Standard Operating Procedure (SOP) 4: Climate Data Specifications, Sampling Frequency, and Measurement Intervals, Version 2.02

Weather and Climate Monitoring Protocol

Arctic (ARCN), Central Alaska (CAKN), and Southeast Alaska (SEAN) Inventory and Monitoring Networks

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #
1.00	December 2006	P. Sousanes	Added specs on communication and power equipment	Incorporated peer review comments	1.01
1.01	March 2017	P. Sousanes K. Hill, B. Johnson, M. Bower	Combined equipment list, links to sensor manuals with the specifications and measurement matrix.	All of the info on equipment, specs, and measurements are in one place. Easier to navigate. Details on current sensor models used in each network are included as appendices, as this will change most often.	2.0
2.0	April 2018	P. Sousanes	Table 4a-1 Added sample interval for RH and added new model # for sat transmitter in Table 4-A1.	Installing new satellite transmitters in ARCN/CAKN in 2018.	2.01
2.01	February 2019	P. Sousanes	Table 4a – added new AT/RH sensor model for CAKN	Replacing 12 year old AT/RH sensors in CAKN with new model	2.02

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Overview

This SOP defines the data collection specifications for the climate monitoring vital sign using research grade automated weather station equipment. Equipment standards and specifications provide the minimum requirements for equipment used in collection of data, along with the necessary maintenance and calibration schedule for that equipment. Details about the data stream order for telemetry and on-site storage are included.

It is important to note that in addition to standard RAWS configurations (as described below), alternative configurations have been employed where stations have been incorporated into existing infrastructure (e.g., GLBA fuel dock, KLGO Sheep Camp Ranger Station) and where site conditions necessitate more robust solutions (e.g., KLGO Chilkoot Pass). Other exceptions may occur in the future. Final station installation specifications including instrument models and sensor heights are recorded as a component of station metadata on station visit worksheets.

Data Collection

Each NPS Campbell Scientific, Inc (CSI) weather station consists of a datalogger, a satellite transmitter, measurement sensors, a sensor mast/tower, and the power system. Precipitation, wind speed and direction, air temperature, solar radiation, and soil temperatures are sampled every 60 seconds and then averaged once per hour (rainfall is a cumulative measurement and is reset on January 1 each year). Snow depth and relative humidity are sampled once per hour. The hourly peak wind gust and gust direction are recorded from the 60 second sample measurements. The hourly minimum and maximum air temperatures are also recorded based on the 60 second air temperature measurements.

The resultant data stream from this sampling protocol is of hourly resolution. The data is output through the satellite transmitter in the following order: precipitation, wind speed, wind direction, air temperature, relative humidity, battery voltage, peak wind direction, peak wind speed, solar radiation, snow depth, soil temperature 1, soil temperature 2, and soil temperature 3. Physical site visits are made annually to collect the stored measurements and to perform station maintenance (See Appendix A and Appendix B for a detailed list).

The satellite transmitter relays the hourly data stream through the GOES West satellite to the National Interagency Fire Center, where it becomes part of the Wildland Fire Management Information (WFMI) system. Once in the WFMI system various data portals such as the Western Regional Climate Center, the University of Utah’s Mesowest, the Alaska Interagency Fire Center, the National Weather Service HADS system, and other weather data dissemination portals pull the data and post it to the public. The telemetered data have not gone through data validation and are therefore subject to review. The primary purpose of the telemetered data is for weather forecasting purposes, safety, and to troubleshoot site issues between visits.

Datalogger, Communication, and Power System

The specifications for the most current configuration of the datalogger, satellite transmitter, sensor, hardware, power system, and electric fence installation are included in the tables in Appendices A and B.

Datalogger

The datalogger is the essential component of a weather station, which is used to scan measurements of sensors, perform programmed calculations, convert data to other units of measurement, and store the data in memory. The stored data is transmitted through a satellite transmitter and is also downloaded on each annual maintenance visit. The technology for the data logger changes about every 10 years; operating system updates occur more frequently.

Communication

Communication devices store and retrieve data acquired by the datalogger. There are multiple ways to communicate with the datalogger, including: data cables (cable from field laptop to datalogger for data display, download, and programming), CR10KD keypad (data viewing, programming), a portable handheld device (PDA) (for data display, data collection, and programming), and a satellite transmitter for data transmission from remote site to receiving station.

The satellite transmitter interfaces with the datalogger to transmit the hourly data via antenna and Geostationary Operational Environmental Satellites (GOES) to a receiving station. The details about obtaining a site specific ID through the National Oceanic and Atmospheric Administration (NOAA) and the data flow through the NOAA receiving station and WFMI is described in SOP 7.

There is a list of additional equipment that is necessary when using a GOES transmitter including a GOES antenna, GPS antenna, and appropriate cables (Appendix Tables SOP 4-A3 and SOP 4-B3). The transmitter technology changes every 2-3 years. It may be necessary to upgrade the transmitter to stay in compliance with the Federal Communication Commission (FCC).

Power

Standard remote stations require an external power system that consists of two or three 12-Volt deep cycle storage batteries, a solar panel, and a charging regulator (Appendix Tables SOP 4-A4 and SOP 4-B4).

Battery

Two or three 12-Volt deep cycle batteries (150-200 amp hours total depending on location) are used in the power set–up and are run in parallel (same voltage, double or triple capacity). The batteries are joined in parallel with one cable that connects both positive terminals and another cable that connects both negative terminals (positive to positive, negative to negative). The power cable (connecting the battery to the data logger) is then connected to one of the batteries. The station does not require this much power; it is overdesigned because the stations are remote and are visited only once a year. The detailed battery specifications are described in the next section. The batteries are

housed in a heavy duty molded plastic case, with holes drilled in the bottom to allow for air movement and moisture escape. The batteries should be replaced every 10 years.

Solar Panels

A 50-100 watt solar panel is recommended to keep the batteries charged. Solar panel specifications and prices fluctuate often. There is no preferred manufacturer. The size is important. The panel mounts on the south side of the tower or mast and can act as a sail or shading device. The best design features a panel that can either run vertical with the mast or horizontal to the mast if it sits directly in front of the enclosure. There are various ways to mount a solar panel depending on the frame. The panels should be replaced when they no longer charge the batteries.

Charging Regulator

A charging regulator is necessary to ensure the batteries are only charged to capacity and not above.

Tower and Mounting

The enclosure that houses the datalogger and satellite transmitter, the sensors, the antennas, and the solar panel are all mounted on either a 10-foot tripod or a 10-foot tower, depending on the site conditions. In some locations an electric wildlife fence is installed to protect the instrumentation (Appendix Tables SOP 4-A5, SOP 4-A6, SOP 4-B5 and SOP 4-B6).

Sensor and Data Requirements

Equipment standards and specifications provide the minimum requirements for equipment used in collection of data, along with the necessary maintenance and calibration schedule for that equipment. The data standard specifies the type of measurement and the measurement interval for each parameter. The data element descriptions provide the information used by the WFMI system and include the data stream order, the header used in the WFMI system, a description of the measurement, the measurement unit, and the Standard Hydrometeorological Exchange Format (SHEF) code, which is a documented set of rules for coding of data in a form for both visual and computer recognition (SOP 6). The ‘Data Short Header’ is used as the ‘Label Name’ to set up a data set in Aquarius, the data quality control software (SOP 11).

The parameters are described in the following order: rainfall, wind speed, wind direction, air temperature, relative humidity, battery voltage, solar radiation, snow depth, and soil temperature.

Rainfall

The remote weather stations will measure the amount of summer rain (liquid precipitation only) that falls on the surface. The stations do not have the power capacity for heated gauges or winterized gauges that are necessary to measure snow, sleet, or hail.

<u>Sensor Standard</u>

Sampling Height	1-10 feet, varies with tower and site conditions
Measurement Units	Inches
Range	00.00 through 99.99 inches
Resolution	0.01 inches

Accuracy	+/- 3.0% of total

Data Standard - Cumulative

Type of Measurement	Continuous cumulative measurement
Data Logged	Hourly

Data Element Descriptions for the WFMI System

Element #	1
Data Short Header	RNIN
Description	Rain Accumulation
Units	Inches
SHEF Code	PC

Maintenance and Calibration

- Inspect sensor annually; check tipping mechanism, check funnel orifice for debris, re-level if necessary.
- Replace every 5 years with calibrated sensor.
- Replace sooner if the data looks suspicious.

Wind Speed

The NPS weather stations will measure wind speed which is the rate at which air passes a given point.

Sensor Standards

Sampling Height	6 feet or higher
Measurement Units:	Statute miles per hour
Range:	0-100 miles per hour
Resolution	1 statute mile per hour

Data Standard – Hourly Average

Type of Measurement	Hourly average (60 minute average taken from the previous 60 minutes samples)
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	2
Data Short Header	WSM
Description	Wind Speed Miles per Hour (mph)
Units	Miles per hour (mph)
SHEF Code	US

Data Standard – Peak Wind Speed

Type of Measurement	Maximum wind speed for previous 60 minutes
Data Logged	Hourly

Data Element Descriptions for the WFMI System

Element #	8
Data Short Header	WSMP
Description	Wind Speed Peak Miles per Hour (mph)
Units	Miles per Hour (MPH)
SHEF Code	UP

Wind Direction

Wind direction, the direction from which the air is moving past a given point, is also measured.

Sensor Standards

Sampling Height	6 feet or higher
Measurement Units	Degrees from true north
Range	0-360 degrees
Resolution	1 degree
Accuracy	+/- 5 degrees

Data Standard – Hourly Average

Type of Measurement	Hourly average (60 minute average taken from the previous 60 minute samples)
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	3
Data Short Header	WDD
Description	Wind Direction Degrees
Units	Degrees
SHEF Code	UD

Data Standard – Peak Wind Direction

Type of Measurement	Direction of peak wind gust over past 60 minutes
Data Logged	Hourly

Data Element Descriptions for the WFMI System

Element #	9
Data Short Header	WDDP
Description	Wind Direction Peak Degrees
Units	Degrees
SHEF Code	UX

Maintenance and Calibration

- Inspect sensor annually; check wind direction and speed during annual maintenance visit.
- Replace every 3 years with calibrated sensor.
- Replace sooner if the anemometer bearings become noisy, or the wind speed threshold increases above 224 mph.

Air Temperature

Air Temperature refers to the ambient temperature of the air ~ 6 feet above the ground surface.

Sensor Standards

Sampling Height	4-8 feet in a naturally aspirated gilled radiation shield
Measurement Units	Degrees Celsius or Fahrenheit
Range	-50° to +50° Celsius
	-58° to +140 ° Fahrenheit
Resolution	1°C /1°F
Accuracy	+/- 1°F
	+/- .6°C

Data Standard – Hourly Average

Type of Measurement	Hourly average (60 minute average taken from the previous 60 minute samples)
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	4
Data Short Header	ATF
Description	Air Temperature
Units	Degrees Fahrenheit (°F)
SHEF Code	TA

Data Standard – Hourly Minimum

Type of Measurement	Minimum air temperature for previous 60 minutes
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	12
Data Short Header	AT1L
Description	Air Temperature, 1 hour Low
Units	Degrees Fahrenheit (°F)
SHEF Code	TN

Data Standard – Hourly Maximum

Type of Measurement	Maximum air temperature for previous 60 minutes
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	13
Data Short Header	AT1H
Description	Air Temperature, 1 Hour High
Units	Degrees Fahrenheit (°F)
SHEF Code	TX

Maintenance and Calibration

- The sensor must be inspected annually for any physical damage.
- A single-point field calibration can be done using an ice-slurry to test the temperature at 0°C.
- Sensors should be replaced every 3 years with a freshly calibrated sensor from CSI.
- Look at the data, if something seems wrong, inspect the sensor and /or replace the sensor.

Relative Humidity

Relative humidity is the percentage ratio of the amount of water vapor in the air to the amount of water vapor required for saturation at existing temperature. The sensor measures both air temperature and relative humidity. Because of the inverse relationship between relative humidity and air temperature, finding the mean relative humidity is meaningless, instead a sample is taken once per hour.

Sensor Standards

Sampling Height	4-8 feet
Measurement Units	Percent
Range	0-100%
Resolution	1%
Accuracy	0% - 80% +/- 2% at 25°C
	80% - 100% +/- 5% at 25 °F

Data Standard – Relative Humidity Hourly Average

Type of Measurement	Sample
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	6
Data Short Header	RHP
Description	Relative Humidity
Units	Percent (%)
SHEF Code	XR

Maintenance and Calibration

- Recalibrate or service the sensor annually, as recommended by manufacturer.
- Make sure that the radiation shield is free from debris.

Battery Voltage

The battery voltage measurement is recorded to help with remote troubleshooting issues and can be useful for data certification purposes.

Data Standard – Hourly Average

Range	0-15 Volts (11.8 considered minimum)
Accuracy	0.1 Volts
Type of Measurement	Hourly average (60 minute average taken from the previous 60 minutes samples)
Data Logged	Hourly

Data Element Descriptions for the WFMI System

Element #	7
Data Short Header	BVV
Description	Battery Voltage
Units	volts
SHEF Code	XR

Maintenance and Calibration

- Inspect battery terminals, clean with wire brush if needed.
- Replace every 10 years, or sooner, if battery will not hold a charge.

Solar Radiation

Measures the amount of sunlight that hits the surface.

Sensor Standards

Sampling Height	5-8 feet (eliminate any shading)
Measurement Units	Millivolts
Resolution	1 Millivolt
Output	Watts per meter squared
Accuracy	+/- 5%

Data Standard – Hourly Average

Type of Measurement	Hourly average (60 minute average taken from the previous 60 minutes samples)
Data logged	Hourly

Data Element Description for the WFMI System

Element #	10
Data Short Header	SRW
Description	Solar Radiation
Units	Watts per meter squared (W m^{-2})
SHEF Code	RD

Maintenance and Calibration

- During annual maintenance trip make sure the mounting base and pyranometer are level.
- Clean any debris or dust from the sensor head, but take care not to scratch the surface.
- Recalibrate every 2 years.

Snow Depth

An ultrasonic distance sensor measures the depth of snow under the sensor head that is mounted on the station (optional sensor).

Sensor Standards (for NPS)

Sampling Height	6-10 feet (depending on location and depth of maximum snow)
Measurement Units	Inches
Resolution	0.10 inches
Accuracy	+/- 1 inch

Data Standard – Hourly Average

Type of Measurement	Sample (once per hour)
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	11
Data Short Header	SDI
Description	Snow Depth
Units	Inches
SHEF Code	SD

Maintenance and Calibration

- Inspect desiccant, if necessary/required, and replace on a regular basis, especially in humid environments.
- The sensor housing assembly should be inspected annually and replaced every 3 years as recommended by manufacturer.
- Check the level of the sensor head on an annual basis (SR50A-L).

Soil temperature

At most sites, soil temperature is measured with three individual sensors at 10, 20, and 50 cm depths. At some locations a fourth soil temperature sensor may be added (depth of the deepest soil temperature sensor may vary based on local site conditions).

Sensor Standards (for NPS)

Sampling Depth	10, 20, and 50 cm below ground surface
Measurement Units	Degrees (°) Fahrenheit or Celsius
Resolution	1° Fahrenheit/Celsius
Accuracy	+/- 1° Fahrenheit/Celsius

Data Standard – Hourly Average

Type of Measurement	Hourly average (60 minute average taken from the previous 60 minutes samples)
Data logged	Hourly

Data Element Descriptions for the WFMI System

Element #	14 (soil temperature at 10 cm depth)
Data Short Header	STF
Description	Soil Temperature F
Units	°F
SHEF Code	TG
Element #	15 (soil temperature at 20 cm depth)
Data Short Header	STF2
Description	Soil Temperature F 2
Units	°F
SHEF Code	TG
Element #	16 (soil temperature at 50 cm depth)
Data Short Header	STF3
Description	Soil Temperature F 3
Units	°F
SHEF Code	TG
Element #	17 (soil temperature at 100 cm (or other) depth)
Data Short Header	STF4
Description	Soil Temperature F 4
Units	°F
SHEF Code	TG

Maintenance and Calibration

- Inspect the sensor cables on an annual basis.
- Look at the data; if something is wrong replace the sensor.

Telemetered Data and On-site Data Storage

Data are processed within the datalogger and are stored at an hourly resolution. The order that the data are transmitted and the order of the hourly data table within the datalogger are important for the receiving stations (WFMI) and for data processing.

Telemetered Data

The data from the NPS climate sites goes through the National Interagency Fire Wildland Fire Management Information System and the parameters need to be in the correct order for ingest. The datalogger are programmed to transmit the data in the following order:

Order	Measurement	Standard Meteorological Exchange Format (SHEF) Code
01	Rainfall	PC
02	Avg. Wind Speed	US
03	Avg. Wind Direction	UD
04	Air Temperature	TA
05	Fuel Temperature	MT (Not measured at network NPS sites)
06	Avg. Relative Humidity	XR
07	Battery Voltage	VB
08	Wind Direction Peak	UX
09	Wind Speed Peak	UP
10	Avg. Solar Radiation	RD
11	Snow Depth	SD
12	Minimum Air Temperature	TN
13	Maximum Air Temperature	TX
14	Soil Temperature 1 (10 cm)	TG
15	Soil temperature 2 (20 cm)	TG
16	Soil Temperature 3 (50 cm)	TG
17	Soil temperature 4 (100 cm)	TG

On-site Data Storage

All of the data are stored on the datalogger and are retrieved on an annual basis. Existing data are not explicitly erased but do eventually get overwritten as the logger cycles through its ring buffer.

Wildland Fire Management Information (WFMI) System Access

The data that are transmitted via satellite are ingested through the National Interagency Fire Center in Boise, Idaho and managed under the Wildland Fire Management Information system (SOP 7).

Keeping Maintenance Records

Maintenance and calibration records must be maintained for the life of the weather station site. Records must be kept of all field and laboratory procedures and include the maintenance and calibration of each sensor by its serial number.

A simple Excel spreadsheet is used to keep track of the sensor calibration schedule. Project staff update the spreadsheet at the end of the field season and record which sensors were swapped at each station (SOP 9). At the beginning of the field season the spreadsheet is used to create the site visit worksheets for each station (SOP 8).

The serial numbers for individual sensors are logged on the site worksheets and the original calibration sheets for every sensor are archived each year (SOP 10). An annual operations report is

compiled after each field season documenting what has been done at each site (deliverable WC_H; SOP 12).

Sensor Calibrations

Each spring, well before the field season starts, the sensors from the previous year are inventoried and those that need to be calibrated or repaired are sent to Campbell Scientific, Inc. (CSI). CSI has a standard returned-materials-authorization (RMA) process for these services. You must have an RMA number for the work to proceed. Follow the instructions below for calibrations or repairs:

Repairs or Maintenance

Follow these steps to return products for repair or maintenance:

1. An application engineer (AE) must determine the nature of the problem. To talk to an AE, contact Campbell Scientific, Inc., by phone at 435-227-9100.
2. After an application engineer determines the nature of the problem, you will be given a returned material authorization (RMA) number by our Service Department (during the same phone call).
3. You will then receive an RMA Confirmation email that contains instructions for completing the required paperwork and shipping the product.

Calibration

Follow these steps to return products for calibration:

1. Request a returned material authorization (RMA) number from our Service Department by calling 435-227-9105.
2. You will then receive an RMA Confirmation email that contains instructions for completing the required paperwork and shipping the product.
3. To prevent contamination and to ensure the safety of the CSI employees, all sensors and equipment that are returned must be clean and uncontaminated with harmful substances, such as chemicals, biohazards, and insects. As part of CSI policy a Statement of Product Cleanliness and Decontamination form must be submitted before shipping products to Campbell Scientific.

Refer to the CSI Repair and Calibration page on the company website for updates or questions.

Calibration Certificates

The calibrated sensors will be returned with a calibration certificate with information that includes the serial number of the sensor, the calibration date, the previous calibration date, and recommended next calibration date. It will also have other information specific to that sensor such as the calibration factor, output, calibration procedure and traceability. The certificate is generally signed and dated by

a certified technician. These hard copy calibration certificates should be filed and then compiled at the end of the field season as a deliverable product (SOP 10; WC_I).

The following tables provide a compiled list of the specifications for the sensors (Table SOP 4-A1), datalogger (Table SOP 4-A2), satellite communications (Table SOP 4-A3), power system (Table SOP 4-A4), and hardware (Table SOP 4-A5; Table SOP 4-A6).

Table SOP 4-A1. Sensor Specifications

Parameter	Sensor/Manufacturer	Sampling Frequency	Measurement Process/ Recording Interval/Units	Sensor Height	Calibration Schedule*
Air Temperature Primary (AT)	Campbell Scientific, Inc. 109 Temperature Probe	Every 60 seconds	Average, minima, maxima stored hourly °F	Sensor housed inside 6-plate radiation shield 2 m (~6')above surface	Every 3 years
Air Temperature Secondary(AT)/Relative Humidity (RH)	Vaisala HMP45C (older model) or Vaisala HMP-155A (new model) or Campbell Scientific, Inc. EE181	AT:Every 60 seconds RH:Sample 1x/hour	AT:Average, minima, maxima stored hourly °F RH: Sampled each hour	Sensor housed in 10-plate radiation shield 2 m (~6') above surface	Annually
Wind Speed (WS) Wind Direction (WD)	RM Young Wind Monitor 05103/05108	Every 60 seconds	Mean horizontal WS mph, unit vector mean WD in degrees, peak WS mph, direction of peak gust degrees stored hourly	3 m (~10') above ground level	Every 3 years
Solar Radiation (SR)	Li-Cor LI-200X Pyra-nometer	Every 60 seconds	Averages stored hourly (W/m²)	3 m above ground level	Every 2 years
Precipitation (P)	Texas Electronics 525WS Tipping Bucket	Every 60 seconds	Cumulative Reset on Jan 1 each year. inches	3m above ground to protect from wildlife; rainfall only at >0°C	Annual Field Calibration Swap every 5 years
Soil Temperature (ST1,ST2, ST3)	Campbell Scientific, Inc. 107 Temperature Probe	Every 60 seconds	Average stored hourly °F	3 separate sensors at 10, 20, and 50 cm depths	As needed
Snow Depth (SD)	SR50A-L Ultrasonic Distance Sensor	Sample 1x/hour	Sample value stored hourly - inches	Sensor placed above max snow depth	Every 3 years
Battery Voltage (BV)	12 V - 100 Amp Hour External Battery	Every 60 seconds	Average stored hourly - volts	Housed in insulated battery box	Every 10 years

*Calibration schedule assumes normal wear and tear. Pay attention to site specific conditions and sensor condition on each maintenance visit. Extreme conditions may accelerate calibration schedule.

Table SOP 4-A2. Datalogger Specifications.

Datalogger	Purchased from:
CR1000-XT Measurement and Control System	Campbell Scientific

Table SOP 4-A3. Satellite Communication Specifications

Satellite Communication	Model/Item #	Purchased From:
GOES Satellite transmitter	TX312/TX320/TX321 high data rate GOES Transmitter	Campbell Scientific
GPS Antenna	GPS antenna 3.3 V (17992)	Campbell Scientific
GPS Cable	Antenna cable (18017)	Campbell Scientific
GOES Antenna	GOES 11 dBi YAGI RHCP antenna (25316)	Campbell Scientific
Coaxial Cable	Antenna cable RG8 (COAXNTN)	Campbell Scientific

Table SOP 4-A4. Power Specifications

Power	Model	Purchased form:
Batteries	Concorde Sun Extender PV 1040 T 12 Volt 100 Amp hour (2)	ABS Alaskan
Solar Panel	60-75 watt	Varies depending on prices
Battery Box	Pelican Hardigg single lid case	AllCases
Charging Regulator	CH100/CH200 12V Charging Regulator	Campbell Scientific

Table SOP 4-A5. Hardware Specifications

Station Hardware - Item	Type/Model	Purchased from:
Tripod	CM110 10 ft. stainless-steel tripod w/grounding kit	Campbell Scientific
Guy Kit	Guy Kit for tripod (19239)	Campbell Scientific
Crossarm – 4 ft./6ft.	CM204/CM206 Sensor crossarm with mounting hardware	Campbell Scientific
Enclosure with (2) 1.5” diameter holes for cables	Weather resistant 16” x 18” enclosure ENC 16/18 (DC –MM)	Campbell Scientific

Table SOP 4-A6. Electric Fence Specifications

Electric Fence Parts	Type/Model	Purchased from:
Metal fence posts	6 ft. T-Posts	Various local vendors
T-Post Insulators	5-inch extender insulators	Various local vendors
Poly wire	200 ft. Polywire	Various local vendors
Solar fence charger	10 mile low impedance fence charger – various models	Various local vendors

Appendix SOP 4 - B. SEAN Weather Station Specifications: Current Sensor Models and Equipment

The following tables provide a compiled list of the specifications for the sensors (Table SOP 4-B1), datalogger (Table SOP 4-B2), satellite communications (Table SOP 4-B3), power system (Table SOP 4-B4), and hardware (Tables SOP 4-B5 and SOP 4-B6).

Table SOP 4-B2. Sensor Specifications

Parameter	Sensor/Manufacturer	Sampling Frequency	Measurement Process/ Recording Interval/Units	Sensor Height	Calibration / Service Schedule*
Air Temperature Primary (AT)	Campbell Scientific, Inc. 109 Temperature Probe	Every 60 seconds	Average, minima, maxima stored hourly °F	Sensor housed inside 6-plate radiation shield 2 m (~6')above surface	Every 3 years
Air Temperature Secondary (AT) / Relative Humidity (RH)	Vaisala HMP-45c or Vaisala HMP 60	AT: Every 60 seconds RH: Every 60 minutes	AT: Average, minima, maxima stored hourly °F RH: point sampled once per hour	Sensor housed in 10-plate radiation shield 2 m (~6') above surface	Annually
Wind Speed (WS) Wind Direction (WD)	RM Young Wind Monitor 05103	Every 60 seconds	Mean horizontal WS mph, unit vector mean WD in degrees, peak WS mph, direction of peak gust degrees stored hourly	3 m (~10') above ground level	Every 3 years
Solar Radiation (SR)	Li-Cor LI-200X or Li-Cor LI-200RX Pyranometer	Every 60 seconds	Averages stored hourly (W/m²)	3 m above ground level	Every 2 years
Precipitation (P)	Texas Electronics 525WS Tipping Bucket or MetOne 385 Heated Tipping Bucket	Every 60 seconds	Cumulative Reset on Oct 1 each year. inches	3m above ground to protect from wildlife; rainfall only at >0°C	Annual Field Calibration Service every 5 years
Soil Temperature (ST1,ST2, ST3)	Campbell Scientific 107 or 109 Temperature Probe	Every 60 seconds	Average stored hourly °F	3 separate sensors at 10, 20, and 50 cm depths	Not required under normal operation

Snow Depth (SD)	Judd Distance Sensor	Every 60 seconds	Average stored hourly - inches	Sensor placed above max snow depth	Every 3 years
Battery Voltage (BV)	Internal circuit within CR1000 datalogger	Every 60 seconds	Average stored hourly - volts	Inside enclosure	Every 3 years for CR1000
Barometric Pressure ()	Setra CS100 barometer	Every 60 minutes	Point sampled once per hour	Inside enclosure	Annually

*Calibration schedule assumes normal wear and tear. Pay attention to site specific conditions and sensor condition on each maintenance visit. Extreme conditions may accelerate calibration schedule.

Table SOP 4-B2. Datalogger Specifications.

Datalogger	Purchased from:
CR1000-XT Measurement and Control System	Campbell Scientific

Table SOP 4-B3. Satellite Communication Specifications

Satellite Communication	Model/Item #	Purchased From:
GOES Satellite transmitter	TX312/TX320/TX321 high data rate GOES Transmitter	Campbell Scientific
GOES Antenna	GOES 11 dBi YAGI RHCP antenna (25316)	Campbell Scientific
GPS Antenna	GPS antenna 3.3 V (17992)	Campbell Scientific
Combined GOES/GPS antenna	EON2 CS2 GOES antenna with GPS option	FTS
Coaxial Cable	Antenna cable RG8 (COAXNTN)	Campbell Scientific
GPS Cable	Antenna cable (18017)	Campbell Scientific

Table SOP 4-B4. Power Specifications

Power	Model	Purchased from:
Batteries	Optima 8016-003 12 Volt 55 Amp hour (3)	Best price vendor
Solar Panel	55 watt minimum	Best price vendor
Battery Box	Moeller 8D MOE-042209	Best price vendor
Charging Regulator	Morningstar Sunsaver 10A	Best price vendor

Table SOP 4-B5. Hardware Specifications

Station Hardware - Item	Type/Model	Purchased from:
Tower	UT10 10 foot tower with mast	Campbell Scientific
Tripod	CM110 10 ft. stainless-steel tripod w/grounding kit	Campbell Scientific
Guy Kit	Guy Kit for tripod (19239)	Campbell Scientific

Crossarm – 4 ft./6ft.	CM204/CM206 Sensor crossarm with mounting hardware	Campbell Scientific
Enclosure with (2) 1.5” diameter holes for cables	Weather resistant 16” x 18” enclosure ENC 16/18 (DC–MM or DC-TM)	Campbell Scientific

Table SOP 4-B6. Electric Fence Specifications

Electric Fence Parts	Type/Model	Purchased from:
Metal fence posts	6 ft. T-Posts	Various local vendors
T-Post Insulators	5-inch extender insulators	Various local vendors
Poly wire	200 ft. Polywire	Various local vendors
Solar fence charger	10 mile low impedance fence charger – various models	Various local vendors