoring stations are located throughout national parks in Alaska and provide essential data for tracking changes.

Climate Change at High Latitude Parks

The National Park Service is focusing efforts to understand and respond to the effects of climate change in four key areas. The Alaska region is serving as the high latitude representative while parks in other regions are serving as representatives of coastal, arid and high elevation areas. These four areas are considered particularly responsive to climate change because of the sensitivity of these ecosystems to climate drivers (e.g., temperature, precipitation, sea level).

Networks within the Alaska Inventory and Monitoring Program have identified over 30 vital signs to monitor long-term trends and conditions of park ecosystems through the collection and analysis of robust, high-quality data. These monitoring efforts began in 1992 and have been expanded and improved whenever feasible. They include vital signs in the areas of air and climate, geology and soils, water, biological integrity, human use and landscape patterns. While all of the vital signs are relevant to understanding and responding to climate change, monitoring efforts for glaciers, permafrost, seasonal processes and alpine vegetation are being enhanced as part of the Climate Change Response Strategy.

National Park Service. 2010. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado.

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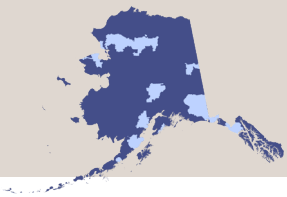


Resource Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Arctic Network Central Alaska Network Southeast Alaska Network Southwest Alaska Network

Glaciers and Climate Change

Background

Approximately one fourth (4.6 million acres) of Alaska's glaciers occur within the boundaries of national parks. Most of Alaska's glaciers have been receding over the last century. Recent findings suggest the rate of recession has significantly increased in recent years (Arendt, Walsh, Harrison, 2009). The effects of melting glaciers are not yet fully understood; however, given the tremendous amount of water stored in glaciers, there will likely be significant changes to the productivity of fresh water flow systems, vegetation and coastal marine ecosystems.

As part of the Climate Change Response Strategy developed by the National Park Service in September of 2010, the Alaska Region has enhanced existing glacier monitoring efforts. These enhanced efforts are outlined here and include extent mapping and volume change analysis for glaciers within all Alaska Inventory and Monitoring networks. In addition, the project will include detailed descriptions and analyses of a select group of focus glaciers within each network.

> Recent findings suggest the rate of recession has significantly increased in recent years (Arendt et al, 2009).

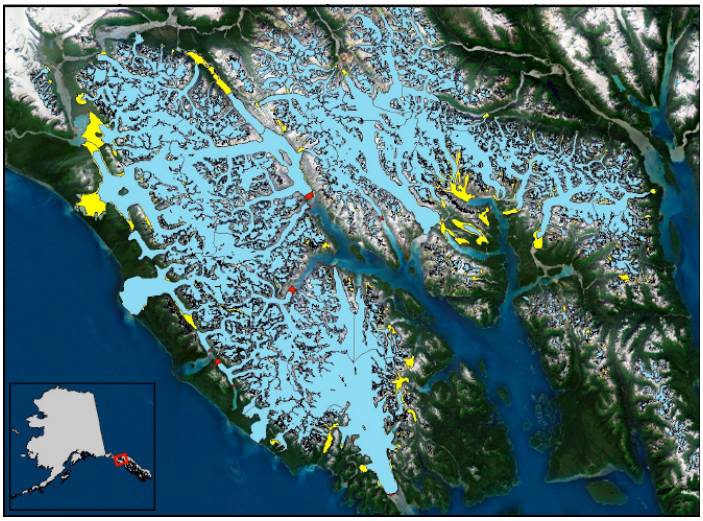


Image: NPS Glaciers First Progress Report, 2011

Changes in glacier area between the 1950 and 2010 in Glacier Bay NPP. Red areas show advances, yellow areas show retreat, and blue areas signify no change.

Photo: Luke Rosier/NPS

An NPS researcher records a GPS waypoint at an exposed mass balance stake on the Harding Icefield in Kenai Fjords National Park.

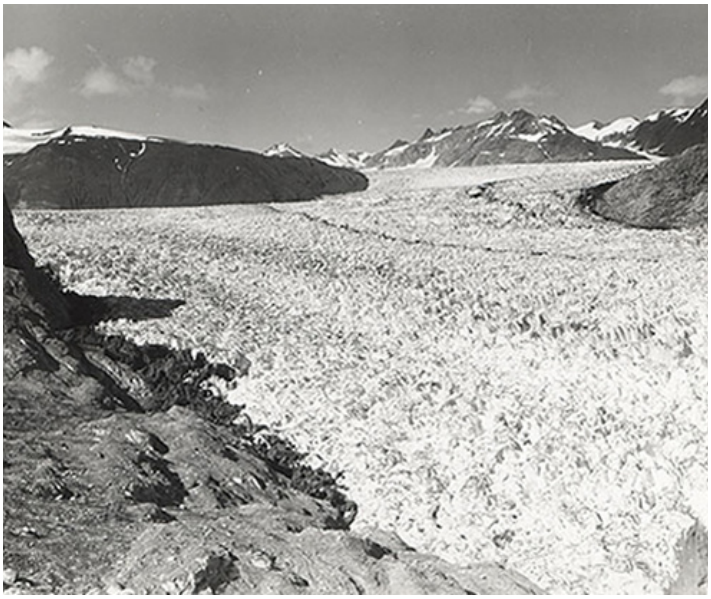
Enhanced Monitoring

Long-term monitoring of glaciers is a multi-tiered approach involving partners at individual parks, the Geophysical Institute at University of Alaska Fairbanks and Alaska Pacific University. This glacier study will take place over the next several years and will measure glaciers in three primary ways: changes in extent (area) for all glaciers, changes in glacier volume for all glaciers with available altimetry data and an interpretive-style description of one to three focus glaciers per park unit.

Extent mapping is being conducted for two time periods using 1950s era USGS quadrangle maps and latest available satellite imagery (Landsat). Maps containing both outlines will be created and compared for each glacier in Alaska's national parks. Data sets describing the physical characteristics of each glacier (length, width, slope, area, elevation) will also be developed. This extensive data set describing glaciers within Alaska's national parks is unique and will have widespread applications.

Volume change analysis is being conducted on glaciers within parks using existing altimetry data. Altimetry data is an elevation profile, which is collected via aircraft and accurate to ± 30 cm, along the center flowline of glaciers. Based on the altimetry data for a given glacier, elevation for the entire surface of the glacier is being projected using best available Digital Elevation Models (DEMs). Volume change will be calculated for glaciers with multiple

Photos: GLBA/NPS (1950 image), Bruce Molnia/USGS (2004 image)

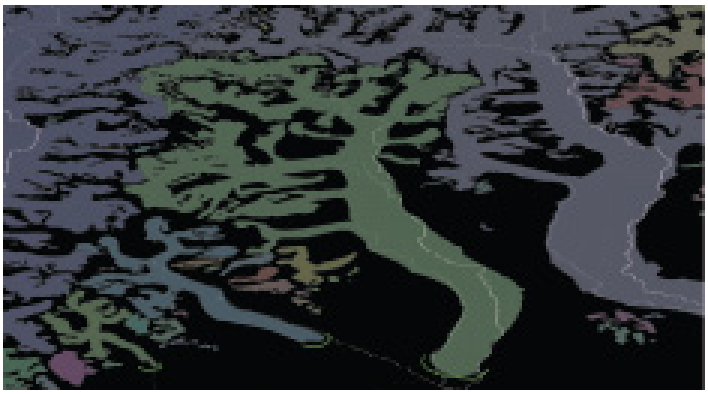


Muir Glacier in Glacier Bay National Park is one of approximately 20 focus glaciers being analyzed and described as part of the enhancements to glacier monitoring in Alaska's national parks. The two images show Muir Glacier in 1950 (l) and in 2004 (r).

elevation profiles, which have been obtained at various times from mid-1990s to current. Glacier volume change can then be projected beyond this suite of measured glaciers to larger regions that exhibit glaciers with similar physical characteristics.

The focus glaciers, of which there are approximately 20 located throughout the parks, have been studied extensively over time and are collectively representative of the diversity of glacier types in Alaska's national parks. Researchers will combine existing data with new analyses to provide detailed time lines and summaries of focus glacier status and trends. The detailed discussions of focus glaciers will provide information to be used in understanding how these glaciers may be responding to a changing climate. Project findings and focus glacier discussions will be summarized in a technical report. This information will also be developed into an interpretive publication that will take the form of a detailed, illustrated guide to glaciers in Alaska's national parks.

Image: NPS Glaciers First Progress Report, 2011



Extent mapping product: Individual polygons for each glacier in Alaska's national parks are the end result of combining assembled imagery (or digital maps) and digital elevation models with a basin delineation alogorithm. (from Toklat and Ruth Glaciers, Denali National Park and Preserve)

Initial Results

The first progress report for "Alaskan National Park Glaciers: Status and Trends" was provided by principal investigators to NPS program managers in September 2011. Year one results include extent mapping of all glaciers in Denali and Glacier Bay National Parks and Preserves, surface elevation changes for select glaciers in Glacier Bay and focus glacier research on several glaciers in Glacier Bay.

Notable initial results include the following:

- Glaciation in Glacer Bay diminished by 11% (from 53.5 to 48.4% coverage) between 1952 and 2010.
- Denali lost 8% of its glacier cover (16.9 to 15.5% coverage) between 1952 and 2010.
- The vast majority of glaciers in both parks have shrunk considerably, mainly by terminus retreat, in that time.
- Laser altimetry indicates that 13 of 16 glaciers studied in Glacier Bay National Park and Preserve exhibit thinning over the study period (1994-2011).

Principal Investigators: Anthony Arendt and Chris Larsen (Geophysical Institute, University of Alaska Fairbanks), Michael Loso (Alaska PAcific University)

Literature cited: Arendt, A., Walsh, J., Harrison, J. (2009). Changes of Glaciers and Climate in Northwestern North America During the late Twentieth Century. Journal of Climate, 22, 4117 - 4134. doi:10.1175/2009JCLI2784.1

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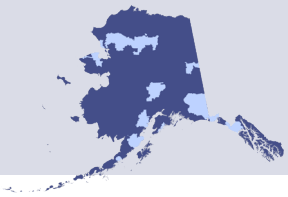

Resource Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Arctic Network Central Alaska Network Southeast Alaska Network Southwest Alaska Network

Permafrost and Climate Change

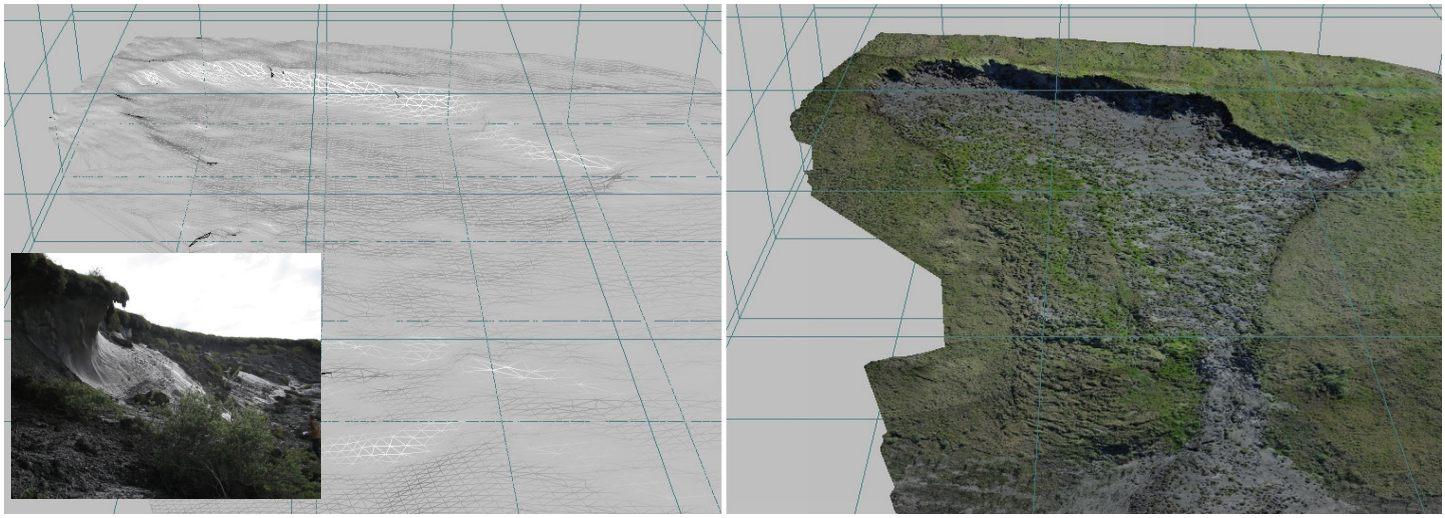

Photo: Dave Swanson/NPS

The photo and 3D model show a retrogressive thaw slump in Noatak National Preserve. Slumps result from a combination of land subsidence due to thaw of large ice masses and downhill transport of sediment by sliding or water erosion.

Background

Permafrost is ground that remains frozen longer than two consecutive years. It dominates the landscape in northern Alaska and is found in 10 of Alaska's 16 national parks. Significant thaw of permafrost is considered likely with future climate change (IPCC 2007). Permafrost has previously been identified by the Arctic (ARCN) and Central Alaska Networks (CAKN) as a vital sign in Alaska's national parks. *Existing monitoring efforts have been enhanced as part of the National Park Service's expanding commitment to understand and respond to climate change and its potential effects as outlined in the Climate Change Response Strategy developed in September 2010*. The enhanced efforts combine direct and indirect measurements of temperature and landscape features and utilize existing partnerships to increase overall understanding of status and trends of permafrost conditions in Alaska.

Photo: Nichole Andler/NPS

Muskox occur in Bering Land Bridge National Preserve and are an Arctic adapted species that may be effected by climate change.

Enhanced Monitoring

The goal of the Alaska Region's expanded permafrost monitoring effort is to understand the magnitude of thawing and the current and potential effects on ecosystems in Alaska's national parks. There are several challenges unique to permafrost monitoring, including the vast area of roadless wilderness and wide variety of responses by the landscape to permafrost thaw. With these challenges in mind, the monitoring team, which includes partners from the Arctic and Western Alaska Landscape Conservation Cooperatives and the U.S. Fish and Wildlife Service, has developed a plan that combines direct and indirect measurements to gain a better understanding of permafrost and thaw cycles. Protocols from both ARCN and CAKN are being applied to this broader, coordinated effort. This multi-faceted approach will result in an efficient, more robust monitoring program.

Maps of permafrost location and condition for all parks in ARCN and CAKN will be developed using models that utilize near surface ground temperatue data as well as data from existing landscape and soil inventories. Near surface ground temperatures (0 to 2 m), a direct measurement, is being collected on a continual basis. Measurements are taken using temperature sensors located at existing weather monitoring stations, new weather monitoring stations installed in 2011, and others slated for installation in 2012. Near surface ground temperatures will be monitored in all parks within the ARCN and CAKN as a result of this project.

Putting it All Together

The dynamics of permafrost landforms will be monitored via several indirect measurements. Satellite imagery is being used to inventory natural features associated with permafrost. Features indicative of thaw, such as areas covered by water or bare soil, are being mapped using moderate resolution imagery. Where rapid thawing and conspicuous changes are occurring, such as slumping or landslides caused by melting, 3D models using advanced technologies like LIDAR and stereophotogrammetry are then applied to focus areas.

Additional monitoring efforts are also being considered and may be included in future protocols. Periodic temperature measurements from deep boreholes (up to 20 m) taken from areas adjacent to the parks may be analyzed and summarized. The thickness of the active layer, the area between the ground surface and permafrost layers subject to seasonal frost, may be measured during annual summer thawing at sites with fine-grained soils that are accessible by road. Active layer monitoring would follow an established international protocol established by the Circumpolar Active Layer Monitoring Network (CALM).

Thermokarst, the term collectively applied to subsidence features related to permafrost thaw, includes slumps and depressions in the landscape and the formation, enlargement or drying of lakes and other bodies of water among other features. Effects of thermokarst include erosion, associated landslides, increased sediment loads in lakes and streams, changes in vegetation growth patterns and altered nutrient cycles.

This monitoring effort will result in an inventory of areas likely to contain permafrost, a current assessment of permafrost conditions, trends in melting and effects of melting for eight parks in Alaska. This information will be used to inform decisions about park management. Results will be organized into a technical report summarizing data. In addition, an interpretive document summarizing permafrost changes will be made available to park managers, policy makers, the general public and others. Data will be made available via online resources. Permafrost thaw features in many of the national parks within ARCN have already been mapped, and this expanded effort will focus on unmapped parks in which areas of permafrost occur. Protocols for this expnded effort were finalized in mid-2011. Progress reports and initial results are expected in early 2012.

Photo: Larissa Yocum/NPS

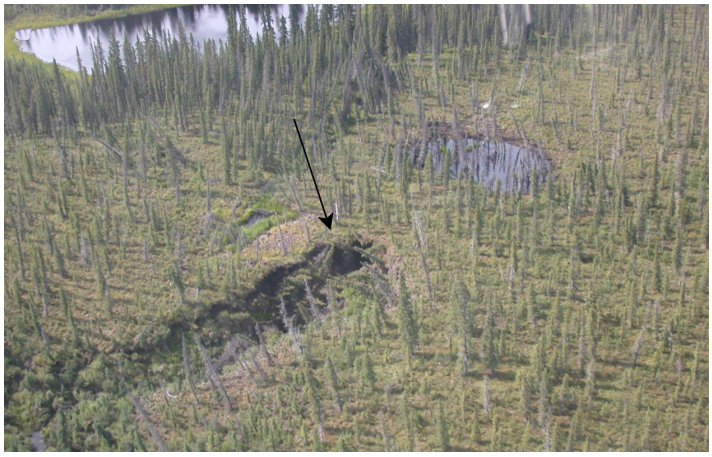

Photo: Larissa Yocum/NPS

Images showing two perspectives of Hook's Hole thermokarst in the Toklat Basin within Denali National Park. The large cave-like space and tilted trees are a result of thawing permafrost. Notice the person in the top image for scale.

Permafrost and Rising Temperatures

Monitoring changes in permafrost condition is a high priority due to the potential for accelerated thaw rates which may fundamentally change ecological processes across major portions of the Alaska landscape. A multi-tiered approach utilizing existing partnerships, established protocols and regional support is being applied to expand this program. A combination of on-site measurements, satellite imagery, and modeling will provide information needed to form a baseline data set of permafrost metrics in Alaska's national parks. Continued monitoring of permafrost areas will help researchers, managers, and the public understand and respond to the potential effects of climate change on permafrost. The results from this enhanced monitoring effort will be made available via online databases.

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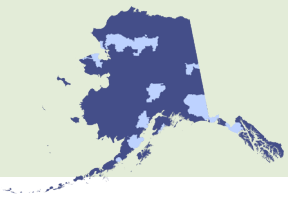


Resource Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

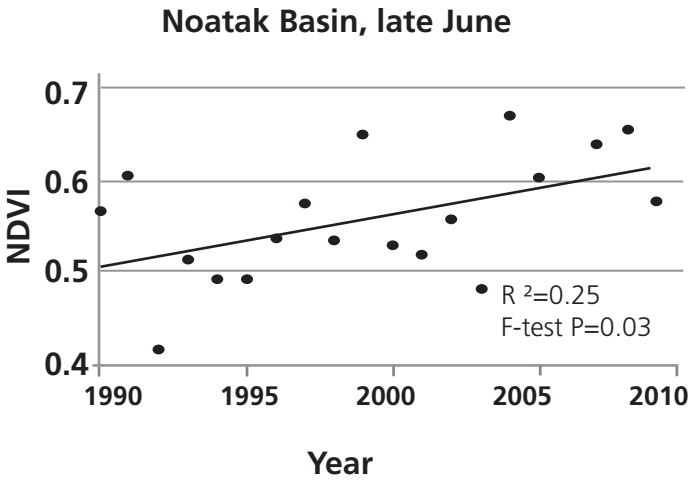
Arctic Network Central Alaska Network Southeast Alaska Network Southwest Alaska Network

Seasonal Processes and Climate Change

Background

Seasonal processes, as defined by the Alaska Inventory & Monitoring Networks, include a number of physical and biological events that occur seasonally, such as the breakup of ice on lakes or the emergence of new leaves on plants in spring. Documenting seasonal processes can help determine the effects of large scale changes in a particular area or species. To date, relatively little is known about the various seasonal processes of many species in Alaska because of the vastness and inaccessibility of much of the state. Inventory and Monitoring networks within the Alaska region have previously identified seasonal processes as a vital sign and several networks have already begun conducting monitoring activities. *As part of the National Park Service's Climate Change Response Strategy, efforts to enhance existing monitoring programs are underway.* This multi-faceted approach integrates data collected from satellite imagery, remote cameras installed at weather stations and field observations to monitor seasonal variation in lake ice, snow cover and growing season length in Alaska's national parks.

> Increased warming is expected to result in greater variation in the seasonality of vegetation, snowpack and lake ice dynamics across Alaska.



Many sites in the Arctic, including the Noatak Basin region, above, showed a significant increase in NDVI, a measure of greenness, over the period 1990-2009. The increase in NDVI reflects an increase in plant biomass that is likely due to warming (Swanson 2010).

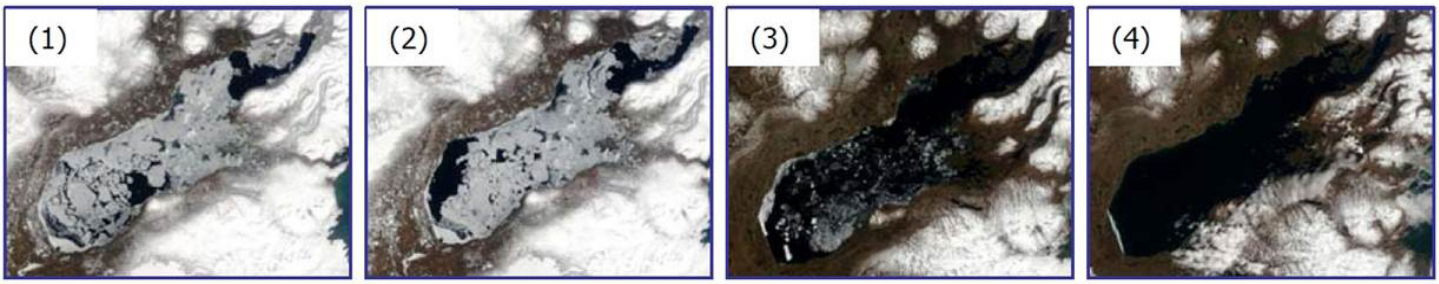
Photo: Amy Miller/NPS

A National Park Service researcher installs a remote camera on an existing weather station in Katmai National Park.

Enhanced Monitoring

Satellite imagery data from Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Very High Resolution Radiometer (AVHRR) are collected one to two times daily over Alaska and are currently being archived at, and distributed by, the University of Alaska – Geographic Information Network of Alaska (GINA). The high temporal resolution of MODIS and AVHRR data make them well-suited for regional-scale monitoring of seasonal processes. To date, MODIS and AVHRR data from the Southwest Alaska and Arctic Networks have been summarized over the periods of record for snow, vegetation (NDVI) and lake ice (2001-2008, Reed et al. 2009; 1989-2009, Swanson 2010; 2001-2010, Lindsay et al. 2011). Enhancements to monitoring include summarizing data for the remaining two networks. Finer-scale data are being collected at a subset of sites using remote cameras installed at weather stations. The cameras are capturing daily images that will be used to monitor snowpack development, snow melt and the start and end of the growing season. Plans are in place to install additional remote cameras at weather stations throughout the region.

Finally, field observations are being used in the Central Alaska Network to describe the seasonal events of selected tree species. NPS is working with several partners to expand a species list developed by the National Phenology Network (NPN) to include Alaskan species. Field data will be uploaded to NPN.



Photos: Chuck Lindsay/NPS

The two sets of images show examples of data that will be analyzed to better understand seasonal processes. (a) Satellite images (MODIS) from April 15 to May 10, 2005 show ice break up on Lake Iliamna south of Lake Clark National Park. (b) Images taken by a remote camera station in Lake Clark National Park provide detail on the variation of snow cover in one winter season, which is not easily detected by satellite imagery.

Putting it All Together

Increased warming is expected to result in greater variation in the seasonality of vegetation, snowpack and lake ice dynamics across Alaska (Reed et al. 2009), which in turn may affect a broad suite of ecological processes (e.g., river discharge, wildlife foraging and movement, etc.).

The networks are using multiple approaches to enhance monitoring of seasonal processes. (1) Satellite imagery (MODIS, AVHRR) is available online through web coverage (WCS) and web mapping services (WMS) hosted by GINA, and methods for calculating seasonal metrics are being automated to the extent possible. (2) Protocols and deliverables for time-lapse data collected by remote cameras are in development using established methods outlined by the PhenoCam Network, a collaborator with NPN. (3) Methods for field data collection have been reviewed for compatibility with NPN, and data uploads to NPN will commence in the near future. (4) Expansion of the National Phenology Network's species lists to more adequately address Alaskan ecosystems is planned for 2011 and will involve collaboration with U.S. Fish and Wildlife and the Alaska Natural Heritage Program.

As a result of the expanded monitoring effort in Alaska's national parks, technical reports and interpretive materials stemming from network monitoring efforts are being developed and will be distributed to park managers, interpretative staff, the scientific community and the general public. Data summaries are expected to be updated every 1-5 years.

Tracking Nature's Calendar in Alaska's Parks

Satellite imagery data collected using established protocols will be combined with new data from remote cameras and ongoing collaboration with the National Phenology Network to provide a more comprehensive understanding of seasonal processes in Alaska's national parks. Satellite imagery data focuses on broad scale snow, lake ice and vegetation cover, whereas time-lapse photos and on-site observations focus on small scale events. This expanded monitoring effort will be ongoing, and should result in improved characterization of both interannual variability and long-term trends in seasonal processes.

Lindsay, C., Spencer, P., & B. Hill. (2011). Interannual variability of lake ice phenology in southwest Alaska: Integrating remote sensing and climate data. 2011 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites. New Orleans, LA.

Reed, B., Budde, M., Spencer, P & Miller, A. (2009). Integration of MODIS-derived metrics to assess interannual variability in snowpack, lake ice, and NDVI in southwest Alaska. Remote Sensing of Environment, 113, 1443–1452. doi:10.1016/j.rse.2008.07.020

Swanson, D. (2010). Satellite Greenness Data Summary for the Arctic Inventory and Monitoring Network, 1990-2009. Natural Resource Data Series, NPS/ARCN/NRDS, 2010/124.

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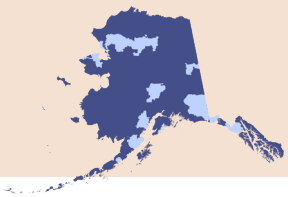


Resource Brief
Alaska

National Park Service
U.S. Department of the Interior

Inventory and Monitoring Program
Alaska Region

Arctic Network *Central Alaska Network* *Southeast Alaska Network* *Southwest Alaska Network*

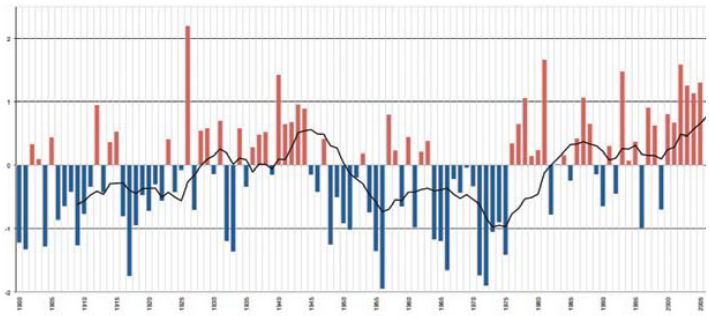
Weather and Climate Change

Background

Accurate data on climate, or the long-term statistical expression of short-term weather, is at the foundation of all monitoring efforts and scientific research conducted within Alaska's national parks. Average Arctic temperatures have been increasing at almost twice the rate of the rest of the world, and effects are evident in the decrease in extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, shrinking glaciers and altered distribution of species (IPCC 2007). This further raises the importance of high quality weather and climate data in understanding and responding to the current and potential effects of climate change. *The Alaska Region has been identified as the high latitude representative in the National Park Service's Climate Change Response Strategy and is currently implementing enhancements to several monitoring efforts within the Inventory and Monitoring Program.*

In Alaska, weather and climate data has historically been recorded in easily accessible, low elevation areas. The 54 million acres of national parks in Alaska include areas with diverse landforms and localized weather patterns. A large percentage of the parklands are also located in remote, roadless areas. The Inventory and Monitoring Program is currently collecting data at remote area weather stations (RAWS) located throughout national parks in Alaska and plans to install additional stations in representative areas throughout the parks.

> Average Arctic temperatures have been increasing at almost twice the rate of the rest of the world (IPCC, 2007).



Mean annual temperature departure for Central Alaska; blue bars are negative and red bars are positive departures. The phase shift in the PDO is apparent as it shifts from a cool to warm phase in 1976.

photo: Nichole Andler/BELA/NPS

The National Park Service is monitoring weather in many remote, roadless areas never before monitored, including Bering Land Bridge National Preserve.

Monitoring

The NPS Inventory & Monitoring program has installed 28 new climate stations over the past eight years, with at least 12 more planned for installation, to understand the climate patterns and trends within Alaska's national parks. Prior to the recent installations, the observational record for the state was almost exclusively from low elevations, near populated areas and along the coasts and river systems, and therefore was not representative of the vast upland areas that characterize parks within Alaska. The NPS lands in Alaska encompass most of the mountainous areas of the state and provide a great opportunity to fill in data gaps in the climate record.

The Inventory and Monitoring Networks within Alaska share common goals and objectives to meet this challenge: identify long and short term trends by monitoring and recording weather conditions at representative locations in the parks, a commitment to making these data available to everyone and utilizing these data for larger-scale climate monitoring and modeling efforts.

The focus for the Central and Southwest Alaska Networks over

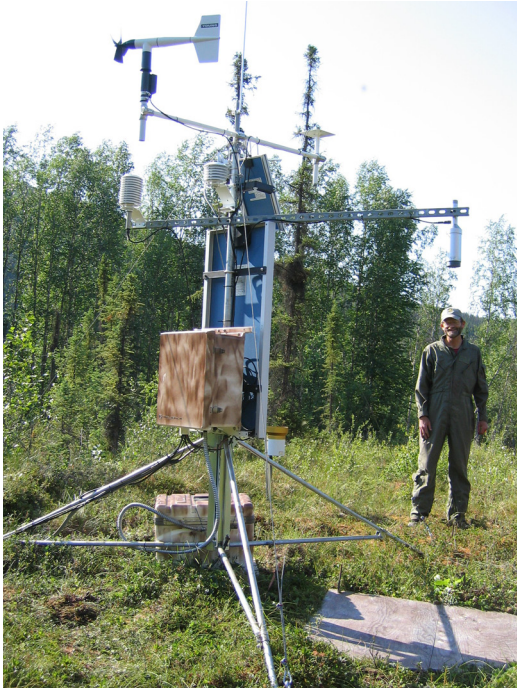
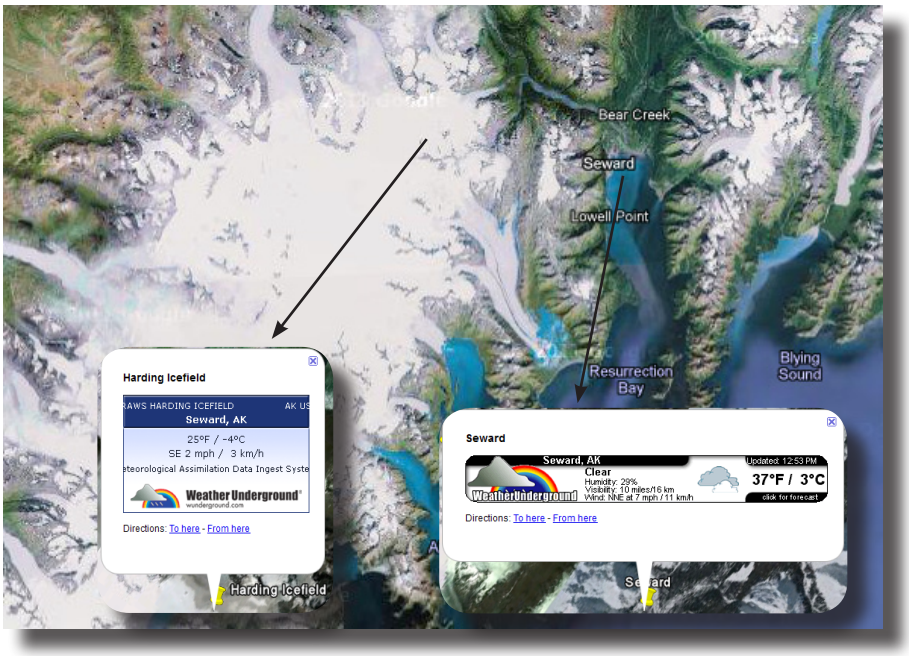


photo: Pam Sousanes/NPS

A researcher with the National Park Service conducts routine maintenance on a remote area weather station located in Yukon-Charley Rivers National Preserve.



Real-time weather data for stations located within the Southwest Alaska Network are available online through Google Earth. The example above shows data taken at approximately 1 p.m. on March 9, 2011. Local weather at Seward (37 ° F), which is located at an elevation of 83 ft, differed significantly from weather at Harding Ice Field (25 °F), which is located at 4296 ft. The two remote weather stations are located approximately 12 miles from each other.

the next few years is to maintain the integrity of the new stations, promote the use of data for ecological and climatic analysis, improve data query tools and integrate the NPS climate products with other climate change research and monitoring efforts. The NPS recently partnered with the PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Group at Oregon State University to update the gridded monthly and annual precipitation and temperature data sets for Alaska for the 1971 - 2000 climate period. These maps help estimate variations in temperature and precipitation around existing climate stations and will be used to update the projected climate change scenarios for the national park units in the state.

The Arctic and Southeast Alaska Networks are currently focused on developing a detailed climate monitoring plan using the foundation established by the Central and Southwest Alaska Networks. This will result in installations of new stations in areas where data is critical, including the vast upland areas of the Arctic parks and the coastal areas in Southeast Alaska.

Putting it All Together

The climate monitoring program now has products available for use in understanding climate and ecosystem change, such as publicly accessible data and data analysis tools, climate summary maps and reports summarizing annual climate factors and long-term trends (Davey et al. 2006, Keen 2008). Climate data can be used in the analysis of other vital signs to better understand the effects of climate change, including the four vital signs monitoring efforts being enhanced as part of the National Park Service's Climate Change Response Strategy in Alaska: glaciers, permafrost, seasonal processes and alpine vegetation.

Climate Monitoring in Alaska

Climate is considered the most important broad-scale factor influencing ecosystems. Because global climate models indicate that climate change and variability will be greatest at high latitudes, climate monitoring will be critical to understanding the changing conditions of park ecosystems. Potential effects in national parks include a reduced snowpack, earlier ice break-up on lakes, warmer winters and wetter summers. These changes may affect the distribution, abundance, growth and productivity of plants and animals. The NPS has invested substantial time and effort to develop an effective and robust climate monitoring program that will answer critical questions about how the trends in temperature and precipitation are changing in Alaska national parks. These data will make a critical difference in our understanding of climate trends in Alaska over the next 50 years.

Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Davey, C.A., K.T. Redmond, and D.B. Simeral. 2006. Weather and Climate Inventory, National Park Service, Arctic Network. Natural Resources Technical Report NPS/ARCN/NRTR -2006/005.

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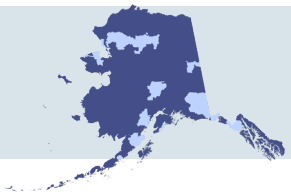
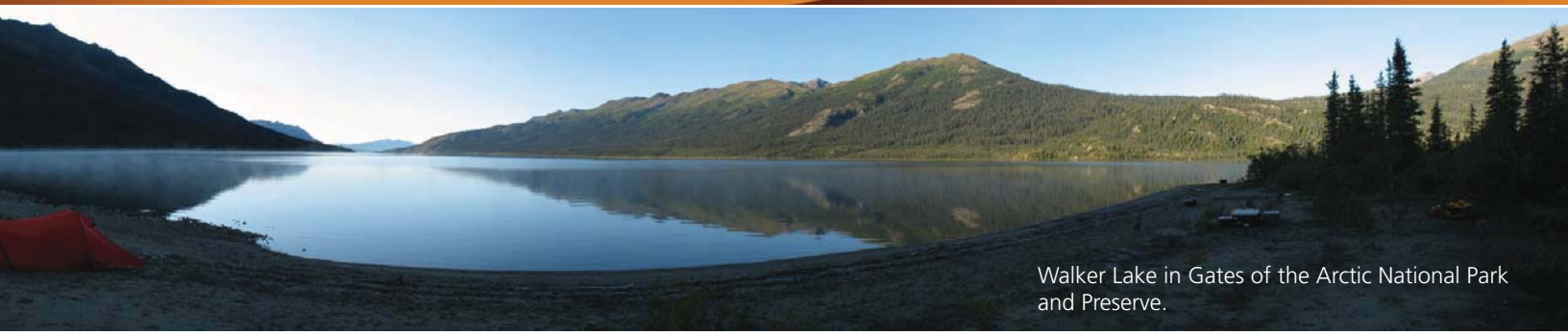


Arctic Network

Bering Land Bridge N Pres. Cape Krusenstern NM
Noatak N Pres. Kobuk Valley NP Gates of the Arctic NP & Pres.

Climate Change Resource Brief



Walker Lake in Gates of the Arctic National Park and Preserve.

Climate Change and Arctic Alaska

The NPS Arctic Network (ARCN) is designing programs in Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Gates of the Arctic National Park and Preserve, Kobuk Valley National Park and Noatak National Preserve to monitor various ecosystem components including the deposition of contaminants, coastal erosion, permafrost extent, water quality and aquatic systems, wildlife, vegetation, and terrestrial processes such as wildland fire patterns that are likely to be altered by climate change. For the five national park units in ARCN, scientists are predicting that the average temperature may rise 10°F by 2080. Winter temperatures are expected to increase more than summer temperatures. Predicted increases in precipitation are not expected to keep pace with the increases in evaporation caused by the warmer temperatures. This may have drastic effects on the region's landscapes and waterways. Below we describe some key vital signs that will give us insight with respect to climate change.

Air and Climate

Climate and Snowpack Monitoring – Climate monitoring will be critical to understanding the changing conditions in the Arctic Network of parks as global climate models indicate that climate change and variability will be greatest at high latitudes. In an attempt to better understand climate variation as well as long-term changes in park ecosystems, several new climate monitoring stations are being proposed throughout the network. We will also track changes in duration of snow through instrumentation at the weather stations and through satellite imagery.

Wet and Dry Deposition and Air Quality – ARCN parks can act as sinks of air pollution because of their cold climates and the trans-continental air masses that flow over them. Changes in global circulation patterns associated with climate change will alter how contaminants are deposited in the environment. ARCN is tracking long-term trends in environmental deposition of a few key contaminants by monitoring uptake by a moss species and in the tissue of freshwater fish to determine how current contaminant levels fit into established thresholds and to document how climate change will influence deposition patterns. In addition, in July 2008, ARCN installed an air quality monitoring station in Bettles, Alaska to track changes in air quality.

A winter landscape in Bering Land Bridge National Preserve.

Geology and Soils

Coastal Erosion – ARCN contains approximately 250 miles of shoreline including bay and barrier island ecosystems. Nearshore coastal water and shoreline habitats are currently experiencing dramatic changes that may be accelerated with climate change including changes in seasonal sea ice coverage, melting permafrost, increases in storm intensity and frequency, and sea-level rise. Coastal change is one of the most observable and sensitive indicators of environmental change that ARCN is monitoring.

Coastal erosion can be very rapid when frozen sediments thaw and collapse.

Permafrost – ARCN is underlain by permafrost (ground that has been frozen for two or more years). Unusually warm weather can thaw permafrost, which in turn can cause landslides and subsidence that expose bare soil and shed sediment into lakes and streams. Detailed satellite images of ARCN have allowed us to make comprehensive surveys of slump features in Cape Krusenstern National Monument and Bering Land Bridge National Preserve. In Cape Krusenstern we found seven fresh landslides that result from the thaw of permafrost, covering just 0.95 ha (2.3 ac) in the 267,000-ha National Monument. In Bering Land Bridge (which covers over a million hectares) we found 21 of these landslides, covering a total area of about 3 ha (7.4 ac), including ten active-layer detachments along one 4-km (2.5 mile) stretch of creek. ARCN is applying this and other methodologies to other areas in the network where more slumping due to permafrost melt has been noted.

A permafrost rich landscape in Bering Landbridge National Preserve.

Water

Coastal Lagoons, Lakes and Streams – ARCN contains a variety of brackish and freshwater aquatic systems including coastal lagoons, shallow lakes, large lakes and streams. These aquatic ecosystems are important to wildlife, subsistence users and the scenic quality of the parks. Aquatic systems are sensitive indicators of climate change because they act as integrators of water shed level processes. ARCN is tracking changes in coastal erosion rates, water body depth and surface area, water chemistry, and aquatic insect and plant communities in coastal lagoons, lakes and streams.

Muskoxen are an arctic adapted species that may be affected by climate change. Within the NPS muskoxen are only found in ARCN.

Biological Integrity

Wildlife – ARCN contains a number of unique northern and arctic species of wildlife that may be threatened by habitat shifts associated with climate change. Species such as yellow-billed loons, muskoxen and some landbirds are found nowhere else in the National Park System. Dall's sheep, an alpine species at the northern end of their distribution may be affected by elevational changes in habitat. Brown bears and caribou may also be affected by habitat shifts from tundra-dominated ecosystems to shrublands and forest. ARCN is monitoring population size and distribution of these species which may be affected by climate change.

Terrestrial Vegetation, Soils and Landscape Patterns – Studies in northern Alaska, including ARCN, have already shown changes in arctic and subarctic vegetation in response to climatic warming. Vegetation is affected through changes in the length and warmth of the growing season, through more rapid nutrient cycling and changes in soil wetness, and through the frequency of occurrence, extent and severity of fires. Lichens, the primary forage for caribou and a cornerstone of arctic biodiversity, may be extirpated from much of its current range under climate change scenarios in which tundra yields to shrub or forest dominated system. Hydrology will be affected by changes in permafrost, snowpack persistence, freezing and thawing of lakes and streams, and the persistence and distribution of water on the landscape. By using on-the-ground vegetation measurements at index sites and low altitude aerial photography, ARCN will be able to track changes in vegetation such as expansion of shrubs. We will also track changes in growing season length using weather stations and satellite imagery. Baseline monitoring of vegetation, soils, fires and landscapes will inform managers about the complex relationship between climate, ecological disturbance and northern landscapes.

NPS employees sampling tundra vegetation in Bering Land Bridge National Preserve. Shrubs are expanding in tundra landscapes such as this.

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Central Alaska Network

Denali NP & Pres. Wrangell-St. Elias NP & Pres. Yukon-Charley Rivers N. Pres.

Climate Change Resource Brief

Climate Station at the Gates Glacier in Wrangell-St. Elias National Park & Preserve

Climate Change and Central Alaska

The Central Alaska Network (CAKN) spans 443 miles from north to south, 448 miles from east to west and includes a variety of ecosystems from coastal rainforest to very dry interior boreal forest. Due to the large distances and landforms the network includes, the climate is variable across the network. Correspondingly, any future change in climate may be very different over the span of the network. For interior Alaska portions of the network, scientists predict that more precipitation will be offset by warmer temperatures and it generally will be drier. In contrast, scientists believe climate change will mean a wetter and warmer climate in the coastal areas of Wrangell-St. Elias. Regardless of exactly how the climate changes over the next decades, the monitoring program of the CAKN has been developed with the ability to measure the resulting change in its ecosystems and detect change in climatic drivers. The CAKN is structured to measure change across multiple spatial scales, multiple time scales and from low to high in the food chains of network ecosystems. Below we describe some key vital signs we are monitoring with respect to climate change.

Climate

Climate is one of the key drivers for Alaska's ecosystems and since 1940, Alaska's climate has warmed an average 4°F. Through robust monitoring we can put this change in the context of ongoing cycles and better understand the scale of climate change in central Alaska. Prior to 2004, measurements made on the climate of interior Alaska were based on data from a few weather stations and then projecting that data for several hundred miles. Additionally, most historic climate stations are located in low-lying areas and do not accurately measure winter precipitation, which results in a lopsided climate picture. The CAKN has added 16 climate stations positioned strategically throughout the network to provide a more balanced picture of the networks' climate. With just five years of data collected at higher elevation sites, climatologists have made significant revisions to the climate maps of Alaska which provide more accurate climatic summary and serve as an improved baseline from which to assess change.

Clouds over the landscape in Denali National Park & Preserve.

Vegetation

We are monitoring several facets of climate change with respect to vegetation. At the coarsest scale we are monitoring changes in vegetation structure and composition on 2.5km plots across each park. To inform us about changes in the growing season each year and across years, we are monitoring the timing of aspen leaf-out at sites in each CAKN park. Finally, we have also acquired historic photographs of various locations in the parks and conducted repeat photography at those locations. These photo-pairs allow assessment of decadal scale trends in plant communities.

Animals

It is expected that animals will respond to climate change in part, by altering their ranges as the habitat they require changes. For example, scientists expect to see a general shift to the north for many species as the southern portions of their ranges cannot sustain necessary habitat. The CAKN has strategically chosen to monitor animal species that occur across elevation ranges and across the north-south gradient of the network. We have also sought to monitor species in different ecological positions in the food chain so that we are monitoring those high in the food chain (e.g. predatory species like eagles, wolves) and low in the food chain (e.g. prey species like passerine birds, moose). Our monitoring will inform parks of how animal distributions and population sizes change as climate changes.

Aquatic Resources

Shallow Lakes – Water plays a large role in defining the nature of the various ecosystems in the Central Alaska Network. We are focusing our monitoring on two primary water resources shallow lake systems and streams. Shallow lakes are a prominent feature of the network landscape and provide important habitat and ecosystem functions. The physical properties of shallow lakes make them good potential indicators of climate change because while they may be more likely to dry up if temperatures warm, we may also see more lakes formed as permafrost melts. The shallow lake program collects water chemistry, physical (e.g. lake depth) and biological data (e.g. aquatic insects, plants) from lakes as well as remotely sensed data. Taken together, these data have the power to inform us on the changing status of this important resource as the climate changes.

Streams – Like shallow lakes, stream systems provide important habitat for plants and animals in our network as well as performing important ecosystem functions. The biggest changes we anticipate from climate change which will affect streams are increases in glacial melt, permafrost melt, timing and amount of precipitation and air temperature. We expect to observe corresponding changes in water chemistry, stream channel form and flow as well as the biological components (e.g. aquatic insects, fish, plants) of our stream systems. Measuring the change in our stream systems at several spatial scales is a key aspect of the program.

Summary

Climate change models and the like help park managers anticipate what to expect in coming decades, however it is most likely that none of the models or scenarios are entirely correct. Therefore it is crucial that we monitor our resources in a manner that allows us to detect ecosystem changes due to climate change and other agents of change. In so doing we can provide the most complete information to park managers who, in turn, must make optimal decisions for the management of National Park resources.

A small sampling of the species that inhabit Central Alaska Network parks.

Vegetation on a small pond in Yukon-Charley Rivers National Preserve.

Esker Stream in Disenchantment Bay, Wrangell-St. Elias National Park & Preserve.

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Southeast Alaska Network
Glacier Bay NP & Pres. Klondike Gold Rush NHP Sitka NHP

Climate Change Resource Brief

Lewis Sharman of Glacier Bay National Park and Preserve (GLBA) prepares to collect a vertical profile of physical oceanographic conditions at a station in Glacier Bay proper.

Climate Change and Southeast Alaska

Global climate change is expected to manifest in Southeast Alaska as warmer, wetter conditions. This region is largely defined by water – delivered, transported, and residing as humidity, mist, rain, snow, glaciers, icefields, icebergs, rivers, estuaries, bays, and the open ocean. Changes in the amount, timing and form of water delivered to SEAN parks will drive both dramatic and subtle patterns and processes in plants, wildlife, and landform. The SEAN comprises three parks: Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLGO), and Sitka National Historical Park (SITK).

Glaciers

Sensitive to seasonal variation in temperature and precipitation, glaciers are excellent indicators of regional and global climate. More than 50 glaciers cover 1,375 square miles in GLBA – fully 27% of the park. Glaciers continue to shape the park's dramatic scenery, topography, and landforms while providing billions of gallons of freshwater to a pristine glacial fjord ecosystem. Even seemingly subtle changes in glacial dynamics can have far-reaching consequences, through changes in hydrology and runoff patterns, degree of ocean stratification, carbon delivery, and capacity of the system to buffer against ocean acidification. In coordination with the approaches of other Alaska Networks, SEAN will initiate area and surface elevation monitoring for selected index glaciers in 2010.

Johns Hopkins Inlet in the upper west arm of Glacier Bay.

Water Quality and Quantity

Freshwater systems within the national parks of SEAN support a wide variety of aquatic life, including robust populations of all five Pacific salmon species. Continuous monitoring of physical characteristics and stream discharge occurs in surface waters of all network parks. The four core water quality parameters being monitored are dissolved oxygen, pH, specific conductance and temperature. In KLGO, we will also monitor turbidity in the Taiya River, a glacier-fed river where sediment loads and temperature are expected to change with warmer, wetter conditions. SEAN will be adding a freshwater contaminants monitoring program to complement our marine and airborne contaminants programs in all three parks. As valuable indicators of freshwater ecosystem condition, macroinvertebrates will be sampled in SITK where residential development in the Indian River watershed continues to increase.

Pink salmon return to spawn in the Indian River at Sitka National Historical Park (SITK).

Physical Oceanography

Along with weather, glaciers, and landform, ocean waters drive ecosystems and dynamics of many biological communities in Southeast Alaska, from primary producers to apex predators. A number of other SEAN Vital Signs (e.g., Marine Predators, Kittlitz's Murrelets, Humpback Whales) are themselves directly or indirectly influenced by oceanography. By collecting vertical water column profiles throughout the year, we can detect changes that may influence the condition of many resources throughout the park. Oceanographic monitoring improves our understanding of the Southeast Alaska marine system, linkages between atmospheric and oceanic systems, and implications of climate change in high-latitude marine systems.

Reid Glacier, Glacier Bay National Park and Preserve.

Ocean Acidification

The world's oceans act as a vast buffer against global climate change, absorbing and storing approximately 1/3 of annual anthropogenic carbon dioxide emissions. But this ecological function comes at a risk; the process by which oceans absorb CO_2 also produces carbonic acid. The result is that ocean surface water is, on average, 30 percent more acidic than records dating to 25 million years. Though these changes are well documented and not much debated, the impacts of increased acidity on marine calcifying organisms – the very foundation of marine food webs – are not well understood. Scientists are concerned that increased acidity will result in reduced productivity of these calcifying organisms, with profound impacts up the food chain. SEAN is developing a project to better understand ocean pH dynamics, the degree of acidity, and potential impacts on the incredibly productive waters of Glacier Bay proper.

Populations of apex predators, including threatened Steller sea lions, endangered humpback whales, killer whales, sea otters, and seabirds may be severely impacted if increased ocean acidity disrupts marine food webs.

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Monitoring Responses to Climate Change in Southwest Alaska

Climate change is expected to result in large-scale changes to the Southwest Alaska Network. Many of the metrics we are monitoring are specifically geared toward detecting changes resulting from climate change. Mean annual winter temperatures in Southwest Alaska Network parks hover near the freezing point. Therefore, small increases in temperature will likely have enormous impacts on snow pack, winter survival of moose, and hydrologic factors that govern these landscapes. Below are some of the specific Vital Signs that SWAN has identified to inform managers and the public about how climate change is impacting ecosystems of the parks.

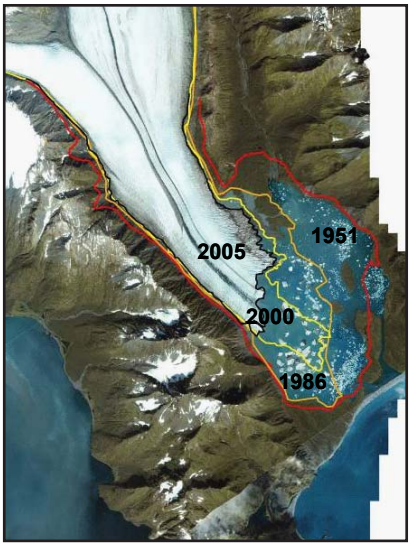
Weather and Climate

SWAN installed nine remote automated weather stations to address the scarcity of climate information for its park units. These strategically-placed stations form a network documenting a wide range of climate conditions (elevation and ecosystem gradients) that are present within SWAN. These data will provide a more detailed understanding of short-term weather conditions and long-term climate trends across the diverse landscape of SWAN.

SWAN staff install RAWS climate station at Hickerson Lake, a high elevation inland site (LACL).

Glacial Extent

Although about one-fifth of the landmass of this Network is covered by ice or permanent snowfield, widespread reductions in glacial volume and extent over the last 100 years are evident. Landsat imagery and historic aerial photography are being used to map glacial extent on a decadal scale in SWAN. Glacial mapping indicates a 7.7% loss of glacial extent in KATM since 1974 and a 1.6% loss in KEFJ since 1951. Mapping work is ongoing for LACL.



Bear Glacier, Kenai Fjords National Park. Glacier terminus positions are shown for 1951, 1986, 2000, and 2005. Terminus positions were digitized from LANDSAT and IKONOS imagery.

Landscape Processes

Impacts of global climate change are expected to result in greater variation in the seasonality of snowpack, lake ice, and vegetation dynamics in southwest Alaska. All have wide-reaching physical and biological effects in the region. SWAN is using MODIS satellite data to monitor landscape metrics such as snow cover duration and timing, and lake ice onset and duration on several large lakes across the region. Annual vegetation growth (NDVI) differences are also being monitored.

Vegetation

Vegetation is integral to ecosystem function and element cycling, and is a sensitive indicator of environmental conditions. Vegetation composition and structure are expected to respond to increasing variability in climate. Remotely-sensed data are used to detect broad-scale changes in vegetation and landscape features. Ground-based monitoring will target fine-scale changes in vegetation composition and structure. Sensitive plant communities are targeted for additional monitoring, including salt marshes and nunataks (alpine ridges surrounded by ice). Vegetation plots have been established to monitor these targeted plant communities in KATM, KEFJ and LACL. Additional alpine monitoring is planned as part of the international GLORIA monitoring network.

Moose

Moose are an integral component of terrestrial systems. Moose browsing can influence the structure and function of vegetation communities during periods of high moose abundance. Conversely, as climate changes, vegetation communities previously utilized by moose may change into something less desirable. Aerial surveys will be used in portions of KATM and LACL to monitor moose abundance and bull:cow ratios.

Surface Hydrology and Freshwater Chemistry

Many factors contribute to the impacts of climate change on SWAN freshwater systems, including altered hydrology, precipitation and primary productivity. Change may be experienced through gradual shifts in water quality or through abrupt shifts as climatic variables cross threshold points. These changes will have impacts on aquatic process, such as lake productivity and fish reproductive success. Water level, water temperature and water quality parameters are being measured across the large lakes and rivers of KATM, KEFJ and LACL.

Marine Nearshore

The marine coastline of SWAN spans 1,900 km (1180 mi) and encompasses some of the most biologically productive nearshore ecosystems in the Gulf of Alaska. These nearshore systems are susceptible to the effects of sea level rise, increased storm activity, ocean acidification, and temperature changes associated with climate change. A suite of physical, chemical and biological metrics are being monitored in KATM, KEFJ, and LACL to assess the impacts of climate change on key nearshore species.

SWAN plant ecologist and biological technician collect frequency data on non-vascular and vascular plants during plot establishment in spruce woodlands (KATM).

Aquatic ecologists use a multi-parameter sonde to collect water quality data in Lake Clark.

USGS and contract biologists measure clams as part of invertebrate density and abundance monitoring on the KATM coast.

For more information
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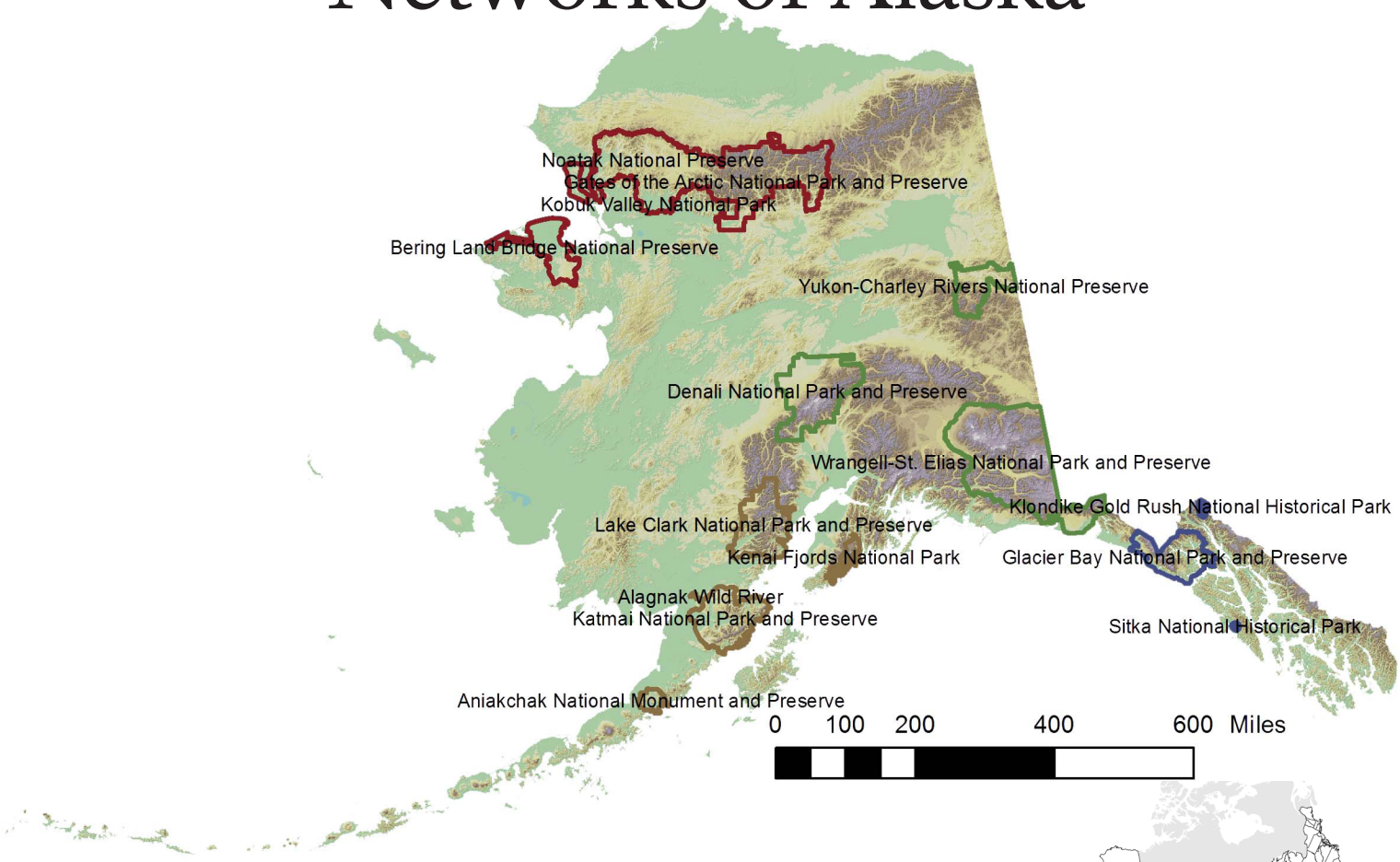
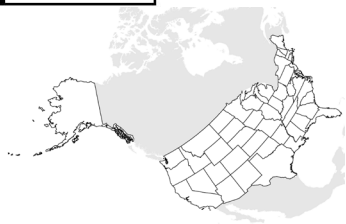
Inventory and Monitoring Networks of Alaska





Arctic Network

Bering Land Bridge National Preserve	2.7 million acres
Cape Krusenstern National Monument	650,000 acres
Gates of the Arctic National Park and Preserve	8.5 million acres
Kobuk Valley National Park	1.8 million acres
Noatak National Preserve	6.6 million acres

Central Alaska Network

Denali National Park and Preserve	6.1 million acres
Wrangell-St. Elias National Park and Preserve	13.1 million acres
Yukon-Charlie Rivers National Preserve	2.5 million acres

Southwest Alaska Network

Alagnak Wild River	31,000 acres
Aniakchak National Monument and Preserve	600,000 acres
Katmai National Park and Preserve	4.2 million acres
Kenai Fjords National Park	700,000 acres
Lake Clark National Park and Preserve	4 million acres

Southeast Alaska Network

Glacier Bay National Park and Preserve	3.3 million acres
Klondike Gold Rush National Historical Park	13,000 acres
Sitka National Historical Park	110 acres

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