



Protocol Implementation Plan for Monitoring Weather and Climate in the Arctic Network

Natural Resource Report NPS/ARCN/NRR—2017/1537



ON THE COVER

Howard Pass weather station in Noatak National Preserve.
Photograph courtesy of Ken Hill, National Park Service.

Protocol Implementation Plan for Monitoring Weather and Climate in the Arctic Network

Natural Resource Report NPS/ARCN/NRR—2017/1537

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October 2017

U.S. Department of the Interior

National Park Service

Natural Resource Stewardship and Science

Fort Collins, Colorado

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This report received formal peer review based on the importance of its content. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager. The methods presented in this report are based on established, peer-reviewed protocols.

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Please cite this publication as:

Sousanes, P. J., K. R. Hill, W. F. Johnson, and S. D. Miller. 2017. Protocol implementation plan for monitoring weather and climate in the Arctic Network. Natural Resource Report NPS/ARC/NRR—2017/1537. National Park Service, Fort Collins, Colorado.

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Introduction and Summary

Climate 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. For these reasons climate has been selected as a high priority vital sign for the Arctic Network (ARCN). The network includes Arctic coastal parks including Bering Land Bridge National Preserve and Cape Krusenstern National Monument, and three interior Arctic parks including Noatak National Preserve, Kobuk Valley National Park, and Gates of the Arctic National Park and Preserve. The main objectives are to monitor and record weather conditions at representative locations in the Arctic parks in order to identify long and short-term trends, provide reliable climate data to park managers, park scientists, and other researchers, and to participate in larger scale climate monitoring and modeling efforts.

This plan outlines the means by which monitoring data will be collected, managed, and reported for the *Weather and Climate* Vital Sign as described in the approved ARCN monitoring plan (Lawler et al. 2009). The ARCN will implement the peer-reviewed and approved protocol in use by the Central Alaska Network (CAKN) in its entirety (Sousanes 2006), including the Standard Operating Procedure updates 2017 (Sousanes et al. 2017; links to individual SOPs in Table 4).

Implementation of the CAKN climate protocol in ARCN parks will occur with the following modifications:

1. There are seventeen ARCN weather stations currently installed that will be maintained and managed by ARCN staff in the five park units. This brings the total number of stations managed by the CAKN and ARCN weather and climate monitoring programs to 30. The seventeen ARCN weather stations are referred to as ARCN Remote Automated Weather Stations (RAWS).
2. Currently one snow telemetry (SNOTEL) site is managed in ARCN under a cooperative agreement with the Natural Resources Conservation Service (NRCS). Maintenance, data collection, processing, dissemination, and archiving will be done by NRCS. NPS will provide access to the site and annual funds for operating the site. The NPS and NRCS agree to maintain the interagency agreement into the foreseeable future.
3. There are weather and climate stations in and around ARCN that are operated by other state and federal agencies that complement the ARCN weather stations. When feasible, ARCN will coordinate with other agencies to assure that the data from these sites are maintained. An example of this type of coordination would be assisting with annual maintenance of National Interagency Fire Center (NIFC) remote automated weather stations (RAWS) that are located inside ARCN park boundaries. The ARCN parks are remote and access is a challenge, so coordination is critical.
4. Timing of the annual site visits will be timed so as not to interfere with subsistence hunting on park lands. Coordination with cultural resource staff will occur prior to each field season to determine the optimal timing.

These protocols along with foundation documents drafted by the Western Regional Climate Center (Davey 2007) were used to design and develop a strategy that focuses on high latitude climate issues and remote station operations. The success of these efforts is dependent on the efforts of various agencies and institutions that contribute to the holistic view of climate in northwest Alaska.

Conceptual Framework for Monitoring

Weather and climate are key drivers in ecosystem structure and function and all of the ARCN vital signs are directly or indirectly affected by variability and changes in climate conditions. Climatic stressors may be one of the foremost issues that Arctic park managers will deal with in the next few decades. Global climate models indicate that subtle climate changes will have the most dramatic effect in arctic regions (IPCC 2013). These changes will be observable in many arctic system features, such as permafrost dynamics, snowpack persistence, variations in timing of wildlife migrations, plant phenology, albedo, and sea ice extent and duration.

The severe climate of the Arctic is integral to the character of these park units, and imposes a significant influence on biological, cultural, and physical function. Information on climate for national park units is currently in wide-ranging demand by visitors, managers, the research community, and for routine operations by park staff. Prior to the ARCN weather and climate protocol development there were very few weather stations within the Arctic parks and across the northern region of Alaska. Large swaths of land with no monitoring at all, resulted in the lowest spatial weather station density of all NPS units nationwide (Redmond and Simeral 2010).

Measurable Objectives

The main objective for the ARCN weather and climate monitoring program is to monitor and record weather conditions at representative locations in the Arctic parks 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.

Specifically we have the following monitoring objectives:

1. Determine long and short term trends in climate by recording weather parameters at sites that capture the primary climate gradients within the Arctic parks.
2. Use all relevant weather and climate data to analyze, summarize and report on climatic averages and extremes in the northwest Alaska region.

The basic approach to meeting the objectives will be to 1) ensure that all existing long-term climate and weather stations in and around the network continue to operate and produce high quality data; 2) continue to operate NPS owned and operated ARCN weather stations within the parks that measure and record air temperature, soil temperature, wind speed and direction, snow depth, relative humidity, solar radiation, and summer rainfall; 3) ensure that the maintenance and calibration of the stations and sensors is a priority; 4) engage in partnerships with state and federal agencies involved in climate and weather monitoring in the interior Arctic and work with university researchers interested in high latitude climate changes; 5) ensure that the data produced by the ARCN weather stations are available for use by NPS staff, researchers, and the public via the internet; 6) analyze and summarize the data in useful formats to show averages, totals, trends, and extremes; and 7) archive the raw digital datasets with the Western Regional Climate Center and in the NPS Data Store under the ARCN weather and climate vital sign program.

An annual report will summarize the synoptic climate data for the network including the current state of the climate for large-scale climate indices (i.e., the Arctic Oscillation, the Pacific Decadal Oscillation, and El Niño events) along with summaries of current year observations from all relevant weather and climate stations for the network. If staffing and time permits, brief seasonal/annual summaries will be compiled to share current weather information with park managers, staff, and the general public. Every 10 years an in-depth analysis of climate trends will be produced.

Methods

The ARCN, CAKN, and Southeast Alaska Network (SEAN) have committed to the use of standardized procedures for weather and climate monitoring to promote regional consistency and efficiency. Each network will be utilizing the most recent SOP versions associated with the original CAKN climate monitoring protocol of Sousanes (2006) to implement their respective weather and climate monitoring programs. To facilitate this shared approach, SOPs were recently revised to standardize methods to the extent practical and incorporate network-specific implementation details where necessary (Sousanes et al. 2017).

Primary operational elements of the ARCN weather and climate monitoring program includes:

1. **Field Data Collection:** Campbell Scientific, Incorporated (CSI) research-grade meteorological instrumentation will be used to collect weather data. The standard array includes the following sensors: air temperature sensor (rated to -60°C), air temperature + relative humidity sensor, rain gauge for summer rainfall, acoustic snow depth sensor for snow depth, pyranometer for solar radiation, anemometer for wind speed and direction, and three soil temperature probes (10, 20, and 50 cm depths). A fourth soil sensor may be added at some sites (100 cm depth). Data are continuously recorded on an hourly interval and stored within the datalogger on site and transmitted via satellite in near real-time. Time lapse phenology cameras will be added to a select number of sites.
2. **Annual site maintenance visits** will occur at each weather station. The site visits include: annual data download, sensor calibration, programming/equipment upgrades or updates (if needed), photo documentation, basic maintenance of the site (tighten bolts, repairs, fix electric bear fence, site brushing.), and completion of a site visit worksheet.
3. **Data management:** The continuous time series data that are generated by the weather and climate vital sign will be managed by ARCN staff using Aquarius software. Final data are provided to the Western Regional Climate Center for incorporation into the Applied Climate Information System (ACIS) archive. Data will also be stored internally on the network drive and on the Integrated Resources Management Application (IRMA) Data Store server.
4. **Reporting:** A network-wide maintenance report and a network-wide annual report will be published on an annual basis. Brief seasonal or annual weather summaries will be completed as time/staffing level allows. The annual reports will be published under the Natural Resource Publication Management guidelines and published in the Integrated Resource Management Applications (IRMA). All of the documents related to the Arctic Network Weather and Climate Monitoring Protocol are under IRMA Project Code: [2210690](#).

Sampling Design and Monitoring Schedule

Sampling Design

The sampling design for the ARCN weather and climate protocol is unique to the ARCN parks including Bering Land Bridge National Preserve (BELA), Cape Krusenstern National Monument (CAKR), Noatak National Preserve (NOAT), Kobuk Valley National Park and Preserve (KOVA), and Gates of the Arctic National Park and Preserve (GAAR) and as such is described below:

Davey et al. 2007, compiled a weather and climate inventory report for the Arctic Network in 2007. As described in the inventory report, there were large portions of the ARCN park units that had no station coverage, including western GAAR, northern KOVA, far-eastern and west-central portions of NOAT, all of CAKR, and the northwestern areas of BELA. In general there were very few observations from the interior of the Seward Peninsula and there were no weather stations that adequately characterized the higher elevation of the Brooks Range, the upland areas of the Noatak River drainage, or the northern mountainous areas of Kobuk Valley. There was also a lack of weather observations from the coast of the Chukchi Sea to the inland areas of Cape Krusenstern.

During the initial scoping process for weather and climate monitoring, a series of workshops were held to solicit input from climatologists, meteorologists, and resource managers concerning the need for climate data in the Arctic parks (Nolan 2007). A few general guiding principles emerged. For example, make the best use of prior experience and research to guide new protocols; solicit broad end-user participation to ensure long-term viability; and for long-term study studies, it's better to make measurements at fewer sites more reliably than to have a lot of sites with poor reliability. These principles are reflected in the "Ten Climate Monitoring Principles" (Karl 1995).

Potential climate sites were evaluated in the ARCN parks between 2008 and 2010 using the information gathered from the scoping process. During the evaluation process, a site checklist was used to record information on site conditions such as GPS location, aspect, area, vegetation description, ground cover, soil properties, and access. A report was compiled that described each of the sites, as well as the instrumentation, programming, and power systems recommended for the design of the weather stations (Sousanes 2010). The report was distributed to a solicited panel of climatologists for review. The review panel included 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 and Larry Weddle – NPS Fire/Fire Weather Program Manager Alaska Interagency Coordination Center, Fairbanks Alaska. The Western Regional Climate Center staff also wrote a formal review for the site evaluation process (Redmond and Simeral 2010). The feedback on the design and scope of the program was positive and a prioritized list of sites for each of the ARCN parks was formulated. These sites were then forwarded to the NPS compliance teams to review the weather station installations under the National Environmental Policy Act.

Cultural resource specialists reviewed each site and approved the final locations (Devinney 2010). An Environmental Assessment was completed and the three NPS superintendents of the Arctic parks signed a Finding of No Significant Impact (FONSI) for the deployment of seventeen climate sites in

the five Arctic parks. These sites are part of the Remote Automated Weather Station (RAWS) network administered through the National Interagency Fire Center (NIFC) in Boise, Idaho. The stations are collectively called ARCN RAWS. The locations of the sites selected are shown in Figure 1 along with the existing sites that will be used in analysis and reporting including National Weather Service Cooperative (COOP) sites, Fire RAWS, and Snow Telemetry (Snotel) sites in or adjacent to the ARCN parks.

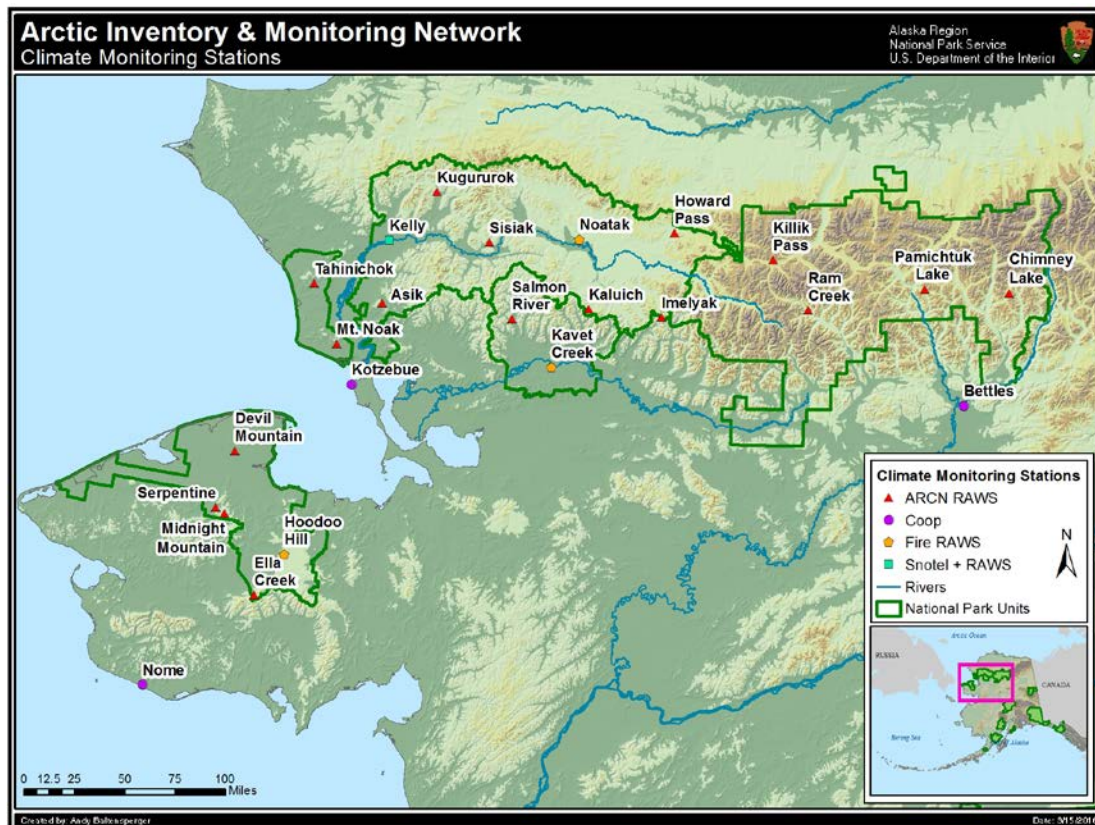


Figure 1. Map showing the location of the ARCN RAWS.

Monitoring Schedule

The ARCN weather stations will record and transmit hourly mean values for air temperature, relative humidity, wind speed, wind direction, solar radiation, and soil temperatures. Additional values that will be recorded each hour are: minimum temperature, maximum temperature, total rainfall, peak wind gust and direction of gust, and snow depth.

Data Management, Analysis, and Reporting

The outcome of the network's weather and climate monitoring vital sign takes the form of ten formal deliverable products described in the Weather and Climate Monitoring Standard Operating Procedure (SOP) 10 and listed in Table 1 here. These include data products, detailed metadata products required for users to properly interpret the data, and associated NPS reports.

The authoritative repository for all these deliverables is the NPS Data Store (<https://irma.nps.gov/DataStore/>). Permanent archiving, disaster recovery, and public accessibility of the deliverables are accomplished through the enterprise facilities built into the Data Store.

IRMA is the only authoritative repository for mission critical climate data products. The data from the NPS weather stations are available in near real-time from various weather and climate web portals. These sources have disclaimers that state that data are provisional and subject to further review and editing.

Table 1. Data processing and certification matrix for the ARCN climate monitoring protocol.

Deliverable Title	Description	Provided as	Frequency Produced	Builder	Responsibilities Validator	Accepter
WC_A: Protocol-PIP-QAP-DQS-SOPs	The detailed document set defining this weather and climate monitoring program throughout its history and published as NRR reports in the NPS Data Store.	PDF files.	New documents as needed, but always prior to the field season they operate on.	Project Leader	Peer Review Panel	Regional I&M Coordinator
WC_B: Site map	Map documenting location of stations participating in network's climate monitoring.	ESRI layer, JPEG, and KMZ files	As needed to accommodate new sites.	Project Staff	Project Leader	Project Leader
WC_C: Site visit worksheets	One worksheet per site visit documenting in a standard form the condition of the site, actions taken, and final configuration. Packaged as a cumulative set of all worksheets for all stations in a particular field season zipped into one file.	Windows files in XLSX format, wrapped into a single ZIP file.	One zip file per year created after completion of all field work.	Project Staff	Project Leader	Project Leader

Table 2 (continued). Data processing and certification matrix for the ARCN climate monitoring protocol.

Deliverable Title	Description	Provided as	Frequency Produced	Builder	Responsibilities Validator	Acceptor
WC_D: Datalogger program	The program source code installed into dataloggers for all stations over a field season. They authoritatively document the exact nature of parameters collected.	A ZIP of text files containing all versions of programs used by stations in a field season.	One zip file per year created after completion of all field work.	Project Staff	Project Leader	Project Leader
WC_E: Site photo sets	One set of photos per site per field season used to document physical conditions.	Windows JPEG data files wrapped into a single ZIP file for each site/year.	One ZIP file per site per year created after completion of all field work.	Project Staff	Project Leader	Project Leader
WC_F: Station download	The cumulative collection of RAWs station observations in Campbell Scientific .DAT format. It is extracted from the station datalogger during each visit to each site. Multiple years are stored in a ring buffer in the station and the entire buffer is captured on each visit. No data corrections are directly applied to this Processing Level 0 product.	Windows data files of datalogger output in .DAT format wrapped into a single ZIP file for each field season.	One ZIP file per field season containing typically one downloaded file from each station visited that year.	Project Staff	Project Leader	Project Leader

Table 3 (continued). Data processing and certification matrix for the ARCN climate monitoring protocol.

Deliverable Title	Description	Provided as	Frequency Produced	Builder	Responsibilities Validator	Acceptor
WC_G: RAWS corrected data	The collection of RAWS output for all stations in ASCII CSV format at Processing Level 1B having duplicate readings removed, standard formatting applied, measurement units made consistent, and quality flags plus selected metadata added. This contains all network station data for all years and all stations.	A single Windows ASCII CSV data file.	Annually, after the WC_F station downloads and WC_C site visit worksheets are accepted.	Project Staff	Project Leader	Project Leader
WC_H: Annual operations report	Annual report summarizing operations and data in the form of an NPS NRR or NRDS publication. Deliverable WC_D is a prerequisite.	One PDF file.	One PDF file per year created after completion of all field work	Project Leader	Peer Review Panel	Network Program Manager
WC_I: Calibration certificate images	Scanned images of sensor calibration records provided by instrument vendor/servicer having printed dates that are in one calendar year.	One PDF file covering all instruments in the year.	One PDF file per calendar year following receipt of the year's last calibrated instrument.	Project Staff	Project Leader	Project Leader
WC_J: Periodic report	Multi-year climate analysis based in the parameters collected by stations, written in the form of an NPS NRR publication.	One PDF file.	Once every ten years.	Project Leader	Peer Review Panel	Regional I&M Coordinator

Data Processing and Workflow

1. Field data and supporting metadata are collected from each weather station on an annual basis. After field data collection the data are first manually checked by network staff. The RAWS station data (Level 0) are then formatted and run through the Aquarius tools developed for the weather and climate vital sign (SOP 11) for processing. The Level 1B

RAWS corrected data files are the core data files. The other deliverables in Table 1 support the process of collecting, processing and disseminating these data.

2. Certification and publication of data sets will occur annually after the field season.
3. Climate data analysis, visualization, and dissemination continues to evolve at a rapid pace; the core datasets will remain the same but the path to value-added Level 2 type data products will likely change.
4. Data from other sites (NWS COOP, SNOTEL, fire RAWS, etc.) used for statistics and analysis will be acquired through the Applied Climate Information System data portal.
5. Reporting will occur minimally on an annual basis.

Defined Data Levels

Level 0 – RAWS Station Download

- Data products are unprocessed (raw) hourly weather data files from the weather station datalogger, downloaded annually during site visit (format .dat). See Figure 2.
- This is deliverable WC_F in the ARCN weather and climate vital sign product matrix.

Level 1B– RAWS Corrected Data

- The RAWS corrected data WC_G is the collection of all RAWS output for all stations in ASCII CSV format at Processing Level 1B having duplicate readings removed, standard formatting applied, consistent measurement units enforced, and quality flags plus selected metadata added (details in SOP 11).
- This provides researchers and data aggregators Level 1B containing the monitoring program's best corrected data in a single file.
- This is deliverable WC_G in the weather and climate vital sign product matrix. See Figure 3.

Level 2 – Value Added Data

- Data products are derived climate variables from the Level 1B source data and may include: 1) calculation of climate statistics on a variety of time scales, hourly to decadal (mean, totals, median); 2) calculation of climate trends and anomalies; and 3) calculation of derived climate variables (i.e., thaw degree days, $P > 1$ inch, $T > \text{freezing}$).

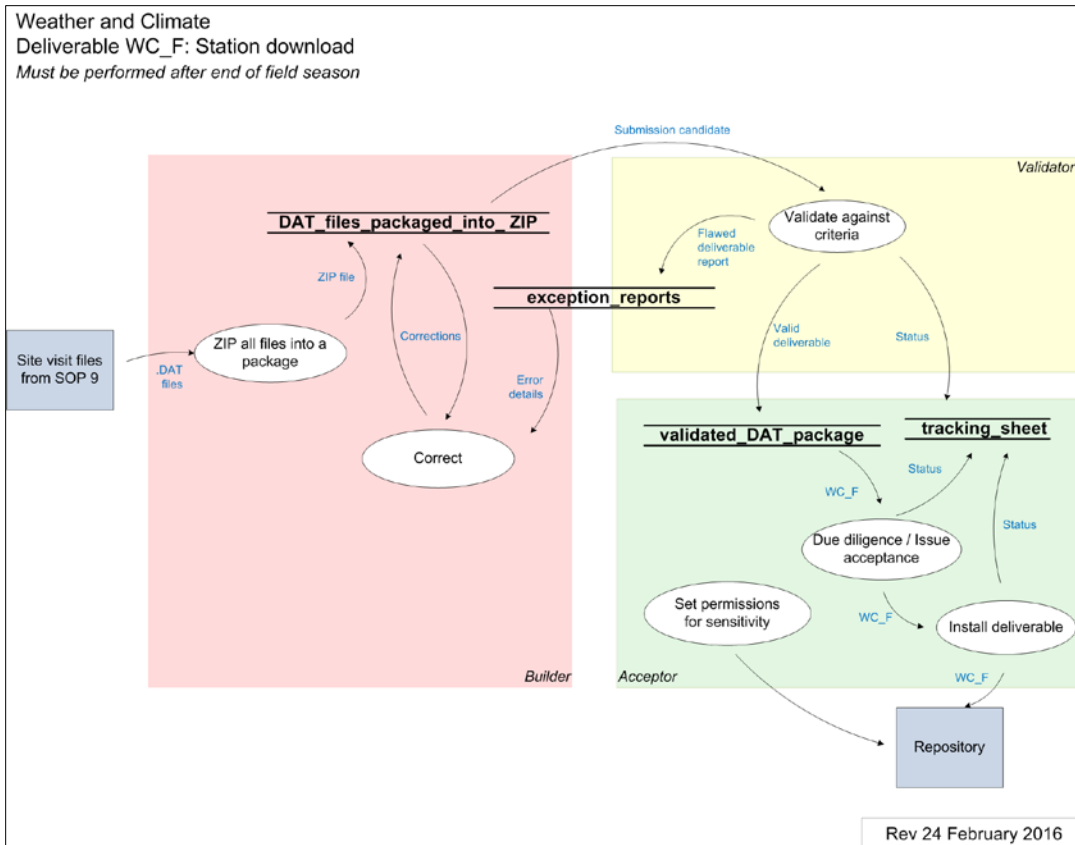
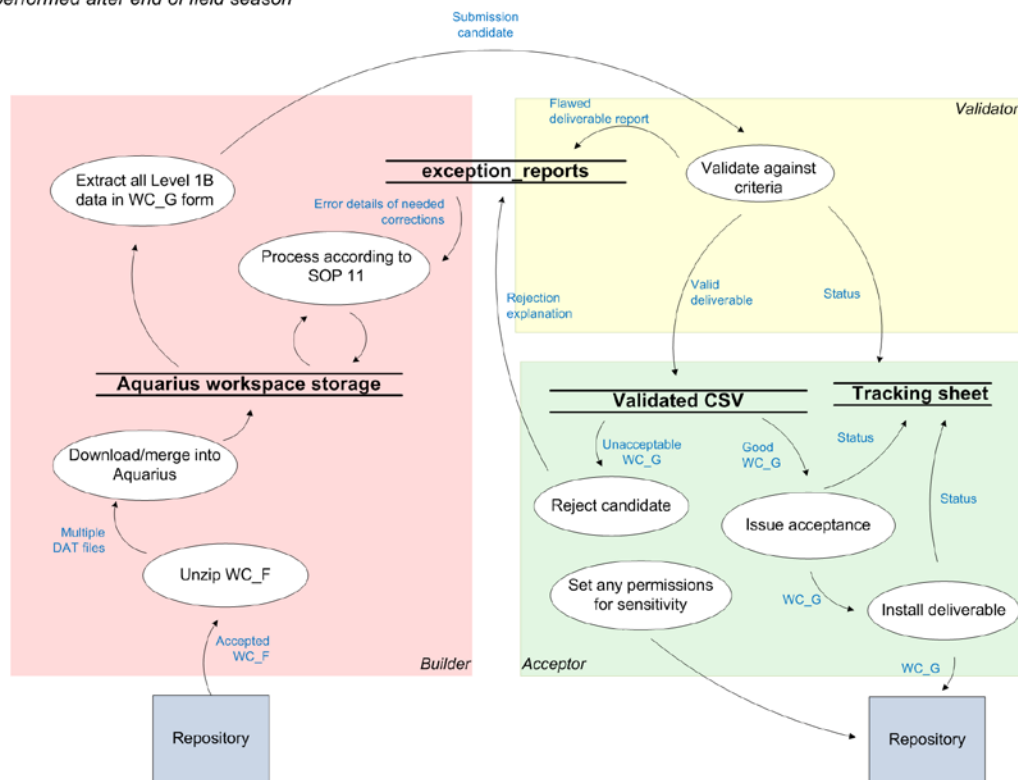


Figure 2. Flow chart of the RAWS station download (Level 0) comprising the WC_F annual deliverable.

Weather and Climate
 Deliverable WC_G: RAWS corrected data
Must be performed after end of field season



Rev 3 March 2016

Figure 3. Flow chart for the RAWS corrected data (Level 1b) comprising the WC_G annual deliverable.

Budget

Table 2 outlines the basic costs of implementing the weather and climate protocol in the Arctic Network.

Table 4. Estimated annual operating cost (based on FY2016 dollars) for implementation of the ARCN Weather and Climate Vital Sign Protocol.

Category	Costs (FY 2016)	Notes
Personnel: ARCN/CAKN Physical Scientist	57,453	0.45 FTE GS-12
Personnel: ARCN Physical Scientist	45,520	0.50 FTE GS-9
Total Personnel Costs	\$102,973	
Aviation	Estimate \$2,500 per site x 17 climate sites SNOTEL site access = \$3,000	–
Total Aviation Costs	\$45,500	
Travel	2 people Fairbanks to Nome for 1 week. (1200/person x 2) = 2,400 2 people Fairbanks to Kotzebue for 1 week (1200/person x 2) = 2400 2 people Fairbanks to Dahl Creek (Backcountry 4 days at 100/person) = 200 2 people Fairbanks to Bettles (500/person) = 1000	Lodging at NPS bunkhouse in Nome and Kotzebue, Backcountry per diem other locations
Total Travel Costs	\$6,000	–
Interagency Agreements/CESU	\$2,500 for SNOTEL site maintenance	–
Total Agreement Costs	\$2,500	–
Equipment and Supplies	Sensor calibrations \$5,000 Equipment Replacement \$5,000 Field Supplies, misc. \$3,000	–
Total Equipment Costs	\$13,000	–
Total Project (without personnel costs)	\$67,000	–
Total Cost (including personnel)	\$169,973	–

Staffing

The ARCN and CAKN model for executing the climate monitoring vital sign includes two physical scientists. The ‘two-deep’ staffing level was intentional. The CAKN/ARCN physical scientist currently serves as the project lead and the ARCN physical scientist collaborates on implementation. Both staff members are involved in all aspects of the program from data collection to data analysis with one focused on overseeing the program as a whole (principal investigator) and the other on the data processing and data quality procedures. The project lead maintains the scientific integrity and

the relevancy of the data being collected through ongoing collaborations with regional climate scientists.

The two networks collectively cover ~40 million acres of park lands with 45 weather and climate stations that operate as part of the vital sign; the current staffing level is necessary to adequately cover the depth and breadth of the program. The SOPs identify the training requirements that would be necessary for staff replacement; ideally anyone executing the protocol in the future would accompany an experienced person in the field and take the required training listed in the SOPs.

Safety

A primary goal of the Arctic Network (ARCN) is to ensure the safety of its staff and partners while conducting inventory and monitoring activities in parks. Encountering hazardous situations is inherent in outdoor monitoring activities, and all staff need to be aware and committed to ensuring that all monitoring personnel receive adequate training on National Park Service (NPS) safety procedures, incident reporting, and emergency response prior to fieldwork.

There are four different levels of training and safety related policies that need to be followed in order to conduct a safe and successful weather and climate monitoring program: 1) National/NPS level policy, 2) ARCN or Inventory and Monitoring (I&M) policy, 3) Regional policy, and 4) Park level policy.

For Alaska-based fieldwork, the Alaska Region Communication Center (ARCC) staff are available to answer radio or satellite phone calls 24 hours a day/ 7 days a week throughout the field season. Flight, float, or backcountry plans are filed with the ARCC prior to the field mission, which include established check-in times.

Risks Inherent in Weather and Climate Monitoring in the Arctic Alaska Parks

The parks in interior Alaska are remote and rugged with challenging weather extremes. Protection against sun, rain, wind, and snow is critical. Extra food and survival gear is a must. Protection from mosquitos is absolutely necessary. The weather stations are remote and could involve commercial airline flights, long drives on remote roads, long boat rides, strenuous hikes, fixed-wing flights to remote airstrips, and helicopter flights to the weather stations. The cumulative stress of multiple forms of transportation and a long field day is an inherent risk for field staff.

Standard Operating Procedure (SOP)³- Safety addresses specific concerns for monitoring weather and climate in the Alaska parks with links to park safety requirements.

Standard Operating Procedures

To ensure consistent implementation of this protocol over time, the following Standard Operating Procedures (SOPs) have been identified (Table 3). To the greatest extent possible, SOPs are adopted from procedures approved and implemented programmatically through the Central Alaska Network climate vital sign monitoring effort. The approved SOPs are available through the IRMA Data Store under each network (ARCN, CAKN, SEAN); the latest approved versions of operational SOPs are published as part of the annual deliverable schedule for each network <http://irma.nps.gov>.

Table 3. Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Narrative	Climate Vital Sign and Standard Operating Procedures (SOPs)	Sousanes, P. J. 2006. Climate monitoring protocol for the Central Alaska Network – Denali National Park and Preserve, Yukon-Charley River National Preserve, and Wrangell -St. Elias National Park and Preserve. National Park Service, Denali Park, Alaska.	The methods and the rationale for monitoring climate are described in the CAKN climate monitoring protocol narrative along with the standard operating procedures (SOPs).	https://irma.nps.gov/DataStore/Reference/Profile/2192457
Narrative	Standard Operating Procedures Update 2017	Sousanes, P.J., et al. 2017. Standard operating procedure updates 2017: Central Alaska Network (CAKN) climate monitoring protocol. Natural Resource Report NPS/CAKN/NRR—2017/1504. National Park Service, Fort Collins, Colorado.	In 2017 the ARCN, CAKN, and SEAN staff worked collectively to update the CAKN climate monitoring standard operating procedures (SOPs), which integrated programmatic aspects of the ARCN and SEAN networks. The updated SOPs now include information that apply to all three networks.	https://irma.nps.gov/DataStore/Reference/Profile/2243728

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Standard Operating Procedures	Deliverables	SOP 1: Annual Deliverable Schedule Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 1: Annual Deliverable Schedule, Version 1.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Outlines typical annual work plan and product deliverable schedule.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243685 .
Standard Operating Procedures	Compliance, Permitting, and Site Locations	SOP 2: Compliance, Permitting, Updating Site Maps Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 2: Compliance, Permitting, and Updating Site Maps (WC_B), Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	NEPA compliance and permitting requirements to conduct weather and climate monitoring in ARCN, CAKN, and SEAN	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243687

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Standard Operating Procedures	Safety	SOP 3: Field Safety Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 3: Field Safety, Version 1.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Information on basic safety principles and risks inherent in remote fieldwork.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243689
Standard Operating Procedures	Climate Station Specifications	SOP 4: Climate Station Specifications, Sampling Frequency, and Measurement Intervals Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 4: Climate Data Specifications, Sampling Frequency, and Measurement Intervals, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Defines the data collection methods for the weather and climate monitoring vital sign using research grade automated weather station equipment.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243690

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Standard Operating Procedures	Field Laptop	SOP 5: Field Laptop Setup Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 5: Field Laptop Setup, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Step-by-step procedures for preparing a field laptop to directly communicate with the weather station data loggers.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243691
Standard Operating Procedures	Programming	SOP 6: Datalogger Programming Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 6: Datalogger Programming, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Describes the process for programming the weather station datalogger.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243693

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Standard Operating Procedures	Satellite Transmitter	SOP 7: Satellite Transmitter Programming (GOES) and Data ingest System (WFMI). Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 7: Satellite Transmitter Programming (GOES) and Data Ingest System (WFMI), Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Outlines the process for setting up a remote weather station to transmit near real-time hourly weather data from the climate network.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243694
Standard Operating Procedures	Climate Station Installation and Maintenance Equipment List	SOP 8: Site Installation and Maintenance Equipment Checklist Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 8: Site Installation and Maintenance Equipment Checklist, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska	Describes the individual components of a network weather station and the maintenance equipment that is required for every site visit.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243696

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Standard Operating Procedures	Annual Site Visit	SOP 9: Annual Site Visit Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 9: Annual Site Visit, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska	Includes all the instructions necessary to conduct an annual site visit at a weather station.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243697
Data Management	Data	SOP 10: Data Deliverable Creation, Validation, Certification and Dissemination Johnson, W., K. Hill, S. Miller, P. Sousanes, and M. Bower. 2017. Standard Operating Procedure (SOP) 10: Data Deliverable Creation, Validation, Acceptance, and Dissemination, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Documents the technical specification of the ten formal deliverable products for the weather and climate monitoring program.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243699

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Data Management	Quality Control	SOP 11: Quality Control and Record Processing Ken Hill, W. Johnson, P. Sousanes, M. Bower, and S. Miller. 2017. Standard Operating Procedure (SOP) 11: Quality Control and Record Processing, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Outlines quality control and quality assurance procedures for storing, processing, and exporting continuous weather and climate data.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243700
Reporting	Reporting	SOP 12: Annual Reporting and Deliverable Publishing Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 12: Annual Reporting and Deliverable Publishing, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Describes the method for reporting on the weather and climate monitoring protocol.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243701

Table 3 (continued). Narrative documents and standard operating procedures for the ARCN weather and climate monitoring vital sign.

Subject	Topic	Citation	Notes	Links to Published/Document Record
Revisions	Protocol revisions	SOP 13: Revising the Protocol Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 13: Revising the Protocol, Version 2.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	This outlines how changes and revisions are made to the protocol or standard operating procedures.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243704
Standard Operating Procedures	Deliverables	SOP 1: Annual Deliverable Schedule Sousanes, P., K. Hill, M. Bower, W. Johnson, and S. Miller. 2017. Standard Operating Procedure (SOP) 1: Annual Deliverable Schedule, Version 1.0. Weather and Climate Monitoring Protocol, Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska.	Outlines typical annual work plan and product deliverable schedule.	Available online at https://irma.nps.gov/DataStore/Reference/Profile/2243685 .

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NPS 953/140457, October 2017

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