National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

# Climate Monitoring Protocol for the Central Alaska Network

## *Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve, Version 1.01*

Natural Resource Report NPS/CAKN/NRR—2018/1599



ON THE COVER
Eielson Visitor Center climate station in Denali National Park and Preserve.
Photograph by Ken Hill, National Park Service.

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Natural Resource Report NPS/CAKN/NRR—2018/1599

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# Revision History Log

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|---|---|---|---|---|---|
| 1.00 | 12/20/2006 | P. Sousanes | Edits for clarity and content | Incorporated peer-reviewed comments | 1.01 |
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# Standard Operating Procedures

Important Note: The CAKN Climate Monitoring Protocol consists of this Protocol Narrative and the following Standard Operating Procedures (SOPs):

**Adding Sites to the Climate Monitoring Program**

SOP 1: Evaluating New Climate Station Locations
SOP 2: Compliance and Permitting

**Climate Station Set-up Procedures**

SOP 3: Initial Climate Station Equipment List
SOP 4: Climate Station Specifications/Sensor matrix
SOP 5: Datalogger Software Instructions
SOP 6: Datalogger Programming
SOP 7: Obtaining a GOES/DCS ID
SOP 8: Programming the HDR GOES Transmitter
SOP 9: Station Deployment Equipment List
SOP 10: Climate Station Installation
SOP 11: Links to Instruction Manuals

**Annual Data Collection and Maintenance Procedures**

SOP 12: Climate Station Data Collection – PDA
SOP 13: Climate Station Data Collection – Loggernet
SOP 14: Climate Station Data Collection – Storage Module
SOP 15: Station Maintenance/Calibration Schedule
SOP 16: Station Maintenance Check-list
SOP 17: Photographical Documentation
SOP 18: Keeping Maintenance Logs

**Data Management and Reporting Procedures**

SOP 19: Data Quality – Accessing ASCADS
SOP 20: Entering Metadata into ASCADS
SOP 21: Data Access and Archiving

**Analysis and Reporting**

SOP 22: Climate Data Analysis
SOP 23: Climate Monitoring - Reporting
SOP 24: Revising the Protocol

# Abstract

This document is the narrative for the Climate Monitoring Protocol for the Central Alaska Network. The narrative explains the rationale for monitoring climate and sets forth the objectives. The narrative discusses the specific parameters to be monitored and provides a history of protocol development. The narrative also describes the sampling design and provides an overview of the standard operating procedures required to implement climate monitoring and report findings.

# I. Introduction

## Issue being Addressed and Rationale for Monitoring Climate

Climate, by determining 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. In order to properly monitor an ecosystem, the changes in the physical environment must be properly monitored and documented. In general, Alaska has a sparse dispersion of climate monitoring sites (Simpson et al. 2002). Currently, the few permanent long-term climate monitoring sites in the CAKN region are biased towards low elevation areas of human habitation bordering the parks. There are large regions within CAKN parks with no climate monitoring stations at all (e.g., YUCH, WRST).

The Central Alaska Network (CAKN) encompasses strong climate gradients, from the maritime climates in the southern parts of Wrangell – St. Elias National Park and Preserve (WRST) where it borders the North Pacific Ocean, to the strongly continental climates found in northern parts of Denali National Park and Preserve (DENA) and Yukon –Charley Rivers National Preserve (YUCH). A transitional climate region lies between the coast and the interior influenced by major mountain ranges which act not only as the environmental controls to drive climate but also contribute to the highly localized micro climates found in complex mountain terrain. The climate gradients are intrinsic to the ecosystem patterns, and vegetative and faunal communities found in CAKN parks.

Records of temperature and precipitation are especially important to documenting climate and understanding climate effects on ecosystems. Strategic deployment of new climate stations in the CAKN parks will provide data not heretofore available on climate patterns and extreme events, such as floods, droughts, and severe temperatures. In addition, the climate stations will provide real-time weather data which is of immediate use to park management and park operations. Climate data from the CAKN will also contribute significantly to the understanding of Alaska climate by filling in some of the big gaps in the existing multi-agency climate monitoring station network, and by contributing accurate measurements of winter precipitation.

A predominant feature of climate in high latitude regions is the presence of a seasonal snowpack. The snowpack is a major influence on hydrology, vegetation, and faunal communities (Jones, et al. 2001). Accordingly, the Central Alaska Network identified climate, and snowpack--as the dominating feature of the regional climate--as an important Vital Sign (MacCluskie and Oakley 2003). Although snowpack is inherently related to climate the sampling methods for monitoring snow vary enough from those of climate monitoring to warrant a separate protocol.

## Development of the Protocol

The development of the climate monitoring protocol for CAKN was built on the existing foundation of weather monitoring initiated in 1992 at Denali National Park and Preserve as part of the Long-term Ecological Monitoring Program (LTEM). Initially, weather monitoring at Denali consisted of six climate stations at different elevations within a single watershed. The spatial extent of weather monitoring was expanded over the years to incorporate existing stations in the park operating for various reasons, such as fire weather, aviation safety, and forecasting. In 2001, the LTEM program underwent a review and the shift of the program moved beyond the Rock Creek watershed. During this review, park staff made recommendations for new climate stations at various locations around the park. These determinations were made primarily based on siting stations in areas where there was no existing information, areas co-located with other monitoring efforts, and areas that were accessible via fixed-wing aircraft.

In 2002, the LTEM program was integrated with the newly formed network and the spatial extent of climate monitoring needed to expand in order to characterize the various ecoregions of the 21.7 million acres of network parklands. The development of the CAKN climate monitoring program took approximately two years, and included scoping workshops, regular meetings, equipment testing, site evaluations, documentation, and external reviews.

Table 1 below outlines the major milestones of the climate monitoring protocol development to date; italicized text indicates the item was a LTEM function prior to the formation of CAKN, but critical to the development of the program. (Please note that, as a better representation of long term monitoring, the terminology changed from weather monitoring to climate monitoring as the program was integrated with CAKN).

Table 1. Milestones of the CAKN Climate Monitoring Program

| Task/Action/Event | Date | Outcome |
|---|---|---|
| Denali Long-term Ecological Monitoring (LTEM) Weather Program at Denali | 1993-2001 | - Development of weather monitoring protocols at watershed level<br>- Eight years of micrometeorological data from Rock Creek watershed in Denali |
| Denali LTEM Meetings | October/November 2001 | - Developed conceptual model of physical environment -Climate came across as primary of ecosystem dynamics.<br>- Expand spatially to determine how average climatic conditions vary throughout the park, and to provide a baseline from which to measure future climatic shifts affecting the Denali ecosystem. |
| CAKN Scoping Meeting | April 2002 | - Presented physical monitoring strategy, including climate and snow monitoring, developed from Denali LTEM work and physical science staff work sessions.<br>- Panel of experts convened to address sampling design and strategy for climate monitoring (as well as other physical components). |
| Integration of Denali LTEM Program and CAKN | June 2002 | - Synthesis report completed on weather monitoring at Denali, including recommendation for future monitoring efforts. |
| Equipment Purchased for (10) CAKN Climate Stations | September 2002 | - Data on physical science environment desired by all subject areas – CAKN technical committee prioritized these needs first. |
| Physical Science Work Group Meeting | November 2002 | - Discussions on instrument installation, additional equipment needs, snow monitoring ideas beyond traditional snow surveys, sampling frequency, sampling units, and equipment standards |
| CAKN Vital Signs Monitoring Plan Phase I Report Completed | December 2002 | - Introductory and background material on CAKN, including goals and preliminary objectives, overview of existing information, development of plan, and conceptual models. |
| NOAA Climate Reference Network Workshop | March 2003 | - NOAA presented background information on Alaska's climate (PRISM and ANUSPLIN) climate models and discussed ideas and asked for comments regarding implementation of network in Alaska. Potential partner opportunity discussed between NPS and NOAA. |
| Installation of Climate Station "test farm" at Denali | May 2003 | - Set-up new stations near Denali park headquarters to develop designs for added instrumentation, work out programming bugs, and familiarize personnel with instrument nuances. |
| Site Visits | June-August 2003 | - Visited over 40 potential climate station sites in DENA, WRST, and YUCH. |
| Site Evaluation Document | September–December 2003 | - Compiled all site visit documentation into report titled, "Climate Monitoring Site Evaluation 2004". Report included site descriptions, photos, and location maps, as well as a summary of existing climate stations. |
| Site Evaluation review | January–March 2004 | - Solicited substantial review of site evaluation from climate experts. Met individually with five review panels to present and discuss the climate monitoring program development. |
| Final Site Evaluation Document | May 2004 | - Final report on site evaluation process with reviewer's comments and list of prioritized sites. Report also includes substantial background information on existing sites. |
| Protocol Development Summary | June 2004 | - Short summary on monitoring approach, objectives, schedule, budget and products. |
| Initial Equipment Deployment | June–September 2004 | - Installed 3 new sites and upgraded 3 LTEM sites to CAKN specifications |
| Protocol Development | September–November 2004 | - Develop protocols for the climate monitoring program |
| Protocol Review | 2005–2006 | - Review of protocols |

## Climate Monitoring in Alaska

This section of the narrative will briefly describe the state of the climate in Alaska based on current literature and information, including climate trends over the past few decades and the consequences of a changing climate on Alaska's ecosystems. The CAKN climate monitoring program will, over the next few decades, add to the understanding of the climate of central Alaska, by providing more information on weather and climate patterns in areas that are currently under represented. Existing climate models can only be run with information that is currently available, and by adding more stations to the array, the information will be tighter and hopefully more representative of the highly complex and varied Alaskan climate.

The International Panel on Climate Change (IPCC) Third Assessment Report summarized the evidence that the Earth's, and more particularly the Arctic's, climate is changing more rapidly and persistently than at any time since the beginning of civilization. Alaska has warmed substantially over the 20th century, particularly over the past few decades (Overpeck, et al.1997). Average warming since the 1950s has been 4°F (2°C). The largest warming, about 7°F (4°C), has occurred in the interior of Alaska in winter (Chapman and Walsh 1993; Weller, et al. 1998). The growing season has lengthened by more than 14 days since the 1950s (Keyser, et al. 2000). Some records suggest that much of the recent warming occurred suddenly around 1977, coincident with the most recent of the large-scale Arctic atmosphere and ocean regime shifts (Weller and Anderson 1998).

Alaska has also grown wetter recently, with precipitation over most of the state increasing 30% between 1968 and 1990 (Parson 2000). The observed warming is part of a larger trend through most of the Arctic corroborated by many independent measurements of sea ice, glaciers, permafrost, vegetation, and snow cover. In contrast to other regions, the most severe environmental stresses in Alaska at present are climate-related.

It is difficult to tell how much of Alaska's climate change is due to global warming and how much is due to natural climate cycles. The Pacific Decadal Oscillation (PDO) - an El Niño-like fluctuation of temperatures between the north and tropical Pacific that takes place over 20-30 years - flipped Alaska into a warming phase in the 1970s. The North Atlantic Oscillation has also contributed to warmer winters in Alaska since the late 1960s (Thompson and Wallace 2001).

Dramatic melting of snow and ice in Alaska has been occurring over the last few decades due to the warming climate. Warming has caused melting of permafrost and permanent snowfields as well as a reduction in seasonal snowfall and shorter seasons of river and lake ice. Permafrost temperatures over most of the sub-Arctic land areas have increased by several tenths of a degree C up to 2°C during the past few decades, and the depth of the layer that thaws each year is increasing in many areas. Over the coming hundred years, these changes are projected to continue and their rate to increase, with permafrost degradation projected to occur over 10-20% of the present permafrost area, and the southern limit of permafrost is projected to shift northward by several hundred kilometers. Continued warming will cause further reductions in snow cover, permafrost and a corresponding shift in landscape processes.

One of the most important outcomes of the winter climate of the subarctic is the creation of a snow cover. This snow cover protects and insulates the ground and low-lying plants, reduces desiccation, and maintains ground temperatures that range from 5° to 30°C higher than air temperatures. Active-layer thickness and spring snowmelt run-off, often the peak discharge of the year, all depend on the amount and distribution of the snow (Olsson, et al. 2002).

The major subarctic vegetation zones include the boreal forest and tundra. Models predict community shifts from tundra to forest, black spruce to deciduous forest, and forest to grasslands, bogs and wetlands (Starfield and Chapin 1996; Alaska Regional Assessment Group 1999). This change, along with rising sea levels, is projected to shrink tundra area to its lowest extent in at least the past 21,000 years, potentially reducing the breeding area for many migratory bird species and the grazing areas for land animals that depend on the open landscape of tundra. Half the current tundra area is projected to disappear in this century. Caribou herds depend on the availability of abundant tundra vegetation and good foraging conditions, especially during the calving season. Warmer temperatures will result in a longer growing season, and changes in precipitation and community types will result in changes in wildlife distribution and habitat use. Riparian areas,

wetlands, dry habitats, and areas with discontinuous permafrost are the most vulnerable to warming temperatures and will provide the best signals of change (Weller and Lange 1999).

Recent warming has also been accompanied by unprecedented increases in forest disturbances, including insects, blow-downs and fire. Increases in fire frequency and intensity, both related to summer warming, have occurred. Simultaneously, the potential damage from forest fires has increased due to a rapid increase in dispersed human settlement in forests.

## Climate Models for Alaska

Climate is a broad scale phenomenon and understanding aspects of Alaska's climate is important to provide context for the CAKN climate monitoring program. Latitude, altitude and continentality are the primary determinants of climate in Alaska. However, there are two factors that make detailed descriptions of climate in mountain terrain more difficult than simply assessing these factors. First is the varied topography within a mountain range, which produces microclimatic differences over very short distances. Second, there are few good high-altitude climate stations in existence because of feasibility, reliability, accessibility, and accuracy. The development of the CAKN climate monitoring program considered what is known about Alaska's climate and will attempt to expand the knowledge base by placing climate stations where the statistical analysis for existing models is weak, where they will contribute the most valuable information to the understanding of Alaska's climate as a whole, and where they are most representative of a surrounding ecosystem. All of which pose huge challenges. The following information was used as a tool for siting new climate stations, with the help of the authors that could interpolate the models and suggest where there was need for improved observations. Many of the areas that were under represented in the models were within the boundaries of Wrangell – St. Elias National Park and Preserve and Yukon-Charley Rivers National Preserve.

Mean monthly climate maps of surface temperature and precipitation in Alaska produced by the Australian National University Spline Interpolator (ANUSPLIN, Hutchinson, 1995) and Parameter-elevation Regression on Independent Slopes Model (PRISM) models were analyzed in 2002 and 2003 (Simpson et al., 2002; 2003). The PRISM model (Daly, et al. 1994; 2001) assumes that a localized region elevation is the most important factor in the distribution of temperature and precipitation. ANUSPLIN (Vose, et al. 1992) uses elevation as an independent third variable with latitude and longitude to define interpolated surfaces. This allows regional climate variations associated with latitude and continentality to be taken into account simultaneously with elevation and rain shadow effects, provided that these are captured sufficiently by the station network (Fleming, et al. 2000). ANUSPLIN uses a spatially sparser input data set compared to that used by PRISM, with a varying period of record that ranges from 10-50 years or more. Differences between the two data sets provide guidance for an improved operational climate services program currently under implementation and described below. There are some serious limitations, especially for the absolute values of precipitation that affect both ANUSPLIN and PRISM to varying degrees. The very sparse precipitation gauge network in Alaska suffers from the same systematic errors and inhomogeneities in precipitation measurements observed elsewhere (Sevruk 1982). Inhomogeneity is especially severe in Alaska. This information can, in turn, be used to design a better climate observing system for Alaska. The PRISM model data set provides the best currently available spatial coverage. Figures 1a, b, c show the mean annual precipitation, the January mean temperature, and the July mean temperature maps of Alaska

James Simpson from the Scripps Institution of Oceanography presented information on long-term climate patterns in Alaska from two recent publications (Simpson, et al. 2002 and 2003). The summary of his presentation was valuable for the development of the CAKN climate monitoring program. Key points are listed below:

- Alaska is divided into an interior zone with a small coastal extension in south central Alaska with consistent seasonal differences (extremes in temperature; moderate variation in precipitation) that contrasts with the consistent seasonal differences in the coastal domain (moderate variation in temperature; extremes in precipitation).
- The boundary between these zones is a region of maximum interannual variability (little year to year consistency in temperature and precipitation) but low mean long term variability.

- The annual cycle, El Nino Southern Oscillation (ENSO), reversals in the Pacific Decadal Oscillation (PDO), Arctic Oscillation (AO), continentality, and seasonal changes in the direction of storms into Alaska explain most of the variability in Alaska climate.
- Interior Alaska and Western Canadian temperatures are more strongly influenced by PDO.
- AO also influences precipitation more than temperature, especially along the northern coast and interior Alaska.
- The first Advanced Very High Resolution Radiometer (AVHRR)-based Alaska vegetation map defined four ecosystems (coastal rainforest, western coastal shrub tundra, Arctic tundra and Interior boreal forest).
- One major transition zone exists between the boreal forest and the coastal rainforest, formed by Cook Inlet and Copper River basins.
- The total energy balance, precipitation and their temporal phase explains much of the climate/vegetation relations.

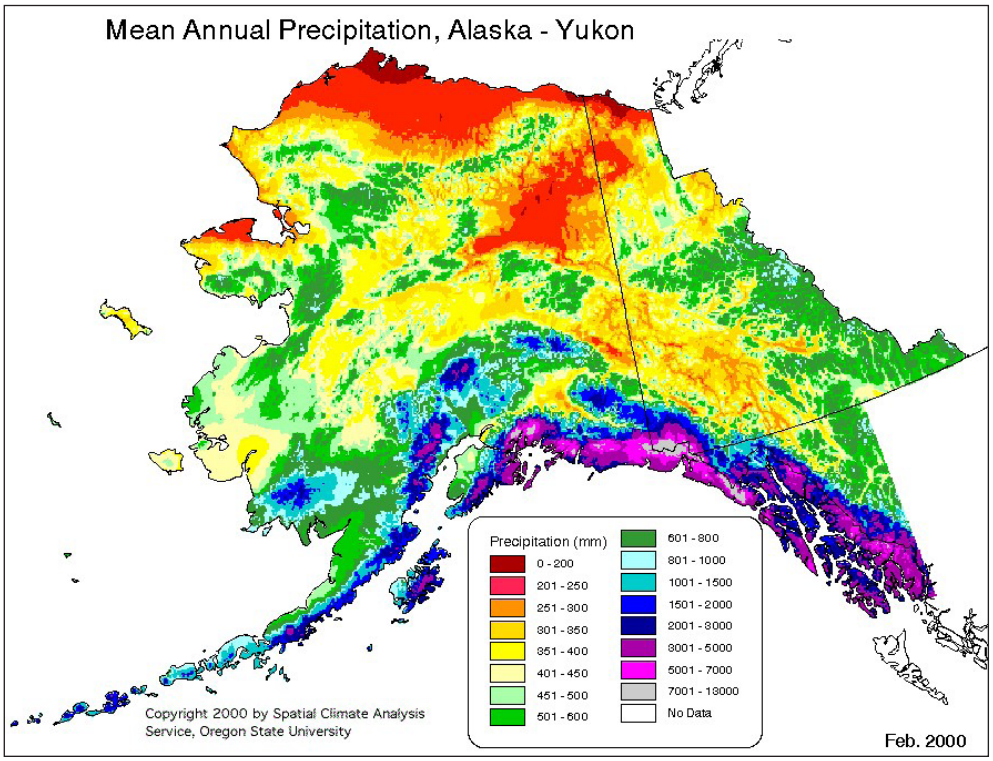



Figure 1a. PRISM map of Alaska: mean annual precipitation, Alaska - Yukon. Copyright © 2000, PRISM Group, Oregon State University, http://www.prismclimate.org. Maps created February 2000.

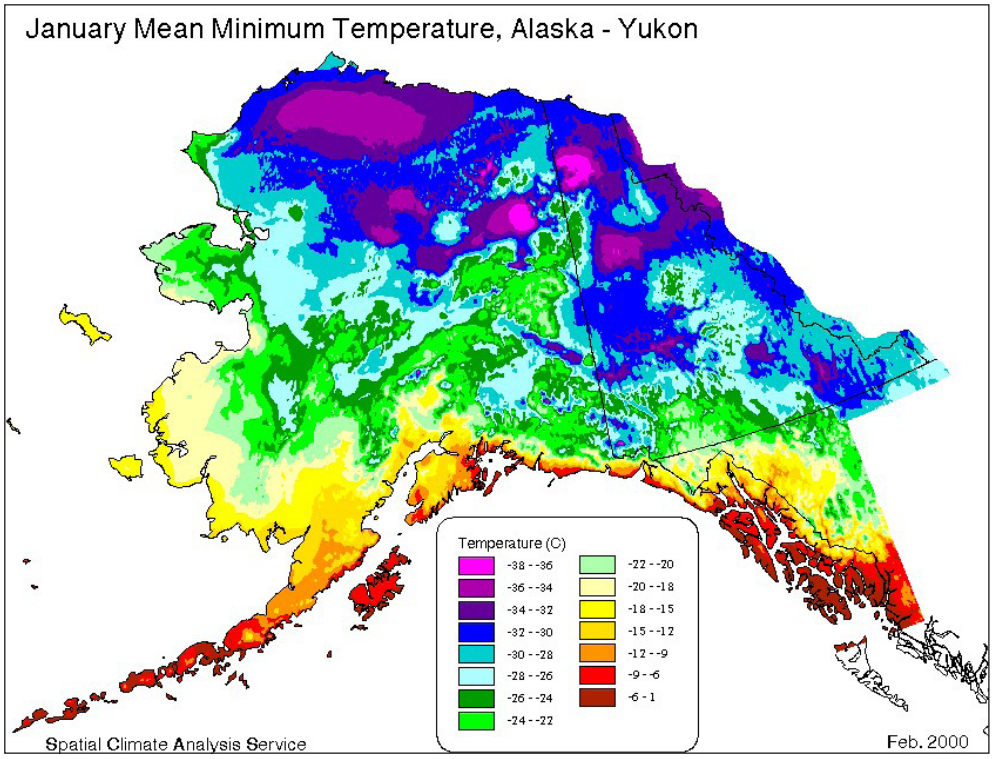



Figure 1b. PRISM map of Alaska: January mean minimum temperature, Alaska - Yukon. Copyright © 2000, PRISM Group, Oregon State University, http://www.prismclimate.org. Maps created February 2000.

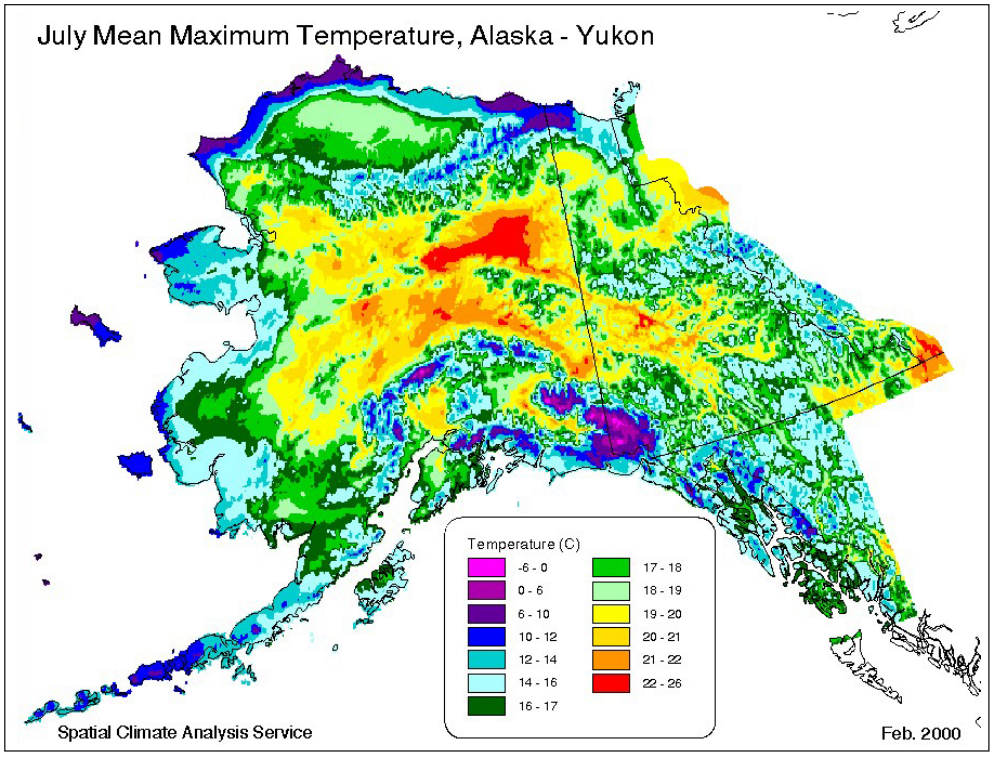



Figure 1c. PRISM map of Alaska: July mean maximum temperature, Alaska - Yukon. Copyright © 2000, PRISM Group, Oregon State University, http://www.prismclimate.org. Maps created February 2000.

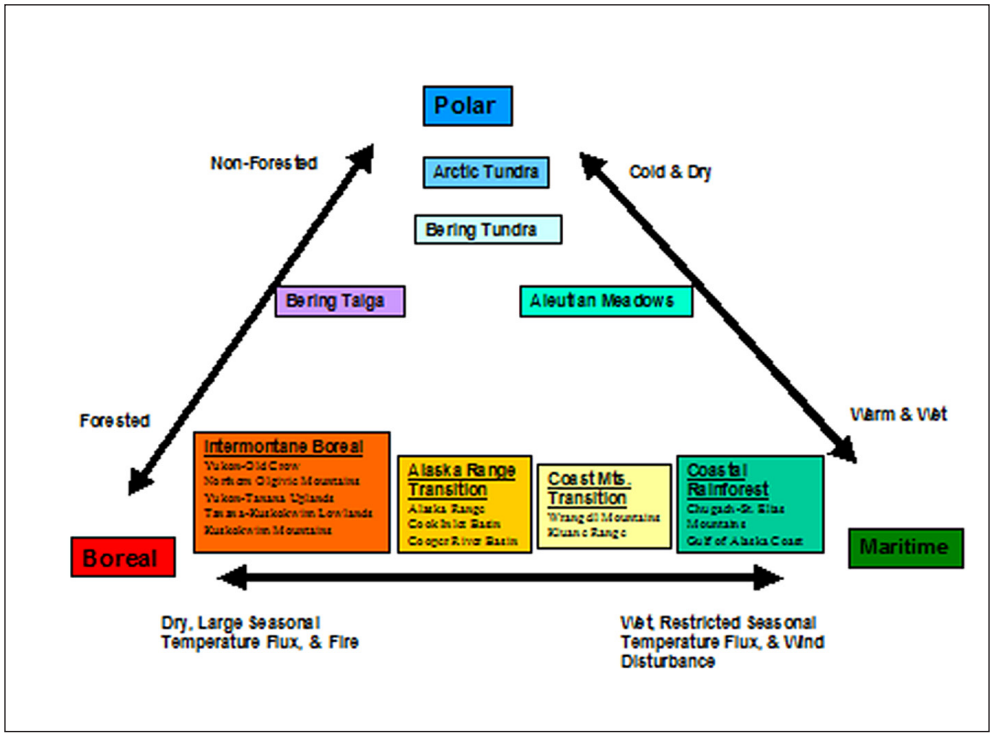



Figure 2. Climatic and environmental relationships among ecoregions in Alaska (from Nowacki et al. 2002). Ecoregions found in Central Alaska Network parks are shown grouped by ecoregion regime.

## Conceptual Models of Climate-Environment Relationships in CAKN

The conceptual models discussed in both the Central Alaska Network Vital Signs Monitoring Plan, Phase I Report (MacCluskie and Oakley 2002) and Phase II Report (MacCluskie and Oakley 2003) are also integral to understanding the complexity of the climate variations of elevational and latitudinal gradients within the parks. The CAKN parks fall within the continuum of a maritime climate to an interior boreal forest regime with transitional climate regions between the two complicated by major mountain ranges which act not only as the environmental controls to drive climate but also contribute to the highly localized climates found in complex mountain terrain (Figure 2). There is a vast region where additional climate stations can greatly enhance our knowledge of the Alaskan climate, and in particular the climate dynamics of the ecoregions of the CAKN.

In an attempt to better understand climate variation as well as possible long-term changes in ecosystems of the Central Alaska Network, new long-term climate monitoring stations will be installed throughout the three parks in the coming years. These stations will be added to the existing array of climate stations within and around the three parks operating under various federal and state programs.

## CAKN Climate Monitoring Objectives

The main objective is to monitor and record weather conditions at representative locations in order to quantify one of the drivers in Alaskan ecosystems, identify long and short-term trends, provide reliable climate data to other researchers, and to participate in larger scale climate monitoring and modeling efforts.

Specific objectives:

1. Record long-term trends in temperature and precipitation through fully instrumented sites placed in the parks at representative areas, and maintain the integrity of existing National Weather Service (NWS) Cooperative sites with long-term records [additional upland sites in interior Alaska and sites on the leeward side of the Wrangell-St. Elias mountain range will fill considerable gaps in climate knowledge of the network as well as the state of Alaska. *Justification: Measurements of temperature and precipitation will provide information on the primary driver of an ecosystem that in*

*turn affects all other components being monitored within the program.*

2. Record long-term trends in secondary climate drivers such as wind speed, solar radiation, and relative humidity. These measurements provide information on the localized climate. These data are also very useful indicators for fire ecology. *Justification: These measurements are standard measurements that can easily be added to an existing station that is recording air temperature and precipitation. These data are useful for a variety of research projects including vegetation studies, avian monitoring, fire ecology, as well as management issues such as building specifications, aviation, and safety.*
3. Distribute data in convenient formats to evaluate the influence of local and global climate cycles on resources within the ecosystem. *Justification: The CAKN has prioritized the need to monitor the potential of global climate change and climate patterns to influence species and ecosystems within the parks. The existing long-term dataset at a number of National Weather Service Cooperative Observer Stations in and around DENA, WRST, and YUCH offer a substantial history and a head start toward meeting this objective, additional climate stations will provide more information in the remote areas that lack basic data. These stations, once placed, will provide critical climate information with the intent of operating undisturbed for the next 50-100 years.*

The CAKN Climate Monitoring program objectives will greatly enhance our knowledge of the changing climate and provide a robust baseline to assess future changes.

# II. Sampling Design

This section of the narrative will briefly describe the existing array of climate stations in and around the three CAKN parks, the critical information used to develop the strategy of climate monitoring taken from national programs and local climate user meetings and workshops, and finally a description of the two year CAKN climate monitoring site evaluation process. This final phase included site visits, site documentation, a comprehensive report, formal presentations, a review by a panel of experts, a comment period, and finally a fully justified list of prioritized sites for climate monitoring stations. The narrative in this section is directly related to the following Standard Operating Procedures:

**Adding Sites to the Climate Monitoring Program**

SOP 1: Evaluating New Climate Station Locations

SOP 2: Compliance and Permitting

## Existing Suite of Information

Existing weather stations within the Central Alaska Network and around the state of Alaska are generally located in communities and along the road system at low-lying elevations. There are few sites at higher elevations or in remote locations. Weather stations that currently exist in and around the Central Alaska Network are managed by various federal agencies and private entities. It will be a priority for the network to ensure that climate stations with long-term data sets continue to operate indefinitely so that valuable datasets are not compromised. The stations are operated and maintained by the National Weather Service, Bureau of Land Management, U.S. Forest Service, Natural Resources Conservation Service and the Federal Aviation Administration. These stations are part of larger networks with existing operating procedures and protocols. As part of the Central Alaska Network they will continue to operate under the same guidelines. It will be important to maintain a working relationship with the other agencies in order to maintain the integrity of theses sites and the data derived from them. The objectives of these various agencies are obviously not the same as the CAKN objective; therefore, an interagency agreement may be necessary to maintain the longevity of a site. If a site is in jeopardy of being shut down, and it is a site with a long-term record valuable to the network, a co-located CAKN site should run concurrently next to the site for as long as possible, and then be used in place of the station being removed. The existing programs and networks are described in Appendix A.

The CAKN climate monitoring program, as described before, was built on the foundation of the LTEM program in Denali. The locations of the five climate stations that have been in operation in the Rock Creek watershed located near headquarters since 1993-1994 are also described in Appendix A.

## Critical Information used in the CAKN Climate Monitoring Strategy

During the development phase of the climate program park staff attended a workshop in Anchorage sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) regarding a new national program known as the U.S. Climate Reference Network (USCRN). The USCRN is a network of climate stations now being developed as part of a NOAA initiative to provide future long-term homogeneous observations of temperature and precipitation that can be coupled to long-term historical observations for the detection and attribution of present and future climate change. If fully implemented, the network will consist of about 300 stations nationwide. The philosophical-technological base of the USCRN is derived from the *Climate Monitoring Principles* as initially formulated with and reviewed by the government and academic climate communities in 1992 (see Appendix B).

In 2003, the National Weather Service began to optimize the design of an improved Alaskan climate observing system in support of its new Climate Services Program (Livezy 2003), which included the development of the USCRN within the state of Alaska. Simpson, et al. (2002 and 2003) analyzed mean monthly climate maps of surface temperature and precipitation in Alaska produced by the ANUSPLIN and PRISM models. Based on the analyses of these models and in response to the NWS objective, the following suggestions were made for improving the climate observation system in the state:

1. Variability in surface temperature and precipitation is not uniform throughout Alaska. Therefore, we believe that a uniformly-spaced grid is not appropriate.
2. The regions of largest uncertainty in Alaskan climate variables are in some of the most remote places (e.g. the Brooks Range, the North Slope, the Wrangell-St. Elias Mountains, portions of interior Alaska and western Canada, the Aleutian Islands). Upgrading an Alaskan climatic observing network should emphasize the instrumentation (with satellite-telemetry capability) of such remote and under sampled areas.
3. In locating new observing stations, attention should be given to the vast upland areas of the Alaskan interior. In winter, the interior atmosphere is often decoupled vertically, due to persistent inversions. It is possible that large scale atmospheric variations such as ENSO and PDO will affect low-lying areas within the inversion layer very differently than upland areas in the free atmosphere above this layer. Currently, observational data represent low-lying areas almost exclusively.
4. Precipitation gauges in Alaska should be shielded to minimize undercatch. Undercatch of precipitation, especially during winter, is now known to be a source of significant measurement uncertainty, which can confound analyses of precipitation amount and variability both in space and time.
5. Given the magnitude and cost of the task, partnerships should be actively sought with other agencies which share similar needs and objectives.
6. A common set of quality instruments, calibration, analyses, and reporting procedures should also be adapted by partnering agencies.
7. Care should be exercised to avoid placing sites in convenient but unrepresentative locations (e.g. near airports) simply because they are easy to access and maintain or meet other objectives.
8. Common metadata standards should be defined and implemented by partnering to ensure easy access and use of climate data by the community.
9. Electronic delivery of data should be encouraged. All data belong in the public domain.

These recommendations were presented at the workshop in Anchorage as a preliminary step to the placement of new USCRN sites in the state. The NPS can play a critical role in the nationwide effort by collaborating with NOAA on site selections for (Climate Reference Network) sites. NPS units are preferred locations for long-term monitoring efforts due to their protected status.

This workshop and Simpson's recommendations coincided with the planning stages for the development of the climate monitoring plan for CAKN and played a crucial role in the development process for the site evaluation plan carried out in 2003-2004 for the network. The USCRN is in the next stage of development for Alaska and will be looking at the possibility of placing new sites within NPS units. The collaboration of NPS and NOAA makes strategic sense and satisfies the objectives of both programs.

## CAKN Site Selection Process

In an effort to fill some of the gaps in the existing climate monitoring network and increase the knowledge of climate variability across the three CAKN parks, we identified and evaluated a number of potential new sites during the summer of 2003. Our main criteria in locating sites were: 1) to get the best possible coverage across each park, 2) to sample different ecoregions within each park, and 3) to get a good elevational gradient between sites. Additionally, we considered the issue of access: a site must not be too difficult and/or costly to access for routine maintenance over the next many decades. Sites were also considered if they could be co-located with other monitoring components to reduce logistical costs by pooling resources. Criteria used in locating sites varied by park. Each park had to be evaluated differently due to both the extent of natural variations within each park and park management concerns and policies, including, for example, wilderness and historic district designations, helicopter compliance regulations, and variations in landscapes and ecoregions. The NPS Geographic Information System (GIS) available for all Alaska parks was used to map ecoregions, precipitation patterns, and land designations. Existing weather sites were plotted on these maps, from that point potential new sites were identified in areas not covered by the existing network, but critical to understanding regional climate patterns.

Over fifty sites were visited in the three parks. A site evaluation checklist was used at each site and information such as location, aspect, area, vegetation description, ground cover, soil properties and access was recorded, and at least two photographs of each site were taken. This information was compiled into a comprehensive report that described each of the sites evaluated, as well as the instrumentation, programming and power systems recommended for the climate stations. The report was distributed to a solicited review panel for comments. Formal presentations were also provided for key individuals or groups. The review panel included Gary Hufford, Jim Jones, Jim Hunter, and Larry Rundquist – NWS/NOAA, Anchorage, Alaska; Rick Thoman and Eric Stevens – NWS/NOAA, Fairbanks, AK; Rick McClure – Natural Resources Conservation Service, Anchorage, AK; Kelly Redmond and Dave Simeral – Western Regional Climate Center, Reno, Nevada, and Sharon Alden – NPS Meteorologist/Fire Weather Program Manager Alaska Interagency Coordination Center, Fairbanks Alaska. The review panel was asked to provide a list of prioritized sites for new climate monitoring stations and provide feedback on the design development of the process to date. The feedback was positive and a prioritized list of sites for each of the three parks was formulated. This initial scoping process can be used to site more stations in the future as time and budgets permit.

The comprehensive site evaluation report described above is included as Appendix C: Climate Monitoring Site Evaluation 2004. New sites were selected based on the following list of criteria developed by NPS staff after the comprehensive site evaluation review process, with recommendations from NPS scientists and the climate experts:

- Ecoregion representation
- Vegetation and soil type
- Known precipitation and temperature trends
- Gaps in knowledge
- Access to site
- Elevation, slope, aspect
- Land management issues
- Use patterns (hiking, snowmobile, etc.)
- Wildlife habitat, wildlife trails
- Exposure (solar and satellite capabilities)
- Wind scour
- Proximity to large water bodies or obstructions

Maps showing the locations of the new sites selected are shown in Figure 3. SOP #1, "Evaluating New Climate Station Locations," also has maps of the site locations as well as the prioritized list of sites, and the specific methods used for evaluation at each park.

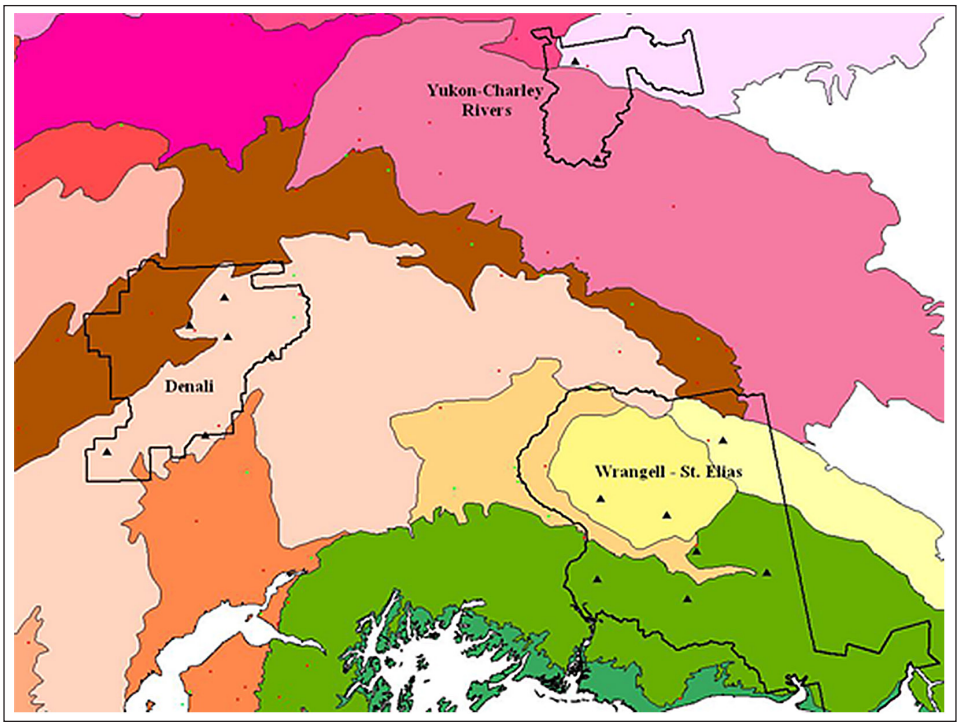


Figure 3. Location of new climate monitoring sites for CAKN

SOP #2, "Initiating Compliance and Permitting" addresses the issue of permitting and compliance for adding these additional sites within NPS guidelines.

While new sites will enhance our knowledge, we must realize that any site that is chosen will not be free form localized effects such as topography, latitude, elevation, and continentality. The severity of conditions that must be endured can vary greatly in short distances, and thus need to be evaluated individually for each site. Especially in regions of high topographic relief, but even in seemingly simpler situations, it is often better to think of stations as providing "index" values, rather than values of the "true" climate, which vary continuously and on fine scales, even to a few meters. The question of what a "representative" site actually represents seldom has a simple and straightforward answer. Climate measurements must meet a higher standard than "weather" measurements. The most demanding of these is consistency through long periods of time. A time frame of 50–100 years should be envisioned (Redmond and Simeral 2004).

# III. Deployment and Operation of Climate Stations

In this section, we provide an overview of how climate stations are acquired, programmed, deployed and operated. This section provides a context for the specific SOPs included in the CAKN Climate Monitoring Protocol shown below:

**Climate Station Set-up Procedures**

SOP 3: Initial Climate Station Equipment List

SOP 4: Climate Station Specifications/Sensor matrix

SOP 5: Datalogger Software Instructions

SOP 6: Datalogger Programming

SOP 7: Obtaining a GOES/DCS ID

SOP 8: Programming the HDR GOES Transmitter

SOP 9: Station Deployment Equipment List

SOP 10: Climate Station Installation

SOP 11:Links to Instruction Manuals

## Parameters Being Monitored

Temperature and precipitation were identified as the most important variables or drivers in the ecosystem context, followed by wind, solar radiation, and relative humidity. These parameters will be measured at each of the CAKN climate monitoring sites. The standards used, which refer to the distance of the sensors from the ground surface, are based on the World Meteorological Organization's (WMO) Guide to Meteorological Instrument and Observing Practices (WMO, 1971) and the National Science Foundation (NSF) Long-term Ecological Research Site Climate Protocols (Greenland 1986). The list of equipment necessary for procurement for a climate station is described in SOP #3, "Initial Climate Station Equipment List" and the climate station specifications are outlined in a matrix in SOP #4, "Climate Station Specifications/Sensor Matrix".

Measuring precipitation in Alaska is inherently difficult. While rainfall in summer is relatively easy to measure the transitional fall and winter precipitation events and the snowfall in winter are difficult to measure accurately, especially when a station is remote. It has been well documented that wind-induced gauge undercatch of precipitation, among other known systematic errors, is the greatest source of bias in precipitation observation (Yang, et al. 1999). To reduce the wind-induced undercatch various types of shields can be used depending on the location and wind exposure. The initial CAKN climate stations will have shielded tipping buckets on site to record summer rainfall and an ultrasonic distance sensor that will record the current snowpack depth.

In order to accurately measure year-round precipitation CAKN will work cooperatively with the Natural Resources Conservation Service (NRCS). The NRCS has been successfully running remote SNOTEL sites, or snow telemetry sites, in the state of Alaska for many years. The details of snowpack monitoring are described in the Snowpack Monitoring Protocol for the Central Alaska Network.

## Equipment Purchase

Campbell Scientific, Incorporated (CSI) research-grade meteorological instrumentation is being used for the CAKN climate stations. Although the equipment is purchased through this vendor the sensor array is not limited to this manufacturer. For example, a R. M. Young Wind Monitor is used to measure wind speed and direction, but the instrument is sold through CSI for compatibility with their datalogger. SOP #3 identifies the initial equipment list that was purchased for this project. Equipment was purchased in FY2002 and assembled and operated locally for trouble-shooting and assessment. During FY2003, two stations were also tested in field locations in cooperation with other park projects. In 2004, remote stations were deployed for further testing within the design development phase. This testing phase is an extremely valuable stage for the network. Inherent bugs in programming, instrumentation, power systems, and many other miscellaneous problems will be identified before the stations are fully operational. The stations were specifically designed for remote, high latitude, extreme cold conditions. The stations are simple and robust. Adding additional sensors on to the equipment for other research projects is discouraged. Keeping the stations consistent and simple will aid in the longevity of the monitoring program. Separate dataloggers and equipment should

be used for ancillary research projects, the main objective of these stations is to collect climate data for the next 50–100 years.

## Datalogger Programming

A CSI CR10X datalogger is being used for the initial installation. Technological advances in this type of equipment should be expected and planned for in the budget. The CR10X data logger is currently programmed with the software LoggerNet produced by Campbell Scientific, Incorporated. See SOP #5, "Datalogger Software Instructions". The version used during the climate station installation in 2004 is Version 2.1C. This version will most likely be updated within the next year. It is important to keep the software current. Downloads of patches for upgrades are generally available on the CSI website at http://www.campbellsci.com. It is recommended that CSI technicians be contacted at least once a year to verify which versions of software are being used; they also make this information available via their website and mailings.

CSI CR21X dataloggers are being used for the LTEM sites located in Denali. These dataloggers are retired (meaning they don't sell them anymore), but still supported by CSI. These dataloggers will be replaced with CR10X dataloggers and the stations will be upgraded with satellite transmitters as the budget permits. Instructions manuals for these older dataloggers are available via hardcopy at Denali National Park and Preserve or by request at CSI. The current software described below supports these older models.

EDLOG is the name of the module within LoggerNet that allows for individually tailored programs to be compiled by the station operator depending upon the sensors used and the time intervals desired for measurements. This programming tool provides flexibility not found in other instrumentation. The initial program developed for the design phase deployment is named CAKN_1 and is included in SOP #6, "Datalogger Programming" along with a brief explanation of the functions of the EDLOG software. The nomenclature for future programming versions should include a date but the file name cannot exceed 8 characters, an example would be V1_12004 where V1_1 is Version 1.1 created in 2004, subsequent versions would increment to the next number, i.e. V1._22005. The CR10X Measurement and Control System's Operator's Manual should be made available to anyone programming the dataloggers. These manuals come with the original purchase of the datalogger or can be obtained by contacting CSI.

## Satellite Communication

The hourly data from the climate stations are transmitted via satellite telemetry. Prior to programming a satellite transmitter a Geostationary Operational Environmental Satellites (GOES) Data Collection System (DCS) ID needs to be obtained from the National Atmospheric and Oceanic Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS). The GOES Data Collection System (DCS) is a relay system used to collect information from earth-based platforms. These platforms transmit an electronic signal, containing the environmental data observed by the sensors on the platform, at predefined wavelengths and times. The transponder on board the satellite detects this signal, and then rebroadcasts it so that it can be picked up by the ground equipment at the Wallops Command and Data Acquisition (CDA) station, in Wallops Island, Virginia. Use of the GOES Data Collection System is regulated, by law, to the collection of environmental data by U.S. federal, state, and local government agencies, and by international government agencies and research organizations with a U.S. government **sponsor.** A prospective user must first apply for and be granted a System Use Agreement (SUA) by NESDIS, which is typically renewable every 5 years (2 years for manufacturers). Once the SUA has been approved and signed, the user must purchase equipment that has been certified to be compatible with the GOES DCS. In 2002, the CAKN requested, and received thirteen new IDs; currently 11 of the 13 are assigned to specific locations. SOP #7, "Obtaining a GOES/DCS ID" includes the DCS System User Agreement form that needs to be included in the application for new user IDs along with the user agreements and the current IDs assigned for the CAKN climate stations.

A Seimac High Data Rate (HDR) satellite transmitter is being used for the initial installation of climate stations. There will be periodic updates to the software of the transmitter. Prior to any field visit contact Campbell Scientific, Inc., to inquire about the latest upgrades. The transmitter is programmed using DCPComm for Windows distributed by

Seimac Limited. The software is included with the purchase of the transmitter. Version 1.9 build 2 was used during the initial installation. The current operating program used in the transmitters is Version 3.2.4 current as of August 2004. The version of the operating program will be continually updated. SOP #8, "Programming the HDR GOES Transmitter" describes the methods used to program the SAT HDR GOES Transmitter using DCPComm software.

## Equipment Deployment

Prior to going to the field to install a station a number of steps need to be taken. All equipment must be prepared, packed, and double-checked before the trip commences. SOP #9, "Station Deployment Equipment List" describes: a) the method to packing the equipment that will ensure the package is complete for transport and, b) the tool list required for installation and maintenance of CAKN climate stations. The climate station will be installed according to the CSI Instruction Manual entitled "Tripod Weather Station." Installation procedures specific to CAKN climate stations is described in SOP #10, "Climate Station Installation."

The complete tower or tripod can be procured through Campbell Scientific, Inc. This package will include a tripod, grounding rod, ground cables, lightning rod, and tripod rebar pegs. This set-up can also be built, but will require the purchase of all hardware necessary for a complete tripod installation. The power system (including deep cycle sealed lead acid batteries, arctic grade wire, and solar panels) was purchased within the state of Alaska. Procurement of a solar panel that will power the current array of sensors is required. At the time of the initial installation a combination of solar panels with a total wattage of between 60 – 75 watts was being used. Two 100 amp hour 12 Volt batteries were used at each site with terminal connectors connecting the batteries in parallel. Arctic grade wire, resistant to freezing and UV damage was used for all wiring connections. Slight modifications to some of the sensor mounting devices were made to ensure accurate measurements. Because a larger solar panel was mounted on the tripod this necessitated moving the air temperature sensor away from the tripod mast so as not to be affected by the shading or warming produced by the panel. The extended arm for the air temperature sensor used channel unistrut for a mounting device and was counter balanced with the snow depth sensor extending in the other direction between two of the tripod legs. This placement was necessary so that the snow depth sensor would not read the leg of the tripod when sending an ultrasonic reading towards the ground to determine snowpack depth. A 4' x 4' piece of plywood was anchored to the ground under the snow sensor to maintain the horizontal surface for accurate measurements. A four foot pipe was used to mount the tipping bucket away from the tripod, and flexible conduit was used to protect the 25' sensor lead. Soil temperature probes were placed at .5 and 1 meter depths using a combination of a soil auger and digging bar. In some cases a square meter pit was dug and the probes pushed into the soil horizon at the appropriate depth. The use of the soil auger method is preferred because it requires fewer disturbances to the ground. Standard mounting arms were used for the wind monitor and pyranometer.

Each of the sensors used as part of climate station have individual instruction manuals that contain important information on the sensor specifications, including, wiring diagrams, programming examples, and maintenance requirements, including calibration schedules. It is convenient to have two copies of each instruction manual for each sensor, one for the office and one for the field. These manuals can also be downloaded from the CSI website. SOP #11, "Links to Instruction Manuals" contains links to all of the current instruction manuals used for the initial deployment.

The CR10X datalogger should be programmed before the field deployment. The program will be available via laptop and Personal Digital Assistant (PDA) for field circumstances, but prior to deploying a site the program should be loaded, run and tested. The GOES High Data Rate transmitter (or current transmitter) should also be programmed before field deployment. It is recommended that both the program and the satellite communication set-up be tested at the office at least a few weeks before the installation.

Station deployment may require the logistical coordination of a fixed-wing aircraft, helicopter or vehicle depending upon the site selected. The weight of a complete station, including tools is approximately 550 lbs. The equipment fits well in a Cessna 206, but would require two trips in a Cessna 185. Depending on the size of the helicopter and the personnel involved it might require multiple

trips to complete an installation. For maintenance trips one flight should be adequate. Each park and adjacent land owner follows different protocols or guidelines for flights within their jurisdiction. All proper protocols need to be followed, with arrangements made well before the trip is scheduled to take place. This will require inquiries as to the conditions of remote airstrips, fuel locations and availability, potential hazards, required OAS training, the required Personal Protective Equipment (PPE). On the day of the trip, flight plans should be filed with the appropriate authority involved whether it is the park communication center or the Federal Aviation Administration.

# IV. Annual Data Retrieval

This section describes the methods for retrieving the data from the dataloggers on an annual basis. The data are transmitted hourly and archived at various locations and a record of each hour is also stored on the datalogger itself. The datalogger dataset will be more complete than the satellite transmitted data. Inevitably a station will miss a transmission for any number of reasons, such as maintenance at the receiving facility, intense solar activity, message overlaps on either end of the transmission window, etc. The section also describes the maintenance procedures that are critical to a long term climate program. This section provides the context for the SOP section called, "Annual Data Collection and Maintenance Procedures" and includes the list of SOPs below.

SOP 12: Climate Station Data Collection – PDA

SOP 13: Climate Station Data Collection – Loggernet

SOP 14: Climate Station Data Collection – Storage Module

SOP 15: Station Maintenance/Calibration Schedule

SOP 16: Station Maintenance Check-list

SOP 17: Photographical Documentation

SOP 18: Keeping Maintenance Logs

## Data Retrieval

The CR10X data loggers have a memory capacity of 2 MB. This capacity can store the current amount of generated data for more than a year before beginning to overwrite the earliest information. Measurements are recorded every 60 seconds and each hour calculations (average, minimum, total, etc.) are made and moved to a final storage area. Each hour the datalogger is programmed to send the data stream to the GOES transmitter for a satellite transmission. These data will remain in final storage until the datalogger is accessed via computer or laptop and manually downloaded. These data should be downloaded each time the site is visited and stored in appropriate files. SOP #12, "Climate Station Data Collection – PDA" details the file download procedures using a Palm Personal Digital Assistant (PDA) and SOP #13, "Climate Station Data Collection – LoggerNet" describes the procedures for data download using a laptop computer with LoggerNet software. These data will be sent via File Transfer Program (FTP) to the Western Regional Climate Center for permanent archiving. This will ensure that the satellite transmitted data (received automatically by WRCC through the GOES system) matches the data record from the datalogger. It is likely that there will be missed transmissions, but the record in the datalogger will be complete.

The CR21X data loggers used for the LTEM climate stations in Denali NP&P store the data onsite in SM192/SM716 Storage Modules. These storage modules need to be manually swapped every couple months. SOP #14, Climate Station Data Collection-Storage Module" details the methods for collecting data using a CSI Storage Module. These stations will be upgraded in the near future with satellite transmitters and CR10X dataloggers and will then follow the same procedures for data retrieval as listed above and described in SOP #13.

The GOES transmitter is programmed to relay the data via the GOES west satellite each hour. The data are then received by the NOAA NESDIS Wallops Command and data Acquisition Station in Wallops Island, VA. The Wallops Command and Data Acquisition Station is responsible for ensuring scheduled data flow from NOAA satellites to designated user subsystems. It acquires, maintains, and distributes a continuous flow of meteorological satellite data. At this point anyone who has the satellite ID for a specific climate station can access the data. The data is stored onsite at Wallops for 72 hours and is available via the internet at http://dcs.noaa.gov/default.asp. The site requires each new user to fill out an application for accessing the site. The agencies that have access to the site that are cooperating with the NPS are the BLM National Interagency Fire Center (NIFC) in Boise, ID, the Western Regional Climate Center (WRCC) in Reno, NV, and the National Weather Service (NWS), Alaska Region.

The climate stations of the CAKN have been set-up to go through the existing Remote Automated Weather Station (RAWS) system headquartered at NIFC. There are advantages to the data flowing through NIFC. They are:

1. the data have quality control through a built-in watchdog system
2. NIFC has a software program that can post process the data
3. the data are automatically set up to link to WRCC and NWS
4. the existing RAWS depot infrastructure is capable of handling additional stations
5. the Automated Sorting, Conversion and Distribution System (ASCADS) takes the selected data from Wallops Island Data Collection System and sorts it into a relational database
6. WRCC and NWS automatically receive the data from NIFC so additional work is unnecessary
7. the ASCADS software system tracks changes to the site including maintenance trips, sensor serial numbers, sensor types and a narrative section for any comments pertaining to the station

## Maintenance and Calibration

Although these systems are automated they need human oversight and continued attention to provide the quality of data that will be useful for creating a long term climate record. The acquisition and deployment costs are a small fraction of the lifetime costs that include maintenance, quality control and data handling. In order to ensure accurate weather readings, a program of regularly scheduled maintenance/calibration, and timely response to system failures (emergency repair) is required. This maintenance plan requires every CAKN station to receive at a minimum, an annual rehabilitation/maintenance site visit. If the station is easy to access (you can walk or drive to it) the site should be visited every 6 months.

All sensors are calibrated before installation using NIST-traceable standards. The data loggers are calibrated over their environmental range by the manufacturer using NIST-traceable standards of voltage and frequency. The sensors are then calibrated on a schedule suitable to the individual sensor described in SOP #15, "Station Maintenance/calibration schedule". The timing of calibration is important; a calibrated sensor has a shelf life, so calibration should occur only prior to deployment. Annual maintenance trips will be scheduled to deal with routine maintenance issues, sensor calibration rotations, and data downloads. Additionally, if a station goes offline for any period of time emergency maintenance might be required to repair the station as soon as possible so that data gaps are minimal. This might require additional expenses in the winter when use of aircraft is somewhat prohibitive due to availability of aircraft contractors and temperature extremes. All visits to the sites will be well documented and included with the metadata for the site. SOP #16, "Station Maintenance Checklist" and SOP #17, Photographical Documentation" contain the information needed to do a complete station visit including photographical documentation. An appropriate maintenance frequency and intensity will be recommended following the first three years of station operation to assess within and between year maintenance needs. At least one annual maintenance trip per site will be necessary to download data and calibrate sensors. Each maintenance trip will be logged in two places. One is within the ASCADS system, and the other is the station operator's maintenance logs SOP #18, "Keeping Maintenance Logs"

# V. Data Management

Management and stewardship are some of the most important activities to be undertaken in climate monitoring to ensure that high-quality climate data records are collected, retained and are accessible for analysis and/or re-analysis by current and future generations of scientists, park staff/management, and the general public. The preservation of the data for future use requires facilities and infrastructure to ensure the long-term storage of the data. Once data are in electronic format, the data must be continually migrated to newer storage devices and access software or consistent format in order to preserve the data for sustained future use. Another key component of data management includes adequate monitoring of the data stream. This includes timely quality control of the observations and notification to observing system operators and managers of both random and systematic errors, so that corrective action can occur. This section provides the context for the SOP section called, "Data Management and Reporting Procedures", and includes the list of SOPs below.

SOP 19: Data Quality – Accessing ASCADS

SOP 20: Entering Metadata into ASCADS

SOP 21: Data Access and Archiving

## Overview of Data Flow

The data from the climate stations is transmitted via satellite to Wallops Island, Virginia and from there is intercepted by NIFC where it is processed and sent on to WRCC for archiving and NWS for weather forecasting and archiving. All data is stored in the datalogger on site and downloaded via computer on an annual basis. The dataset from the datalogger is sent to WRCC to ensure the data archive is complete. The data are then available via clickable link through the WRCC website which will be linked to the CAKN website. Near real-time data will be available as well as archived data.

## Data Quality Control

The CAKN climate data is automatically set up to be ingested by ASCADS. ASCADS has three primary functions:

- Retrieve data from the Geostationary Operational Environmental Satellite (GOES), convert it to a format compatible with various national systems and forward the data to those systems.
- Track entire RAWS network, regardless of agency, regardless of telemetry method. This database includes comprehensive metadata about the stations.
- Provide an on-line shared database containing documentation of annual calibration and maintenance of each individual automated weather station operated by the wildland fire community (The NPS CAKN stations are included in this database).

To assure data quality for CAKN climate stations the system will be monitored at all levels of data acquisition and storage. The Principal Investigator is responsible for the first level of quality assurance including:

- ensuring that maintenance is performed and individual maintenance logs are kept up to date.
- documentation of activities on each station is completed in ASCADS.
- visually checking outputs from the station on a regular basis (daily) to assure that the information is reflective of actual conditions.

Quality of the data is checked through the ASCADS watchdog summary reports that are sent weekly to the station operators. These summaries flag anomalies in the data stream and alert the operator. The ASCADS system logs all anomalies which are available for review by the station operator. It is imperative that the current station operator's name, phone number, and e-mail are included in the database. Datasets can be reconciled at a later date after the datalogger is downloaded manually. If there are obvious anomalies, for example if the soil temperature at .5 meters reads –53°C, there is obviously a problem with the sensor or the programming. These data will be flagged within the dataset and the anomaly will be recorded in the metadata associated with the station. The contacts for NIFC, including the user agreement form that must be completed before using ASCADS is detailed in SOP #19, " Data Quality- Accessing ASCADS" and SOP #20, "Entering Metadata into ASCADS" describes using ASCADS.

Once a problem is detected it is the responsibility of the station Principal Investigator to determine the response time for repair. If the manager is relatively confident that the problem is with the telemetry, he/she may choose to wait for a logistically opportune time to visit the site knowing that the data logger is most likely recording the hourly data on-site. For example, if the station stops transmitting in January and there is a memo regarding the potential failure of the satellite transmitter, it might be more logistically and financially feasible to wait until warmer weather so that the visit is more productive. This section of the protocol regarding response time needs to be developed further after a few years of remote testing gives a more realistic view of average repair frequency.

According to the CAKN Data Management Plan:

> A statement addressing data quality for a given I&M project will be written by the project lead immediately after completion of data verification and validation. The data quality statement will be included in the project metadata. Subsequent data collection, entry and validation events executed under the same I&M project will be accompanied by additional data-quality statements by the project lead. Each iteration of data collection, entry and validation will be clearly recorded in the project metadata such that all such data events for the project are discernible.

To accomplish this task for climate data, ideally every month the climate monitoring specialist would monitor the data availability statistics generated by the WRCC data analysis tool. Stations that have had less than 97% data availability for the month are flagged. During the next site visit the data are downloaded and sent to WRCC and the data availability is checked again. The annual report will include the data availability for all CAKN stations and reasons behind any missing data will be recorded in the metadata.

## Metadata Procedures

Many inconsistencies and apparent biases and inhomogeneities in the data can be addressed if adequate metadata information is available. International standards and procedures for the storage and exchange of metadata are in the process of being developed and implemented for world wide climate observing systems. In 2004, the WMO Commission for Climatology (CCl) published guidelines for metadata and homogeneity that begins to address this concern. The CAKN climate monitoring plan has made every effort to be consistent with the current climate observation standards and will stay abreast of any developments in the field so that the stations can record the most consistent and comparable data.

Complete documentation on each system down to the individual sensor level is integral for the program. Documentation on site visits will be a standard procedure that follows the guideline described in SOP 18 and 19. The metadata will include site photos and panoramas; lists of all instruments by serial number; dates of installation and removal of instruments; sensor calibration histories; site installation and maintenance histories; procedures for installation, calibration, and maintenance, and any and all other details associated with the instrument, site, data stream, etc. remembering that it is not possible to over document.

These site visit checklists will be filed as hard-copies and used by the program manager to update ASCADS upon return to the office. The period of update should be no longer than 5 days after the site visit so that the details of the trip are fresh. Any requests by WRCC or NIFC for metadata should be complied with in a timely manner.

## Data Archiving Procedures: National and Network

Climate data archives, more so than any other monitoring component, will be accessed long after the current station operators and program managers are gone. It is imperative that the climate data recorded by the CAKN stations are assimilated into national databases so that these data can be accessed by the public. All CAKN climate data that are transmitted via satellite telemetry will automatically be archived with the Western Regional Climate Center (WRCC) and within the Applied Climate Information System (ACIS).

> The mission of the WRCC is to disseminate high quality climate data and information pertaining to the western United States; foster better use of this information in decision-making; conduct applied research related t o

climate issues; and improve the coordination of climate-related activities at state, regional and national scales. The WRCC, inaugurated in 1986, is one of six regional climate centers in the United States. The regional climate center program is administered by the National Oceanic and Atmospheric Administration. Specific oversight is provided by the National Climatic Data Center (NCDC) of the National Environmental Satellite, Data, and Information Service (NESDIS).

All other climate data collected by the CAKN climate monitoring program, which are not transmitted via satellite, will be transferred to the WRCC via file transfer at periodic intervals. This is outlined in the cooperative agreement initiated in 2004 and included as Appendix D. These data will then be disseminated via the WRCC/CAKN website and archived at WRCC. These data, mainly the LTEM prototype data from Denali will be transferred in their entirety to the WRCC archives so that the electronic data archive is complete and in one place. This specific task is addressed in the 2004 cooperative agreement with WRCC

## Accessing Data

The climate data are available via the WRCC web site in near real-time. Daily and monthly summaries can be generated, and complete data records can be downloaded. Electronic files can be downloaded on an annual basis for inclusion in the network database if desired, however the NPS system is currently not set up for a database of this size. The continuous flow of climate data on an hourly basis from all of the CAKN climate stations would require the use of a larger system, such as Oracle, capable of handling large volumes of data. Perhaps in the future a national Inventory and Monitoring database for climate will be developed to handle the volume of data, but for now we will use the WRCC repository. SOP #21, "Data Access and Archiving" describes the data access and archiving process.

The data management plan outlined in this protocol has been discussed with both Doug Wilder, CAKN data manager and Jon Paynter, Denali GIS specialist, and both agreed that this action for data dissemination and archiving of climate data seems logistically sound. The process should be reviewed after the data contracts and cooperative agreements are completed and the program is fully operational.

# VI. Analysis and Reporting

This section describes the methods for analysis and reporting that are being developed for the climate monitoring program. This section will likely change significantly in the first few years of operation as current contracts are completed and the process for reporting is streamlined for maximum usefulness and efficiency. This section includes the SOPS under the subheading analysis and reporting and includes the following:

SOP 22: Climate Data Analysis

SOP 23: Climate Monitoring - Reporting

SOP 24: Revising the Protocol

## Climate Data Analysis

The details of the data analysis are being developed through a data analysis contract concurrent with the protocol development and will be finalized in 2006. The reporting tools are also being developed through a cooperative agreement with the Western Regional Climate Center. Critical tasks outlined in the cooperative agreements and contracts pertaining to data analysis include the following:

WRCC Agreement

- Develop web based tools for analysis of CAKN climate data. Products may include capabilities to produce and analyze data derived from original climate data, including departures from normal, interim averages and trends, trends and manipulations (averages, etc) of individual data streams. An ability to compare data with derived data. Chart and table production and download capability (in common file formats). A packaged report suite that could serve as a period report for CAKN parks (i.e.: "annual station report for CAKN" might include charts parameter with all stations on the chart, a table of station averages and departures from normal, comparisons to longer-term Alaska stations (FAI, ANC).

Climate data Analysis Contract

- Analyze existing data – mean, maxima, and minima temperatures, diurnal temperature ranges, and total precipitation for all sites using statistical methods most suitable to the dataset. Produce climate norms for weather stations with data sets with 30+ year records, and highlight years where there were marked shifts from the norm. A full narrative description of the steps involved in the analysis will be included in the findings.

SOP #22, "Climate Data Analysis" will be completed when the data analysis contract is finished and the methods have been reviewed and accepted.

## Annual Reporting

These data will be used in unlimited ways by researchers, park scientists, park managers, various federal and state agencies, and the general public. However, a standard reporting format should be agreed upon that will provide the reader with a general concept of a given climate year. A report of this nature would include a general climatic synopsis derived from climate summaries from around the state paired with specific data from the sites such as mean annual air temperature, extreme temperatures, precipitation totals, growing degree days, average wind speeds and direction, snow depth and duration, and incoming solar radiation during the growing season. Correlations could be made to the 30-year climate norms available for major cities and towns with long climate records. The procedures for reporting are described in SOP #23, "Climate Monitoring -Reporting". An example of a LTEM climate report is included as Appendix E. This report also includes the monthly data for all stations; CAKN climate reports will most likely omit raw data and include only the summary and compilation information. The complete dataset will always be available via the archives on the internet.

The data management plan outlined in this protocol has been discussed with both Doug Wilder, CAKN data manager and Jon Paynter, Denali GIS specialist, and both agreed that this action for data dissemination and archiving of climate data seems logistically sound. The process should be reviewed after the data contracts and cooperative agreements are completed and the program is fully operational.

# VII. Personnel Requirements and Training

## Roles and Responsibilities

Climate Program Manager –The climate monitoring specialist will take the lead in implementing this monitoring program supervised by the Physical Scientist at Denali National Park and Preserve. The program manager is responsible for appropriate site selection and placement of climate stations, station maintenance, and assurance that accurate observations are taken and transmitted via satellite. This includes reading and assuring appropriate response to "watchdog" reports, addressing maintenance issues with promptness, and visual checks of data on a frequent basis to assure that station readings are reflective of actual conditions. The data management aspect of the monitoring is the joint responsibility of the project manager, CAKN data manager and the entities under agreement with the climate monitoring program for climate data archiving and dissemination. Data QA/QC is the responsibility of the program manager and the contractors and partners under agreements. The program manager will be the technical representative on all contracts related to climate data archiving and dissemination and will stay up to date on technological advances in the field, ensuring that the CAKN climate monitoring program is consistent with other national programs. The program manager is also responsible for climate monitoring reporting on an annual basis. Currently the work is being done by one individual with assistance with logistics and field work provided by park staff at the three parks.

These are the additional positions that should be considered in the future if climate monitoring is addressed on a regional basis rather than at the network level.

- **Field Support Technician/First Responder** - Responsible for performing annual site maintenance and for responding to system failures in a timely manner, and documenting in AS-CADS. Provides status reports to the Principal Investigator.
- **Agency/Regional Climate Coordinator** - Responsible for agency/regional level oversight and quality control. This includes spot checks for data accuracy and station status. Assures that training is available at the regional/local level as needed. Assists with station operation and life-cycle management planning. Integrates climate monitoring program with other I&M disciplines at the regional level.
- **Maintenance Depot Manager** - Responsible for regional level oversight of climate station maintenance. Maintains warehouse of sensors and equipment necessary for station maintenance. Manages logistics and maintenance schedules. Field support technicians would be based out of the maintenance depot.

## Qualifications and Training

Before engaging in CSI datalogger programming, it is highly recommended that the station manager attend the three day CR10X/Loggernet training course offered by CSI. There is a high level of technical skill required to keep the climate stations running. Effective troubleshooting must be done in the field to eliminate redundant site visits that incur high logistical costs such as helicopter time. The quality of the data produced is determined by the attention to maintenance details by the program manager.

## Partnerships

The data quality is also dependent on outside agencies and contractors that will be represented by the program manager. Understanding how the data flow through the various steps of the process is integral to making the program run smoothly and efficiently. If there is a problem, the program manger must determine at which level the problem is occurring, and how best to manage the problem if it resides outside of the agencies responsibilities. The success of the climate monitoring program is built upon partnerships and how they are effectively managed. Table 2 provides the list of partners critical to the success of the climate monitoring program and the current contact information.

Table 2. Partnerships between the NPS CAKN and other agencies

| Partner/Agency | Role | Contact |
|---|---|---|
| Western Regional Climate Center | Data archive, dissemination | Dr. Kelly Redmond – Deputy Regional Climatologist<br>Dave Simeral – Assistant Meteorologist |
| National Interagency Fire Center | Data retrieval, QA/QC and dissemination | Buddy Adams – RAWS depot manager |
| National Weather Service - Anchorage | Regional data dissemination, regional networking | Gary Hufford – Climate Services Program Manager<br>Jim Jones – Chief Data Acquisition |
| National Weather Service Fairbanks | Regional data dissemination, regional QA/QC, networking | Rick Thoman – Lead forecaster<br>Eric Stevens – Regional Climatologist |
| National Climatic Data Center | Data archive | Sharon LeDuc – Deputy Director |
| Alaska Fire Service | Coordination and collaboration for RAWS network | Kent Gale – Program Manager<br>Sharon Alden – Fire Weather Program Manager |

# VIII. Operational Requirements

## Annual Workload and Field Schedule

Climate monitoring is ongoing and constant. Data are transmitted every hour, of every day, 365 days a year. However, it is preferable that annual maintenance trips be scheduled between May and September to avoid working in extreme conditions. Travel to remote locations is generally safer in the summer months when surviving the elements is not as critical. Each station in the CAKN climate monitoring network needs to be visited for maintenance and calibration at least once a year. It is preferable to visit stations once in the spring and again in the fall before the long winter. If a station is offline, that station should have priority and be visited as soon as reasonably possible. A response time for station repairs needs to be determined after a few years of "burn in" time to determine the frequency of potential repairs. One day per station should be allotted for maintenance. The LTEM stations in Denali require a site visit at least every two months. Problems with these stations are only discovered when the site is visited since there is no telemetry involved. This requires two days to access all of the sites and perform basic maintenance.

It is important to keep the climate monitoring program current and integrated. This involves attending meeting and conferences where work can be presented and shared among colleagues. It also includes attending national meetings, conferences and training sessions directly related to the climate field. One of the more useful forums for the development phase of the program was to meet in person with the various climatologists in the state and region to discuss climatology, instrumentation, siting issues, new technology, problems and accomplishments, this type of opportunity needs to continue into the future. Periodic meetings with key partners are also critical to foster successful long-term relationships.

## Facility and Equipment Needs

The inventory for the climate monitoring program consists of sensor replacements, tools, field equipment, batteries, solar panels, steel pipes, channel unistrut, plywood, and other miscellaneous equipment. This equipment now occupies an entire office at Denali NP&P. This office is scheduled to be removed in 2005. A replacement storage area is needed to house this equipment. It is preferable to have a heated storage area so that the space can double as a workspace for anticipated electronic repairs and testing. An office for the program manager including a computer and limited equipment storage is provided at Denali. A vehicle will be necessary for the field visits between the three parks. This vehicle will travel between Denali and Fairbanks and Denali and Glenallen with periodic trips to Anchorage. Equipment needs are listed in SOP #18 Maintenance Checklist.

Future considerations for a climate depot that would house the program manager, maintenance manager, and maintenance crew for the Alaska region are being discussed with partner agencies. This type of facility would serve the NPS climate monitoring programs as well as the BLM, NWS, and other federal and state climate monitoring programs for the state of Alaska.

## Startup Costs and Budget Considerations

For the operational phase costs the personnel expenses are based on one field technician for the summer season between May and September. The dates will vary from year to year. The fieldwork travel includes the program manager plus the field technician's travel between the three parks in the network, plus any field time within the individual parks. The OAS costs include travel to and from remote sites via fixed-wing aircraft or helicopter. The initial equipment was purchased in 2002 and is itemized in SOP 3 – Initial Equipment List. The annual equipment and supplies cost will include sensor calibrations, sensor replacements, upgrades, maintenance, and new equipment when necessary. Cooperative agreements for data archiving and data dissemination will be initiated with the Western Regional Climate Center and renewed every 5–10 years. The estimated annual cost of climate monitoring is shown in Table 3.

## Procedures for Making Changes to and Archiving Previous Versions of the Protocol

Over time, revisions to both the Protocol Narrative and to specific Standard Operating Procedures (SOPs) are to be expected. Careful documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in within the program.

Table 3. Estimated design and operational costs of climate monitoring program.

| Estimated Costs | Design Phase | Operational Phase |
|---|---|---|
| Field Work (Technician Salary) | 11,000 | 11,000 |
| Field Work (Travel) | 3,000 | 5,000 |
| OAS Aircraft Costs | 18,000 | 15,000 |
| Startup Equipment Costs | 100,000 | |
| Annual equipment/supplies | | 10,000 |
| Cooperative Agreement WRCC/Data Contract | 34,000 | 5,000 |
| **Total** | **166,000** | **46,000** |

The rationale for dividing a sampling protocol into a Protocol Narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of the sampling methods, but that does not provide all of the methodological details. The Protocol Narrative will only be revised if major changes are made to the protocol.
- The SOPs, in contrast, are very specific step-by-step instructions for performing a given task. They are expected to be revised more frequently than the protocol narrative.
- When a SOP is revised, in most cases, it is not necessary to revise the Protocol Narrative to reflect the specific changes made to the SOP.
- All versions of the Protocol Narrative and SOPs will be archived in a Protocol Library.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in SOP # 23, "Revising the Protocol". Each SOP contains a Revision History Log that should be filled out each time a SOP is revised to explain why the change was made, and to assign a new Version Number to the revised SOP. The new version of the SOP and/or Protocol Narrative should then be archived in the CAKN Protocol Library under the appropriate folder (Peitz, et al. 2002).

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# Appendix A: Existing Climate/Weather Station Networks

## A.1 Rock Creek Long-term Ecological Monitoring Weather Stations (Rock Creek)

As part of the Long-term Ecological Monitoring program 5 weather stations were installed in the Rock Creek watershed adjacent to Denali National Park headquarters. Two 10-meter meteorological towers were installed at a mid and high elevation to capture regional weather conditions and three additional stations were installed in different vegetation zones, including a tundra area underlain by permafrost, a site at treeline, and one within the boreal forest.



Figure A1. Ten meter tower at Upper Ridge permafrost station



Figure A2. Upper Ridge permafrost station

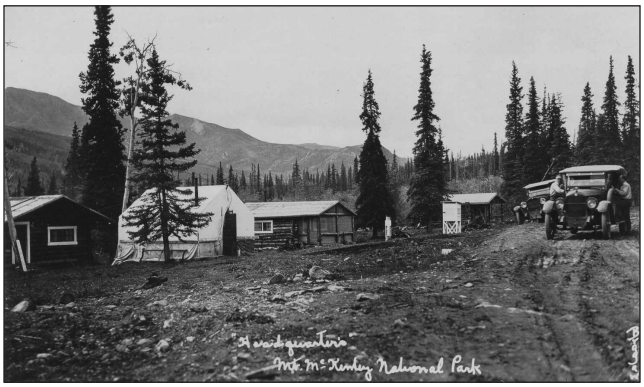


Figure A3. Original NWS COOP Station at McKinley Park Headquarters 1927

The objectives of this program were to develop and test standardized meteorological measurements (including snow) for long term ecological monitoring sites as follows: (a) establish baseline meteorological conditions for site characterization, (b) document cyclic and long-term changes in the physical environment, and (c) provide a record of the physical environment for describing ecological relationships and assisting the development of environmental models.

## A.2 National Weather Service (NWS) Cooperative Observer program (COOP)

The NWS COOP was formally created in 1890 under the Organic Act. Its mission is two-fold:

- To provide observational meteorological data, usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, required to define the climate of the United States and to help measure long-term climate changes
- To provide observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS.

## A.3 Remote Automated Weather Station Network (RAWS)

The National Interagency Fire Center (NIFC) Remote Automated Weather Stations (RAWS) Program managed by various federal and state land managers. There are nearly 1,500 interagency Remote Automated Weather Stations (RAWS) strategically located

throughout the United States – mostly in the Western states. These stations monitor the weather including air temperature, wind speed and direction, precipitation, solar radiation, and fuel temperature and moisture. The stations are set up to transmit these data hourly via satellite. Fire managers use these data to predict fire behavior and monitor fuels.

## A.4 USDA/NRCS Snowfall Telemetry (SNOTEL) Network

The Natural Resources Conservation Service (NRCS) National Water and Climate Center manages the Snow Telemetry (SNOTEL) and Snow Course network. The National Water and Climate Center provides real-time snow and climate data using automated remote sensing from sites in the mountainous regions of the Western United States. SNOTEL stations measure snow water equivalent, snow depth, precipitation, temperature and other climatic elements in hourly, daily, monthly and yearly increments (Figures A4 and A5). Manual snow surveys utilize two-person teams to measure snow depth and water content at designated snow courses. A snow course is a long-term sample site that represents snowpack conditions at a given elevation in a given area. Generally, the courses are about 100 feet long and are situated in small meadows or open forests protected from the wind. These data are used for forecasting and management of water supplies.

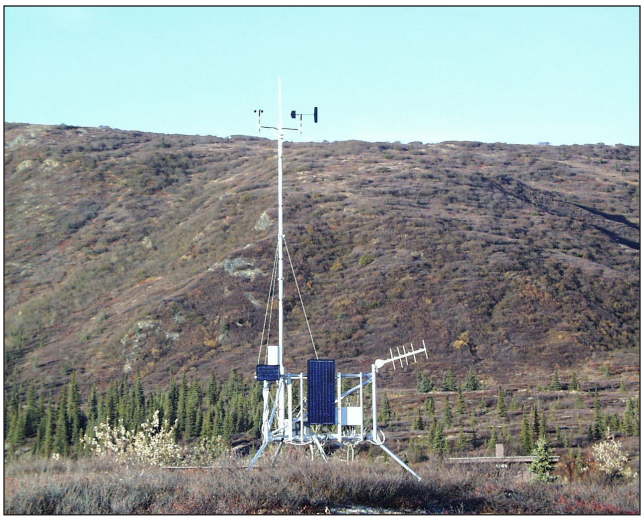


Figure A4. Remote Automated Weather Station (RAWS)

## A.5 NWS/FAA Surface Airways Observation Network (SAO)

The Federal Aviation Administration, the National Weather Service and private parties manage the Surface Airways Observation Network, previously known as the Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS). SAO is a suite of sensors, which measures, collects and broadcasts weather data to help meteorologists, pilots and flight dispatchers prepare and monitor weather forecasts, plan flight routes, and provide necessary information for correct takeoffs and landings. The system provides continuous data on conditions at the runway touchdown level.



Figure A5. NRCS snow telemetry site



Figure A6. NRCS/NPS Snow Course Site

# Appendix B: Climate Monitoring Principles

The National Research Council (NRC, 1999) recommended that the following ten climate monitoring principles, proposed by Karl et al. (1996), should be applied to climate monitoring systems:

## B.1 Management of Network Change

Assess how and the extent to which a proposed change could influence the existing and future climatology obtainable from the system, particularly with respect to climate variability and change. Changes in observing times will adversely affect time series. Without adequate transfer functions, spatial changes and spatially dependent changes will adversely affect the mapping of climate elements.

## B.2 Parallel Testing

Operate the old system simultaneously with the replacement system over a sufficiently long time period to observe the behavior of the two systems over the full range of variation of the climate variable observed. This testing should allow the derivation of a transfer function to convert between climatic data taken before and after the change. When the observing system is of sufficient scope and importance, the results of parallel testing should be documented in peer-reviewed literature.

## B.3 Metadata

Fully document each observing system and its operating procedures. This is particularly important immediately prior to and following any contemplated change. Relevant information includes: instruments, instrument sampling time, calibration, validation, station location, exposure, local environmental conditions, and other platform specifics that could influence the data history. The recording should be a mandatory part of the observing routine and should be archived with the original data. Algorithms used to process observations need proper documentation. Documentation of changes and improvements in the algorithms should be carried along with the data throughout the archiving process.

## B.4 Data Quality and Continuity

Assess data quality and homogeneity as a part of routine operating procedures. This assessment should focus on the requirements for measuring climate variability and change, including routine evaluation of the long-term, high-resolution data capable of revealing and documenting important extreme weather events.

## B.5 Integrated Environmental Assessment

Anticipate the use of the data in the development of environmental assessments, particularly those pertaining to climate variability and change, as part of a climate observing system's strategic plan. National climate assessments and international assessments, (e.g., international ozone or IPCC) are critical to evaluating and maintaining overall consistency of climate data sets. A system's participation in an integrated environmental monitoring program can also be quite beneficial for maintaining climate relevancy. Time series of data achieve value only with regular scientific analysis.

## B.6 Historical Significance

Maintain operation of observing systems that have provided homogeneous data sets over a period of many decades to a century or more. A list of protected sites within each major observing system should be developed, based on their prioritized contribution to documenting the long-term record.

## B.7 Complementary Data

Give the highest priority in the design and implementation of new sites or instruments within an observing system to data-poor regions, poorly observed variables, regions sensitive to change, and key measurements with inadequate temporal resolution. Data sets archived in non-electronic format should be converted for efficient electronic access.

## B.8 Climate Requirements

Give network designers, operators, and instrument engineers climate monitoring requirements, at the outset of network design. Instruments must have adequate accuracy with biases sufficiently small to resolve climate variations and changes of primary interest. Modeling and theoretical studies must identify spatial and temporal resolution requirements.

## B.9 Continuity of Purpose

Maintain a stable, long-term commitment to these observations, and develop a clear transition plan from serving research needs to serving operational purposes.

## B.10 Data and Metadata Access

Develop data management systems that facilitate access, use, and interpretation of the data and data products by users. Freedom of access, low cost mechanisms that facilitate use (directories, catalogs, browse capabilities, availability of metadata on station histories, algorithm accessibility and documentation, etc.), and quality control should be an integral part of data management. International cooperation is critical for successful data management.

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# Appendix C: Climate Site Evaluation

## C.1 File Reference

The Central Alaska Network completed a comprehensive site evaluation document in 2004. The complete document is available at: http://www1.nature.nps.gov/im/units/cakn/reportpubs.cfm. This abbreviated version includes a description of each park, park maps, site location tables, and one example of the individual site documentation. Please refer to the original document for the complete list of sites that were evaluated in the process.

## C.2 Introduction

The three park units of the Central Alaska Network together span an enormous area measuring approximately 650 km from north to south and 650 km from east to west. Elevations range from sea level to 6194 m (20,320'); latitudes reach to more than 65 degrees north. They contain 12 of the 32 unified ecoregions of Alaska, and include the highest mountain ranges and some of the largest rivers in North America (Figure C1). Climate in this vast area is extremely variable, ranging from strongly maritime to strongly continental, with large differences in temperature and precipitation (Figure C2).

In an attempt to better understand climate variation as well as possible long-term changes in ecosystems of the Central Alaska Network, new long-term climate monitoring stations will be installed throughout the three parks in the coming years. In the summer of 2003 numerous sites were visited at each of the parks to obtain specific information on the suitability of each site for climate station installation. The initial site selection process involved numerous conversations with park staff and climate experts. This report presents an evaluation of a number of sites identified within each of the three CAKN units for potential placement of these stations.

## C.3 Existing Climate Monitoring Sites

A network of climate monitoring sites currently exists in and around all three parks. Most existing sites are located at relatively low elevations in settlements surrounding the parks, and records are commonly short-term or sporadic. There are long-term National Weather Service cooperative observer weather stations in or near each of the three parks with records of daily minimum and maximum temperatures, total precipitation, and snowfall. The Remote Automated Weather Station (RAWS) sites were added in the 1990s as part of the fire monitoring network. Records for these stations were initially gathered during the summer fire months only, although attempts are now being made to keep them operating year-round. See C.7 for existing climate site location tables.

## C.4 Potential New Sites

In an effort to fill some of the holes in the existing climate monitoring network and increase our knowledge of climate variability across the three CAKN parks, a number of potential new sites were identified and evaluated during the summer of 2003. The main criteria in locating sites were (1) to get the best possible coverage across each park, (2) to sample different ecoregions within each park, and (3) to get a good elevational gradient between sites. Additionally, we considered the issue of access: a site must not be too difficult and/or costly to access for routine maintenance over the next many decades. Criteria used in locating sites varied by park. Each park had to be evaluated differently due to their many differences, including, for example, wilderness and historic district designations, helicopter compliance regulations, and variations in landscapes and ecoregions.

### *C.4.1 Wrangell-St. Elias National Park and Preserve*

Wrangell-St. Elias NP&P contains both coastal and interior climatic regimes as well a transition zone. Two high elevation mountain ranges disrupt movement of weather systems resulting in numerous localized climatic conditions. Because of the immensity of Wrangell-St. Elias NP&P, the extensive amount of high elevation terrain and large number of climatic regimes, a model to characterize the area will be based upon a transect of sites perpendicular to the coast. This transect will contain south and north facing mountain range aspects, sites at high and low elevation, sites in both the coastal and interior regimes, as well as sites within the transition zone This transect will by necessity incorporate Remote Automated Weather Stations that exist outside the park boundary. Geologist Danny Rosenkrans provided extensive knowledge and expertise in identifying different climatic regimes and representative areas, and locating potential sites within the park. Sites were

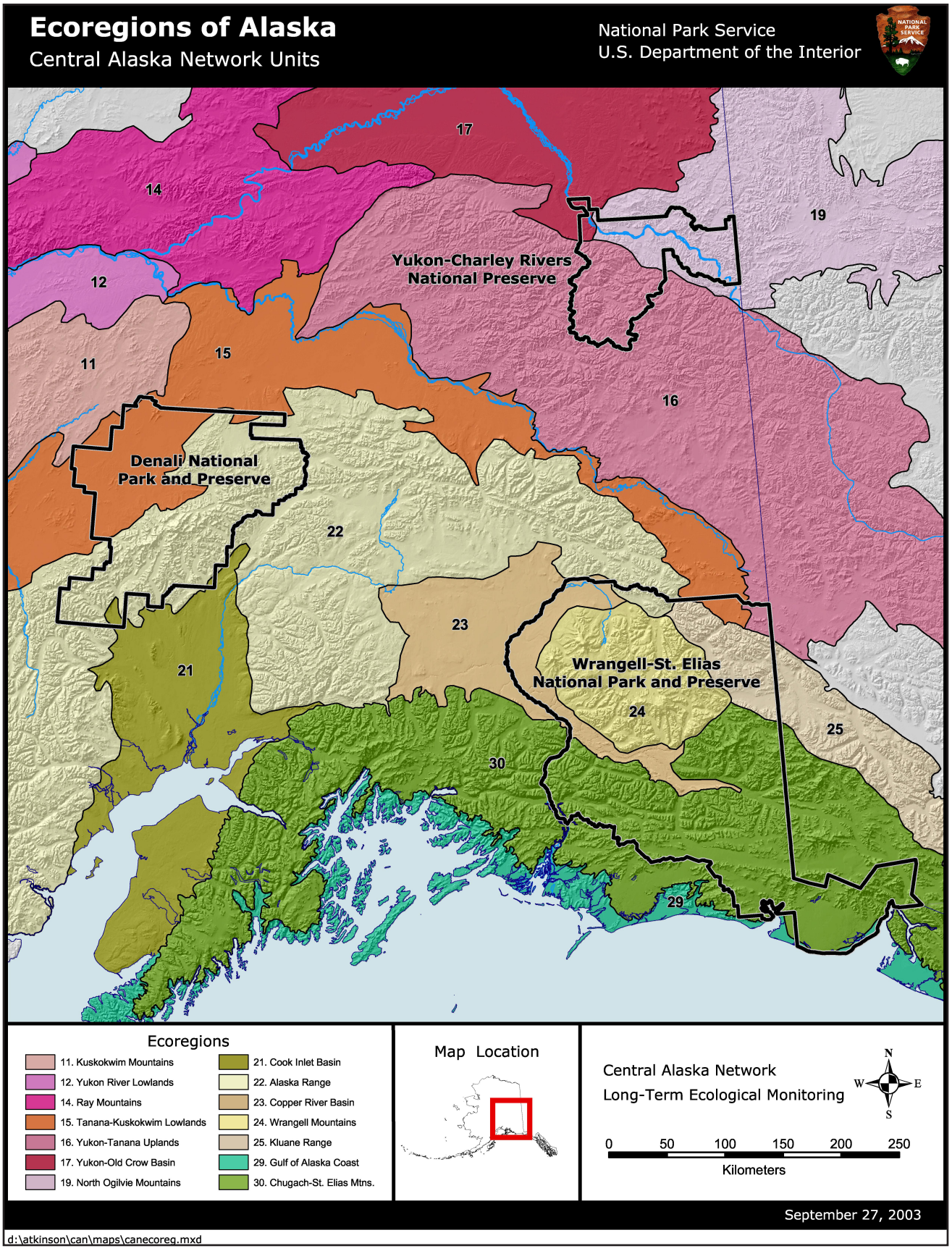



Figure C1. Ecoregions of Alaska with Central Alaska Network park boundaries

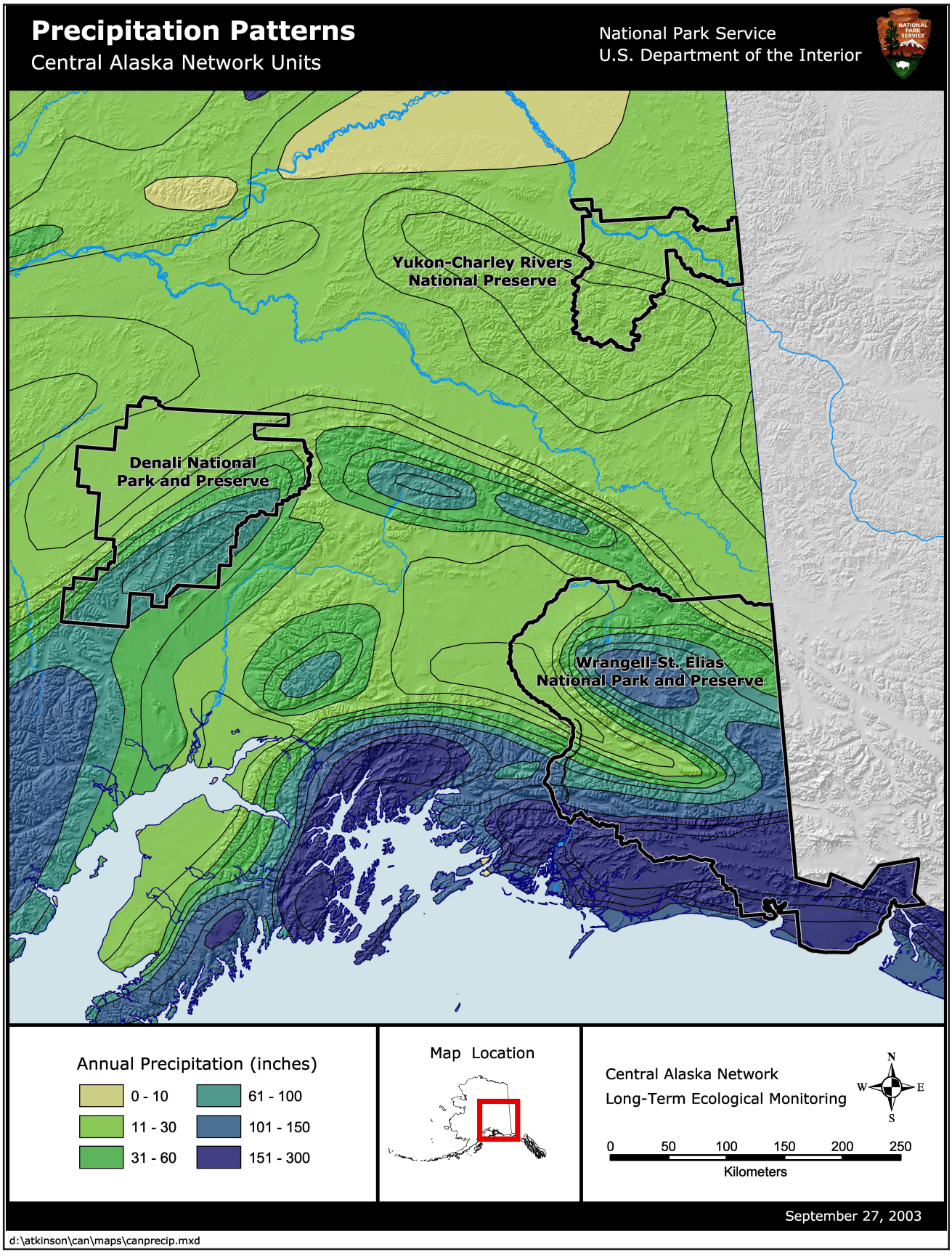



Figure C2. Precipitation map of Alaska with Central Alaska Network park boundaries

located along a general north-south transect through the park, utilizing several existing stations along this transect (Chisana, McCarthy, and May Creek). These existing stations are at relatively low elevations, so sites for proposed new stations were located mostly in higher areas in order to get an elevational as well as latitudinal gradient between sites. A number of possible sites were located in each identified area (Chisana, McCarthy, and Tana River). In addition, several other areas outside the transect but representing different ecoregions and/or climatic regimes, or enhancing the spatial extent of the network were identified (Upper Chitina Valley, Tebay Lakes, and Cheshnina areas). Table C1 lists all potential sites and summarizes key points for each; Figure C3 shows the locations of potential areas and sites, as well as the relation to existing sites, wilderness boundaries, and ecoregions.

Table C1. Potential sites identified within Wrangell-St. Elias National Park and Preserve

| Site | Area | Site Type | Elev (ft) | Latitude (NAD27) | Longitude (NAD27) | Access* | Wilderness? | Historic District? |
|---|---|---|---|---|---|---|---|---|
| Gates Peninsula | McCarthy | high elevation | 4060 | 61° 36′ 10.41″ | 143° 00′ 47.54″ | H | Y | N |
| Kennicott Glacier | McCarthy | high elevation | 3900 | 61° 36′ 15.57″ | 143° 05′ 59.34″ | F/H | Y | N |
| Jumbo | McCarthy | high elevation | 3700 | 61° 30′ 20.36″ | 142° 51′ 50.38″ | Trail | N | Y |
| Fireweed | McCarthy | high elevation | 3770 | 61° 27′ 40.06″ | 142° 59′ 10.30″ | H | N | N |
| Nikolai Mine | McCarthy | high elevation | 4700 | 61° 27′ 58.85″ | 142° 40′ 33.26″ | H | N | N |
| Nikolai Pass | McCarthy | high elevation | 4400 | 61° 25′ 58.88″ | 142° 39′ 34.24″ | F/H | N | N |
| Sourdough Ridge | McCarthy | high elevation | 4160 | 61° 24′ 29.07″ | 142° 45′ 26.20″ | H | N | N |
| Chititu | McCarthy | high elevation | 4600 | 61° 16′ 26.44″ | 142° 37′ 08.71″ | H | N | N |
| Iceberg Lake | Tana River | mod elevation | 3300 | 60° 47′ 44.55″ | 142° 58′ 05.74″ | F/H | Y | N |
| Iceberg Bench | Tana River | high elevation | 3990 | 60° 49′ 08.53″ | 142° 58′ 17.17″ | H/F | Y | N |
| Tana Glacier Seismic | Tana River | high elevation | 4150 | 60° 45′ 17.68″ | 142° 49′ 43.18″ | HC | Y | N |
| Ross Green Bench | Tana River | mid elevation | 2520 | 60° 44′ 08.47″ | 142° 29′ 03.23″ | H/F | Y | N |
| Twelvemile Ck | Tana River | mid elevation | 3080 | 60° 45′ 05.95″ | 142° 31′ 40.96″ | H/F | Y | N |
| West Fork Tana | Tana River | mod elevation | 3450 | 60° 54′ 29.79″ | 142° 53′ 58.61″ | H | Y | N |
| Tana River | Tana River | low elevation | 1440 | 60° 56′ 22.18″ | 142° 41′ 51.68″ | F | Y | N |
| Euchre | Chisana | high elevation | 6860 | 62° 03′ 19.89″ | 142° 11′ 04.36″ | HC/S | boundary | N |
| Chicken Airstrip | Chisana | high elevation | 5260 | 62° 07′ 27.64″ | 141° 50′ 42.76″ | F/H/S | N | Y |
| Gold Hill | Chisana | high elevation | 5930 | 62° 05′ 36.45″ | 141° 54′ 00.48″ | H/F/S | N | Y |
| California Creek | Chisana | high elevation | 5480 | 62° 03′ 55.23″ | 141° 46′ 42.63″ | H/F/S | boundary | N |
| Beaver Lake | Chisana | high elevation | 5450 | 62° 01′ 38.20″ | 141° 53′ 04.86″ | H/F/S | Y | N |
| Chitina Glacier Seismic | Upper Chitina | mobile | 4950 | 60° 57′ 54.69″ | 141° 20′ 16.28″ | HC | Y | N |
| Notch Airstrip | Upper Chitina | mobile | 2600 | 61° 00′ 22.41″ | 141° 31′ 55.89″ | F | Y | N |
| Huberts | Upper Chitina | mobile | 2200 | 61° 01′ 36.96″ | 141° 38′ 05.16″ | F/H | Y | N |
| Barnard Glacier | Upper Chitina | mobile | 1900 | 61° 04′ 31.91″ | 141° 47′ 56.80″ | H/F | Y | N |
| Tebay | Tebay Lakes | mobile | 2000 | 61° 11′ 17.33″ | 144° 24′ 01.34″ | F/H | boundary | N |
| Tebay Cabin | Tebay Lakes | mobile | 1880 | 61° 10′ 54.12″ | 144° 20′ 15.95″ | H/F | N | N |
| Cheshnina | Cheshnina | mobile | 4940 | 61° 48′ 46.41″ | 144° 25′ 46.39″ | H | boundary | N |
| Long Glacier | Cheshnina | mobile | 4820 | 61° 49′ 19.84″ | 144° 04′ 40.59″ | H/F | Y | N |

Note – Only one site was considered in each of the areas (color-coded).

* Access: (H) helicopter; (F) fixed-wing aircraft; (S) snowmachine/ATV; (HC) helicopter, colocated with seismic station or radio repeater, listed in order of most likely type of access

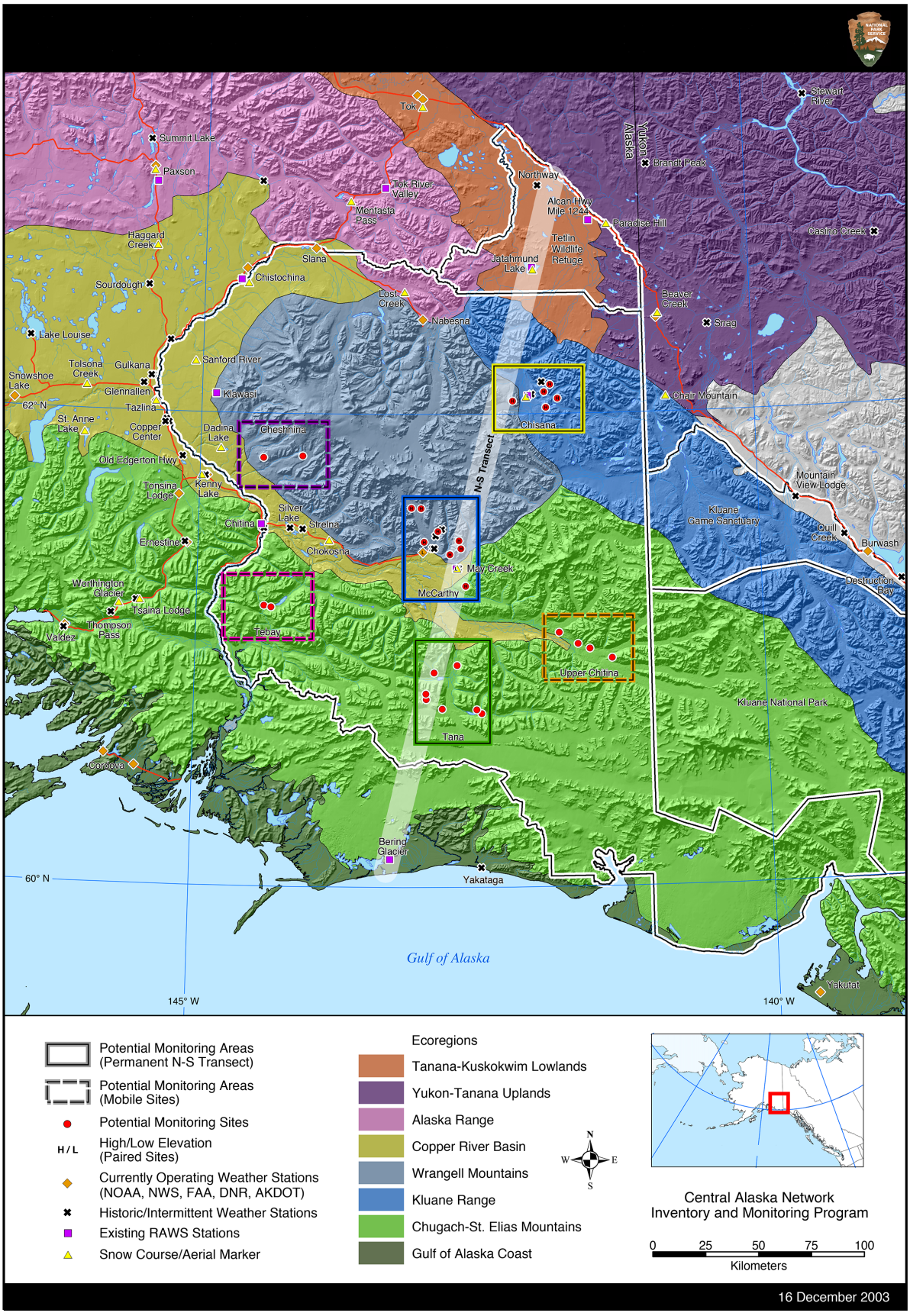



Figure C3. Location of existing and potential climate monitoring sites in relation to Alaska Ecoregions, Wrangell-St. Elias National Park and Preserve.

### *C.4.2 Yukon-Charley Rivers National Preserve*

Yukon Charley Rivers encompasses three ecoregions including the Yukon – Old Crow Basin, the North Ogilvie Mountains, and the Yukon-Tanana Uplands. The Yukon-Tanana uplands have no existing representative climate station so potential siting in that area was a priority. Potential sites in Yukon-Charley were selected based on valuable information on the area supplied by Nikolina Guldager (Yukon-Charley wildlife biologist), Jay Martin (Yukon-Charley Park pilot) and Rick Thoman (National Weather Service meteorologist). Several factors influenced potential site locations including the ecoregions map and the annual precipitation pattern map, and the general climate pattern described by Rick Thoman. Thoman pointed out that a marked change in climate patterns seems to occur at the 144° West parallel with colder temperatures in the hills and valleys east of the parallel which is just west of the Yukon-Charley Rivers boundary.

Several other considerations were given to the area. Firstly, the few climate monitoring sites that currently exist in and around Yukon-Charley are at lower elevations, so an effort was made to find potential new sites at higher elevations within the preserve. Secondly, five new aerial snow markers were installed by Guldager within the preserve in 2001 and 2002, and an effort was made to locate sites near these markers for correlation with snow survey data. Finally, helicopter access in Yukon-Charley is subject to strict compliance regulations, so we attempted to locate sites proximal to existing airstrips for fixed-wing access. Table C2 lists the potential sites and summarizes key points for each; Figure C4 shows the locations and the relation to existing sites and ecoregions.

Table C2. Potential sites identified in Yukon-Charley Rivers National Preserve

| Site | Area-Ecoregion | Site Type | Elev (ft.) | Latitude (NAD27) | Longitude (NAD27) | Access* | Wilderness? | Historic District? |
|---|---|---|---|---|---|---|---|---|
| Three Fingers | Yukon Tanana Uplands | high elevation | 3180 | 64° 34′ 32.47″ | 143° 14′ 27.67″ | F | N | N |
| Crescent Creek | Yukon Tanana Uplands | high elevation | 2850 | 64° 48′ 31.53″ | 143° 54′ 37.92″ | F | N | N |
| Golvins Airstrip | Yukon Tanana Uplands | mid elevation | 2100 | 64° 49′ 20.00″ | 143° 25′ 57.00″ | F | N | N |
| Beverly Airstrip | Yukon Tanana Uplands | high elevation | 4110 | 65° 06′ 40.16″ | 143° 50′ 12.20″ | F | N | N |
| Coal Creek | Yukon Tanana Uplands | low elevation | 870 | 65° 18′ 50.05″ | 143° 07′ 56.38″ | F/S | N | Y |

*Access: (H) helicopter, (F) fixed-wing aircraft, (S) snowmachine/ATV

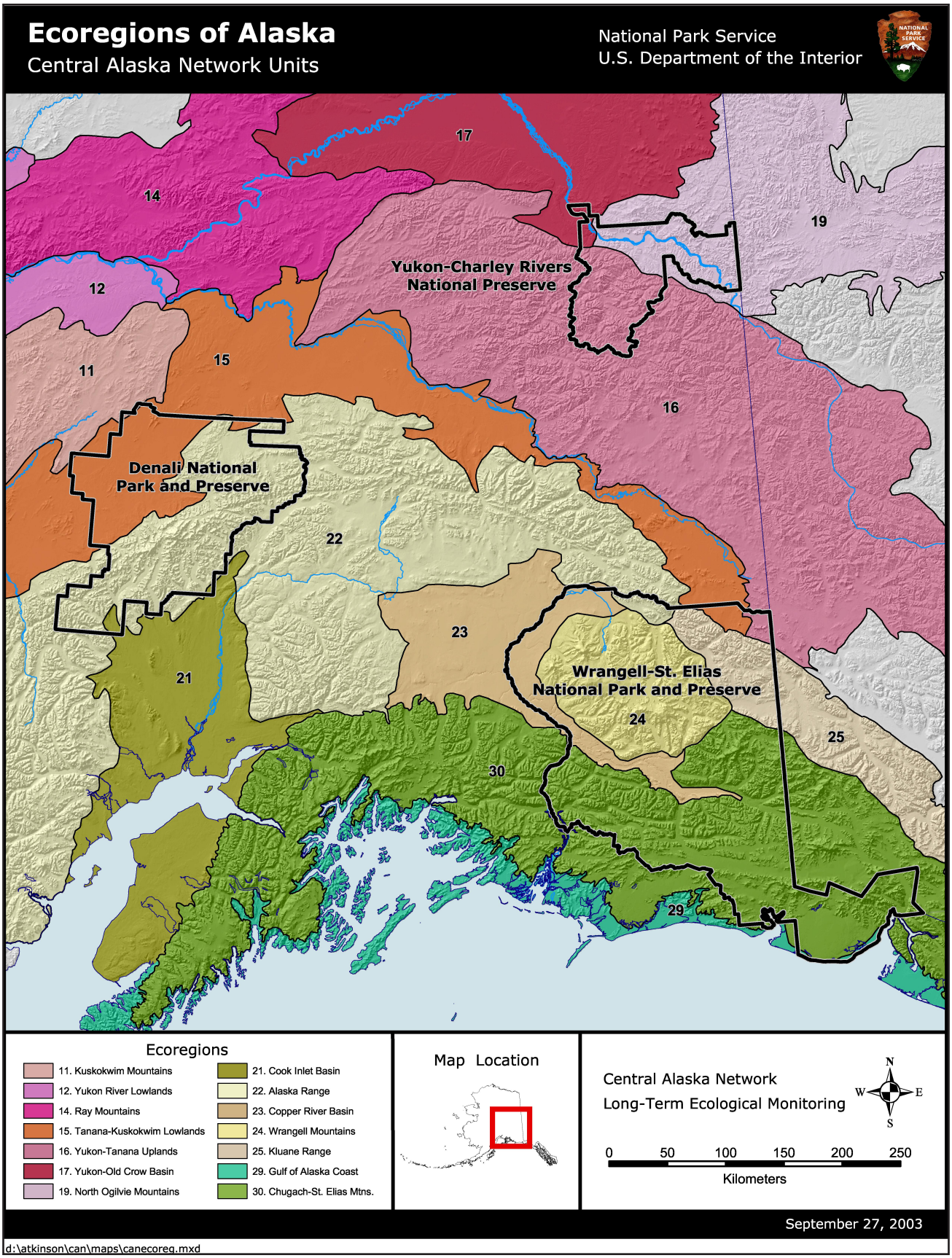



Figure C4. Location of existing and potential climate monitoring sites in relation to Alaska Ecoregions, Yukon-Charley Rivers National Preserve

### *C.4.3 Denali National Park and Preserve*

The climate of Denali National Park and Preserve (DNP&P) is characterized by great spatial variability, and includes both transitional maritime (influenced by the ocean) and continental (influenced by the Alaska Range) climate subtypes. The maritime climate on the south side of the Alaska Range is influenced by the prevailing weather patterns of the Gulf of Alaska, with milder air temperatures and less seasonal variation and more precipitation. On the north side of the range where park headquarters is located, temperatures are typical of a continental climate with strong seasonal variations. There is also less precipitation on the north side because of its location on the leeward side of a major mountain range.

Although Denali encompasses the boundaries of four ecosystems the Alaska Range ecoregion and the Tanana-Kuskokwim Lowlands ecoregion dominate the landscape. The Yentna river confluence in the southwest area of the park is part of the Cook Inlet Basin ecoregion, and small sections in the northwest corner of the park in the Minchumina Basin lie within the Kuskokwim Mountains ecoregion. Denali has had a Long-term Ecological Monitoring (LTEM) program in place for twelve years, and thus has a more extensive network of climate monitoring stations than either Wrangell-St. Elias or Yukon-Charley (although for most of the program, the climate monitoring network was within Rock Creek, a small watershed near Park Headquarters). In 2001, three new locations within the park (Dunkle Hills, Stampede Airstrip, and Wigand Creek) were identified through an internal scoping process with park resource program managers. Standard stations were installed at these sites during the summer of 2003. In addition, Sousanes identified several other potential sites based on representative landscape, wilderness and access issues. These sites were visited for evaluation at various times during the summer by Sousanes, Paul Atkinson, and Rick McClure (NRCS). Table C3 lists the sites and summarizes key points for each; Figure C5 shows the locations and the relation to existing sites, wilderness boundaries, and ecoregions.

Table C3. Potential sites identified in Denali National Park and Preserve

| Site | Area | Site Type | Elev (ft.) | Latitude (NAD27) | Longitude (NAD27) | Access* | Wilderness? | Historic District? |
|---|---|---|---|---|---|---|---|---|
| West Fork Yentna River | South Side | low elevation | 1840 | 62° 32′ 07.80″ | 152° 31′ 41.80″ | H | N | N |
| Tokositna Valley | South Side | low elevation | 860 | 62° 38′ 33.52″ | 150° 47′ 46.90″ | H/S | N | N |
| Eielson Visitor Center | North Side | high elevation | 3730 | 63° 25′ 52.70″ | 150° 18′ 34.00″ | R/H | N | N |
| Kantishna | North Side | low elevation | 1570 | 63° 32′ 17.21″ | 150° 59′ 06.17″ | R/F | N | N |

* Access: (H) helicopter, (F) fixed-wing aircraft, (S) snowmachine/ATV, (R) road

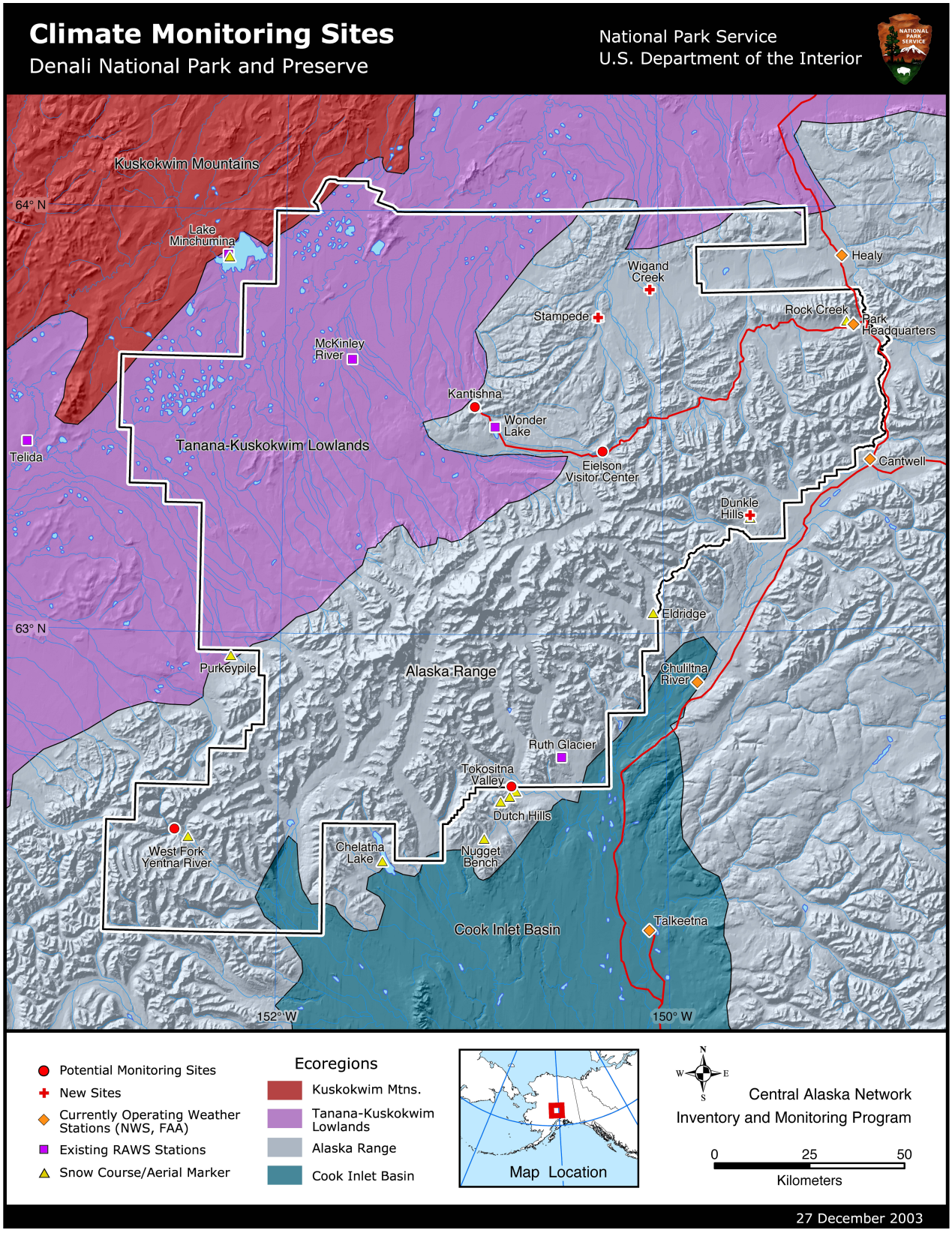



Figure C5. Location of existing and potential climate monitoring sites in relation to Alaska.

## C.5 Basic Station Design

In a 2002 scoping meeting the physical science team met with Larry Hinzman of the University of Alaska Fairbanks to discuss instrumentation. Hinzman has been involved with the Long Term Ecological Research (LTER) areas at Bonanza Creek, Poker Flats and Toolik Lake in Alaska for many years. He made suggestions on instrumentation based on their study design and others like it around the country. Pamela Sousanes took the information and documented different potential phases of instrumentation. Through discussions with the CAKN technical committee it was decided that temperature and precipitation were the most important variables or drivers in the ecosystem context, followed by wind, solar radiation, and relative humidity.

The equipment for the new stations was purchased in 2002 and 2003. Three of these stations have already been deployed in a testing phase at remote locations in Denali; the remaining nine are currently set up near the Denali NP&P Visitor Center for testing and assessment prior to deployment in 2004 (Figure C6). This testing phase is an extremely valuable stage for the network. Inherent bugs in programming, instrumentation, power systems, and many other miscellaneous problems will be identified before these stations go remote. The stations were specifically designed for remote, high latitude, extreme cold conditions. Special consideration was taken to minimize visual and physical impacts by making the stations as compact as possible to comply with wilderness values within national park lands. The stations have a small footprint, low-impact anchoring systems, and wooden platforms to stand on while visiting the site to minimize vegetation disturbance. Stations are powered year-round by two solar panels (Figure C7).

The standard tower is a ten-foot mast on a tripod base, and utilizes a Campbell Scientific, Inc. CR10X datalogger and Seimac High Data Rate GOES satellite data transmitter. Basic instrumentation includes air temperature, relative humidity, wind speed and direction, and incoming solar radiation. Additional instrumentation on an augmented station includes a tipping bucket rain gauge and acoustic snow depth sensor. With the assistance of Natural Resource Conservation Service (NRCS) Hydrologist Rick McClure, the possibility of using year-round recording precipitation gages at selected sites is being explored. There are inherent difficulties in measuring snowfall accurately; however the above mentioned gage is in use all over the state of Alaska and seems to be the preferred method. Figure C8 shows an example of a snow telemetry site using the year round precipitation gage used by NRCS at Turnagain Pass in Alaska. Site specifics will ultimately determine the final design and instrumentation of each station.

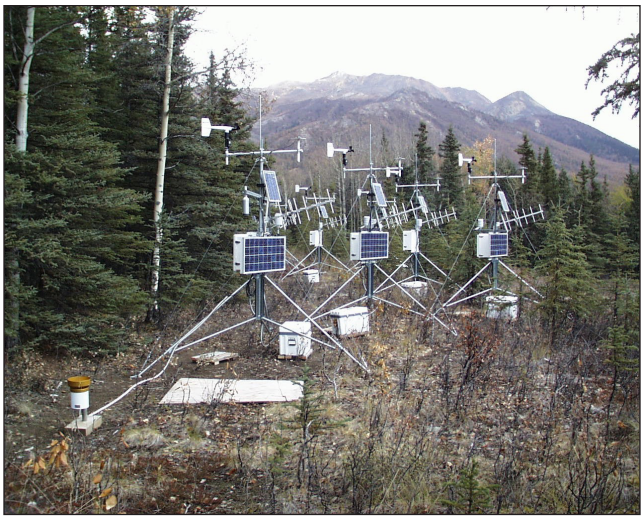


Figure C6. Station testing, Denali National Park and Preserve 2003

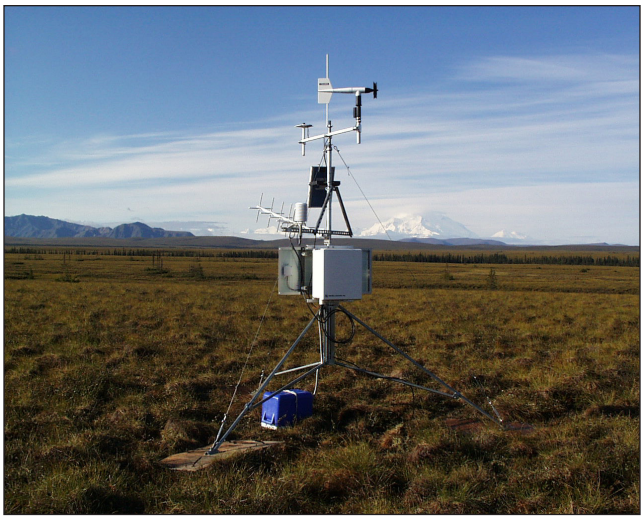


Figure C7. CAKN climate station, remote testing, Denali National Park and Preserve



Figure C8. Turnagaln Pass snow telemetry (snotel) site in fall

## C.6 Site evaluation documentation

Below is an example of the site evaluation documentation that was recorded for each site visited:

**Site:** Gates Peninsula

**Area:** McCarthy High Elevation

**Coordinates:** 61º 36' 10.41'' N, 143º 00' 47.54'' W (NAD27)

**Elevation:** 4060'

**Photo**: (Figure C9)



Figure C9. Example of photo included in site evaluation report

**Description:** Several small, grassy knolls on ridge between Gates and Packsaddle Glaciers; wide open to glaciers to south, east and west; ridge rises to north.

**Access:** Helicopter only.

**Notes:**

- high elevation (higher than Wolverine Glacier climate station [3248'])
- possible local glacier effects
- fairly exposed, snow-blown?
- near candidate glacier monitoring/index site
- See Gates Glacier image
- See Kennicott Glacier image for setting
- Wilderness

## C.7 Existing climate station locations

Table C4-C6 contain information related to the locations of different types of climate stations in and around the three CAKN parks.

Table C4. Climate stations in and around Wrangell-St. Elias National Park and Preserve.

| Area | Station | Type | Years of Record | Elev (ft) | Latitude North | Longitude West |
|---|---|---|---|---|---|---|
| **Inside Park/Preserve Boundary** | Chisana | RAWS | 1988–present | 3320 | 62° 04′ 39″ | 142° 03′ |
| | Klawasi | RAWS | 1991–present | 3100 | 62° 04′ 50″ | 144° 52′ 15″ |
| | May Creek | RAWS | 1990–present | 1650 | 61° 20′ 53″ | 142° 42′ 14″ |
| | McCarthy | NOAA | 1984–present | 1250 | 61° 25′ | 143° 00′ |
| | Nabesna | NOAA | 1967–present | 2900 | 62° 24′ | 143° 00′ |
| | Chisana | Snow Course | 1993–present | 3320 | 62° 04′ 19″ | 142° 03′ 55″ |
| | Chokosna | Snow Course | 1993–present | 1550 | 61° 28′ | 143° 50′ |
| | Dadina Lake | Snow Course | 1985–present | 2160 | 61° 51′ | 144° 49′ |
| | Lost Creek | Snow Course | 1993–present | 3020 | 62° 31′ | 143° 10′ |
| | May Creek | Snow Course | 1993–present | 1650 | 61° 20′ 54″ | 142° 41′ 39″ |
| | Sanford River | Snow Course | 1967–present | 2280 | 62° 13′ | 145° 04′ |
| **Surrounding Area Outside Park/Preserve Boundary** | Alaska Hwy Mile 1244 | RAWS | 1998–2003 | 1900 | 62° 49′ | 141° 28′ |
| | Bering Glacier | RAWS | 1998–present | 75 | 60° 07′ 07″ | 143° 17′ 00″ |
| | Chistochina | RAWS | 2001–present | 2300 | 62° 33′ 55″ | 144° 39′ 53″ |
| | Chitina | RAWS | 1998–present | 581 | 61° 31′ 55″ | 144° 26′ 23″ |
| | Jatahmund Lake | RAWS | 1990–present | 2300 | 62° 36′ | 142° 42′ 14″ |
| | Paxson | RAWS | 1996–present | 2670 | 63° 02′ 04″ | 145° 29′ 48″ |
| | Tok River Valley | RAWS | 1999–present | 2300 | 62° 57′ 26″ | 143° 20′ 48″ |
| | Beaver Creek | Canadian | 1968–present | 2130 | 62° 24′ | 140° 52′ |
| | Chisana | NWS Coop | 1966–1972 | 3175 | 62° 05′ | 142° 00′ 59″ |
| | Chitina | NWS Coop | 1950–1971 | 600 | 61° 31′ | 144° 26′ |
| | Cordova | FAA | 1949–present | 41 | 60° 30′ | 145° 30′ |
| | Glennallen | KCAM | 1965–2001 | 1456 | 62° 07′ | 145° 32′ |
| | Gulkana | FAA | 1949–2001 | 1570 | 62° 09′ | 145° 27′ |
| | Kenny Lake | NWS Coop | 2000–present | 1280 | 61° 44′ | 144° 56′ |
| | Northway | FAA | 1949–2001 | 1710 | 62° 58′ | 141° 56′ |
| | Paxson | NOAA | 1975–present | 2700 | 63° 02′ | 145° 30′ |
| | Slana | NOAA | 1957–present | 2192 | 62° 42′ | 143° 59′ |
| | Snowshoe Lake | NOAA | 1963–present | 2300 | 62° 02′ | 146° 42′ |
| | Tok | NOAA | 1954–present | 1620 | 63° 21′ | 143° 03′ |
| | Tonsina Lodge | NOAA | 1963–present | 1500 | 61° 39′ | 145° 11′ |
| | Valdez | NWS Coop | 1964–present | 50 | 61° 04′ 48″ | 146° 09′ |
| | Yakutat | NWS Coop | 1949–present | 30 | 59° 31′ | 139° 40′ |
| | Beaver Creek | Snow Course | 1975–present | 2150 | 62° 25′ | 140° 51′ |
| | Chair Mountain | Snow Course | 1988–present | 3800 | 62° 04′ | 140° 48′ |
| | Chistochina | Snow Course | 1985–present | 2300 | 62° 33′ | 144° 36′ |
| | Haggard Creek | Snow Course | 1964–present | 2400 | 62° 42′ | 145° 27′ |
| | Jatahmund Lake | Snow Course | 1993–present | 2300 | 63° 37′ | 141° 58′ |

Table C4 (continued). Climate stations in and around Wrangell-St. Elias National Park and Preserve.

| Area | Station | Type | Years of Record | Elev (ft) | Latitude North | Longitude West |
|---|---|---|---|---|---|---|
| **Surrounding Area Outside Park/ Preserve Boundary (continued)** | Kenny Lake | Snow Course | 1980–present | 1300 | 61° 44′ | 144° 59′ |
| | Mentasta Pass | Snow Course | 1962–present | 2430 | 62° 54′ | 143° 40′ |
| | Paradise Hill | Snow Course | 1992–present | 2200 | 62° 48′ | 141° 18′ |
| | Paxson | Snow Course | 1982–present | 2650 | 63° 01′ | 145° 30′ |
| | Tazlina | Snow Course | 1996–present | 1225 | 62° 02′ 30″ | 145° 25′ |
| | Tok Junction | Snow Course | 1960–present | 1650 | 63° 18′ | 143° 00′ |
| | Tolsona Creek | Snow Course | 1985–present | 2000 | 62° 06′ | 146° 03′ |
| | Tsaina River | Snow Course | 1972–present | 1650 | 61° 12′ | 145° 30′ |
| | Worthington Glacier | Snow Course | 1958–present | 2100 | 61° 11′ | 145° 41′ |

Table C5. Climate stations in and around Yukon-Charley Rivers National Preserve

| Area | Station | Type | Years of Record | Elev (ft) | Latitude North | Longitude West |
|---|---|---|---|---|---|---|
| **Inside Preserve Boundary** | Ben Creek | RAWS | 1990–present | 1850 | 65° 17′ | 143° 04′ |
| | Coal Creek | Snow Course | 2002–present | 1000 | 65° 19′ | 143° 10′ |
| | Cathedral Mountain | Aerial Snow Marker | 2002–present | 1800 | 65° 10′ | 141° 09′ |
| | Copper Creek | Aerial Snow Marker | 2002–present | 2000 | 64° 52′ | 143° 24′ |
| | Crescent Creek | Aerial Snow Marker | 2003–present | 2600 | 64° 51′ | 143° 56′ |
| | Tacoma | Aerial Snow Marker | 2002–present | 1450 | 65° 26′ | 143° 44′ |
| | Three Fingers | Aerial Snow Marker | 2002–present | 3350 | 64° 32′ | 143° 09′ |
| **Surrounding Area Outside Preserve Boundry** | Birch Creek | RAWS | 1998–present | 850 | 65° 35′ 05″ | 144° 21′ 49″ |
| | Eagle | RAWS | 1992–present | 879 | 64° 46′ 34″ | 141° 09′ 43″ |
| | Eagle | NWS Coop | 1949–present | 810 | 64° 46′ | 141° 12′ |
| | Mission Creek | Snow Course | 1989–present | 900 | 64° 47′ | 141° 12′ |
| | Step Mountain | Aerial Snow Marker | 2002–present | 2850 | 65° 27′ | 141° 33′ |

Table C6. Climate stations in and around Denali National Park and Preserve

| Area | Station | Type | Years of Record | Elev (ft) | Latitude North | Longitude West |
|---|---|---|---|---|---|---|
| **Inside Park/Preserve Boundary** | McKinley River | RAWS | 1992–present | 840 | 63° 38′ 95″ | 151° 38′ 23″ |
| | Ruth Glacier | RAWS | 1998–present | 3300 | 62° 42′ 35.86″ | 150° 32′ 23.43″ |
| | Wonder Lake | RAWS | 1995–present | 2119 | 63° 29′ 24″ | 150° 52′ 48″ |
| | Dunkle Hills | CAKN new | New 2003 | 2850 | 63° 16′ 30″ | 149° 32′ 21″ |
| | Stampede Airstrip | CAKN new | New 2003 | 1800 | 63° 44′ 52″ | 150° 19′ 41″ |
| | Wigand Creek | CAKN new | New 2003 | 5640 | 63° 48′ 43.5″ | 150° 02′ 59.2″ |
| | HQ Weather | NWS Coop | 1922–present | 2070 | 63° 43′ 10.26″ | 148° 57′ 56.39″ |
| | Rock Creek Air Quality | NADP | 1987–present | 2162 | 63° 43′ 23.59″ | 148° 58′ 02.56″ |
| | Rock Creek Forest | DENA LTEM | 1994–present | 2411 | 63° 43′ 53.53″ | 148° 58′ 58.40″ |
| | Rock Creek Permafrost | DENA LTEM | 1994- present | 2375 | 63° 43′ 36.01″ | 148° 58′ 39.44″ |
| | Rock Creek Treeline | DENA LTEM | 1994–present | 3215 | 63° 44′ 07.41″ | 149° 00′ 24.27″ |
| | Rock Creek Lower Ridge | DENA LTEM | 1994–present | 3241 | 63° 44′ 06.20″ | 149° 00′ 32.33″ |
| | Rock Creek Upper Ridge | DENA LTEM | 1994–present | 4390 | 63° 44′ 48.19″ | 149° 00′ 52.20″ |
| | Rock Creek Bottom | Snow Course | 1993–present | 2100 | 63° 43′ 24.6″ | 148° 57′ 53.5″ |
| | Rock Creek Ridge | Snow Course | 1993–present | 2600 | 63° 43′ 39.91″ | 149° 00′ 02.39″ |
| | Stampede | Snow Course | 2002–present | 1800 | 63° 44′ 58.60″ | 150° 19′ 41.67″ |
| | Dunkle Hills | Snow Course, Aerial Snow Marker | New 2003 | 2770 | 63° 16′ 5.66″ | 149° 32′ 19.92″ |
| | Kantishna | Snow Course | 1995–present | 1670 | 63° 32′ 18.43″ | 150° 59′ 01.14″ |
| | Eldridge | Aerial Snow Marker | 2002 -present | 3260 | 63° 02′ 48.6″ | 150° 03′ 22.6″ |
| | Upper W Fork Yentna | Aerial Snow Marker | 2002–present | 900 | 62° 31′ 00.75″ | 152° 27′ 35.20″ |
| **Surrounding Area Outside Park/Preserve Boundary** | Farewell | RAWS | 1996–present | 775 | 63° 43′ 24″ | 154° 04′ 36″ |
| | Minchumina | RAWS | 1992–present | 740 | 63° 53′ 36″ | 152° 18′ 38″ |
| | Telida | RAWS | 1991–present | 650 | 63° 26′ 24″ | 153° 21′ 24″ |
| | Wein Lake | RAWS | 1988–present | 1050 | 64° 18′ 54″ | 151° 05′ 00″ |
| | Cantwell | NWS Coop | 1983–present | 2150 | 63° 24′ | 148° 54′ |
| | Chulitna River Lodge | NWS Coop | 1971–present | 1250 | 62° 53′ | 149° 50′ |
| | Healy 2 NW | NWS Coop | 1976–present | 1490 | 63° 53′ | 149° 01′ |
| | Minchumina | Snow Course | 1967–present | 730 | 63° 53′ 13.37″ | 152° 18′ 09.92″ |
| | Purkey Pile | Snow Course | 1980–present | 2025 | 62° 56′ 43.55″ | 152° 15′ 26.81″ |
| | Chelatna Lake | Aerial Snow Marker | 1964–present | 1650 | 62° 27′ 52.40″ | 151° 27′ 39.71″ |
| | Dutch Hills | Aerial Snow Marker | 1980–present | 3100 | 62° 36′ 18.56″ | 150° 51′ 18.34″ |
| | Nugget Bench | Aerial Snow Marker | 1968–present | 2010 | 62° 31′ 4.16″ | 150° 56′ 23.87″ |
| | Ramsdyke Creek | Aerial Snow Marker | 1980–present | 2220 | 62° 37′ 0.63″ | 150° 48′ 30.89″ |
| | Tokositna River | Aerial Snow Marker | 1980–present | 850 | 62° 37′ 45.92″ | 150° 46′ 32.80″ |

# Appendix D: Official WRCC Agreement

## Great Basin Cooperative Ecosystem Studies Unit

## Task Agreement

## National Park Service

## TASK AGREEMENT NO.: J8R07040012

**COOPERATIVE AGREEMENT NO.:** H8R07010001

**EFFECTIVE DATES:** 08/07/04 through 02/28/05

**COOPERATOR:** Western Regional Climate Center, Desert Research Institute, Reno, NV.

**PROJECT TITLE:** Climate Data Dissemination, analyses, and Archiving for the Central Alaska Network Inventory and Monitoring Program

**FISCAL YEAR FUNDING:** 2004 ACCOUNT #2103-0413-NII (411C) **NOT TO EXCEED** $14,000.00

**PROJECT ABSTRACT:** The Central Alaska Inventory and Monitoring Network (CAKN) proposes to partner with the DRI/WRCC to assist with the installation of climate monitoring sites within the network, the development of web-based access for near real-time data for climate stations, archiving of climate data collected at the parks, and the development of web based data summary tools and options to generate reports.

**SCOPE OF WORK:** See attached.

Unless otherwise provided herein, the terms and conditions of H8R07010001 apply to this Task Agreement.

| DESERT RESEARCH INSTITUTE | NATIONAL PARK SERVICE PACIFIC WEST REGIONAL OFFICE |
|---|---|
| /s/ John Bees | /s/ Theresa A. Fisher |
| John Bees<br>Director of Sponsored Research | Theresa A. Fisher<br>Contracting Officer |
| 9/7/04 | 8/26/04 |
| Date | Date |

## TASK AGREEMENT NO. J8R07040012

## CLIMATE DATA DISSEMINATION, ANALYSES, AND ARCHIVING FOR THE CENTRAL ALASKA NETWORK INVENTORY AND MONITORING PROGRAM

This Task Agreement by and between the National Park Service (NPS) and the Desert Research Institute (DRI)/ Western Regional Climate Center (WRCC), is issued against the Great Basin CESU Cooperative and Joint Venture Agreement, H8R07010001 for the purpose of mutual assistance in conducting a project entitled, "Climate Data Dissemination, Analyses, and Archiving for the Central Alaska Network Inventory and Monitoring Program. Unless otherwise specified herein, the terms and conditions of H8R07010001 apply to this Task Agreement.

### *ARTICLE 1 – BACKGROUND AND OBJECTIVES*

The Central Alaska Inventory and Monitoring Network (CAKN) proposes to partner with the DRI/WRCC to assist with the installation of climate monitoring sites within the network, the development of web-based access for near real-time data for climate stations, archiving of climate data collected at the parks, and the development of web based data summary tools and options to generate reports.

Current State of Monitoring in CAKN Network The three park units of the CAKN together span an enormous area measuring approximately 650 km from north to south and 650 km from east to west. Elevations range from sea level to 6194 m (20,320'); latitudes reach to more than 65 degrees north. The climate in this vast, northern country is extremely variable, ranging from strongly maritime to strongly continental. Climatic conditions in the high mountainous areas are among the most severe in the world.

Climate records in this region are generally sparse and intermittent. Most weather stations have been located at relatively low elevations in settlements surrounding the parks. The long-term sites are manually operated and require daily site visits to record weather observations. Several remote automated weather stations (RAWS) were deployed in and around the parks in the 1990s, but these were established as part of a fire monitoring network, and placement was determined primarily on the basis of fire potential.

In an attempt to better understand climate variation as well as possible long-term changes in ecosystems of the CAKN, new long-term climate monitoring stations will be installed throughout the three parks starting in the summer of 2004.

**Types of Weather Stations in the CAKN Network:** Several programs administered by various federal agencies and private entities deploy and/or manage weather stations throughout Interior Alaska. These programs are described below:

A. **Automated Surface Observing System** (ASOS - NWS), Automated Weather Observing System (AWOS – FAA) and APAID (NWS) stations are managed by the Federal Aviation Administration (FAA), National Weather Service (NWS), and private parties. ASOS and AWOS are automated systems with a suite of sensors measuring and transmitting weather data to help meteorologists, pilots, and flight dispatchers prepare and monitor weather forecasts, plan flight routes, and provide necessary information for correct takeoffs and landings. The system provides continuous data on conditions at the runway touchdown level. APAID weather stations are private stations under contract with the NWS to provide aviation weather data to the NWS.

B. Cooperative Observer Program administered by the NWS. The NWS COOP was formally created in 1890 under the Organic Act. Its mission is two-fold: to provide observational meteorological data, usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, required to define the climate of the United States and to help measure long-term climate changes; and to provide observational meteorological data in near real-time to support forecast, warning, and other public service programs of the NWS.

C. National Interagency Remote Automated Weather Stations Network (RAWS) managed by various federal and state land managers. There are nearly 1,500 interagency remote automated weather stations located throughout the United States – mostly in the Western states. Many stations are owned by the wildland fire agencies and are placed in locations where

they can monitor fire danger. RAWS sensors typically monitor wind speed and direction, wind gusts, precipitation (rain), air temperature, and relative humidity. These units collect, store, and forward data to a computer system at the National Interagency Fire Center (NIFC) via the Geostationary Operational Environmental Satellite. Data are automatically forwarded to other computer systems including the WRCC in Reno, NV. There are about 100 RAWS in Alaska and seven of these RAWS are in the CAKN parks with many more near the park boundaries. Weather data assists land management agencies with a variety of projects including, monitoring air quality, rating fire danger, and providing information for research applications.

D. SNOwpack/TELemetry (SNOTEL) and Snow Course programs managed by the National Water and Climate Center – a branch of the Natural Resource Conservation Service (NRCS). The National Water and Climate Center provides real-time snow and climate data using automated remote sensing from sites in the mountainous regions of the Western United States. SNOTEL stations measure snow water equivalent, snow depth, precipitation, temperature, and other climatic elements in hourly, daily, monthly, and yearly increments. Manual snow surveys require two-person teams to measure snow depth and water content at designated snow courses. A snow course is a permanent site that represents snow pack conditions at a given elevation in a given area. A particular snow pack may have several courses. Generally, the courses are about 50-75 feet long and are situated in small meadows protected from the wind. Snow survey courses are set up across the western USA and Alaska. Snow surveyors from NRCS and the other cooperating agencies collect data from some 1,600 snow courses several times each winter. They determine the depth and the water content of the snow pack. These data are used for forecasting and management of water supplies http://www.wcc.nrcs.usda.gov/snow/snowhist.html). There are twelve snow courses and eight aerial markers within CAKN and many more just beyond the park boundaries. We have a draft agreement with NRCS to install up to six new SNOTEL sites within CAKN.

**Weather Data Archives:** Weather data is permanently archived in a variety of databases at the National Climatic Data Center (NCDC) and at regional climatic centers across the USA. Alaska is within the purview of the WRCC. The mission of the WRCC is to disseminate high quality climate data and information pertaining to the western United States; foster better use of this information in decision-making; conduct applied research related to climate issues; and improve the coordination of climate-related activities at state, regional and national scales.

SNOTEL and Snow Course data is permanently archived at the National Water and Climate Center (NWCC). The mission of the NWCC is to lead the development and transfer of water and climate information and technology in support of natural resource conservation. SNOTEL data is also available through WRCC.

The new weather stations that will be installed this summer in the CAKN will be equipped with satellite telemetry and will transmit hourly which will make archiving and dissemination of climate data with WRCC. The DRI/WRCC has developed web pages showing current weather conditions at many weather stations in the western USA through graphic and tabular displays.

**Objectives:** 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 other physical processes, can have significant impacts on the entire ecosystem. In order to properly monitor an ecosystem, the changes in the physical environment must be properly monitored and documented. In the 2002 CAKN Scoping meeting, the Physical Monitoring Strategy was discussed at length with various experts in the field including climate experts. A main objective of the strategy is to monitor and record weather conditions at representative locations in order to quantify one of the drivers in Alaskan ecosystems, identify long and short-term trends, provide reliable climate data to other researchers, and to participate in larger scale climate monitoring and modeling efforts.

The specific objectives for this project are to promote the facilitation of the objectives of climate monitoring within the CAKN parks. They are listed below:

1. Develop web access for near real-time data for the climate stations (RAWS, Coop, SNOTEL, and new stations) in and around the CAKN parks which includes Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley National Preserve. This would include an NPS icon linked to maps of the three parks with clickable links to the weather stations.

2. Install new climate stations in the CAKN and become familiar with the technical challenges that exist in siting stations in Alaska.
3. Develop web based data summary tools and report generation options for current and historical data including:

   a. Station Metadata (including photo, description, location info, and ability to add information as more is collected)
   b. Data Lister
   c. Data Inventory
   d. Composite Station Daily Summary
   e. Daily Summary Tool
   f. Daily Summary (with wind Chill and Heat Index)
   g. Monthly Summary
   h. Wind rose Graph and Tables
   i. Hourly frequency
   j. Distribution/Histogram
   k. Monthly and annual summary
4. Develop analytic tools for climate data that would be used to summarize climate data from one or multiple stations for report generation capabilities for the network

### *ARTICLE II – STATEMENT OF WORK*

A. The NPS agrees to:

   a. Provide financial assistance to DRI/WRCC as provided in Article V.
   b. Assign Pamela Sousanes as the Government Technical Representative (GTR) for this project.
   c. Assist DRI/WRCC in the planning and development of this project.
   d. Provide weather data from climate stations within CAKN for permanent archiving at WRCC.
   e. Provide and coordinate aircraft (both fixed-wing and helicopter), and safe and reasonable accommodations for climate station installation (including appropriate Personal Protective Equipment (PPE) for fixed-wing or helicopter transports).
   f. Provide staff for installation of climate stations.
   g. Provide necessary NPS standards and formats for data and web products produced by DRI.
   h. Provide review of web page design report generations for climate stations within CAKN.
   i. Participate and collaborate with DRI/WRCC PI's in a 60-day wrap up period following the receipt of final report.

B. DRI/WRCC agrees to:

   a. Appoint Kelly Redmond as Principal Investigator (PI).
   b. Develop web access for near real-time data for all of the climate stations (RAWS, Coop, SNOTEL, and new stations) in and around the CAKN.
   c. Develop web tools for analysis and monthly/annual report generation capabilities for CAKN climate data.
   d. Accept all FTP data from CAKN weather stations to incorporate into climate data archives.
   e. Provide assistance for field installations during 2004.
   f. Provide a data CD with all CAKN climate data annually.
   g. Work interactively with NPS GTR during web tool development to insure tools meet the needs of CAKN parks.
   h. Provide comments and recommendations on the CAKN Climate Monitoring Site Evaluation Document.
   i. Participate and collaborate with NPS GTR in a 60-day wrap up period following the receipt of final report.

### *ARTICLE III – TERM OF AGREEMENT*

This Task Agreement is effective on August 7, 2004 and will extend through February 28, 2005.

### *ARTICLE IV – KEY OFFICIALS*

A. For NPS:

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B. For DRI/WRCC:

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### *ARTICLE V – AWARD AND PAYMENT*

A. NPS will provide financial assistance to DRI/WRCC on a reimbursable basis in an amount not to exceed $14,000 for FY2004.

B. The chargeable appropriation for this Task Agreement is:
**Account Not to exceed** 2103-0413-NII $14,000.00

C. A Standard Form (SF) 270, Request for Advance of Reimbursement, must be submitted for payment to the Contracting Officer in an original and one copy at the convenience of DRI, but no more frequently than monthly and no less frequently than annually. The request for reimbursement shall be accompanied by a breakdown sheet showing costs in each budgetary item and shall be addressed to:

National Park Service
Pacific West Regional Office
1111 Jackson St., Suite 700
Oakland, CA 94607
Attn: Theresa Fisher

Payment will made via electronic funds transfer directly to DRI/WRCC account at their financial institution.

### *ARTICLE VI - PRODUCTS AND DELIVERABLES*

DRI/WRCC will:

1. Provide comments and recommendations on the CAKN Climate Monitoring Site Evaluation Document by September 30, 2004, including a review of the process, station design, site considerations, and specific climate station site evaluations for the three parks in the network.
2. Provide assistance for station installations in one of the three CAKN parks in 2004 (approximately one week in length).
3. Provide a draft web page design for display of current weather conditions at CAKN weather stations including existing stations and new stations deployed in summer 2004 by September 30, 2004.
4. Archive all incoming climate data from the CAKN with WRCC. Begin process by December 31, 2004.
5. Post data from stations, within Denali National Park and Preserve, that are not currently telemetered through a monthly FTP upload (these data would not be real-time). Begin process by December 31, 2004.
6. Process data that have been downloaded on site from the CAKN stations and sent via FTP to DRI/WRCC to ensure an accurate record with no gaps from missed satellite transmissions. Begin Process by December 31, 2004.
7. Provide a data CD (or current format) to the CAKN Data Manager with data from all of the CAKN climate stations to NPS annually for archiving.
8. Develop web based tools for analysis of CAKN climate data by December 31, 2004. Products may include capabilities to produce and analyze data derived from original climate data, including departures from normal, interim averages and trends, trends and manipulations (averages, etc) of individual data streams. An ability to compare data with derived data. Chart and table production and download capability (in common file formats). A packaged report suite that could serve as a period report for CAKN parks (i.e.: "annual station report for CAKN" might include charts parameter with all stations on the chart, a table of station averages and departures from normal, comparisons to longer-term Alaska stations (FAI, ANC).) Some of the items listed under this task will be ongoing and not necessarily completed by December 31, 2004.

### *ARTICLE VII - LIABILITY*

Each party accepts responsibility for any property damage, injury, or death caused by the acts or omissions of their respective faculty, students, employees, or other representatives, arising under this Task Agreement, to the fullest extent permitted by law.

### *ARTICLE VIII – ATTACHMENTS*

**I. Budget**

**Attachment 1: Budget**

Desert Research Institute
Title: NPS-CAKN Networks Sponsor: NPS (CESU)
Period: 08/07/04–12/31/04

Budget Table

| Catebory | Detail | Rate | Units | Amount |
|---|---|---|---|---|
| Salaries | K. Redmond | $56.93 | 4 | $228 |
| | G. McCurdy | $40.24 | 80 | $3,219 |
| | D. Simeral | $22.81 | 80 | $1,825 |
| **Total Salaries** | – | – | **164** | **%5,272** |
| Fringe Benefits | Profession | 44.10% | – | $2,325 |
| **Total Fringe** | – | – | – | **$2,325** |
| **Total Labor** | – | – | – | **$7.597** |
| Travel to Anchorage, Alaska | Airfare | $800 | 1 | $800 |
| | Per Diem (Meals/ Lodging) | $259 | 10 | $2,590 |
| | Vehicle Rental | $45 | 9 | $405 |
| | Gasoline | – | – | $120 |
| **Total Travel** | – | – | – | **$3,915** |
| Operating Expenses | Copying/ Communications | 2% | – | $152 |
| | Computer Recharge | $1.54 | 164 | $253 |
| **Total Operating Expenses** | – | – | – | **$404** |
| **Total Direct Cost** | – | – | – | **$11,916** |
| Indirect Cost | – | 17.50% | – | $2,084 |
| **TOTAL COST** | | | | **$14,000** |

# Appendix E: Example of Report

## E.1 File reference

This report is available at the Center for Research, Science and Learning's Technical Library at Denali National Park and Preserve. Author: Sousanes, Pamlea J. 2002.

## E.2 Title

2002 Long Term Ecological Monitoring Climate Data Summary Denali National Park and Preserve

## E.3 Executive Summary

Latitude, altitude and continentality are the primary determinants of climate in the mountainous region of Denali National Park & Preserve. However, there are two factors that make detailed descriptions of climate in mountain terrain more difficult than simply assessing these factors. First is the varied topography within a mountain range, which produces microclimatic differences over very short distances. Second, there are few good high-altitude climate stations because of feasibility, reliability, accessibility, and accuracy. Measurements at these stations, especially precipitation measurements, are often inaccurate as a result of the severe high-altitude environment. Further, the measurements may not be representative of the region surrounding the climate station because of microclimate variations.

The climate of Denali National Park and Preserve is characterized by great spatial variability, and includes both transitional maritime (influenced by the ocean) and continental (influenced by the Alaska Range) climate subtypes. On the north side of the range, where park headquarters is located, temperatures are typical of a continental climate with strong seasonal variations. There is also less precipitation on the north side because of its location on the windward side of a major mountain range. The maritime climate on the south side of the Alaska Range is influenced by the prevailing weather patterns of the Gulf of Alaska, with milder air temperatures with less seasonal variation and more precipitation.

There are a number of climate stations within Denali National Park and Preserve. The locations of the stations up until 2002 have been determined by designs catering to micro- meteorological studies within a particular watershed and to fire management. New installations in 2002 will help us gain a better understanding of park climatic conditions on an extensive scale. These additional stations will improve the understanding of the Denali ecosystem while providing timely information on weather conditions to park managers, and by providing valuable data to the National Weather Service (NWS), Natural Resources Conservation Service (NRCS), park researchers, scientists, and the public.

This report summarizes the climate data collected for the Long-term Ecological Monitoring (LTEM) Program at Denali National Park for 2002. It includes climate summaries from thirteen sites around Denali National Park and Preserve. This report is the eighth in a series of annual reports of the Long-Term Ecological Monitoring Meteorology Program starting in 1995.

## E.4 Introduction

Denali National Park & Preserve consists of six million acres with the highest peaks of the Alaska Range arcing east-west creating two major climate regimes within its boundaries, a transitional maritime climate to the south and a continental interior climate to the north.

Temperatures have changed more in Alaska over the past 30 years than they have anywhere else on Earth: winters have warmed by a startling 2-3 °C, compared with a global average of 1 °C. That's guaranteed to have dramatic effects in a subarctic landscape, where even small temperature changes can make the difference between freezing and melting.

It is hard to tell how much of Alaska's climate change is due to global warming and how much is due to natural climate cycles. The Pacific Decadal Oscillation—an El Niño-like fluctuation of temperatures between the north and tropical Pacific that takes place over 20–30 years—flipped Alaska into a warming phase in the 1970s. The North Atlantic Oscillation has also contributed to warmer winters in Alaska since the late 1960s (Thompson and Wallace, 2001). But at the same time it has been associated with a 2-3 °C cooling just across the continent in Greenland. There seems to be a 60-year see-saw in temperatures between the east and west of this part of the Arctic: when one side heats up, the other cools down. In a

few years, this could flip again and reverse Alaska's recent warming trend.

The overall purpose of weather monitoring in Denali is to monitor and record weather conditions at representative locations in order to identify long and short-term trends, provide reliable climate data to other researchers, and to participate in larger scale climate monitoring and modeling efforts.

The parameters that are measured at the stations include air temperature, relative humidity, wind speed, wind direction, and precipitation. In addition to these variables there are certain stations that measure solar radiation and barometric pressure. Table E1 lists the parameters measured at each station.

## E.5 Study Areas

### *E.5.1 LTEM Rock Creek Watershed*

A network of six automated weather stations located in the Rock Creek watershed adjacent to Park headquarters has been running since 1994. In addition to this micro- meteorological monitoring, a single manual National Weather Service (NWS) Cooperative weather station has been operating at park headquarters since the fall of 1923.

The Rock Creek drainage is located on the southern flanks of Mt. Healy in the northeastern portion of Denali National Park at 63°45' N latitude, -149°00'W longitude. The weather stations vary in elevation from 631 meters to 1338 meters, with vegetation communities ranging from forest to tundra. Hourly dated is recorded at the stations in this watershed.

### *E.5.2 Remote Automated Weather Stations (RAWS) and Manual Stations Parkwide*

There are four RAWS stations ranging in elevation from 225 meters to 1006 meters. Three of the four are located on the north side of the Alaska Range, Wonder Lake, McKinley River and Lake Minchumina, and one is located on the south side adjacent to the terminus of the Ruth Glacier. The data from the RAWS stations is managed by the Bureau of Land Management National Interagency Fire Management Center in Boise, Idaho. The data is transmitted every hour via a GOES satellite transmitter. The data is available via the Internet at http://fire.ak.blm.gov. The data is archived by the U.S. Forest Service Weather Information System (WIMS) and the Western Regional Climate Center. Fire management officers at Denali use the fire index data from RAWS stations on a daily basis during fire season to assess climatic conditions for fire weather monitoring. Data quality is only guaranteed during the summer months when there is sufficient sunlight to power the remote systems, and when technicians can access the site (via helicopter) when repairs or replacements are necessary. During the winter months it is not practical to visit the stations due to budget restrictions and safety.

Table E1. Weather station variables

| Station | Air Temp | Relative Humidity | Wind speed & Direction | Precip | Barometric Pressure | Evaporation | Solar Radiation |
|---|---|---|---|---|---|---|---|
| Headquarters | ■ | – | – | ■ | – | ■ | – |
| Eielson Visitor Center | ■ | – | – | ■ | – | – | – |
| Wonder Lake | ■ | – | – | ■ | – | – | – |
| Air Quality | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Permafrost | ■ | ■ | ■ | – | – | – | ■ |
| Forest | ■ | ■ | ■ | – | – | – | ■ |
| Treeline | ■ | ■ | ■ | – | – | – | ■ |
| Lower Ridge | ■ | ■ | ■ | ■ | ■ | – | ■ |
| Upper Ridge | ■ | ■ | ■ | – | – | – | ■ |
| Wonder Lake RAWS | ■ | ■ | ■ | ■ | – | – | – |
| Lake Minchumina RAWS | ■ | ■ | ■ | ■ | – | – | – |
| McKinley River RAWS | ■ | ■ | ■ | ■ | – | – | – |
| Ruth Glacier RAWS | ■ | ■ | ■ | ■ | – | – | – |

■ = parameters measured

The two seasonal NWS Cooperative Stations are located at Wonder Lake Ranger Station and Eielson Visitor Center. Temperature and precipitation readings are taken each day at 0800 or 0900 by observers living or working at these locations.

### *E.5.3 Additional Stations added in 2002*

In summer 2002 two new remote weather stations were installed complete with satellite telemetry. The stations are set up to record air temperature, relative humidity, wind speed and direction, and solar radiation Precipitation gauges and soil temperature probes will be added to the arrays in 2003. The two sites are located at the Stampede Mine Airstrip and the Dunkle Mine Airstrip. These sites were chosen because (1) they represent large climatic regions where there is a lack of basic weather data, (2) they are easy to access with fixed-wing aircraft, or snowmobiles, and (3) these are areas that will not be negatively impacted by the addition of meteorological equipment because they are in previously disturbed areas. All formal compliance documents were completed in the spring prior to the field season. The site visits involved reconnaissance, installation, and a follow-up maintenance trip in the fall. The sites are accessible by skis, snowmobile, or skied aircraft in the winter months if necessary. Reconnaissance for a third remote site was done at the Upper West Fork Yentna while installing an aerial snow marker. The location is suitable, but the cost to get to the location is high given the distance from Talkeetna (1-hour flight time, one-way). See Figure E1 for new site locations. (Maps with pre-2002 site locations are provided in the *1998 Climatological Data Summary-Denali National Park and Preserve on file at the Division of Research and Resource Preservation at Denali National Park and Preserve).*

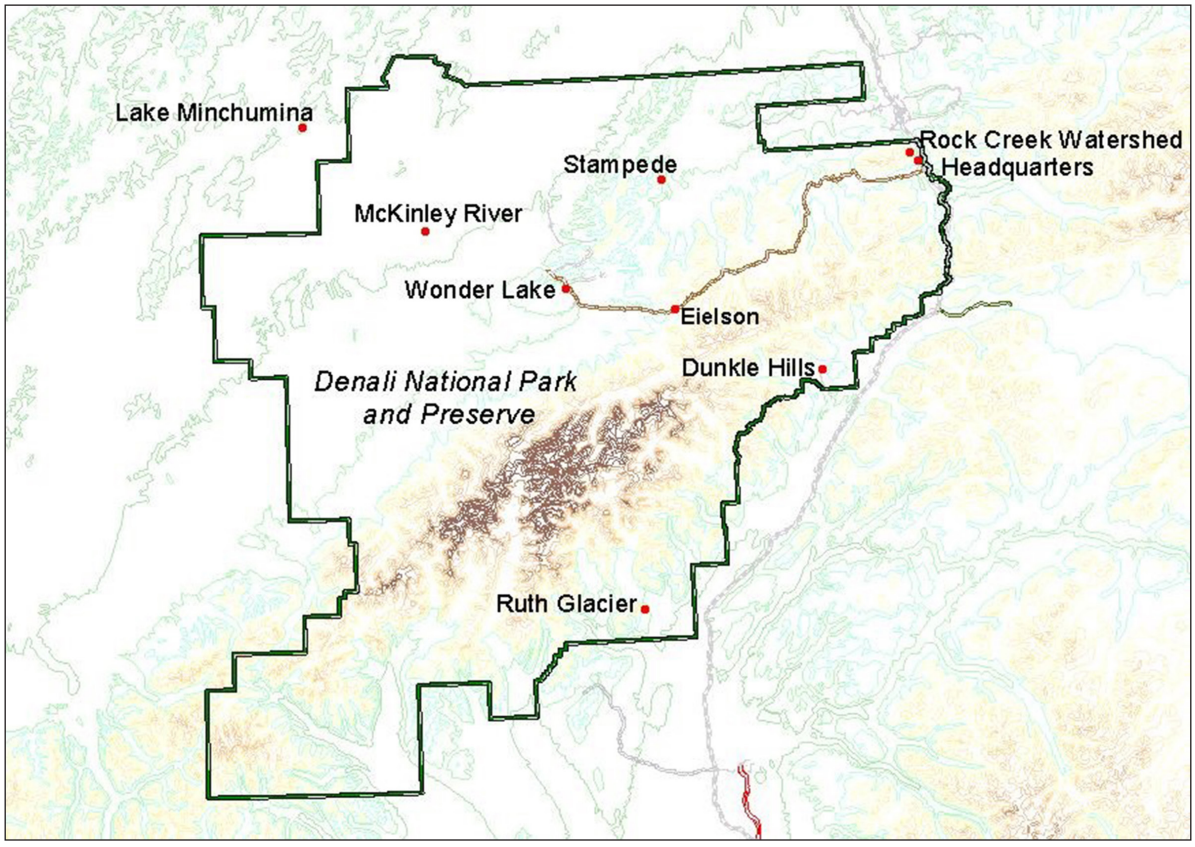



Figure E1. Map of weather station locations in Denali

## E.6 Methods

Methods of the climate monitoring program are explained in the *Weather Monitoring Handbook (1997)*. This document provides all of the information about the equipment used, methods of data collection, and archiving of data.

## E.7 Results

### *E.7.1 Denali National Park and Preserve Headquarters*

These data were taken from the National Weather Service Cooperative Observation Station located near the dog kennels at headquarters.

The year 2002 was marked by warm weather in the autumn and winter months, and relatively cool weather during the spring and summer. See Tables E2 and E3 for monthly air temperature and precipitation amounts recorded at Denali headquarters for 2002 compared with the average values for the period of record (1925-2002) and Figure E2 for a graphical presentation of minimum, maximum, and average air temperatures. Denali experienced above normal temperatures in January, February, and March. The western and northern regions of Alaska were cooler than normal during this period. That situation reversed during April, Denali and the southern portion of Alaska were cooler than normal, and the west and arctic were warm. April also saw above average precipitation in Denali. Nearly 7 cm of total precipitation including 66 cm of snow fell. Although this wasn't record breaking in Denali, it was the wettest and snowiest April on record in Fairbanks. May was

Table E2. Mean monthly air temperatures (MMAT): 2002 and Period of Record

| Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMAT °C 2002 | –10.1 | –10.5 | –10.3 | –5.8 | 7.1 | 10.9 | 12.5 | 9.7 | 6.6 | 0.9 | –2.4 | –9.2 |
| MMAT °C Period of record | –16.6 | –14.4 | –10.5 | –2.8 | 5.2 | 11.1 | 12.7 | 10.3 | 5.0 | –4.3 | –12.3 | –16.3 |

Red = Warmer than normal Blue =Cooler than normal

Table E3. Monthly precipitation amounts: 2002 and Period of Record

| Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation - cm 2002 | 0.38 | 0.00 | 0.17 | 2.75 | 0.80 | 3.78 | 4.59 | 5.37 | 0.81 | 1.11 | 0.17 | 0.26 |
| Precipitation –cm (All years avg.) | 0.72 | 0.59 | 0.43 | 0.44 | 0.80 | 2.19 | 2.96 | 2.68 | 1.61 | 0.98 | 0.72 | 0.78 |

Yellow = Drier than normal Green = wetter than normal

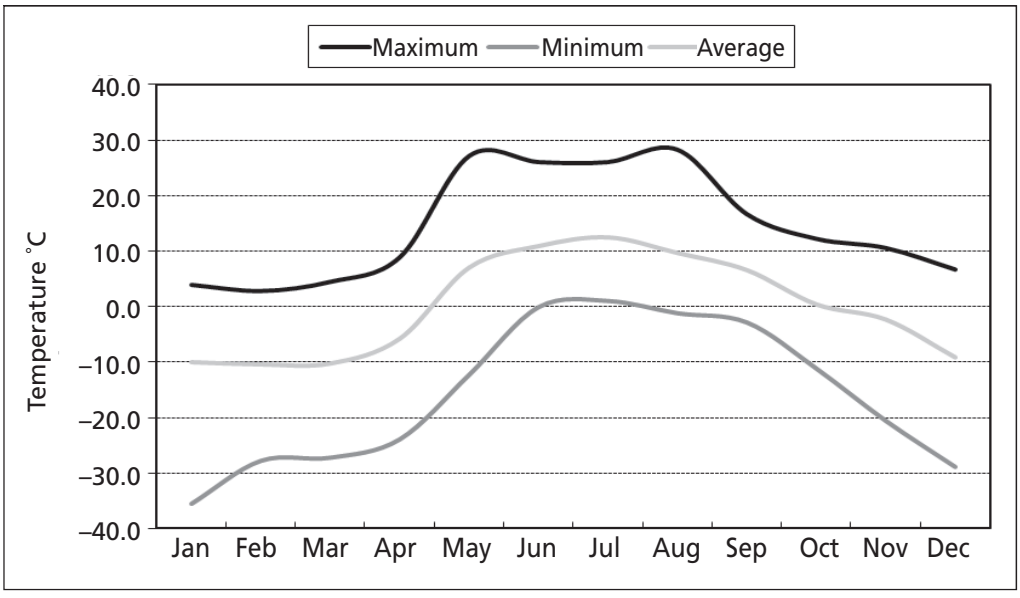



Figure E2. Air temperatures: headquarters

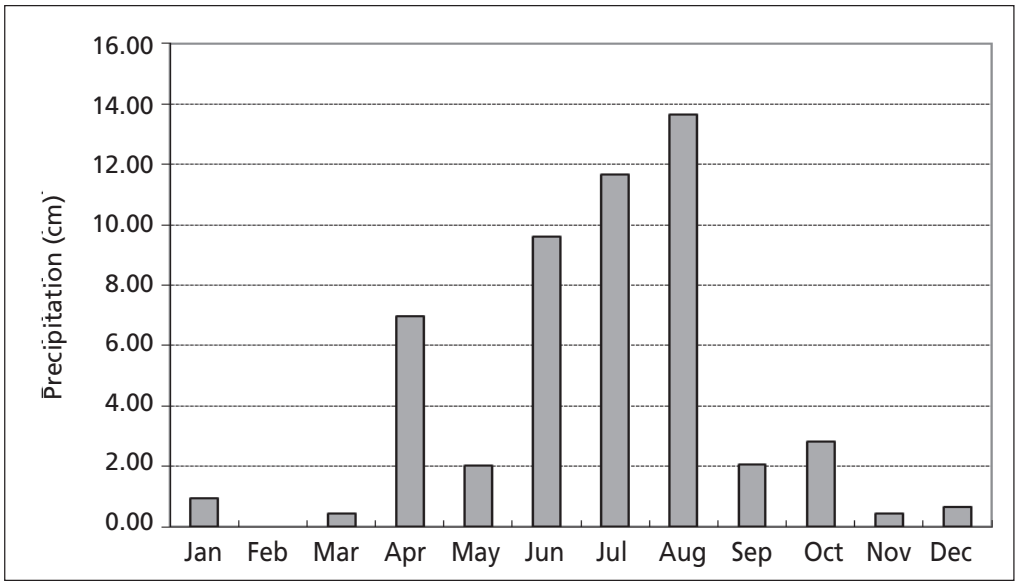



Figure E3. Monthly precipitation totals: park headquarters.

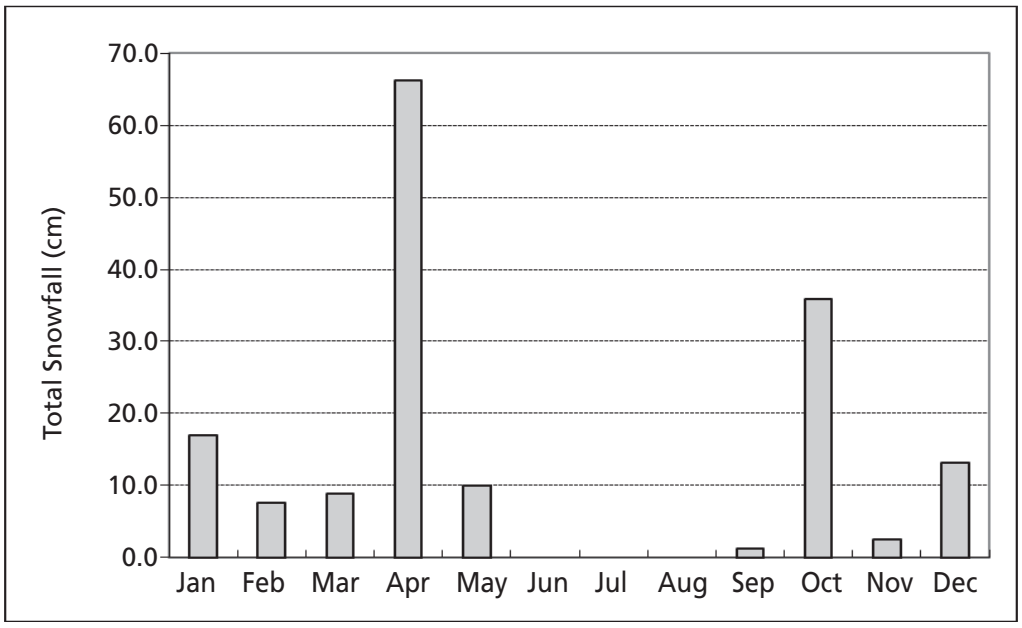



Figure E4. monthly snowfall totals: park headquarters. Note: On 2/11/2002, 3 cm of snow fell and on 2/13/2002, 5 cm of snow fell, but no precipitation was recorded.

just the opposite in Denali, with a total of five new record high temperatures observed, including 27°C on the 26th. June, July, and August temperatures were all near or just below normal in Denali, making for a relatively cool summer. September began a period of above normal temperatures throughout most of Alaska, including Denali. A large and persistent flow pattern resulting in relatively warm southerly air being pushed into Alaska left Denali 1.6°C above normal in September, 5.2°C above normal in October, 9.9°C above normal in November, and 7.1°C above normal in December. Two new record high temperatures were observed in November, 9°C on the 5th and 11°C on the 6th. The warm weather did not retreat until the last week of the year, when the first cold spell arrived bringing temperatures as cold as -29°C. In summary the mean annual temperature for 2002 in Denali was 2.7°C above the 1925 to 2001 average and total precipitation of 51.3cm (water equivalent) was about 13.2 cm above average. Figures E3 and E4 show precipitation and snowfall amounts at headquarters for 2002.

### *E.7.2 Wonder Lake and Eielson Visitor Center*

The temperature and precipitation measurements are only made at these sites during the summer months when the Ranger Station at Wonder Lake and Eielson Visitor Center are staffed with summer rangers. Data were collected at Wonder Lake starting on June 17, 2002, therefore no temperature averages or precipitation totals were calculated for that site. The highest temperature recorded at the National Weather Service Cooperative Observer Stations within the park (Headquarters, Eielson Visitor Center, and Wonder Lake) was 28.9°C recorded at Wonder Lake (646 m) on June 18, 2002. The coldest temperature of the summer was -6.1°C recorded at Eielson Visitor Center (1150 m) on August 20, 2002. The warmer temperatures of the season were recorded at Wonder Lake and the coolest summer t emperatures were recorded at Eielson Visitor Center. Figure E5 shows the monthly mean temperatures at the three sites.

The summer precipitation totals were the highest at Eielson Visitor Center with a total of 73.9 cm for the season. For comparison during July and August Wonder Lake received 25.5 cm of rain, headquarters received 25.3 cm of rain, while Eielson received 56.2 cm of rain. See Figure E6 for the monthly summer precipitation totals for the three sites. The

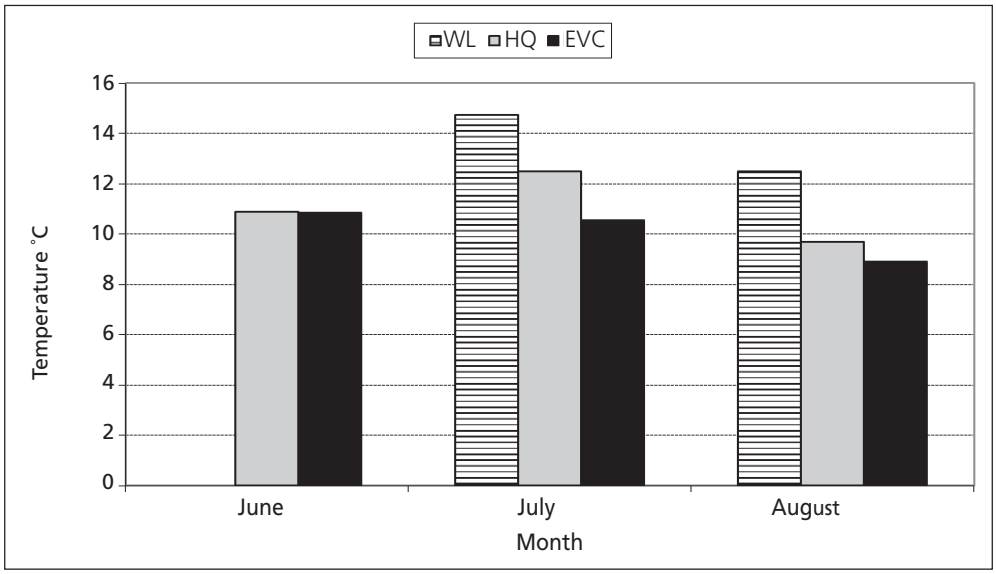



Figure E5. Summer temperatures at Wonder Lake, Eielson Visitor Center, and Park headquarters.

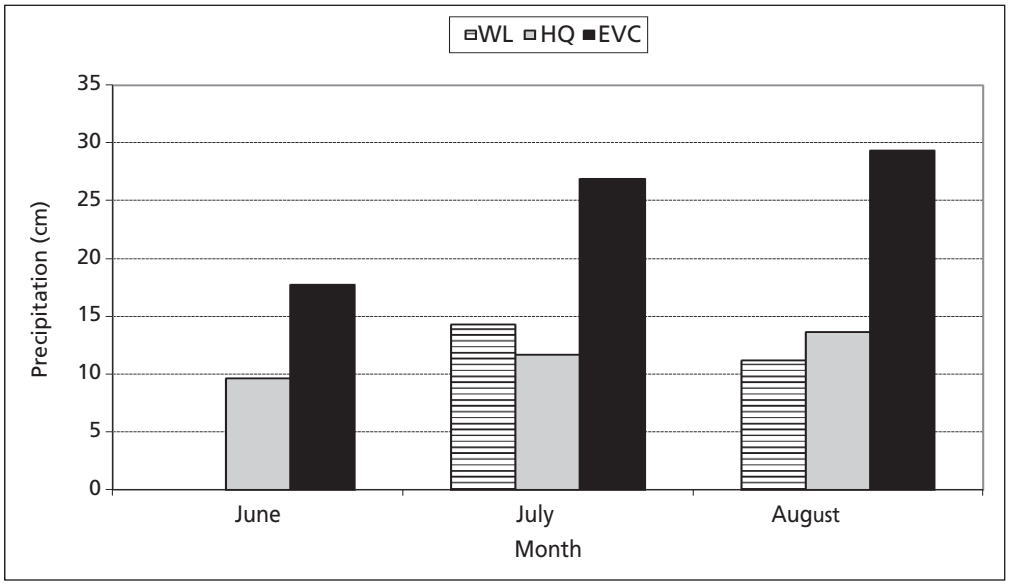



Figure E6. Summer precipitation totals for Wonder Lake, Eielson Visitor Center, and Park headquarters.

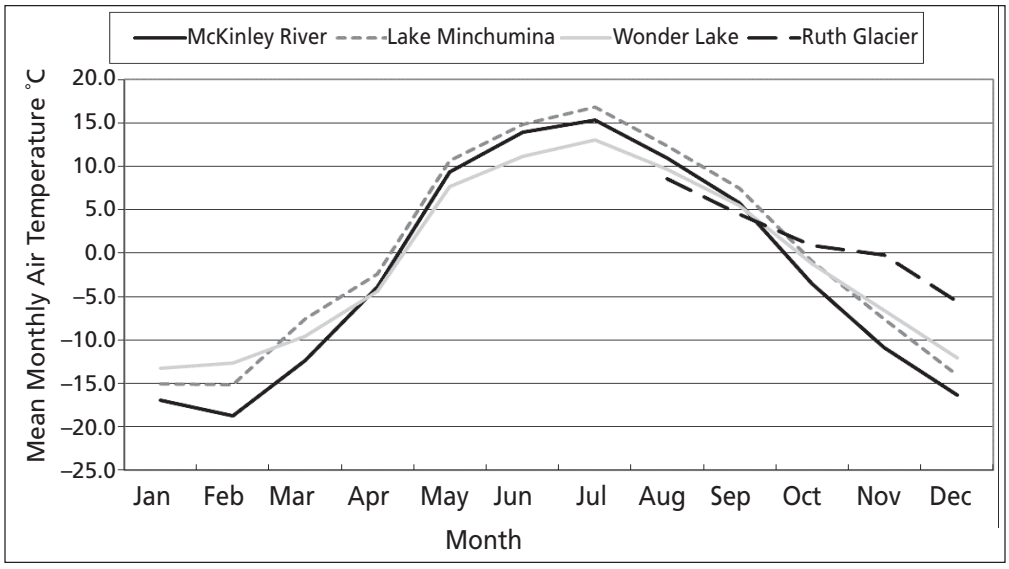



Figure E7. Mean monthly air temperatures (°C) for the four RAWS sites.

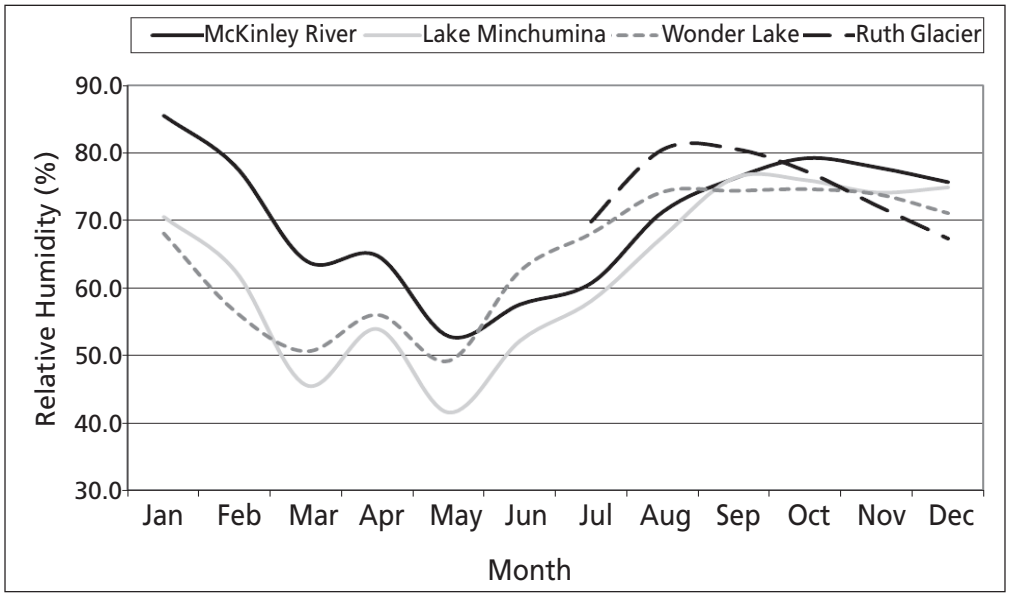



Figure E8. Mean monthly relative humidity at the RAWS sites.

most amount of precipitation recorded in a 24 hour period was 8 cm on August 17, 2002 at Eielson Visitor Center.

### *E.7.3 Remote Automated Weather Stations (RAWS)*

Air Temperature and Relative Humidity: The warmest month for the three north side RAWS sites is July with a mean monthly temperature of 15.1°C. The coldest month for the north side sites is February with a mean monthly temperature of -15.5°C. The south side RAWS site at Ruth Glacier had cooler average summer temperatures and milder mean winter temperatures. This station sits at a higher elevation than any of the north side RAWS sites and is located south of the Alaska Range. The lowest temperature recorded at the RAWS sites was -42.7° C at McKinley River on January 25, 2002. The highest temperature was 32.2°C recorded at Lake Minchumina on August 3, 2002. The mean monthly temperatures for all of the RAWS sites are shown in Figure E7 below. Relative Humidity values were highest at the McKinley River site and lowest at Lake Minchumina. Relative humidity was lowest in May and highest in October based on the averages from all three sites. Ruth Glacier showed much higher relative humidity values in August and September then the north side sites and nearly the same in other months. See Figure E8 for mean monthly relative humidity values for the four RAWS sites.

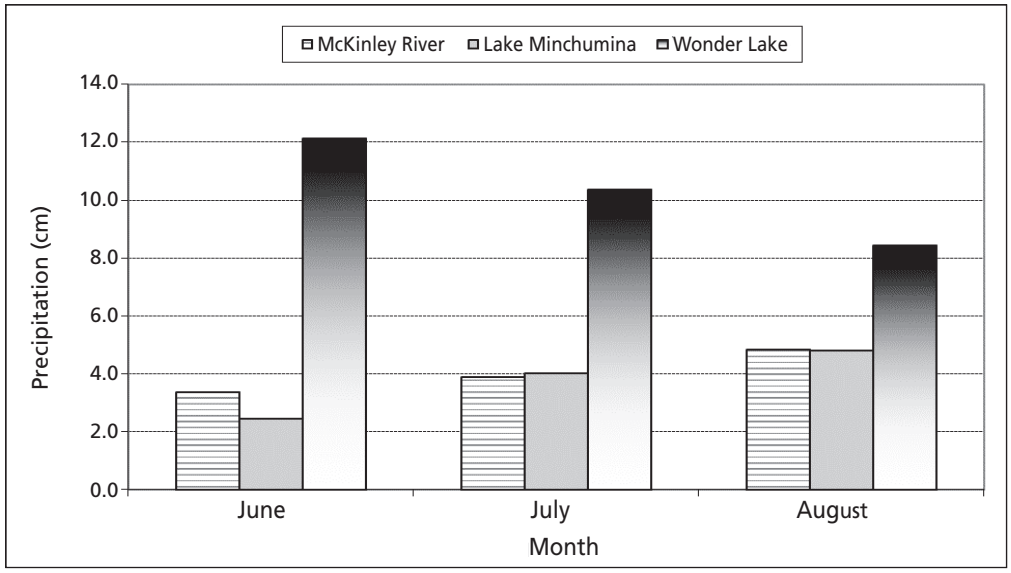



Figure E9. Summer precipitation totals at the three north side RAWS sites

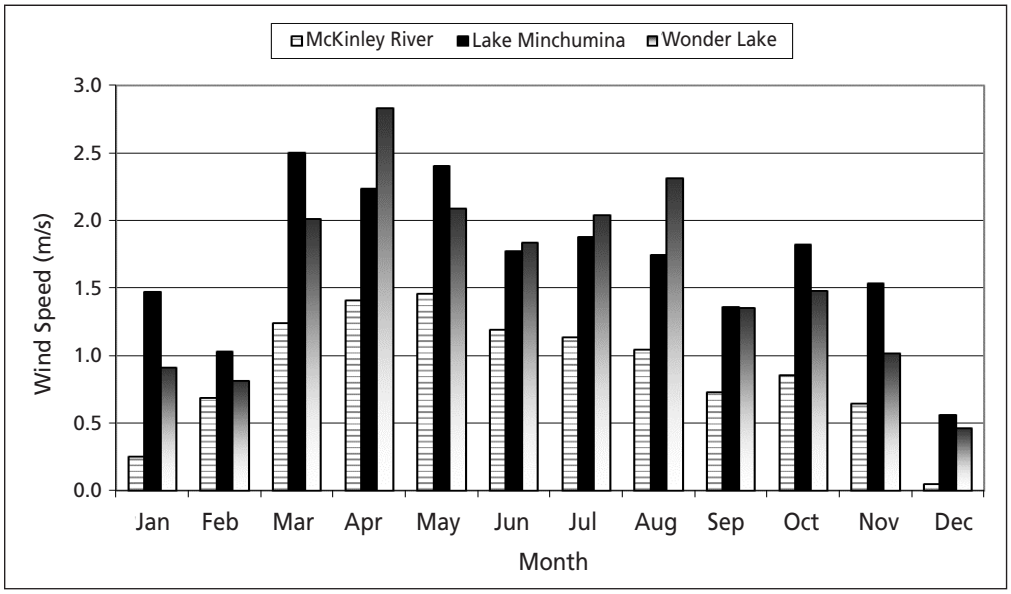



Figure E10. Mean monthly wind speeds at three north side RAWS sites

Precipitation values for the north side RAWS sites varied depending on their proximity to the Alaska Range. Wonder Lake had the greatest annual total precipitation at 40.4 inches, followed by McKinley River and Lake Minchumina at 23.0 cm and 18.3 cm respectively. Although the Ruth glacier site was only in operation from mid-July through the end of the year the total for those 5 months was 85.2 cm. However, because unheated tipping buckets are used to measure the precipitation, only the summer months with mean temperatures above 0° can be used with confidence. See Figure E9 for summer precipitation totals for the north side RAWS sites.

Wind speeds at the three north side RAWS sites were highest in April with an average wind speed at the three sites of 2.2 m/s. Lake Minchumina was the windiest of the three sites and McKinley River was the calmest. See Figure E10 for the mean monthly wind speeds at these sites.

On March 10, 2002 a wind speed of 24.3 m/s was recorded at Lake Minchumina. This was the peak wind speed recorded at all RAWS station for 2002.

### *E.7.4 Rock Creek Watershed*

Air Temperature and Relative Humidity - Average January temperatures were about -9°C at all of the Rock Creek sites except for Upper Ridge which had an average January temperature of -10°C. March was the coldest month for the Rock Creek sites with the lower sites averaging -9.8°C and Upper Ridge averaging -11.1°C for the month. The warmest month was July with an average temperature of 12.7°C for the lower elevations and 9.3°C for the upper site. The warmest temperature recorded in the watershed was 28.6C at Forest on August 3, 2002, and the coldest temperature recorded was -34°C at Permafrost on January 25, 2002. The mean monthly temperatures for all the sites in Rock Creek are shown in Figure E11. It is interesting to note that the yearly average temperatures for both Forest and permafrost are above 0°C (see Figure E12).

Relative Humidity values were highest at the Upper Ridge site and lowest at Permafrost. Relative humidity was lowest in March at 50% and highest in August, September, and December with the average for all months at 79%. See Figure E13 for mean monthly relative humidity values for all of the Rock Creek sites except for Treeline. The values at Treeline were considerably higher than all of the other stations indicating a problem with the sensor.

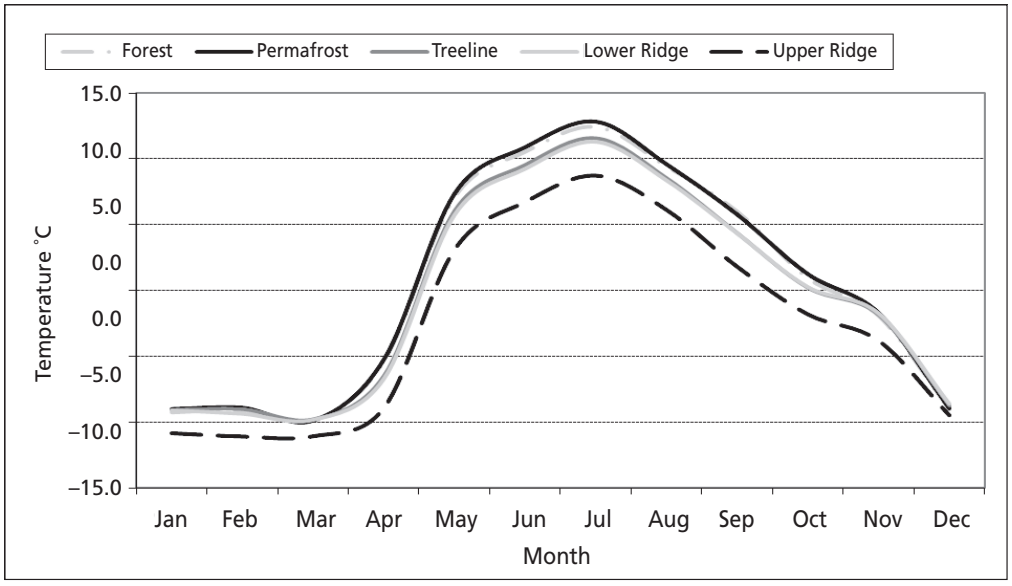



Figure E11. Mean monthly temperatures - Rock Creek sites

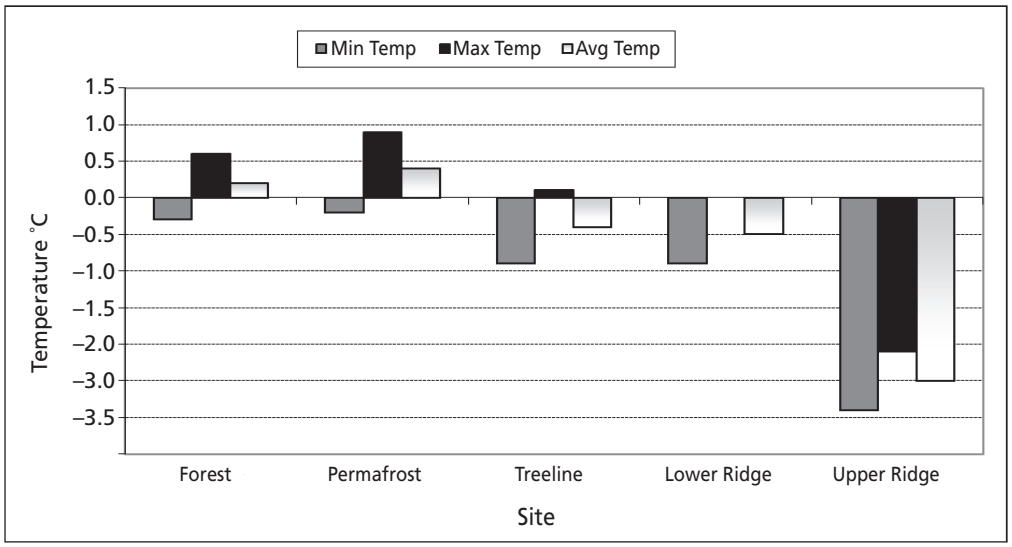



Figure E12. Yearly average minimum, average maximum and average temperatures

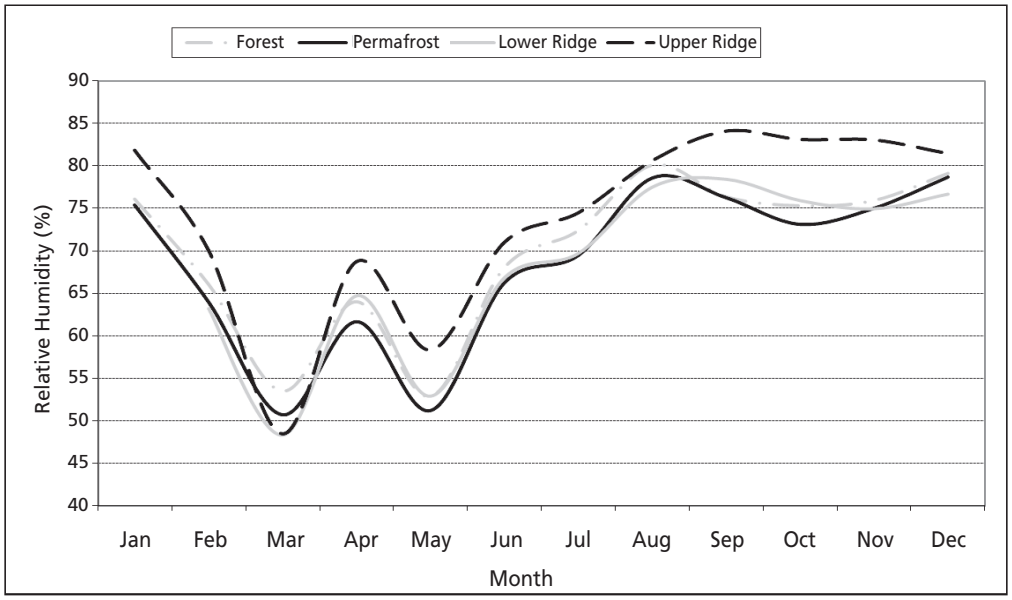



Figure E13. Mean monthly relative humidity values for the Rock Creek sites

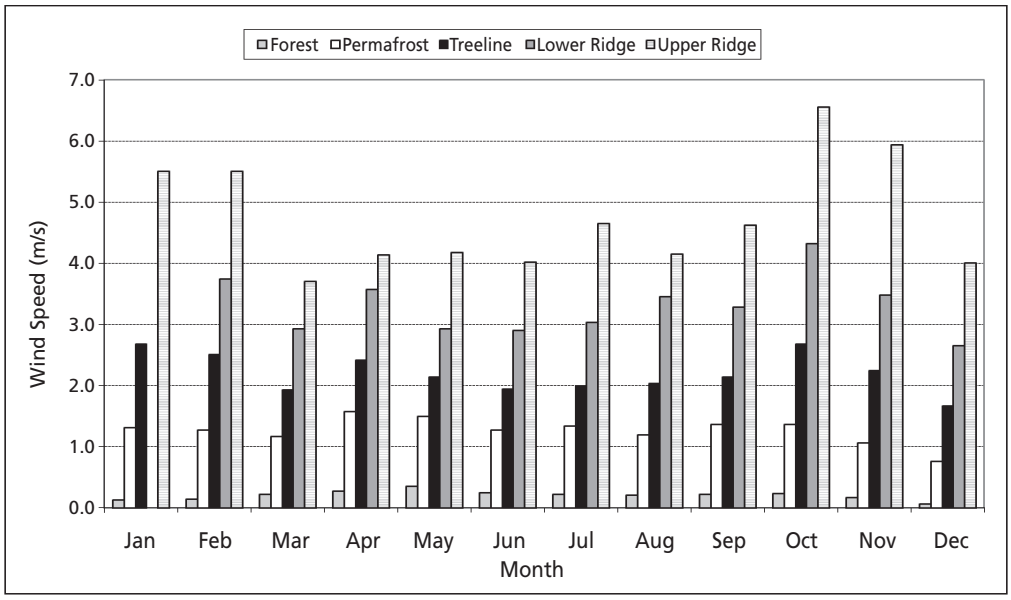



Figure E14. Mean monthly wind speeds - Rock Creek sites

Wind - Southeast winds prevail in the Rock Creek watershed. The average wind direction of the four exposed stations (Permafrost, Treeline, Lower Ridge, and Upper Ridge) is from the southeast at 133° and the average direction for the maximum wind gusts is 138°. The Forest site is located in a dense spruce forest protected from prevailing winds. Wind speeds were highest in October with an average wind speed at the three sites of 3.0 m/s. Upper Ridge was the windiest of the sites at an elevation of 1338 meters it had an average wind speed of 4.7 m/s recorded over the year. The protected Forest site was the calmest with an average wind speed of 0.2 m/s. See Figure E14 for the mean monthly wind speeds at these sites.

On October 9, 2002 a wind speed of 26.4 m/s was recorded at Upper Ridge. This was the peak wind speed recorded in the Rock Creek watershed for 2002. Figure E15 shows the average annual and peak wind speeds for all of the sites. As would be expected the wind speeds were calmer at lower elevations where a mixed spruce forest provided some protection and then increased with elevation where both altitude and exposure influenced the wind speeds.

Solar radiation at all of the sites is relatively consistent among all of the sites that are exposed. The protected Forest site located in the mixed spruce forest records solar radiation values that are 22% of the average of the other sites. See Figure E16 for the monthly solar radiation values at all of the sites. Average solar radiation values were the highest in May in 2002.

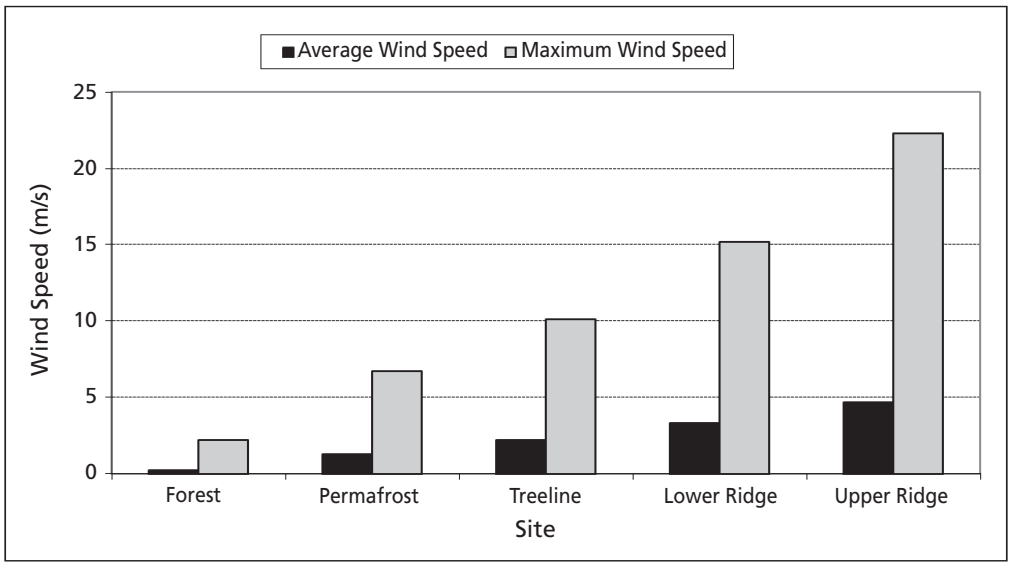



Figure E15. Average and peak wind speeds - Rock Creek sites

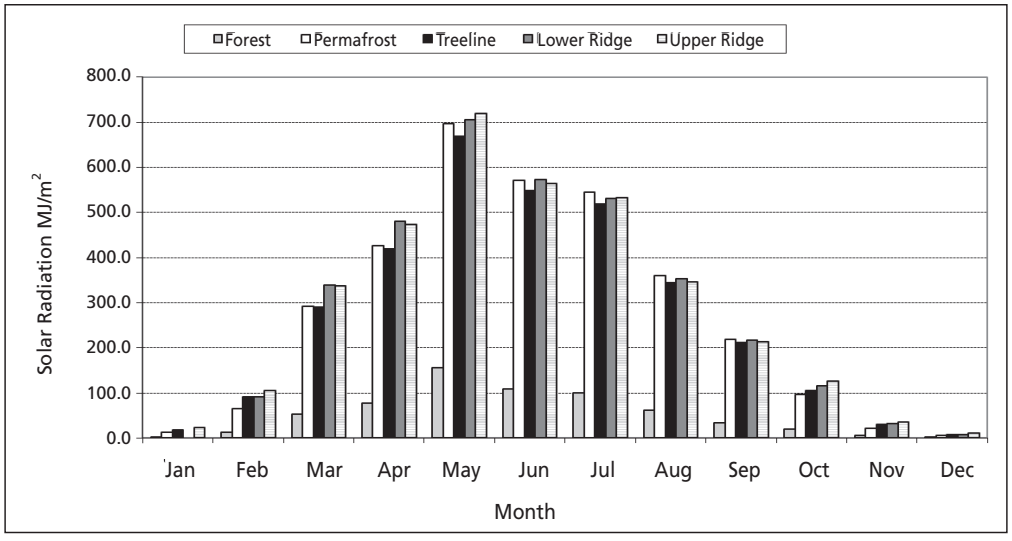



Figure E16. Monthly solar radiation values for Rock Creek sites

## E.8 Example of Monthly Summary

Denali National Park and Preserve Headquarters Station

| | Air Temperature (°C) | | | |
|---|---|---|---|---|
| **Month** | **Max** | **Min** | **Avg.** | **Degree Days** |
| January | 3.9 | -35.6 | -10.1 | 3.1 |
| February | 2.8 | -27.8 | -10.5 | 0 |
| March | 4.4 | -27.2 | -10.3 | 0 |
| April | 8.9 | -23.9 | -5.8 | 9.2 |
| May | 27.2 | -12.2 | 7.0 | 230.3 |
| June | 26.1 | 0.0 | 10.9 | 327.5 |
| July | 26.1 | 1.1 | 12.5 | 387.2 |
| August | 28.3 | -1.1 | 9.7 | 299.7 |
| September | 16.7 | -2.8 | 6.6 | 197.2 |
| October | 12.2 | -11.1 | 0.4 | 78.3 |
| November | 10.6 | -20.6 | -2.4 | 46.1 |
| December | 6.7 | -28.9 | -9.2 | 13.1 |
| Yearly Average | 14.5 | -15.8 | -0.1 | – |

*Degree Days: Sum of average daily temperatures > 0 degree Celsius

Headquarters Site Monthly Precipitation Totals
2002

| **Month** | **Precipitation cm** | **Snow cm** |
|---|---|---|
| January | 0.97 | 17.0 |
| February | 0.00 | 7.6 |
| March | 0.43 | 8.9 |
| April | 6.99 | 66.3 |
| May | 2.03 | 9.9 |
| June | 9.60 | 0.0 |
| July | 11.66 | 0.0 |
| August | 13.64 | 0.0 |
| September | 2.06 | 1.3 |
| October | 2.82 | 35.8 |
| November | 0.43 | 2.5 |
| December | 0.66 | 13.2 |
| Annual Total | 51.28 | 162.6 |

## E.9 Example of Daily Weather Summary

Headquarters Weather Summary January 2002

| Date | Max Temp ° C | Min Temp ° C | Avg Temp ° C | Precipitation cm | Snow cm | Snow on Ground cm |
|---|---|---|---|---|---|---|
| 01-Jan-02 | 1.7 | –13.9 | –6.1 | 0.00 | 0.0 | 23 |
| 02-Jan-02 | 0.6 | –17.8 | –8.6 | 0.00 | 0.0 | 23 |
| 03-Jan-02 | –9.4 | –17.8 | –13.6 | 0.00 | 0.0 | 23 |
| 04-Jan-02 | –3.9 | –15.6 | –9.7 | 0.03 | 0.8 | 23 |
| 05-Jan-02 | –2.8 | –8.9 | –5.8 | T | 0.5 | 23 |
| 06-Jan-02 | 3.3 | –6.7 | –1.7 | T | T | 23 |
| 07-Jan-02 | 3.9 | 0.0 | 1.9 | 0.03 | T | 20 |
| 08-Jan-02 | 2.2 | –7.2 | –2.5 | T | 0.5 | 23 |
| 09-Jan-02 | 3.3 | –1.7 | 0.8 | 0.00 | 0.0 | 20 |
| 10-Jan-02 | 3.3 | –2.8 | 0.3 | T | 0.0 | 20 |
| 11-Jan-02 | –0.6 | –10.6 | –5.6 | 0.00 | 0.0 | 20 |
| 12-Jan-02 | –7.8 | –20.6 | –14.2 | T | 0.3 | 23 |
| 13-Jan-02 | –5.0 | –20.6 | –12.8 | 0.00 | 0.0 | 23 |
| 14-Jan-02 | 0.0 | –11.7 | –5.8 | 0.00 | 0.0 | 23 |
| 15-Jan-02 | 1.1 | –1.7 | –0.3 | 0.03 | 0.3 | 23 |
| 16-Jan-02 | 0.6 | –10.0 | –4.7 | 0.03 | 0.8 | 23 |
| 17-Jan-02 | 2.2 | –8.3 | –3.1 | T | T | 20 |
| 18-Jan-02 | 3.3 | –4.4 | –0.6 | 0.20 | 2.5 | 23 |
| 19-Jan-02 | –0.6 | –8.3 | –4.4 | 0.15 | 2.5 | 25 |
| 20-Jan-02 | –7.2 | –11.7 | –9.4 | 0.05 | 1.3 | 25 |
| 21-Jan-02 | –9.4 | –16.1 | –12.8 | 0.15 | 2.0 | 28 |
| 22-Jan-02 | –13.9 | –27.2 | –20.6 | T | T | 28 |
| 23-Jan-02 | –18.3 | –28.3 | –23.3 | – | 0.3 | 25 |
| 24-Jan-02 | –22.2 | –26.7 | –24.4 | 0.03 | 0.5 | 25 |
| 25-Jan-02 | –25.6 | –34.4 | –30.0 | T | T | 25 |
| 26-Jan-02 | –31.7 | –35.6 | –33.6 | 0.00 | 0.0 | 25 |
| 27-Jan-02 | –17.8 | –31.7 | –24.7 | 0.00 | 0.0 | 25 |
| 28-Jan-02 | –11.1 | –18.3 | –14.7 | 0.05 | 0.8 | 28 |
| 29-Jan-02 | –1.1 | –16.7 | –8.9 | 0.00 | 0.0 | 28 |
| 30-Jan-02 | 1.7 | –7.8 | –3.1 | 0.05 | 0.5 | 28 |
| 31-Jan-02 | –5.0 | –16.1 | –10.6 | 0.18 | 3.6 | 30 |
| **Monthly Maximum** | **3.9** | n/a | n/a | n/a | n/a | n/a |
| **Monthly Minimum** | n/a | **-35.6** | n/a | n/a | n/a | n/a |
| **Monthly Average** | n/a | n/a | **-10.1** | n/a | n/a | n/a |
| **Monthly Total** | n/a | n/a | n/a | **0.97** | **17.2** | n/a |

T = trace precipitation or snowfall

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 184/142821, 190/142821, 191/142821, February 2018

**National Park Service**
**U.S. Department of the Interior**

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