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Surface Observing Program (Land), NDSPD 10-13

REQUIREMENTS AND STANDARDS FOR NWS CLIMATE OBSERVATIONS

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SUMMARY OF REVISIONS: This directive supersedes NWSI 10-1302, *Requirements and Standards for NWS Climate Observations*, dated, April 20, 2018. The following changes were made:

1. In section 2, revised URL link to the OFCM handbook "*Federal Standard for Siting Meteorological Instruments at Airports*."
2. Removed content specific to the Cooperative Observer Program.
3. Retitled sections and tables to use consistent language.
4. Reordered Section 3 for clarity.
5. Relabeled Table of Content and List of Tables in accordance with revised content.

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Requirements and Standards for NWS Climate Observations

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1 Introduction

This instruction describes the requirements and standards for National Weather Service (NWS) meteorological climate observations. These standards are for instrument siting, exposure, performance, and output data for air temperature, precipitation, soil temperature, and evaporation rate. The observations are made principally with NWS Cooperative Observer Program (COOP) instruments described in NWS Manual 10-1315, *Cooperative Station Observations and Maintenance*, https://www.nws.noaa.gov/directives/sym/pd01013015curr.pdf. Policy for management of COOP sites, including historical climatology sites, is found in 10-1307, *Cooperative Program Management and Operations*, https://www.nws.noaa.gov/directives/sym/pd01013007curr.pdf.

Observational equipment that qualify for NWS climate observations are addressed in NWSI 10-1003, *Climate Data Sources,* https://www.nws.noaa.gov/directives/sym/pd01010003curr.pdf . The air temperature and precipitation observing instruments of the Automated Surface Observing System (ASOS) network are included. Requirements for ASOS sensor siting and accuracy are found in the NWS Instruction (NWSI) 10-1301, *Aviation and Synoptic Observations*, https://www.nws.noaa.gov/directives/sym/pd01013001curr.pdf .

The standards for instrument performance, exposure, and data output in this instruction will support the recommendations of the World Meteorological Organization (WMO) as referenced in WMO-No. 100, Guide to Climatological Practices and WMO-No. 8, *Guide to Instruments and Methods of Observation Volume I –Measurement of Meteorological Variables*.

If standards cannot be met by the equipment in place, then the standards should be achieved when stations are changed, equipment is installed, programs are modified, or new stations are established.

As new instruments are introduced, studies to determine adjustment factors to account for

differences between old and new instruments, gauges, and shelters are made. For further information, see NWS Policy Directive (NWSPD) 10-21, *Intercomparison of Hydro-meteorological Instruments and Algorithms,* https://www.nws.noaa.gov/directives/sym/pd01021curr.pdf. The goal is to preserve the temporal continuity of station databases and make the change as seamless as possible in terms of the official climate record.

2 Site and Exposure Standards

Standards in this document will be followed as closely as possible to ensure uniformity of observations to meet national and international climatic observation requirements. Site and exposure standards define and establish specifications and guidelines. The implementation of these should be flexible to achieve a balance between meteorological representativeness, space availability, and cost effectiveness. Site and exposure standards differ between the aviation and climate programs.

The Interagency Council for Advancing Meteorological Services (ICAMS) details the site and exposure standards as they apply to federal and non-federal observers. See FCM-S4-2019, Federal Standard for Siting Meteorological Sensors at Airports (Washington, DC, 2019), accessible on: *Federal Standard for Siting Meteorological Sensors at Airports* (icams-portal.gov). Specific siting standards are found within each hydrometeorological element section.

Instruments are **not** to be sited on rooftops. Relocation of instruments will be accomplished as funds permit and after coordination with NWS Regional Headquarters. In a small number of cases, it is desirable to maintain the rooftop siting in order to maintain the historical climate record. The National Centers for Environmental Information (NCEI) will provide a waiver for the continued maintenance of existing rooftop stations.

3 Air Temperature Measurement Standards

Air temperature is the temperature of the free air conditions surrounding the station at a height between 4 and 6 feet above ground level. The air should be freely exposed to sunshine and wind and not close to or shielded by trees, buildings, or other obstructions.

3.1 Air Temperature Measurement Performance

Temperature instruments will meet the performance standards listed in Table 3.1 and will be shielded from precipitation, direct and reflected sunshine, and direct and reflected thermal energy (i.e., infrared radiation). All thermometers should be shielded with a radiation shelter or thermoscreen just large enough to protect against the elements stated, and slotted sufficiently to allow air to advect naturally into and out of the thermoscreen during calm air conditions. Powered aspirators are not required for these instruments.

All temperature measuring instruments should be issued with a certificate confirming compliance with the appropriate performance specification and accuracy; or be issued with a calibration certificate which gives the corrections that are applied to meet the required accuracy.

This initial testing should be performed by an accredited calibration laboratory or a national testing institution.

Air Temperature Measurement Performance Requirements				
Observed Element	**Range - Fahrenheit**	**Reference Temperature**	**Time Constant**	**Accuracy At Reference Temperature (F)**
Air Temperature	−20º to +115º	+ 50º	25 sec	± 1.0º 95% confidence
Air Temperature, Maximum*	-20º to +115º	+ 50°	25 sec	± 1.0º 95% confidence
	+115º to +140º	+ 120º	25 sec	± 2.0º 90% confidence
Air Temperature, Minimum*	−80º to −20º	- 30º	25 sec	± 2.0º 90% confidence
	−20º to +110º	+ 50º	25 sec	± 1.0º 95% confidence

Table 3.1. Performance Standards for Air Temperature Measurements.

**Standards required for Hardened instruments. See Section 3.1.2.*

3.1.1 General Instrument

The WMO suggests thermometers be able to measure with high certainty in the range of -20ºF to 115ºF, with maximum error less than 0.4ºF. In practice it may not be economical to provide thermometers that meet this performance goal. Less expensive thermometers, calibrated against a laboratory standard, may be used for NWS climate purposes provided they comply with the performance requirement identified in Table 3.1 above.

3.1.2 Hardened Instruments

Current day technology, thermometers may not have the ability to directly measure the temperature extremes identified in Table 3.1. In addition to the general climate instruments, an additional set of instruments to measure extreme air temperature is required for sites where air temperature falls below -20ºF, or rises above 115ºF at least one day per year in the 30-year climate record. A separate instrument is used, or a separate calibration factor is applied to the same instrument, for any observing site that meets this definition of a site that requires hardened instruments. These instruments will meet the standards listed in Table 3.1 for Hardened Instruments.

3.1.3 Air Temperature Siting Standards

Install the temperature instrument according to the following standards:

a. Over level terrain (earth or sod) typical of the area around the station, and, at least

100 feet from any extensive concrete or paved surface.

b. All attempts will be made to avoid:

(1) areas where rough terrain or air drainage are proven to result in non-representative temperature data;

(2) areas where water tends to collect; and

(3) areas where drifting snow collects.

c. If the instrument is within a Cotton Region Shelter, or equivalent, position the shelter so it opens to the north, in the northern hemisphere (to protect the instruments from direct sun exposure) with the floor 4 to 6 feet above the surface. Shelters should be located no closer to an obstruction than four times the height of the obstruction.

d. In the case of remote instruments not enclosed in shelters, the instrument (and display, if configured) will be mounted 4 to 6 feet above the surface and shielded by an integral thermoscreen or radiation shelter. Remote instruments should be located no closer to an obstruction than four times the height of the obstruction.

e. An object will be considered an obstruction if the object is greater than ten degrees in horizontal width as measured from the instrument and within 200 feet of the instrument. The instrument should be no closer than four times the estimated height of any nearby building, tree, fence, or similar obstruction.

3.1.4 Test and Evaluation

The NWS Office of Observations requires traceability of the performance of temperature measuring instruments which are immersed in a temperature bath and evaluated in parallel with precision reference thermometers in accordance with the National Institute of Standards and Technology (NIST) guidelines. The bath enables testing from -80ºC to +55ºC.

These tests are followed by whole system testing (for electronic instruments) inside a walk-in environment chamber. The final phase of testing requires instruments to be evaluated outdoors alongside reference thermometers for a minimum of six months. The uncertainty (i.e., accuracy) in the readings of the NWS reference instruments is estimated in accordance with the National Conference of Standards Laboratory (NCSL) International report, Recommended Practice for Intrinsic/Derived Standards, Volume 5 (i.e., RISP-5), to be ±0.01ºC at 95% confidence level, k=2.

The NWS methodology for testing and evaluating technical systems including observational systems for climate data acquisition, is found in NWSI 80-305, *Test and Evaluation*, https://www.nws.noaa.gov/directives/sym/pd08003005curr.pdf .

3.1.5 Time Constant

This is the time required by the thermometer to register 63% of a step change in air temperature. Instruments possess time constant values that produce step change of 1.0ºF and afford valid measurement of air temperature with 1-minute temporal resolution. The WMO *Guide to Meteorological Instruments and Methods of Observation* advises that the time constant be between 30 and 60 seconds with winds of 10 miles per hour.

3.2 Air Temperature Data Requirements

Table 3.2 gives the minimum requirements for the calculation, storage, and display of air temperature data for instruments with ability to log data. At a minimum, manual retrieval of the observed elements from the instrument display (outdoors) or system console (indoors) is required, but electronic reporting of the data where practical and when in an approved data format is encouraged.

Air Temperature Data Requirements					
Observed Element	**Data Output Resolution**	**Data Average**	**Calculation Update**	**Time Stamped**	**Memory Recall**
Air Temperature - Maximum Daily	0.1-degree F	15 seconds	1 minute	Yes	33 days
				No *	1 day
Air Temperature - Minimum Daily	0.1-degree F	15 seconds	1 minute	Yes	33 days
				No *	1 day
Air Temperature - Current Reading	0.1-degree F	15 seconds	1 minute	No	1 minute

Table 3.2. Data Requirements for Air Temperature.

* *Thermometers without an internal clock, that provide data for one time period, or require manual reset for a single time period, are not required to time segregate or time stamp their Max/Min values.*

4 Precipitation Measurement Requirements

Precipitation data is collected from two principal types of rain gauges. The first type is a manual rain gauge in which daily observations are taken by observers. The second type is a recording rain gauge which provides a recorded measurement of precipitation in coded format. Precipitation rain gauges will meet the accuracy standards listed in Tables 4.1 for manual rain gauges and Table 4.2 for recording rain gauges.

4.1 Manually Measured Precipitation

The COOP Program uses an eight-inch diameter rain gauge for observers to measure the

collected precipitation once every 24 hours. The Standard Rain Gauge consists of an eight-inch diameter metal overflow can, a funnel, a clear plastic collection tube and a measuring stick with marked gradations in hundredths of an inch.

Performance Requirements for Manually Observed Precipitation			
Parameter	**Range**	**Resolution**	**Measurement Accuracy**
Precipitation, Rain	0 to 20 inches	0.01 inches	±0.02 inches
Precipitation, Frozen (Liquid Equivalent)	0 to 24 inches of snow	0.01 inches melted	±0.04 inches melted
	0 to 12 inches of snow	0.01 inches melted	±0.04 inches melted

Table 4.1. Performance Requirements for Manually Observed Precipitation.

4.2 Automatically Measured Precipitation

The ASOS Program and the COOP Program use recording rain gauge that measure the weight of collected precipitation and convert the weight into equivalent hundredths of an inch of liquid precipitation. The COOP program uses the Fischer-Porter Rebuild (FPR) model and the NWS ASOS program uses the All-Weather Precipitation Accumulation Gauge (AWPAG) to meet the NWS requirements for climate observations.

Performance Requirements for Recorded Precipitation			
Parameter	**Range**	**Resolution**	**System Accuracy**
Precipitation, Rain (Hourly)	0 to 20 inches	0.1 inches	±0.1 inches, from 0 to 20 inches
Precipitation, Frozen (Hourly) Liquid Equivalent	0 to 20 inches	0.1 inches	±0.1 inches, from 0 to 20 inches

Table 4.2. Performance Requirements for Recorded Precipitation.

4.3 Recording Rain Gauge Data and Reporting Standard

Table 4.3 gives the minimum requirements for the production of precipitation data from a recording rain gauge, either manual or electronic. The recording gauge should produce, at a minimum, 15-minute data elements that correspond to the clock hour (HH) such that the first

element contains precipitation data measured at HH:15 local standard time. These data elements are date/time stamped and stored in the gauge for a minimum of ninety days, preferably 365 days.

Data Requirements for Recorded Precipitation					
Observed Element	**Calculation Update**	**Data Store Rate**	**Memory, Minimum***	**Data Retrieval**	**Data Quality Control**
Precipitation, Accumulated Rain	5 minutes	15 minutes	90 days*	Monthly	None
Precipitation, Accumulated Frozen	5 minutes	15 minutes	90 days*	Monthly	None

Table 4.3. Data Requirements for Recorded Precipitation.

* *This is minimum data storage, not the minimum amount of data to be retrieved monthly.*

4.4 Snow Measurement Standards

There are two sizes of snow measuring sticks, one for most snowfall events typically 24" long and/or snow depths and the other for heavier snowfall events and/or deeper snow depths typically 48" long. For sites that measure snow depth up to 60 inches, there is a snow stake. A snow board is used to measure the depth of the newly fallen snow (i.e., snowfall) and it is cleared of all snow and frozen precipitation once per day, immediately after the observation is taken. Snow measuring equipment will meet the accuracy standards listed in Table 4.4.

Equipment Standard for Snow Depth				
Parameter	**Equipment**	**Range**	**Resolution**	**Accuracy**
Snowfall / Snow Depth: 0.1 inch to 20 inches	Snow stick (marked) and Snow board	0 to 20 inches	0.1 inch	±0.1 inch
Snowfall / Snow Depth: 20 to 40 inches	Snow stick (marked) and Snow board	0 to 40 inches	0.1 inch	±0.1 inch
Snow Depth: 40 to 60 inches	Snow stake (marked)	0 to 60 inches	1 inch	± 1 inch

Table 4.4. Equipment Standard for Snow Depth.

4.5 Siting Standards for Precipitation Gauges

The exposure of precipitation gauges is of primary importance in the accuracy of precipitation measurements. An ideal exposure would eliminate all turbulence and eddy currents near the

gauge that tend to carry away the precipitation. The loss of precipitation in this manner tends to increase with wind speed and orifice height.

a. The orifice of the gauge will be horizontal and located approximately 3 feet above the ground for standard rain gauges (i.e., daily observation) and approximately 6 feet above the ground for recording gauges (i.e., monthly observation). Exceptions are granted by the NWS Regional Headquarters in writing and described in the station information documentation.

b. If possible, the gauge should be protected in all directions by objects of uniform height. If they are not of uniform height, then use the rain gauge as a baseline to estimate the average height of the obstructions and the average distance of the obstructions from the rain gauge. The gauge should be sited no closer to the nearest obstruction than a distance that is twice the height of the obstruction. In other words, the top of obstruction should not subtend more than a 30-degree angle when sighted from the orifice of the rain gauge.

c. In open areas, the height of an obstruction above the orifice should not exceed one half its distance from the gauge.

5 Soil Temperature Measurement Standards

Soil temperatures are essential to the agricultural industry and should represent the temperature of the natural agricultural soils of the area. A number of forecast offices use Palmer model of soil thermometers to collect and transmit soil temperature readings to agricultural agencies either daily or weekly especially during the beginning and middle portions of the growing season. The observation sites should not be subject to irrigation, overflow, or unusual ground water conditions. The sites should be open to full sunshine and represent the seasonal sun and shade patterns for the growing season. Snow cover should remain natural and undisturbed.

The thermometers should be situated in the center of a plot that measures 10 feet by 10 feet and is enclosed by a chain link fence four to five feet high. The plot should include either or both types of ground cover: bare ground to represent conditions for row-crops, or sod to represent pasture land. The sod-covered plots are trimmed to maintain a uniform two- or three-inch grass height. For the detailed instruction on how to install the soil thermometer refer to NWS Manual (NWSM) 10-1315, *Cooperative Station Observations and Maintenance*, Appendix A, Section 4, https://www.nws.noaa.gov/directives/sym/pd01013015curr.pdf .

5.1 Soil Temperature Measurement Performance

Soil temperature observations should be taken once a day at the same time each day. Generally, this will be between 7am and 8am or between 5pm and 8pm local time. If automated recording instruments are used, the instruments should be checked daily to assure they are operating. Instrument performance is documented through a test and evaluation process that uses a temperature reference generator as described in Section 3.1.

Measurement Standards for Soil Temperature				
Observed Element	**Range – Fahrenheit**	**Reference Temperature**	**Time Constant**	**Accuracy At Reference Temperature**
Soil Temperature, Maximum	0º to +120º	+100º F	60 sec	± 2.0º 90% confidence
Soil Temperature, Minimum	−10º to +90º	+20º F	60 sec	± 2.0º 90% confidence
Soil Temperature, Current	−10º to +120º	+50º F	60 sec	± 2.0º 90% confidence

Table 5.1. Measurement Standards for Soil Temperature.

5.2 Soil Temperature Data Requirement

Soil thermometers should be located under undisturbed soil in close contact with the ambient soil, with no insulating air spaces, or pockets. Soil temperatures should be taken at a depth of 4 inches. If required for special needs, depths of 2 inches, 8 inches, 20 inches, 60 inches, and 120 inches can be reported if they meet the measurement standards described in Table 5.1.

The observer reports in whole degrees the maximum, minimum, and current soil temperatures at one depth: four inches. The shallow soil depths experience the greatest diurnal range in temperature, and soil temperatures in the summer can exceed the air temperature. Seasonal changes are observed at 20 inches. If the observer also reports air temperature, they should take the air temperature observation at the same hour of the day as the soil temperature.

Data Requirements for Soil Temperature				
Observed Element	**Observation Period**	**Observation Frequency**	**Observation Method**	**Data Resolution**
Soil Temperature - Maximum Daily	24-Hours	Daily at a Set Hour (i.e., 7am)	Examine dial / readout	Whole Degree Fahrenheit
Soil Temperature - Minimum Daily	24-Hours	Daily at a Set Hour (i.e., 7am)	Examine dial / readout	Whole Degree Fahrenheit
Soil Temperature - Current Reading	Current	Daily at a Set Hour (i.e., 7am)	Examine dial / readout	Whole Degree Fahrenheit

Table 5.2. Data Requirements for Soil Temperature.

6 Pan Evaporation Measurement Standards

During the growing season when air temperatures are above freezing, observations are taken of the daily evaporation to the nearest hundredth of an inch. These pan evaporation observations are useful for agricultural programs, and the observations are reported by the United States Department of Agriculture (USDA) in the *Weekly Weather and Crop Bulletin*. It is accessible on: https://www.usda.gov/sites/default/files/documents/wwcb.pdf.

When the pan evaporation observation is taken, additional observations are made of water temperature, air temperature, precipitation, and air movement. The detailed instructions for conducting pan evaporation observation are located in NWSM 10-1315, *Cooperative Station Observations and Maintenance*, Appendix B, Section 4.

6.1 Evaporation Pan Siting Standards

The pan should be sited in an open field if possible, in full sunlight, and enclosed by a gated chain link fence, four to five feet high. The pan should also be mounted on a level wooden pallet so the pan sits approximately six inches above the ground surface. The standard size plot measures 16 feet by 20 feet, and could be smaller or larger to accommodate site conditions or additional observing equipment. To prevent possible damage to the pan from ice in the cold season, the pan is emptied and stored indoors, or secured outdoors, inverted. For the detailed description of the Evaporation Pan and its siting, refer to NWSM 10-1315, *Cooperative Station Observations and Maintenance*, Appendix A, Section 3, https://www.nws.noaa.gov/directives/sym/pd01013015curr.pdf .

Observation Requirements for Pan Evaporation				
Parameter	**Frequency**	**Range**	**Resolution**	**Accuracy**
Evaporation	Daily, or as Specified	0 to 10 inches	0.01 inches	±0.02 inch

Table 6.1. Observation Requirements for Pan Evaporation.

6.2 Required Observations

Pan evaporation is an empirical observation with additional observations made on site, within 50 feet of the evaporation pan, and reported to the NWS Weather Forecast Office (WFO) as useful for agricultural interests.

Performance Standards for Water Temperature				
Observed Element	**Range - Fahrenheit**	**Reference Temperature**	**Time Constant**	**Accuracy At Reference (F)**
Water Temperature, Maximum	33º to 120º	80º F	25 sec	± 2.0º 90% confidence
Water Temperature, Minimum	32º to 110º	50º F	25 sec	± 2.0º 90% confidence
Water Temperature, Current Reading	32º to 120º	50º F	25 sec	± 2.0º 90% confidence

Table 6.2. Performance Standards for Water Temperature.

6.2.1 Daily Maximum and Minimum Water and Air Temperatures

Reporting both daily maximum and minimum water and air temperatures are required when reporting evaporation. The water thermometer should be held in a bracket, shielded from sunlight, and submerged in the evaporation pan. The bracket should be mounted such that the sensor tip is along the south wall of the pan or set on the bottom of the pan along the south wall, depending on type. Observations for both water and air are made to the nearest Fahrenheit degree on instruments. Air temperature observations are taken on instruments that comply with those described in Section 3 of this instruction.

6.2.2 Daily Precipitation Accumulation

Precipitation observations are taken on instruments that comply with the requirements described in Section 4. Readings are taken and logged to the hundredth of an inch.

6.2.3 Daily Air Movement

Air movement across the evaporation pan is measured by a totalizing anemometer that complies with the standards described in Table 6.3. Air movement measurements are accurate to ±33% of the actual air movement in miles at the end of 24 hours. The measurement of one mile of wind should represent ten 'counts' on the totalizing anemometer's display. Descriptions of the models of the totalizing anemometer, including the Nova Lynx model, are found in NWSM 10-1315, *Cooperative Station Observations and Maintenance,* https://www.nws.noaa.gov/directives/sym/pd01013015curr.pdf .

Note: If a totalizing anemometer is unavailable, and a recording anemometer is used, then multiply the average 24-hour wind speed by 24 to calculate the miles of wind.

Performance Standards for 24-Hour Air Movement				
Observed Element	**Equipment Display Range**	**Units Per Count**	**Display Controls**	**Accuracy For 24-Hour Total (See Note)**
24-Hr Wind Run	0 to 10,000 Counts	One Tenth of Mile	Non-Resettable	± 33% of total miles as calculated from anemometer

Table 6.3. Minimum Performance Standards for 24-Hour Air Movement.

Note: The totalizing anemometer equipment is considered accurate when it tests in a wind tunnel to within ±33% of the total number of miles calculated from a reference recording anemometer's 24-hour mean wind speed (in miles per hour) multiplied by 24.