AMERICAN ASSOCIATION OF STATE CLIMATOLOGISTS

Recommendations and Best Practices for Mesonets

Version 1

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Preface

This document is the result of 2.5 years of work by two subcommittees of the AASC Mesonet Steering Committee: The Meteorological Data and Metadata Subcommittee and the Functional Standards and Practices Subcommittee. We are grateful to the members of these subcommittees:

<u>Functional Standards and Practices</u>
Kevin Brinson, Delaware Environmental Observing System
Nathan Edwards, South Dakota Mesonet
Jeff Andresen, Michigan State Climatologist's Office
Xiaomao Lin, Office of the Kansas State Climatologist

<u>Meteorological Data and Metadata</u>
Jennie Atkins, Illinois State Water Survey
Megan Schargorodski, Kentucky Climate Center
Chip Redmond, Kansas Mesonet
Pat Guinan, Missouri Climate Center
Stonie Cooper, Nebraska State Climate Office

Four key milestones led to the development of this document. In early 2017, all known State Mesonets were surveyed via a 31-question online survey to assess the range of current metadata and functional standards and practices. Twenty-one State Mesonets submitted detailed feedback via the survey. The next milestone occurred during late 2018 during which an early draft version of this document was created by subcommittee members. This draft formed the basis for discussion and iteration during an intensive 2-day workshop in Nashville in February 2019. During this third milestone, representatives from 17 states met. The final milestone occurred during February through May of 2019, during which twice-weekly teleconferences were held to consolidate feedback, incorporate references, and finalize this document.

This document was approved by majority vote during the Business Meeting of the AASC Annual meeting in Santa Rosa, California on 26 June 2019. Although this is now an official AASC document, we recognize it is Version 1. To submit corrections or suggestions to this document, we ask that you email your feedback to mesonet@stateclimate.org. If you would like to be included in the subcommittees that will work on the next version of this document, we encourage you to contact mesonet@stateclimate.org.

Stuart Foster, Chair of the AASC Mesonets Steering Committee
Chris Fiebrich, Chair of the Meteorological Data and Metadata Subcommittee
Rezaul Mahmood, Chair of the Functional Standards and Practices Subcommittee

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1. Introduction

Over recent decades, mesoscale networks of automated, in-situ stations for weather monitoring have been developed across diverse regional settings (e.g., Mahmood et al., 2017). These networks, commonly referred to as mesonets, have originated independently, are funded at various levels and through various mechanisms, and serve a variety of constituencies and needs. While sharing commonalities, each network has unique strategic, design, and operational elements. As sensor and communications technologies evolve and the demand for environmental data to support decision making grows, mesonets are expected to play an increasing role in support of weather and climate services.

Currently, there exists inconsistent functional practices and metadata reporting among mesonets. This document provides guidance for mesonets regarding functional practices and metadata reporting based on the needs of and supported by scientific research from the mesoscale weather and climate community. Specific recommendations herein aim to improve and recognize quality and harmonize management strategies among mesonets in the United States.

As an AASC community, we define a mesonet as a network of automated weather observing stations that (1) monitor environmental variables in the vertical domain between 10 m above to one meter below ground surface such as air temperature, relative humidity, rainfall, winds, solar radiation, soil temperature, and soil moisture, (2) report data at a sub-hourly temporal resolution, and (3) have a spatial density of approximately one station per 1,000 km^2 or greater (average spacing of approximately 30 kilometers). We further recognize that an emphasis on data quality, reliability, and completeness is vital to a mesonet's ability to effectively deliver services in near real-time and document climatic conditions over the long term.

This document is organized to include recommendations for siting, sampling and reporting procedures, sensor performance, maintenance, quality control, and system reliability. These specific core principles were last formally published in a 1985 report by the American Association of State Climatologists (AASC). There is a growing need by mesonets for guidance on protocols and best practices, and AASC membership is the natural authority with a wealth of experience and expertise to provide this guidance. While we recognize other stakeholders of mesonet data, such as agriculture, energy, public safety, natural resource management, fire weather, air quality, etc., *the guidelines and best practices contained herein do not attempt to address any particular stakeholder-group specific needs*.

2. Siting

The quality and utility of data collected by a mesonet are fundamentally related to the siting of stations and associated sensors. Given the objective of collecting observations that are representative of the mesoscale environment, effort should be dedicated to finding appropriate sites for monitoring and exposing sensors in a manner that minimizes the influence of any potential sources of microscale bias. This section provides recommendations regarding the siting of stations and sensors, as well as the collection of corresponding site metadata.

2.1 Station Siting

Regardless of the number of stations deployed to sample the near-surface environment, those stations cover only a minute subset of the potentially available monitoring sites. The intention thus is to locate stations at sites that are broadly representative of the surrounding mesoscale environment. Doing so inherently demands a broad understanding of the character of the target mesonet environment and the ability to identify sites whose mesoscale representativeness is not unduly comprised by microscale influences. This section addresses challenges and provides recommendations regarding station site selection at the mesoscale, placement of individual sensors with respect to the observing platform, and documentation of corresponding metadata.

Siting guidelines relating to exposure of weather stations to environmental conditions have traditionally focused on individual stations and assessed the quality of a site exposure in relation to an idealized landscape, broadly considered to be a flat, manicured grassy surface in an open, undeveloped area where air flow is unimpeded by obstacles. Such an environment may be thought of as pristine for weather and climate monitoring, minimizing influence from localized, environmental complexities at the microscale (generally < 1 km).

Recognizing this ideal but acknowledging complexities of mesoscale environments, the footprint of a mesonet station should be a flat, or nearly flat, natural surface at least 100 m^2 in area. In many, but not all areas the natural surface cover would be grass. This footprint represents the physical site of the station and is the area that is maintained during regular site visits to ensure long-term site integrity. The recommended character of the station footprint is a standard for all mesonets. Hence, stations not sited over natural surfaces (e.g., stations mounted on rooftops, walls, machinery, vehicles, etc.) are not recognized as being representative of mesoscale environments.

No mesoscale landscape conforms to an isotropic plain. Even a homogeneous mesoscale landscape is characterized by internal variability. Thus, a gently rolling agricultural plain may be sparsely populated with trees, dissected by occasional streams, and altered in places by roads, buildings, and other elements of the built environment. For some measurements, proximity to such natural or built features can have undue influence on observations, producing a microscale bias that causes those observations to be less representative of the broader mesoscale environment. With these considerations in mind we provide the following recommendations for station siting.

Beyond the station footprint, siting should include consideration of the adjacent microscale landscape, extending roughly one kilometer, within the context of the more expansive mesoscale environment. Broadly, the station should be located to minimize undue influence of features present in the microscale environment, particularly those that are not prevalent and do not otherwise have a strong influence on the mesoscale environment. Microscale influences of concern may arise from proximate topographic and terrain features, land use and land cover, and elements of the built environment. Given the complex array of real-world possibilities, a few examples may help to guide best practices. A mesonet should avoid siting a station near a considerable urban influence (e.g., commercial area, industrial zone, etc.) when the representative mesoscale landscape is largely open and rural. A mesonet station should not be located near an isolated reservoir or a lone irrigated farm within a predominantly arid mesoscale landscape. Within a flat to gently rolling mesoscale landscape, a station should not be sited near an extreme topographic or elevation change. To the extent that the composition of the mesoscale environment is of a homogeneous nature, then a single well-sited station will yield data that is broadly representative of the surrounding mesoscale environment, with the degree of representativeness declining with distance from the station.

Mesoscale landscapes can be characterized by a significant degree of heterogeneity. Commonly, heterogeneity is related to topography. Examples include mountain-valley landscapes, dissected plateaus, and coastal transition zones. Typically, these landscapes are also characterized by changes in the predominant land use and land cover. In addition, heterogeneity can arise when rural areas are encroached upon by urbanization, creating a regional mosaic of land uses at the mesoscale.

When the mesoscale environment is heterogeneous, the ability of a single station to be sited in a manner that it is broadly representative of the mesoscale environment is compromised. From a pragmatic perspective, a heterogeneous environment may be viewed as a composite of various landscape types, where each type is prevalent within the mesoscale environment within a given area. For example, a mesoscale environment may include distinct physiographic types (i.e., ridges and valleys, coastal and inland zones, etc.), land use types (i.e., agriculture, low-density development, etc.) and land cover types (i.e., crops, pasture, forest, etc.). In such situations, a given station may be sited to be representative of a particular landscape type, with the goal of siting stations that are representative of the diversity of types present at the mesoscale. In this case, the most representative station to a given location may not be the station in closest physical proximity.

Mesonets, particularly those that extend across regions characterized by heterogeneous landscapes, should document their strategy and approach for siting stations. Documentation should begin with a detailed geographic description highlighting the diversity of landscapes across the mesonet's coverage region and including the identification of landscape types that are prevalent at the mesoscale. This may include landscape and aerial imagery that provide a representative portrayal of those landscapes. Documentation should also explain the strategy and process for identifying and selecting sites to ensure that targeted mesoscale landscapes are appropriately sampled. This may include detailing how the siting decision for a given station within a targeted mesoscale environment may be contingent upon the locations and mesoscale contexts of proximate stations.

In summary, mesonets, by their nature, sample weather at a spatial density and over a spatial extent that requires stations to be sited with a diversity of exposures. Mesonets should be designed to provide representative observations of complex environments and can only do so by incorporating stations with exposures that reflect that diversity, while retaining the ability to represent the mesoscale.

2.2 Sensor Siting

Sensor siting refers to the position of sensors on the station platform and the shielding of those sensors, where appropriate. Recommendations are provided for the siting of sensors deployed to measure variables commonly monitored by mesonets.

Air Temperature and Relative Humidity

Both air temperature and relative humidity should be placed at 1.5 to 2.0 m above ground in a naturally-aspirated, louvered shield to minimize radiational heating and cooling biases. Fan-aspirated shields can be used to further minimize such biases in air temperature measurements. Proximate buildings, asphalt, concrete, shade, localized water bodies, and low-lying areas can result in microscale bias in temperature observations and should be avoided wherever possible. Therefore, stations should generally be sited at least 30 meters from these and other sources of temperature bias where possible (National Oceanic and Atmospheric Administration 2018). For the purposes of inversion monitoring, we recommend identical air temperature sensors (Environmental Protection Agency 2000) placed at 1.5-2.0 m and 9.0-10.0 m and/or 1.0 and 3.0 m. Care must be taken where wind speed and air temperature are taken at the same height to minimize the interference on wind measurements from the air temperature sensor's shielding.

Precipitation (including rainfall only measurements)

The precipitation gauge catch orifice should be at least 15.4 cm in diameter and located at or below 2.0 m above the ground, except where necessary to avoid being buried by snow, and be within the station's 100 m^2 footprint. Wind shielding should be installed to reduce wind-induced undercatch of precipitation. The gauge should be no closer than four times the height of any obstructions (buildings, trees, shrubs, etc.) within 60 m (National Oceanic and Atmospheric Administration 2018).

Wind (Speed and Direction)

Wind requires a station siting in an open area, since obstructions near wind instruments can dramatically reduce fetch and create bias. General guidance is obstructions should be no closer than 10 times their height relative to the station (World Meteorological Organization 2014a). This guideline should not be viewed as an obstacle to monitoring wind conditions on the mesoscale. Where this guideline cannot be achieved, siting metadata are extremely important and should be well documented. Significant obstructions are defined as objects with at least a 10-degree horizontal aspect. Knowledge of local climatological wind direction should be taken into consideration during site selection to capture more representative wind observations. Wind measurements taken at 10 m above ground are preferred, however, it is recognized that certain applications (e.g., reference evapotranspiration calculations) may necessitate wind measurements at other heights, with 3 m being another common measurement height.

Solar Radiation

Solar radiation sensors should be positioned to avoid shade from sunlight during any time of year. This includes selecting sites, where possible, to minimize the influence of large local obstructions on the horizon that would limit exposure to direct sunlight at sunrise or sunset. Exposure to nearby reflective objects should be avoided where possible, as this may artificially inflate solar radiation measurements. These sensors should be placed on the south side of the station to minimize any obstruction by the instrumentation platform. Guy wires used to anchor a station, as well as the observing platform itself can produce momentary shading during the diurnal march of the sun.

Atmospheric Pressure

Pressure measurements are taken at many mesonet stations. These sensors are typically placed within the station's data logger enclosure vented to the ambient atmosphere. Since most applications require reduction of station pressure measurements to sea level pressure, sensor height is not a concern, but it should be documented.

Soil Moisture and Temperature

Where sampled at only one depth, soil moisture and soil temperature sensors should be installed at a depth of 10 cm. Additional recommended depths are 5, 20, 50, and 100 cm (Schaefer et al., 2007). While soil moisture measurements should be taken under natural cover, soil temperature measurements may be taken under either natural cover or bare soil. If possible, the physical properties of sampled soils should be representative of the most common soils of the area. When installing sensors, care should be taken to make sure soil sensors have good contact with the soil and that the soil profile is minimally disturbed.

2.3 Metadata for Station and Sensor Siting

While following sound guidance when siting stations is important, so too is collecting and maintaining detailed station metadata. The information available from metadata is key to determining the appropriateness of mesonet station data for use in certain applications, including the comparability of station data both within and between mesonets.

Suggested metadata elements and descriptions related to a station's siting are identified in Table 1. While many of these elements are static, others are subject to change. Of particular note, changes in vegetation and in land use/land cover often become evident through time. A detailed description of station surroundings should be updated as needed, it is further recommended that site photos be taken and archived on an annual or more frequent basis. Site metadata elements are typically updated following maintenance visits, as described below in Section 4.

Table 1. Suggested siting and exposure metadata elements for a mesonet station.

Metadata Element	**Description**	**Examples**	**Other Resources**
Station Name	Ideally a city/town name, although it could be the name of a significant landmark. Station name can contain azimuth and range.	Acme, Oklahoma Lake Carl Blackwell, Oklahoma May Ranch, Oklahoma, Britain 8 S	
State and County FIPS Code	State and county the station resides in	07001, 21227	
NWS WFO County Warning Area	National Weather Service forecast office county warning area 3-letter code	PHI, OUN	

Internal Station ID	Internal abbreviation used following a standardized protocol in your network.	ACME CARL MAYR 34-0010-05 XSE2 SGVT2	
NWS Location Identifier	National Weather Service assigned location identifier	ATRS2	
Station Latitude	In decimal degrees with at least 3 decimal precision. Should be positive value for northern hemisphere values. Datum should be WGS84.	34.808330	Typically measured with handheld GPS, but could be calculated from Google Earth or USGS 7.5 minute maps
Station Longitude	In decimal degrees with at least 3 decimal precision. Should be negative for western hemisphere values. Datum should be WGS84.	-98.023250	Typically measured with handheld GPS, but could be calculated from Google Earth or USGS topographic maps
Method for Acquiring Horizontal Datum		Google Earth, USGS Topographic Map, GPS Unit	

Elevation	As precise as possible, in meters. Datum should be WGS84.	397	Could be measured with handheld GPS, derived from topographic USGS maps, or calculated using barometer methods.
Method for Acquiring Elevation Datum	Added information for sea level pressure/altimeter reductions	Handheld GPS, Derived from Topographic USGS 7.5 minute map, calculated using pressure benchmarks and a calibrated barometer	
Parameters Measured	Select from a standard list	Air Temperature, Relative Humidity, Wind, Precipitation, Soil Temperature, Soil Moisture, Pressure, Solar Radiation	Information on heights/depths is detailed in later metadata fields.
Site Host Information	Agency (if applicable), First and Last Name of Host/Contact, Address, Phone Number, Email	John Q. Public, Private Landowner, 123 Weather Way, Smalltown, OK 73081, 555-555-5555	Would be required for the network to have this info, but not required to make it public and/or share with AASC.

Vegetation Type	Dominant vegetation type within within station's 10 x 10 meter footprint.	Mowed bermuda grass amongst agricultural fields, native grasslands, deciduous forest, sparse dryland vegetation	Standardized Categories[1]: 1: Broadleaf – Evergreen (Tropical Forest) 2: Broadleaf – Deciduous Trees 3: Broadleaf and Needleleaf Trees (Mixed Forest) 4: Needleleaf – Evergreen Trees 5: Needleleaf – Deciduous Trees (Larch) 6: Broadleaf Trees with Groundcover (Savanna) 7: Groundcover Only (perennial) 8: Broadleaf Shrubs with Perennial Groundcover 9: Broadleaf Shrubs with Bare Soil 10: Dwarf Trees and Shrubs with

[1] Dorman, J.L., and P.J. Sellers, 1989: A global climatology of albedo, roughness length and stomatal resistance for atmospheric general circulation models as represented by the simple biospheremodel. *J.Appl. Meteor.,* **28,** 833-854.

			Groundcover (Tundra) 11: Bare Soil 12: Cultivations (same parameters as for type 7) 13: Glacial (same parameters as for types 11)
Land Use/ Land Cover	Description of dominant land use/land cover features in mesoscale area near station.	Primarily agricultural, on the boundary of urban area, largely forested, coastal	Standardized categories[2]: 1 Urban or Built-up Land 1.1: Residential 1.2: Commercial and Services 1.3: Industrial 1.4: Transportation, Communications, and Utilities 1.5: Industrial and Commercial Complexes 1.6: Mixed Urban or Built-up Land 1.7: Other Urban or Built-up Land 2 Agricultural Land 2.1: Cropland and Pasture

[2] Anderson, J.R.,E.E.Hardy, J.T.Roach, and R.E.Witmer, 1976: A land use and land cover classification system for use with remote sensor data. *U.S. Geol. Survey Prof. Paper 964*, 28 pp.

			2.2: Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas 2.3: Confined Feeding Operations 2.4: Other Agricultural Land 3 Rangeland 3.1: Herbaceous Rangeland 3.2: Shrub and Brush Rangeland 3.3: Mixed Rangeland 4 Forest Land 4.1: Deciduous Forest Land 4.2: Evergreen Forest Land 4.3: Mixed Forest Land 5 Water 5.1: Streams and Canals 5.2: Lakes 5.3: Reservoirs .54: Bays and Estuaries 6 Wetland 6.1: Forested Wetland 6.2: Nonforested Wetland

			7 Barren Land 7.1: Dry Salt Flats. 7.2: Beaches 7.3: Sandy Areas other than Beaches 7.4: Bare Exposed Rock 7.5: Strip Mines Quarries, and Gravel Pits 7.6: Transitional Areas 7.7: Mixed Barren Land 8 Tundra 8.1: Shrub and Brush Tundra 8.2: Herbaceous Tundra 8.3: Bare Ground Tundra 8.4: Wet Tundra 8.5: Mixed Tundra 9 Perennial Snow or Ice 9.1: Perennial Snowfields 9.2: Glaciers
Description of Station Surroundings (and/or Panoramic Photos in 8 cardinal directions)	Internal Station ID's and dates should be used in panoramic photo filenames and possibly in station data filenames.		

Roughness Classification	Davenport roughness classification[3], ideally in each of four compass directions	N: Open, E: Smooth, S: Roughly Open; W: Rough	Recommend use of table on page 182 in 2014 WMO CIMO No. 8. Standard categories: 1: Sea 2: Smooth 3: Open 4: Roughly Open 5: Rough 6: Very Rough 7: Skimming 8: Chaotic
Air Temperature Measurement Height(s)	in meters	1.5 m and 9 m	
Type of Structure Air Temperature Sensor Installed on		3 m tripod, boom on 10 m tower	
Relative Humidity Measurement Height(s)	in meters	1.5 m	
Type of Structure Relative Humidity Sensor Installed on		3 m tripod, boom on 10 m tower	
Wind Measurement Height(s)	in meters	2 m and 10 m	

[3] Wieringa, J., 1992: Updating the Davenport roughness classification. *J. Wind Enginr. Industr. Aerodynamics,* **41-44,** 357-368

Type of Structure Wind Sensor Installed on		on boom on 10 m tower for 2 m, at top of tower for 10 m	
Rain Gauge Measurement Height(s)		0.6 m	
Type of Structure Rain Gauge Sensor Installed on		Baseplate secured with rebar	
Non-ambient Signal Sources	Things that could influence the temperature or relative humidity readings	Buildings or roads nearby that could generate/advect heat, Nearby irrigation that advect moisture	
Soil Texture Characteristics	Could be from soil map or from unique soil sample analysis	10 cm: 73% sand, 20% silt, 7% clay 25 cm: 60% sand, 24% silt, 16% clay or 10 cm: Sandy loam 25 cm: Sandy clay loam	Recommended soil texture analysis be conducted through State Soil Scientist with NRCS.
Underground Infrastructure	Things that could influence soil sensor readings within station sensing footprint	Area has drainage tile installed; subsurface drip irrigation pipes located approximately 5 meters away at 18 cm depth	

3. Sensor Performance, Sampling Rate, and Reporting Rate

The process of selecting sensors for deployment by a mesonet is inherently driven by considerations of performance and cost. Performance encompasses the operational range and accuracy of sensors for measuring specific meteorological variables, as well as their reliability when exposed to the vagaries of the operational environment for extended periods of deployment. Cost includes both the initial acquisition costs and the expected maintenance costs prorated over the expected lifetime of the sensors.

This section makes recommendations regarding the selection of sensors based primarily on operational range and accuracy, recognizing that the role of cost considerations is unique to individual mesonets. Recommendations reflect an effort to synthesize perspectives of WMO-No.8, the Guide to Meteorological Instruments and Methods of Observation (World Meteorological Organization, 2014a); the mission of state mesonets' as long-term environmental monitoring networks (Brock et al., 1995); and the current state of sensor technologies commonly used by mesonets throughout the United States. Besides sensor performance, this section also provides recommendations on sensor sampling and reporting rates. Finally, recommendations are included for documentation of sensor metadata.

3.1 Sensors

Recommendations for sensors are provided for meteorological variables that are commonly measured by mesonets. Where appropriate, additional context is provided that might help to inform decision making when selecting sensors.

Air Temperature

Due to its stability, response rate, and precision, the platinum resistance thermometer (PRT) is the most commonly used instrument for primary temperature measurement in mesonets. Current air temperature sensing technology typically provides +/- 1.0 °C accuracy across the range -50 to -30 °C, +/- 0.5 °C across the range -30 to 50 °C, and +/- 1.0 °C across the range 50 to 60 °C. However, it is recognized that current air temperature sensing technology lags the full range of air temperatures observed across the continental United States, thus the sensing range of air temperature sensors should eventually be extended to -65 °C, which would be consistent with other notable air temperature sensor standards (i.e., NWS Cooperative Observer Program). Where air temperature measurements are necessary at two heights for purposes of inversion monitoring, the relative accuracy of the temperature sensors, not just absolute accuracy, is also a specification of importance. Thus, the temperature sensors in this scenario should be identical in make and model, be installed in the same type of shielding, and have *matched* performance between the sensors of +/- 0.1 °C.

Relative Humidity

Capacitive hygrometers are the predominant sensors used for automated measurement of air relative humidity, and are the preferred choice for mesoscale monitoring due to their ease of maintenance and calibration (World Meteorological Organization 2014a). Although manufacturer specifications may indicate high accuracy, it is often accepted that accuracy of relative humidity sensors should be +/- 3% RH across the operating range of 10 to 90% and +/- 5% RH% outside this range.

Wind Speed

Types of wind sensors commonly used at mesonet stations include an anemometer and vane set, combined anemometer and vane (i.e., propeller-based wind sensors), and ultrasonic wind sensors. Each of these types is acceptable. Wind speed accuracy of the anemometer should be +/- 0.5 m s^{-1} below 5 m s^{-1} and better than 10% above 5 m s^{-1} (World Meteorological Organization, 2014a), with a measurement range of 0-50 m s^{-1} and a measurement threshold of 1.0 m s^{-1}. For wind direction, accuracy should be +/- 5 degrees (World Meteorological Organization, 2014a), with a range of 0 to 359 degrees (maximum of 5 degrees deadband), and a measurement threshold of 1.0 m s^{-1}.

Precipitation

Precipitation can be measured using either a tipping bucket or weighing bucket rain gauge. An unheated tipping bucket rain gauge has been the mainstay of mesonets for decades. However, weighing rain gauges, using load cells or a vibrating wire's frequency, are commonly used in high-quality networks (e.g., U.S. Climate Reference Network).

Many mesonets operate in environments where frozen precipitation is common. Weighing rain gauges are winterized using antifreeze to allow for precipitation measurements of frozen precipitation. Tipping bucket gauges are typically unheated, as heating the gauge can lead to evaporative loss of melting snow, thus introducing bias in precipitation measurements (World Meteorological Organization, 2014a). While weighing rain gauges are generally preferred to unheated tipping bucket rain gauges where frozen precipitation is an important consideration, it is recognized that weighing gauges are significantly more expensive. Thus, many networks have employed unheated tipping bucket rain gauges in areas frequently affected by frozen precipitation due to cost considerations. Care must then be taken when using precipitation data from unheated rain gauges during frozen precipitation events.

Two of the most important factors associated with a rain gauge's accuracy are ambient wind speed effects and precipitation intensity. Wind speed effects on rain gauge measurements can be improved by decreasing the height of the rain gauge and/or by installing wind screens (Alter, 1937) around the rain gauge.

Heavy precipitation events can also be a cause of bias in precipitation measurements made by a tipping bucket gauge. Because it takes up to one-half second for the bucket to rotate about its pivot point, undercatch will exceed 5% when rain rates exceed 100 mm h^{-1} (Duchon et al., 2014).

Tipping bucket rain gauges or weighing rain gauges are recommended for mesonets. The use of wind shields is optional but recommended. The orifice diameter should be at least 15.4 cm. Accuracy of any rain gauge should be at least +/- 5% at rainfall rates up to 50 mm h^{-1}.

Barometric Pressure

Silicon capacitive barometers are the typical sensor for measuring barometric pressure in mesoscale networks. These sensors have the advantage of being low-powered and relatively stable over time. Accuracy of these sensors is +/- 2 hPa, where air temperature is -40 to 60 °C. The range of a barometer should be 700 to 1100 hPa, but could also require a lower minimum threshold if a station is located at high altitude.

Solar Radiation

Both thermopile-based and silicon photovoltaic sensors are used by mesonets to measure solar radiation. The most reliable and accurate options are thermopile-based pyranometers because of their spectrum performance and stability, particularly under cloudy conditions. Despite this, silicon photovoltaic sensors for solar radiation have widely been used in mesonets due to their small size, relatively low cost, and ease of maintenance. Heated pyranometers reduce error during frozen precipitation and condensation events. For mesonets, operating either type of solar radiation sensor is recommended. Absolute accuracy of solar radiation sensors should be +/- 5% for daily totals with a range of 0 to 1500 W m^{-2} (American Society of Agricultural and Biological Engineers, 2015).

Soil Temperature

Soil temperature is typically measured using a thermistor designed for direct burial, often designed in combination with a soil moisture sensor. Accuracy of the sensor should be +/- 0.5 °C with a range of -10 to 60 °C (-40 to 60 °C for cold climates). While recognizing these specifications, proper installation and maintenance of sensors is of particularly importance, as soil erosion, soil cracking, and improper installation often lead to errors far greater than sensor accuracy.

Soil Moisture

The two most common soil moisture parameters observed by mesonets are volumetric water and matric potential. While volumetric water relates to the absolute fraction of water in the soil, matric potential relates to the pressure required for plants to draw water from the soil.

Volumetric water content (VWC) can be measured using various methods (e.g. coaxial impedance dielectric reflectometry (CIDR), time-domain reflectometry (TDR), and frequency domain reflectometry (FDR)). Accuracy of a VWC sensor should be +/- 0.03 $m^3\ m^{-3}$, and it should be capable of capturing the full range of soil water content values for a location's representative soils and a sensing volume diameter < 5 cm.

Proper installation of soil moisture sensors is important. Like soil temperature, soil erosion, soil cracking, and improper installation often lead to errors far larger than sensor accuracy. When measuring volumetric water content, soil properties are key metadata in assessing drought and plant available water. For instance, a volumetric water content of 0.2 indicates wet conditions in sandy soils while it indicating dry conditions for clay soils.

Snow Depth

Snow depth can be measured by laser, sonic, or photographic sensors. Each of these is acceptable. For laser distance sensors, the typical accuracy is +/- 1 mm, while sonic depth sensors are +/- 1 cm. Photographic sensing, which uses cameras to take images of snow relative to markers of known height and distance from the camera device, are typically less accurate (+/- 2.54 to 5.08 cm). Due to uneven accumulation associating with drifting, it is difficult to obtain automated measurements that are both accurate and representative. Recognizing this, a sensor with accuracy within +/- 2.54 cm (1 inch) is recommended.

3.2 Sampling and Reporting Rates

Observations of variables are based upon sampled values. In general, a 3-second sampling rate for sensor measurements and 5-minute reporting rate for processed observations are recommended. The 3-second sampling rate is particularly important for measure extreme wind gusts. For slowly changing variables, such as barometric pressure and soil moisture, or for sensors with high power demands, less frequent sampling and reporting are adequate. For example, many common digital barometers employ a 12-second sampling rate, while soil moisture observations are typically instantaneous.

Table 2 summarizes much of the performance information discussed for each variable in this section. It includes operating ranges, accuracy, reported resolution, sampling rate, and reporting rate. Preferred sensor types for each variable are also included. The 'accuracy' terminology used in this section is an expression of uncertainty, although it is a concept somewhat open to varying interpretations. The accuracies listed are expressed in terms of uncertainty by an error propagation analysis (Lin and Hubbard, 2004; Taylor and Kuyatt, 1994). Please note that external factors can cause field accuracy to be worse than sensor accuracy provided in a sensor manufacturer's specifications. Finally, it is assumed that all sensors must operate in the following environmental conditions in order to reliably perform in a mesonet:

- Temperatures from -40 to 60 °C (ideally -60 to 60 °C for cold climates)*0
- Relative humidity between 0 and 100%, non-condensing
- Barometric pressure between 700 and 1100 hPa
- Wind gusts up to 50 m s^{-1}.

Table 2. Recommended sensor's specifications and sampling and reporting rates.

Variables	**Ranges**	**Accuracy (for entire range)**	**Reported Resolutions**	**Sampling rate**	**Reporting rate**	**Common Sensor Types**
Air temperature	-40 - +60 °C*0	±0.5 ˚C*1	0.1 ˚C	3 s	5 min	PRT or thermistor
Relative humidity	10-90%*2	±3% RH	0.1%	3 s	5 min	Thin-Film Capacitive Hygrometers
Solar Radiation	0-1500 W m^{-2}	±5%*3	0.1 W m^{-2}	3 s	5 min	Thermopile or silicon photovoltaic
Rainfall*4	0-50 mm hr^{-1}	+/-5% up to 50 mm hr^{-1}	0.254 mm	instantaneous	5 min	unheated tipping bucket
Precipitation	0-50 mm hr^{-1}	±1% up to 50 mm hr^{-1}	0.254 mm	6 s to 300 s	5 min	Load Cell, Vibrating wire
Wind speed	0-50 m s^{-1}	±0.3 m s^{-1} < 20 m s^{-1}; 1% otherwise	0.1 m s^{-1}	3 s	5 min*5	Cup, propeller, ultrasonic
Wind direction	0-360˚	±5°	1°	3 s	5 min	Potentiometer or ultrasonic
Soil temperature	-40 - +50 ˚C	±0.5 ˚C	0.1 ˚C	3 to 1800 s	5 to 30 min	PRT or Thermistor
Soil Volumetric Water Content	0.0-0.5 m^3 m^{-3}	±3%	0.1%	3 to 1800 s*6	5 to 30 min	CDIR, TDR or FDR
Atmospheric pressure	700 – 1,100 hPa	±2 hPa*9	0.01 hPa	3 s to 300 s	5 min	Capacitor

Snow Depth	0.0 -	±2.54 - 5.08 cm	0.1 mm	3 s to 300 s	5 min	Sonic, Laser, Photographic

Notes:
*0: -60 to +60 °C for cold climates
*1: this accuracy doesn't include any air temperature radiation shield's effects (Tanner 1990).
*2: sampled air relative humidity can be larger than 100% (supersaturated) thus data logger's coding should set a range of 0-110%.
*3: for daily totals
*4: only for liquid precipitation. Need only perform down to 0 °C.
*5: 1800s sampling rate could significantly save sensor's power consumption without a loss of data integrity if with cautions of data logger's programing for efficient power management.
*6: without including barometric head's shield effects.

3.3 Metadata for Sensors

Metadata about the sensors used in a mesonet is important for users to properly interpret observational data. For stations with multiple sensors measuring the same parameter at different heights or depths, separate metadata entries are recommended for each sensor that is deployed. Table 3 contains suggested metadata elements and descriptions related to a network's sensors.

Table 3. Suggested metadata elements related to sensors.

Metadata Element	Description	Examples	Other Resources
Air Temperature Sensor Model	Model name	RM Young 41342, Thermometrics Air Temperature Sensor, Vaisala HMP45	
Air Temperature Sensor Installation Date	Date installed	2018-04-01, Spring 2018	
Air Temperature Sensor Shielding	Housing in which sensor is placed	Naturally ventilated radiation shield, aspirated radiation shield	
Air Temperature Data Averaging/Processing Procedure	Procedure used to calculate the reported average	3-second samples averaged into 5-minute observations	

Relative Humidity Sensor Model	Model name	Vaisala HMP155, Vaisala HMP45	
Relative Humidity Sensor Installation Date	Date installed	2018-04-01, Spring 2018	
Relative Humidity Sensor Shielding	Housing in which sensor is placed	Naturally ventilated radiation shield, aspirated radiation shield, Unshielded	
Relative Humidity Data Averaging/Processing Procedure	Procedure used to calculate the reported average	3 second samples averaged into 5 minute observations	
Solar Radiation Model	Model name	Li-Cor LI200S	
Solar Radiation Sensor Installation Date	Date installed	2018-04-01, Spring 2018	
Solar Radiation Data Averaging/Processing Procedure	Procedure used to calculate the reported average	3-second samples averaged into 5-minute observations	
Wind Sensor Model	Model name	RM Young 5103 (10 m), RM Young 03001 (2 m)	
Wind Sensor Installation Date	Date installed	2018-04-01, Spring 2018	
Wind Data Averaging/Processing Procedure	Procedure used to calculate the reported average	3-second samples averaged into 5-minute observations for wind speed and direction. Greatest 3-second sample is gust.	Include for wind speed, wind direction, and wind gust
Precipitation Gauge Model	Model name	MetOne 380C/5645 rain gauge, TE525US	

Precipitation Gauge Installation Date	Date installed	2018-04-01, Spring 2018	
Precipitation Gauge Shielding	Wind shield surrounding gauge (if applicable)	121 cm diameter alter shield	
Soil Temperature Model	Model name	Campbell Scientific 229L	
Soil Temperature Installation Date	Date installed	2018-04-01	
Soil Temperature Averaging/Processing Procedure	Procedure used to calculate the reported average	30-second samples averaged into 15-minute observations	
Soil Moisture Model	Model name	Campbell Scientific 229L, Stevens HydraProbe	
Soil Moisture Installation Date	Date installed	2018-04-01	
Soil Moisture Averaging/Processing Procedure	Procedure used to calculate the reported value	Instantaneous observations taken every 30 minutes, 30-second samples averaged into 15-minute observations	
Pressure Sensor Model	Model name	Vaisala PTB110, Vaisala PTB220	
Pressure Sensor Installation Date	Date installed	2018-04-01, Spring 2018	
Pressure Sensor Averaging/Processing Procedure	Procedure used to calculate the reported average	12-second samples averaged into 5-minute observation	

Snow Depth Sensor Model	Model name	SR50A	
Snow Depth Sensor Installation Date	Date Installed	2018-11-15, Fall 2018	
Snow Depth Sensor Averaging/Processing Procedure	Procedure used to calculate the reported average	1-minute samples averages into 5-minute observation	

4. Maintenance

The integrity of a mesonet is fundamentally linked to its commitment to the maintenance of its monitoring stations. Maintenance includes preventative maintenance of sensors, unscheduled maintenance as indicated by quality assurance and quality control triggers, and general site maintenance. Mesonets should document and be transparent regarding their station maintenance practices. This section provides recommendations regarding the development, implementation, and documentation of maintenance activities.

4.1 Types of Maintenance

Maintenance procedures should be developed, be well documented as protocols, and be systematically implemented.

Preventative Maintenance

Regularly scheduled visits to perform preventative maintenance can greatly improve station reliability and data quality (Fiebrich et al., 2005). Tasks to be completed include management of vegetation, sensor rotations, sensor leveling and cleaning, servicing fluids in precipitation gauges, field functionality tests, in-field calibrations, documenting the station with digital photographs, and hardware inspections. Sensors due for calibration should be replaced if they cannot be calibrated in the field. This is also an efficient time to perform in-field calibrations involving comparisons with traveling standards and metadata audits. Tolerances for each instrument should be defined to determine whether it is in compliance. Note that not all sensors (e.g., soil moisture and soil temperature sensors) can be audited or recalibrated due to problems accessing the sensors.

Unscheduled Maintenance

Unscheduled station maintenance visits are made when indicated by quality assurance protocols that recognize data deterioration or loss. Given demands and requirements for mission-critical applications, it is recommended that mesoscale networks establish priorities and associated deadlines for restoring sensors or stations to normal functional status.

General Maintenance

Photo-documentation of “as found” and “as left” site conditions are useful for recording maintenance history. Careful notation of makes, models and serial numbers of installed and removed equipment, sensor audit information, and all other work performed at the site during the visit should be documented as metadata to ensure data and network integrity. Each station in a network should be visited at least once a year by a technician trained by the mesonet to ensure all aspects of the station are fully functional and that all annual metadata elements are recorded properly. Vegetation maintenance and specific sensor requirements may require much more frequent visits throughout the year.

4.2 Metadata for Station Maintenance

Documentation of metadata regarding station maintenance is critical to ensure continuity and completeness of a mesonet’s data record. If well documented, station maintenance metadata enables a mesonet at any point to reconstruct the circumstances and conditions that bear upon the time series of meteorological observations collected at a given station.

Two types of metadata should be collected. Table 4 provides a suggested structure for documenting general maintenance practices, including elements to describe the types of maintenance performed during site visits and the frequencies with which station maintenance is performed.

Table 4. Suggested metadata elements for station maintenance.

Metadata Element	Description	Examples	Other Resources
General Maintenance Procedures	Description of general maintenance procedures performed on stations during regular visits	Sensor bearing replacements, trimming grass, leveling and cleaning of sensors	
General Maintenance Frequency	Frequency (in months) of how often	12 months, 3 months	

	a network's stations are visited for general maintenance		

Mesonets should also keep detailed records of all station maintenance visits. Table 5 identifies suggested metadata elements that should be documented for each station maintenance visit.

Table 5. Suggested metadata elements for sensor maintenance.

Metadata Element	Description	Examples	Other Resources
Date of Maintenance	date that maintenance occurred	2019-04-05	
Description of Work	description of work that occurred	area mowed; bare soil plot sprayed; field buddy check for soil temperature sensors	
Staff	staff member(s) who performed work	J. Doe	Would be required for the network to have this info, but not required to make it public and/or share with AASC.

5. Quality Assurance and Quality Control

Quality assurance (QA) of mesonet data typically encompass the broad efforts of a mesonet to ensure quality data (e.g., proper station siting, station maintenance, sensor calibrations, and automated and manual methods for evaluating the resultant observations). Many of those aspects have been covered in the preceding sections; thus, this section focuses on the automated and manual data evaluations. Generally, a mesonet's quality control (QC) system will consist of software algorithms that assess the accuracy and representativeness of observed sensor data through real-time and periodic tests in order to detect sensor problems or failures.

Since not all data can be perfectly assessed using automated software algorithms, manual assessment through quality assurance procedures is required and should be performed by trained mesonet professionals.

This section describes best practices followed by recommendations. Suggestions for documenting metadata associated with QC and sensor calibrations are also provided. The discussion is targeted at a general level, recognizing that specific implementation of methods may vary based on the environmental context of individual mesonets.

5.1 Best Practices

Automated quality control is broadly comprised of five categories: 1) physical limits (i.e., range) tests, 2) seasonal range tests, 3) sensor intercomparison tests, 4) temporal consistency tests, and 5) spatial coherency tests. A summary of quality assurance procedures used commonly across the United States for mesoscale meteorological data is detailed in Fiebrich et al. (2010).

Physical limits tests are usually based on the operating ranges of the specific sensors operating on a mesonet station, but can also be based on a reasonable expectation of climate extremes in a mesonet's area. For instance, if a sensor cannot measure air temperatures above 80 °C, then screening data for values above this threshold would be necessary, as sensor values above this threshold would be unreliable.

Seasonal range tests are based on extremes in the climatological archive and meant to reduce the likelihood that physically possible, but highly unusual sensor values are accepted without further review. It is common for some overlap to exist in the ranges and thresholds of physical limits tests and seasonal range tests.

Sensor intercomparison tests compare data values between redundant sensors (e.g., two co-located rain gauges) or between different kinds of sensors mounted on the same station platform. These tests can be extremely helpful in identifying sensors that are erroneously responding to certain environmental conditions (e.g., an observation of extremely low relative humidity values coincident with significant rainfall).

Temporal consistency tests set expectations for how much a sensor's values should change over a set duration of time. These are also sometimes referred to as "delta", "step", or "persistence" tests. Like most automated QC tests, these tests may be regionally specific, as the expected rates of change in some environmental parameters differ significantly depending on the general climate of an area or location. Large, dramatic changes in sensor data can indicate a problem, such as a sensor failure. Likewise, data that doesn't change enough (e.g., wind observations stuck at 0 for more than a day) can be flagged for manual review by QA staff.

Finally, spatial coherency tests assess the similarity of a station's sensor data to that of surrounding stations. When properly implemented, spatial coherency tests are very useful for identifying sensors that are possibly out of calibration or are experiencing some kind of operation issue, such as a clogged rain gauge. However, it is critical to consider the degree of similarity in the mesoscale climate between proximate stations, as stations that differ in their mesoscale site exposure can reflect distinctly different climatic influences. Hence, site metadata should be used when selecting stations for comparison in order to minimize the flagging of data as suspect or bad when the sensor values are valid.

The aforementioned general categories of automated QC address the vast majority of sensor data problems. However, as noted above, location- and region-specific quality control tests can help to address influences of unique microclimate features, such as terrain/elevation differences, proximity to water bodies, as well as urban areas and irrigated agriculture. Thus, automated QC procedures can be applied universally for all stations in a mesonet or they can be excluded for some stations because of unique or unusual microclimate features. Ultimately, each mesonet's automated QC system will require some nuance that prevents all mesonet QC systems from looking identical, and this is to be expected. However, as a best practice, mesonets should develop and appropriately employ QC in each of the five previously mentioned automated categories.

In conjunction with a range of quality control tests, mesonets are strongly encouraged to adopt a flagging structure to indicate varying levels of confidence in the quality of each observation (e.g., good, good despite failing automated QC, suspicious, bad, and bad despite passing automated QC). Other flags may be necessary for some mesonets, such as flagging data as suspect when maintenance is being performed on a station, but these five flags generally provide the necessary information to the data user to describe the fitness of the data for use in their work and allows for a more universal understanding of data quality across all mesonets. In addition, automated QC tests can generate good, suspect, and bad flag results, but all suspect data values should be reviewed by trained mesonet QA staff, preferably with meteorological training and experience, within a reasonable time frame to ensure the timeliness and continuity of a mesonet's data quality. The flags "good despite failing automated QC" and "bad despite passing automated QC" provide a flag value that communicates to the data user that a suspect data value has been reviewed by a QA staff member. For each manually reviewed data value, comments explaining the reason for changing the flag value of the data should be recorded with the flag value. This provides data users with additional, corroborating information to determine the fitness of the data for their needs. Still, the majority of data users will simply want the network to provide them only the good data while screening out (or indicating "unavailable") for any observations that are deemed erroneous.

Mesonet Quality Control Recommendation

Recognizing that quality assurance and quality control (QAQC) procedures should adapt to the unique aspects of regional and mesoscale climates and to the operational needs of mesonets, the following recommendations provide general guidance for development and implementation of mesonet QAQC systems. Specifically, systems should incorporate the ability to automatically perform quality control tests on mesonet station data and flag erroneous data due to suspected sensor problems, a quality assurance process for manually reviewing mesonet data whose quality cannot be adequately determined using automated quality control testing, a well-defined flagging structure that clearly communicates the quality of mesonet data, and documentation of the mesonet's automated quality control and manual quality assurance procedures.

5.2 Metadata for Network Quality Assurance/Quality Control Procedures

Detailed metadata should be documented regarding a mesonet's QAQC procedures. Table 6 contains metadata items that describe a network's quality assurance methods. While very general, these items communicate how to interpret the quality of a network's data to its data users.

Table 6. Suggested metadata elements for quality assurance and quality control of data.

Metadata Element	Description	Examples	Other Resources
QAQC Procedures Description	Lists and describes a network's general QAQC procedures	Physical limits tests are performed on all data parameters for all stations. Data flagged by these tests are automatically considered erroneous and flagged as such.	
QAQC Flags Description	List of QAQC Flags and meaning of each flag	0: Good 1: Bad 2: Suspect ...	

5.3 Metadata for Sensor Calibration Procedures

Network operators should strive to provide basic metadata about the calibration of their network's sensors. Table 7 provides some suggested metadata items describing a network's calibration practices. It is expected that calibration metadata will be needed for each type of sensor in a network, as different sensors may have different procedures and/or calibration frequencies. In addition, it is recommended that networks maintain internal metadata of the results of sensor calibrations, including in-field calibration tests.

Table 7. Suggested metadata elements for sensor calibration procedures.

Metadata Element	Description	Examples	Other Resources
Calibration Procedures Description	A description of how a network calibrates its sensors, whether internally or externally	Return T/RH sensor to manufacturer for recalibration	
Sensor Calibration Frequencies	The frequency (in months) of how often a network calibrates a sensor type	24 months, 36 months, Never	

6. Data Processing and Reliability Recommendations

Mesonets supply a wide variety of detailed environmental data and information for making more informed weather- and climate-related decisions. To be effective in application, such information should be credible, available/timely, dependable/reliable, useable, useful, expandable, sustainable, responsive/flexible, and authentic (World Meteorological Organization, 2014b). Thus, it is important that networks follow consistent methods for handling missing data, aggregating observations to create summary variables for hourly, daily, and longer timeframes, and ensuring that data are offered in a reliable fashion.

Operational Data Reliability

Usage of weather and climate information can be generally classified into two broad categories. The first is strategic, which includes products that aid in the general long-term planning and design of projects and policies. The second is tactical, which includes products and data that aid in solving short-term, specific, immediate problems (World Meteorological

Organization, 2018). As such, data reliability and completeness are key attributes for any mesonet. Data completeness also encompasses ensuring that the appropriate number of samples are available in computing the reported five-minute observations. Operators should be mindful to ensure that appropriate samples are available, and ideally, all samples should be available when calculating the official observations (particularly with respect to variables where dynamic or cumulative values are of concern).

One such application that requires the delivery of reliable, high quality mesonet data is NOAA's National Mesonet Program (NMP), which integrates non-federal weather data with weather data from federal networks to create more comprehensive, improved operational weather and climate products. The NMP requires a monthly operational network data availability and completeness value of 95% or higher. It is recommended that mesonets strive to meet or exceed an operational reliability threshold of 95% or higher data completeness for any 60-minute period, for all stations in the network in order to consistently meet data user and application needs.

Aggregating Mesonet Data into Hourly, Daily, and Longer Statistics

Consistency in computing hourly, daily, or longer-term statistics from core, five-minute mesonet observations is crucial to ensuring data remain useful for climate monitoring and other data applications where subtle differences in methodology can result in significant differences in trends and results. Data aggregation methodology and data completeness thresholds are important to deriving consistent longer time-step data. Incomplete data (i.e., missing observations) can be introduced by a sensor, datalogger, telemetry, or other system malfunction or failure. Subsequent problems associated with missing observations range from an incomplete data archive to erroneous application of the data. It is important to note that missing observations are more critical for some environmental variables than for others. This is especially true for extremes or precipitation totals. The limits on the permissible number of missing observations in a given application vary greatly depending on the application and the amount of error a user is willing to accept (Anderson and Gough, 2018). However, to remain consistent with other sub-hourly monitoring networks[4], it is recommended that mesonets use the 75% completeness minimum threshold for calculating data at the hourly or smaller timestep for all non-cumulative parameters (e.g., precipitation). Alternatively, mesonets may provide the percentage of missing observations during the reported time period to its data users.

Calculation of hourly, daily, and monthly values should only be derived from a mesonet's core, five-minute observations (or longer observation time in some cases, such as soil temperature and soil moisture measurements). It is recommended that mesonets follow the convention utilized by NOAA NCEI to derive monthly values. This convention states that a monthly mean value should not be calculated if there are more than five days or more than three

[4] The NWS ASOS network requires 75% of 1 minute observations to derive hourly values (National Oceanic and Atmospheric Administration 1998).

consecutive days of missing values. Adapting this method to a network's typical five-minute data, daily mean values should be derived only if no more than four hours of five-minute data are missing and no more than three consecutive hours of five-minute data are missing. In the case of elements for which the monthly value is a sum of daily values (e.g. precipitation), NCEI provides monthly totals along with the number of missing daily values, and notes if there are any multi-day totals included in the monthly total (Matt Menne, personal communication). It is recommended that mesonets follow this standard at a minimum and provide the number of missing values and note totals derived from multi-timestep values when providing daily or monthly totals.

7. Final Remarks

Mesonets have developed and evolved independently, each within a unique context and operational history. This document provides guidance that is reflective of the current operational diversity of mesonets, as reflected by mesonets affiliated with the AASC and other similar mesonets. Recognizing the diversity of contexts in which mesonets operate and the diversity of practices implemented by mesonets, the AASC Mesonet Committee chose to position this document to provide broad recommendations and an overview of best practices for mesonets, instead of narrowly defined standards and requirements. The Committee envisions that as mesonets evolve and achieve greater commonality in operational practices, there will be a subsequent need to revise this document to provide more detailed guidance. In the meantime, the Committee will continue to collect and evaluate information regarding current and evolving operational practices of mesonets.

The Committee strongly believes that strategic commitments and subsequent investments leading toward greater commonality will create synergies that will help to advance the development and delivery of weather and climate services at the local, state, regional, and national levels. Toward this end, we encourage not only existing mesonets, but also the many partners of the AASC to commit to the ongoing advancement of mesonets in recognition of their key role in the future of weather and climate services.

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