



Data Quality Standards for Weather and Climate Monitoring in the Arctic, Central Alaska, and Southeast Alaska Networks

Natural Resource Report NPS/ARC/NRR—2018/1575



ON THE COVER

Photograph of NPS physical scientists during annual site visit at an Alaska weather station.

Photograph courtesy of Ken Hill, National Park Service

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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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Introduction and Summary

The purpose of this report is to document the standards used by the Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Networks for activities related to the collection, processing, storage, analysis, and publication of climate monitoring data. Based initially on the protocol for monitoring climate in the CAKN (Sousanes 2006), this shared program has now grown to accommodate network-specific conditions across the ARCN, CAKN, and SEAN while providing standardized methods for greater consistency and efficiency (Sousanes et al. 2017, Bower et al. 2017). The most recent standard operating procedures reflecting this new regional scope were completed in 2017 (Sousanes et al. 2017a) and will continue to be reviewed and revised annually.

The policies and procedures in this document supplement the National Inventory & Monitoring Division Quality Management Plan. The standard operating procedures provide detailed protocol/program activities associated with weather and climate monitoring. This plan serves as a guide for all ARCN, CAKN, and SEAN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Protocol Overview

The ARCN, CAKN, and SEAN were established to monitor key components of park ecosystems and to provide that information to park managers for use in stewardship of park resources. Climate is considered to be among the most important broad-scale factors influencing ecosystems and therefore the natural resources of parks (MacCluskie and Oakley 2003). Because global climate models indicate that climate change and variability will be greatest at high latitudes (IPCC 2013), climate monitoring is critical to understanding the changing conditions of park ecosystems in Alaska.

For most places in the country, baseline climate for national parks can be derived from an average of values from weather stations within a park's boundary, and when a value reaches or exceeds a certain threshold, managers can compare it to a known condition. This is not the case for many regions in Alaska and many remote areas within the Alaska national parks. Although models and interpolation are valuable tools, in the case of Alaskan parks, the baseline climate needs to be determined before projections can be affirmed. Climate was considered an important vital sign for all of the monitoring networks in Alaska, and given the paucity of data in the state and especially within park boundaries, it was critical that the networks expand the coverage by installing new climate stations in the parks.

The ARCN, CAKN, and SEAN have invested substantial resources in developing an effective and robust climate monitoring program that will answer critical questions about how trends in temperature and precipitation are changing in Alaska national parks. These data will make a positive difference in our understanding of climate trends in Alaska over the next 50 years.

Protocol Activities and Modules

Data are collected or derived in 20 activities organized into six modules (Table 1).

Climate is a broad scale phenomenon and understanding aspects of Alaska's climate is important to provide context for the ARCN, CAKN, and SEAN climate monitoring programs. 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 weather stations in existence because of feasibility, reliability, and accessibility. The development of the CAKN, ARCN, and SEAN climate monitoring program considered what is known about Alaska's climate and has designed a strategy to expand the knowledge base by placing weather stations where the data for statistical analysis for existing models is sparse, 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 the surrounding ecosystem.

Sites have now been installed, and are operational, in each of the network parks. The sites were selected based on information gained from individual network climate inventories, scoping workshops, wilderness/compliance concerns, and site evaluation surveys. The standard operating procedures (SOPs) and the annual deliverables ensure that metadata and data flow are documented for the climate monitoring protocol.

Climate Monitoring Objectives

ARCN, CAKN, and SEAN programs share common goals and objectives to meet this challenge: 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 objectives are achieved by recording continuous weather and climate data with automated stations operated within the parks. Specific activities include:

1. Site Recon, Establishment, and Maintenance. Data associated with weather station locations (descriptions, locational data, navigation, and surveying data) and/or maintenance logs associated with monitoring station infrastructure.
2. Field Data Collection. Measurements taken and recorded by NPS or cooperator staff during an annual site visit, including the station visit information logged on a site visit worksheet.
3. Sensor data collection. Includes data collected by each of the weather sensors, information associated with sensor deployment and retrieval, calibration, and post-processing.
4. External data. Data from other weather and climate networks that are often used to explain the context of the climate data within the parks.

5. Derivative data. Data loggers are programmed to record means, maxima, minima, totals, samples, and cumulative values depending on the measurement. Post processing may include further aggregation such as daily, monthly or annual statistics.
6. Quality Control data. The raw climate data are downloaded annually from each site and archived along with sensor calibration data, datalogger program version, protocol and SOP version, site visit worksheets, and photos.

Table 1. Protocol activity matrix.

Category	Activity No.	Activity	Activity Description
Site Evaluation, Installation, and Maintenance	1	Site Evaluation	Site evaluation must be made to determine if the site is representative for monitoring weather conditions in the area.
	2	Site Installation	Weather station installation and GPS of permanent site. Location information included and updated in SOP 2, following installation guidance in SOP 8.
	3	Site Maintenance	Conduct annual site visit for data download, sensor calibrations, and basic field maintenance in accordance with SOP 9.
Field Observations	4	Current Sensor Readings	Readings of all sensors on weather station during site visit, prior to data download and at the end of the site visit in accordance with SOP 9.
	5	Sensor Height Measurements	Height of sensors on weather station. Recorded on site visit worksheet as described in SOP9.
	6	Photos	During annual site visit, 17 photos are taken by field staff in accordance with SOP 9.
	7	Site Conditions	Information on site condition is recorded in accordance with SOP 9.
	8	Datalogger Status	Information on datalogger status is recorded in accordance with SOP 9.
	9	Sensor Configuration	Information on sensor configuration, including serial numbers and models of sensors before and after maintenance visit in accordance with SOP 9.
Continuous Weather Data	10	Rainfall	Continuous cumulative measurement logged hourly. Specifications included in SOP4.
	11	Wind Speed	Hourly average (60 minute average taken from previous 60 minute samples) Specifications included in SOP4.
	12	Wind Direction	Hourly average (60 minute average taken from previous 60 minute samples) Specifications included in SOP4.
	13	Air Temperature	Hourly average (60 minute average taken from previous 60 minute samples) Hourly minimum and maximum temperatures recorded. Specifications included in SOP4.
	14	Relative Humidity	Hourly sample recorded. Specifications included in SOP4.
	15	Battery Voltage	Hourly average (60 minute average taken from previous 60 minute samples). Specifications included in SOP4.
	16	Solar Radiation	Hourly average (60 minute average taken from previous 60 minute samples). Specifications included in SOP4.

Table 1 (continued). Protocol activity matrix.

Category	Activity No.	Activity	Activity Description
Continuous Weather Data (continued)	17	Snow Depth	Hourly sample recorded. Specifications included in SOP4.
	18	Soil Temperature	Hourly average (60 minute average taken from previous 60 minute samples). May have between 1 and 4 sensors at various depths depending on site. Specifications included in SOP4.
	19	Phenology Camera Images	Images recorded 5 times per day according to SOP 9 and processed according to ARCN's Terrestrial Landscape Patterns and Dynamic Protocol Appendix C (Swanson 2016). Phenology cameras at select sites only.
External Data	20	Climate data from NOAA/ACIS	Weather station temperature and precipitation data from long-term weather stations used as index sites or reference stations for park data.
Derived Data	21	Daily Summaries	Daily averages, totals, minima, and maxima calculated based on data collected in activities 10-18.
	22	Monthly Summaries	Monthly averages, totals, minima, and maxima calculated based on data collected in activities 10-18.
Quality Control Data	23	Calibration of Sensors	Calibration of all sensors prior to installation with a schedule for calibration or replacement cycle according to SOP 4.
	24	Datalogger Version	Programming used to collect that year's data. Programming described in SOP 6 and data deliverable defined in SOP 10.
	25	Data Editing	Data outliers flagged and removed using Aquarius system according to quality control and record processing described in SOP 11.

Sampling Design

Information regarding the sampling design for the climate monitoring programs for the Arctic, Central Alaska, and Southeast Alaska Networks is provided in Table 2. Numbers match those in the Protocol Activity Matrix (Table 1).

Table 2. Activity-level sample design matrix.

Category	Activity Number(s) *	Activity	Sampling Design	Revisit Design
Site Recon, Establishment, and Maintenance	2	Site Installation	Targeted; Site evaluations occurred in each network prior to site installations. Documentation of final site selection for each network included: climate inventory report, site evaluations, NEPA compliance, and site visit information (Davey et al. 2007, 2007a; Sousanes 2009).	Revisit every 1 year
	3	Site Maintenance	Targeted; Annual site visit to every NPS weather station for sensor swap, calibration, field checks, and data download.	Revisit every 1 year
Field Observations	4-9	Sensor readings, sensor heights, photos, station status, and sensor configuration.	Targeted; Annual site visit to every NPS weather station for sensor swaps, calibration, field checks, and data download.	Revisit every 1 year
Continuous Weather Data	10-18	Rainfall, wind speed and direction, temperature, relative humidity, battery voltage, solar radiation, snow depth, and soil temperatures.	Targeted: Permanent NPS weather stations in ARCN, CAKN, and SEAN parks.	Continuous measurements recorded at hourly intervals.
	19	Phenology camera images	Targeted: Co-located on select weather stations in ARCN, CAKN, and SEAN parks.	Continuous, store 5 images per day.

* Numbers match those in the Protocol Activity Matrix (Table 1).

Data Quality Objectives

Data quality values and standards for implementation are provided in Table 3 through Table 5.

Table 3. Data Quality Values (DQVs).

Type	Data Quality Value	Definition	Protocol Considerations
Intrinsic Data Quality	Accuracy	Measurements reflect the true value of the parameter being observed. This applies to measures (length, width, position) or classes (species, types, or categories). Includes components of precision and bias.	Pre-deployment calibration of sensors are conducted in a controlled laboratory environment with calibration and accuracy documentation for every sensor by serial number in accordance with methods described in SOP 4. Maintenance site visits are conducted in accordance with schedule and methodologies described in SOP 1, 4, and 9.
	Representativeness	Measurements represent conditions at a permanent sampling location over time. Combined with accuracy, leads to robust data collection.	Parameters and methods are chosen such that they measure representative conditions.
Contextual Data Quality	Comparability	At all stations, data are collected using compatible (i.e., same specifications) field monitoring equipment. All stations are operated and maintained on a consistent schedule using standardized procedures. Data are edited in accordance with consistent procedures described in SOP 11.	Instrumentation, standard operating procedures, calibration procedures, and routine maintenance schedule is similar for all NPS weather stations. Data management and editing is conducted in accordance with standard operating procedures that are consistent between stations and between networks (SOP 1-12).
	Timeliness / Currency	Data at each station are collected on 60 minute/24 hours per day/365 days per year schedule. Provisional data are available in near real time on internet via partnership with the National Interagency Fire Center and the Western Regional Climate Center. Certified datasets with level 1b processed data are archived on NPS Data Store after each field season.	Real time availability of data allows for timely identification of weather conditions for park management. These data are not used as the certified data set and a data disclaimer is posted on each web based portal to that effect. Complete processing of data occurs on an annual basis. Data management and editing are done in accordance with standardized procedures described in SOP 11. Certification of data completed on an annual basis and archived on Data Store.

Table 3 (continued). Data Quality Values (DQVs).

Type	Data Quality Value	Definition	Protocol Considerations
Contextual Data Quality (continued)	Completeness	All data/ measures required to evaluate accuracy representativeness are present; incomplete data sets (either at a location, across sampling locations, or over time) lose utility or relevance. Data records contain values as planned across the period of record; missing values are left as blank values within the time series.	Methods, instrumentation, measurement intervals, and analyses are designed and implemented such that they result in a complete dataset across space and the planned period of record. Note that this value is for a collection of data records; how many measures are deemed valid and suitable for use at the completion of all QA/QC procedures.
Representational Data Quality	Consistent Representation	Use of standard definitions when describing data quality or resource quality based on data	Standard definitions of data quality are provided. Provisional data indicate data that have been not been reviewed and are not certified. Certified data are defined as those data that have been reviewed, QA/QC checked, and edited in accordance with procedures described in SOP 11. Data are reported and flagged in comparison to established management or ecological, or thresholds in accordance with procedures described in SOP 11.
Data Accessibility	Secure	Access to data, products, and systems limited to appropriate audiences.	Continuous weather station data undergo quality control in Aquarius following procedures described in SOP 11. The certified data sets and protocol deliverables are managed in the NPS IRMA Data Store following SOP 10. No protected data will be generated as part of the ARCN, CAKN, and SEAN climate monitoring protocol.

Table 4. Measurement Quality Objectives.

Measure	Quality Indicator	Quality Objective
Site Establishment	Location Accuracy	Weather stations are located at permanent locations in the ARCN, CAKN, and SEAN parks. Geographic coordinates, period of record, and other metadata are available online for all weather stations. An up-to-date GIS layer is maintained as an annual deliverable for the protocol.
	Location Description Detail	Most of these sites are remote and require either a boat or aircraft to access. GPS coordinates are necessary. Updated GIS maps with current locations are an annual deliverable described in SOP 2.
Rainfall	Type of Measurement	Continuous cumulative measurement
	Data logged	Hourly
	Measurement Units	inches
	Range	00.00 to 99.99 inches
	Accuracy	+/- 3.0% of total
Wind Speed	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	Miles per hour (mph)
	Range	0-100 miles per hour
	Resolution	1 statute mile per hour
Wind Direction	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	Degrees from true north
	Range	0-360 degrees
	Accuracy	+/- 5 degrees
Air Temperature	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	°F/°C
	Range	-50°to 70° Celsius; -58 to +140°Fahrenheit
	Accuracy	+/- 1°F; +/- 0.6°C

Table 4 (continued). Measurement Quality Objectives.

Measure	Quality Indicator	Quality Objective
Relative Humidity	Type of Measurement	Sample (once per hour)
	Data logged	Hourly
	Measurement Units	Percent %
	Range	0-100%
	Accuracy	0% -80% +/-2% at 25°C; 80%-100% +/- 5% at 25°C
Battery Voltage	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	Volts
	Range	0-15 Volts
	Accuracy	0.1 Volts
Solar Radiation	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	Millivolts
	Output	Watts per meter squared (w/m ²)
	Resolution	1 Millivolt
	Accuracy	+/- 5% (maximum) Absolute error in natural daylight; +/- 3% (typical)
Snow Depth	Type of Measurement	Sample (once per hour)
	Data logged	Hourly
	Measurement Units	Inches
	Range	0 inches to Sensor height
	Accuracy	+/- 1 inch
Soil Temperature	Type of Measurement	Hourly average (60 minute average taken from previous 60 minutes samples)
	Data logged	Hourly
	Measurement Units	Degrees (°) Fahrenheit or Celsius
	Range	-35°to 50° Celsius; -31 to +122° Fahrenheit
	Accuracy	+/- 0.4°C; +/- 1.0°F

Table 5. Data Protection Standards.

Type of Data	Data	Level of Protection	Rules for Dissemination
Continuous Weather Data and Information	Weather and Climate Data	Unprotected	Data available on-line as public information
Location Data and Information	Permanent Sampling Locations	Unprotected	Data available on-line as public information
Personally Identifiable Information	Non-NPS Staff Information	Legally Protected	All but first name and last initial redacted from public release

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