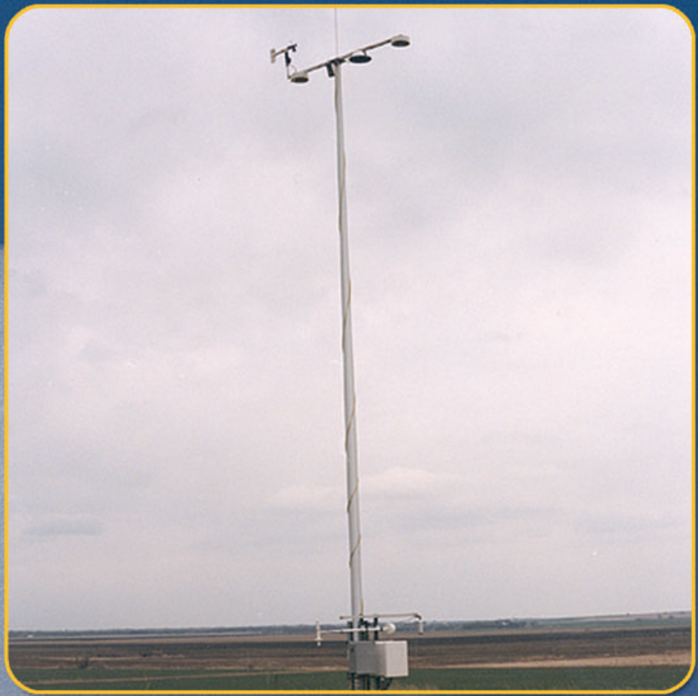
ARM TR-031

Surface Meteorological Observation System Handbook



January 2005

Atmospheric Radiation Measurement Climate Research Facility
U.S. Department of Energy

Work supported by the U.S. Department of Energy
Office of Science, Office of Biological and Environmental Research

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Surface Meteorological Observation System (SMOS) Handbook

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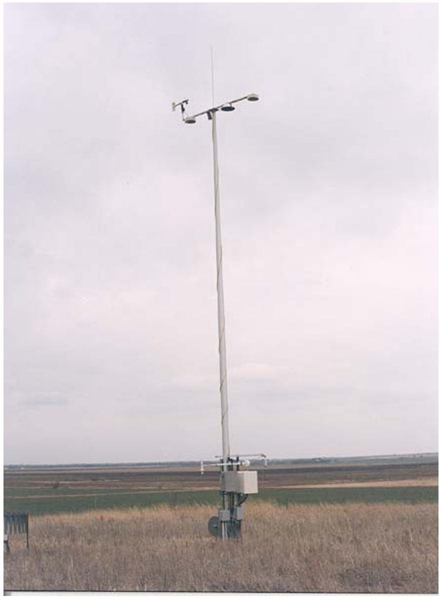
1. General Overview

The Surface Meteorological Observation System (SMOS) mostly uses conventional in situ sensors to obtain 1-minute, 30-minute, and 1440-minute (daily) averages of surface wind speed, wind direction, air temperature, relative humidity (RH), barometric pressure, and precipitation at the Central Facility and many of the extended facilities of the Southern Great Plains (SGP) climate research site. The SMOSs are not calibrated as systems. The sensors and the data logger (which includes the analog-to-digital converter, or A/D) are calibrated separately. All systems are installed using components that have a current calibration. SMOSs have not been installed at extended facilities located within about 10 km of existing surface meteorological stations, such as those of the Oklahoma Mesonet.

The Surface Meteorological Observation Systems are used to create climatology for each particular location, and to verify the output of numerical weather forecast and other model output. They are also used to "ground-truth" other remote sensing equipment.



2. Contacts

2.1 Mentor

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2.2 Instrument Developer

Data logger and Temperature/Relative Humidity (T/RH) Probe
Campbell Scientific, Inc.
815 W. 1800 N.
Logan, UT 84321
Phone: 801-753-2342
Fax: 801-750-9540
Web: http://www.campbellsci.com

Aspiration Radiation Shields and Wind Speed/Direction Sensors
R.M. Young Company
2801 Aero Park Drive
Traverse City, MI 49686
Phone: 231-946-3980
Fax: 231-946-4772
Web: http://www.youngusa.com/

Barometer
Vaisala
100 Commerce Way
Woburn, MA 01801-1068
Phone: 617-933-4500
Fax: 617-933-8029
Web: http://www.vaisala.com

Precipitation Gauge
NovaLynx Corporation
P.O. Box 240
Grass Valley, CA 95945-0240
Phone: 530-823-7185
USA Toll Free: 1-800-321-3577
Fax: 530-823-8997
Web: http://www.novalynx.com

3. Deployment Locations and History

Fully operational SMOSs are installed at the following locations: (SGP Overview Map)

Table 1.

Location	Date Installed	Date Removed	Status
E1-Larned, KS	1995/08/29		operational
E3-LeRoy, KS	1995/12/12		operational

Table 1. (cont'd)

Location	Date Installed	Date Removed	Status
E4-Plevna, KS	1995/03/28		operational
E5-Halstead, KS	1996/05/30		operational
E6-Towanda, KS	1995/12/14		operational
E7-Elk Falls, KS	1995/03/09		operational
E8-Coldwater, KS	1993/03/30		operational
E9-Ashton, KS	1993/03/31		operational
E11-Byron, OK	1995/06/23		operational
E13 (CF)-Lamont, OK	1993/03/29		operational
E15-Ringwood, OK	1993/04/01		operational
E20-Meeker,OK	1993/04/02		operational
E21-Okmulgee,OK	1999/07/27		operational
E24-Cyril, OK	1995/08/23		operational
E25-Seminole, OK	1996/12/13	2002/04/08	
E27-Earlsboro, OK	2003/05/02		operational

4. Near-Real-Time Data Plots

Near-real-time data plots can be found at the following locations:

- http://www.nsdl.arm.gov/Visualization/quicklook_interface.shtml
- http://www.nsdl.arm.gov/Visualization/ncvweb.shtml.

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

Table 2.

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
Wind Speed	wspd	m/s	10m	1 & 30 min	0.01
Vector Average Wind Speed	wspd_va	m/s	10m	1 & 30 min	0.01
Wind Direction	wdir	deg	10m	1 & 30 min	0.1
Standard Deviation of Wind Direction	sd_deg	deg	10m	1 & 30 min	0.1
Temperature	temp	C	2m	1 & 30 min	0.01

Table 2. (cont'd)

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
RH	rh	%	2m	1 & 30 min	0.1
Vapor Pressure	vap_pres	kPa	2m	1 & 30 min	0.001
Barometric Pressure	bar_pres	kPa	1m	1 & 30 min	0.1
Snow Depth	snow	mm	sfc	30 min	0.1
Precipitation Total	precip	mm	sfc	1 & 30 min	0.001
Maximum Wind Speed	max_wspd	m/s	10m	1440 min	0.01
Time of Maximum Wind Speed	time_max_wspd	HHMM	10m	1440 min	N/A
Minimum Wind Speed	min_wspd	m/s	10m	1440 min	0.01
Time of Minimum Wind Speed	time_min_wspd	HHMM	10m	1440 min	N/A
Maximum Temperature	max_temp	C	2m	1440 min	0.01
Time of Maximum Temperature	time_max_temp	HHMM	2m	1440 min	N/A
Minimum Temperature	min_temp	C	2m	1440 min	0.01
Time of Minimum Temperature	time_min_temp	HHMM	2m	1440 min	N/A
Maximum RH	max_rh	%	2m	1440 min	0.1
Time of Maximum RH	time_max_rh	HHMM	2m	1440 min	N/A
Minimum RH	min_rh	%	2m	1440 min	0.1
Time of Minimum RH	time_min_rh	HHMM	2m	1440 min	N/A
Maximum Vapor Pressure	max_vap_pres	kPa	2m	1440 min	0.001
Time of Maximum Vapor Pressure	time_max_vap_pres	HHMM	2m	1440 min	N/A
Minimum Vapor Pressure	min_vap_pres	kPa	2m	1440 min	0.001
Time of Minimum Vapor Pressure	time_min_vap_pres	HHMM	2m	1440 min	N/A
Maximum Barometric Pressure	max_bar_pres	kPa	1m	1440 min	0.01
Time of Maximum Barometric Pressure	time_max_bar_pres	HHMM	1m	1440 min	N/A
Minimum Barometric Pressure	min_bar_pres	kPa	1m	1440 min	0.01

Table 2. (cont'd)

Quantity	Variable	Unit	Measurement Level	Measurement Interval	Resolution
Time of Minimum Barometric Pressure	time_min_bar_pres	HHMM	1m	1440 min	N/A
Maximum Snow Depth	max_snow	mm	sfc	1440 min	0.1
Time of Maximum Snow Depth	time_max_snow	HHMM	sfc	1440 min	N/A
Minimum Snow Depth	min_snow	mm	sfc	1440 min	0.1
Time of Minimum Snow Depth	time_min_snow	HHMM	sfc	1440 min	N/A

5.1.1.1 Definition of Uncertainty

We define uncertainty as the range of probable maximum deviation of a measured value from the true value within a 95% confidence interval. Given a bias (mean) error *B* and uncorrelated random errors characterized by a variance σ^2, the root-mean-square error (RMSE) is defined as the vector sum of these,

$$RMSE = \left(B^2 + \sigma^2\right)^{1/2}$$

(*B* may be generalized to be the sum of the various contributors to the bias and σ^2 the sum of the variances of the contributors to the random errors). To determine the 95% confidence interval we use the Student's *t* distribution: $t_{n;0.025} \approx 2$, assuming the RMSE was computed for a reasonably large ensemble. Then the *uncertainty* is calculated as twice the RMSE.

5.1.2 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

Table 3.

Quantity	Variable	Measurement Interval
Snow Depth Sensor	snow_sen	30 min
Battery Voltage	vbat	30 min
Standard Deviation of Wind Speed	sd_wspd	30 min
Standard Deviation of Temperature	sd_temp	30 min
Standard Deviation of RH	sd_rh	30 min
Standard Deviation of Vapor Pressure	sd_vap_pres	30 min
Standard Deviation of Barometric Pressure	sd_bar_pres	30 min

5.1.4 Data Quality Flags

Quality Check Results on:

Table 4.

Quantity	Variable	Measurement Interval	Min	Max	Delta
sample time	qc_time	1 min, 30 min & 1440 min			
Wind Speed	qc_wspd	1 min & 30 min	0	45	N/A
Wind Speed (vector averaged)	qc_wspd_va	1 min & 30 min	0	45	N/A
Wind Direction	qc_wdir	1 min & 30 min	0	360	N/A
Standard Deviation of wind direction	qc_sd_deg	1 min & 30 min	0	90	N/A
Temperature	qc_temp	1 min & 30 min	-40	60	N/A
RH	qc_rh	1 min & 30 min	-2	104	N/A
Vapor Pressure	qc_vap_pres	1 min & 30 min	0	10	N/A
Snow Depth	qc_snow	30 min	-25	1500	N/A
Snow Depth Sensor	qc_snow_sen	30 min	0	1	N/A
Precipitation Total	qc_precip	1 min & 30 min	0	10 for 1 min, 150 for 30 min	N/A
Battery Voltage	qc_vbat	30 min	9.6	16	N/A
Standard Deviation of Wind Speed	qc_sd_wspd	30 min	0	9	N/A
Standard Deviation of Temperature	qc_sd_temp	30 min	0	2	N/A
Standard Deviation of RH	qc_sd_rh	30 min	0	20	N/A
Standard Deviation of Vapor Pressure	qc_sd_vap_pres	30 min	0	N/A	N/A
Standard Deviation of Barometric Pressure	qc_sd_bar_pres	30 min	0	N/A	N/A

5.1.5 Dimension Variables

Table 5.

Quantity	Variable	Measurement Interval	Unit
Base time in Epoch	base_time	1 min, 30 min & 1440 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset from base_time	time_offset	1 min, 30 min & 1440 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset form midnight	time	1 min, 30 min & 1440 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
north latitude	lat	1 min, 30 min & 1440 min	degrees
east longitude	lon	1 min, 30 min & 1440 min	degrees
altitude	alt	1 min, 30 min & 1440 min	meters above sea level

Note: lat/lon/alt refers to the ground where the instrument is sited, NOT the height of the sensor.

5.2 Annotated Examples

This section is not applicable to this instrument.

5.3 User Notes and Known Problems

Incorrect Alignment of Towers

Some of the SMOS towers were incorrectly aligned to true north. Offsets were added to the following SMOS sites on the indicated dates. Any data prior to these dates will have to be manually corrected. A request for reprocessing the data has been made. Dates when the data has been reprocessed will be added to the table when appropriate.

Table 6.

Site	Offset	Program Changed	Reprocessed
E3	-7 deg	3/9/05 @ 1705 GMT	
E4	-7 deg	3/9/05 @ 1739 GMT	
E6	-7 deg	3/10/05 @ 1610 GMT	
E7	-6 deg	3/8/05 @ 2015 GMT	
E27	-7 deg	5/11/05 @ 1615 GMT	

Snow Depth Sensors Removed

In the summer of 2002, the Snow Depth Sensors were removed from service. The variable remains in the data stream as a placeholder. All data should be –9999.

Error Flags During Routine Maintenance

When maintenance occurs, error flags are generated when the technicians disable intermediate processing. The following is a description of what happens when intermediate processing is disabled.

No data is sent to the intermediate storage area, which is where values are accumulated for output instructions such as average, min, and max. Any values that were put there before disabling intermediate processing will be used in calculations. Therefore, if a tech disables intermediate processing at 30 s past a minute, the 1-min average will only use 30 values to calculate the 1-min average. During maintenance, the 30-min average value will only use the seconds during which the intermediate processing was not disabled. Therefore, if maintenance takes 5 min during which the intermediate processing was disabled the 30-min average will only use 1500 1-sec values instead of 1800. The reason 6999 is output for 1-min values are because output instructions for the 1-min are not disabled for the rain gage tiptest. When the intermediate storage location has accumulated no values and the logger must output something- -it puts out 6999. If the values are high resolution, the value output is 99999. Both of these values are positive. Negative values such as -6999 and -99999 are output when there is a problem with the sensor (i.e., overranging or no data from the sensor). This allows for a differentiation on what the logger is collecting. If values of 6999 and 99999 are output then the intermediate processing has been disabled and no values are collected but the logger is still required to have an output. If values of -6999 and -99999 are output then intermediate processing is enabled but there is something wrong with the data being collected (out of range, missing, etc). This differentiation allows for a known state during maintenance. If values at anytime are positive 6999 or 99999 then maintenance is probably occurring.

5.4 Frequently Asked Questions

What is the accuracy (quality) of the RH measurements?

The UNCERTAINTY of ± 2.06% RH (0% to 90% RH) or ± 3.04% RH (90% to 100% RH) is for a calibrated probe. The RH values reported by the probe normally drift slowly upward over time. Whenever a probe falls outside the range of uncertainty for a SIX-MONTH SENSOR VERIFICATION or reports values exceeding 104% RH, the probe is replaced by one that has been recently calibrated. Occasionally, a sensor will report values that are suspiciously low. A work order is then issued to perform a verification check and replacement if needed. A data quality report is issued for known erroneous data.

What is the accuracy (quality) of the snow depth measurements?

As the snow depth sensor and data logger were initially configured, the snow depth data are quite noisy. Sonic echos were often received from waving grass below the sensor and only a single reading was taken every 30-min. In DEC 95, a PIF, P951219.2 “Noisy Snow Depth data from SMOS” was issued. During the spring of 1996, the data logger program was changed to average readings taken every 3 min. The program change contained an error that was not discovered until the summer of 2001. The program was corrected and Snow Depth data were collected during the winter of 2001/2002. It was found that the Snow Depth sensors were not very stable and they were removed from service in August 2002.

Where can SMOS-like data be obtained for extended facilities that do not have SMOS data?

Several sources of surface meteorological data exist and are available as "external data" to ARM science team members. The Oklahoma Mesonet has more than 50 surface stations within the boundaries of the SGP site, the Kansas State network has 4-5 stations, and each of the boundary facilities has a surface meteorological station associated with the 404-MHz radar wind profiler operated by the National Oceanic and Atmospheric Administration. The status and contacts for external data can be found on the Web at location http://arm3.das.bnl.gov/sisg/ext.html.

http://www.mesonet.ou.edu/sites/

6. Data Quality

6.1 Data Quality Health and Status

Data Quality Health and Status (DQ HandS) http://dq.arm.gov.

NCVweb - for interactive data plotting using http://dq.arm.gov/ncvweb/ncvweb.cgi.

6.2 Data Reviews by Instrument Mentor

This section is not applicable to this instrument.

6.3 Data Assessments by Site Scientist/Data Quality Office

The ARM Data Quality Office uses the Data Quality Assessment (DQA) system to inform the ARM Site Operators, Site Scientists, and Instrument Team members of instrument and data flow problems as well as general data quality observations. The routine assessment reports are performed on the most recently collected ARM data, and used with the Data Quality Problem reports tool to initiate and track the problem resolution process.

http://dq.arm.gov/weekly_reports/weekly_reports.html

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM Program are met through the analysis and processing of existing data products into "value-added" products or VAPs. Despite extensive instrumentation deployed at the ARM sites, there will always be quantities of interest that are either impractical or impossible to measure directly or routinely. Physical models using ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some VAPs not in order to fill unmet measurement needs, but instead to improve the quality of existing measurements. In addition, when more than one measurement is available, ARM also produces "best estimate" VAPs. A special class of VAP called a Quality Measurement Experiment (QME) does not output geophysical parameters of scientific interest. Rather, a QME adds value to the input datastreams by providing for continuous assessment of the quality of the input data based on internal consistency checks, comparisons between independent similar measurements, or comparisons between measurement with modeled results, and so forth. For more information, see the VAPs and QMEs web page http://www.arm.gov/data/vaps.stm.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Wind speed and direction sensor: Propeller anemometer and wind vane, R. M. Young Model 05103 Wind Monitor.

T/RH sensor: Thermistor and Vaisala RH, Campbell Scientific Model HMP35C Temperature and RH Probe.

Barometric pressure sensor: Digital barometer, Vaisala Model PTB201A.

Precipitation: Electrically heated, tipping bucket precipitation gauge, Novalynx Model 260-2500E-12 Rain/Snow Gage.

Snow depth sensor: Ultrasonic depth gauge, Campbell Scientific Model UDG01 **Removed from service Summer 2002**.

Data logger: Campbell Scientific Model CR10 Measurement & Control Module and Model SM716 Storage Module, Precision: A function of input type and range, Uncertainty: 0.2% of Full Scale Range for Analog Inputs.

7.1.2 System Configuration and Measurement Methods

Description of all SMOS stations except at E21, Okmulgee, OK

The SMOS sensors are mounted on a 10-m triangular tower, except for the rain gauge.

The wind monitor propeller anemometer produces a magnetically controlled AC output whose frequency is proportional to the wind speed. The Wind Monitor direction vane drives a potentiometer, which is part of a resistance bridge. The Wind Monitor is mounted on a cross-arm at a height of 10 m.

The T-RH probe thermistor is part of a resistance bridge. The Vaisala RH circuitry produces a voltage that is proportional to the capacitance of a water vapor absorbing, thin polymer film. For all SMOSs, except the one at the central facility, the T-RH probe is mounted in a naturally aspirated R. M. Young Model 41002 Gill Multi-plate Radiation Shield. The central facilities (E13) T-RH probe is mounted in an R. M. Young Model 43408 Gill Aspirated Radiation Shield. The Radiation Shields are mounted at a height of 2 m on the southwestern leg of the tower.

The snow depth sensor determines the distance from the sensor to the surface by measuring the time of travel of a series of ultrasonic pulses. It is mounted to the tower on a boom at a height of approximately 1.5 m.

The barometric pressure sensor uses a silicon capacitive pressure sensor and is housed in a weatherproof enclosure along with a data logger, a storage module, and serial communications equipment, all mounted on the tower at a height of 1 m.

The rain-snow gauge has a 12-in. orifice and is located near the tower. A thermostatically controlled heater melts frozen precipitation. The water is funneled to a tipping bucket, which triggers a magnetic reed switch. An Alter Shield is used to increase the reliability of rain collection in high winds and of snow collection.

The data logger measures each input once per second except for barometric pressure, which is measured once per minute, and snow depth, which is measured every 3 min. The vapor pressure is computed from the air temperature and RH. The data logger produces 1- and 30-min averages of wind speed, vector-averaged wind speed, vector-averaged wind direction, air temperature, RH, and vapor pressure. An algorithm computes the standard deviation of the wind direction. The 1-min output includes the barometric pressure reading and total precipitation during the minute. The 30-min output includes the battery voltage, 30-min-total precipitation, and an average snow depth. The 30-min output also includes the standard deviations of wind speed, temperature, RH, vapor pressure, and barometric pressure.

Description of SMOS at E21, Okmulgee, OK

The same sensors that are used on the other SMOS stations are used on the E21 SMOS except no snow depth sensor is included. Since this SMOS is in a forested site, the sensors are mounted on a 20-m tower that extends above the top of the forest canopy. During the summer of 1999, the canopy height was estimated to be 47 ft or 14.3 m. The air temperature and RH probe is mounted at 17.0 m or approximately 2.7 m above the average canopy height facing north. The wind speed and direction sensor is mounted at 18 m or approximately 3.7 m above the average canopy height on a boom 10ft out from the tower facing north. The barometric pressure sensor is mounted at 19 m or approximately 4.7 m above the average canopy height. New booms for sensor mounting were installed in July 2002. The two sensors affected are the wind speed and direction sensor and the T/RH probe. The height of the wind speed and direction sensor did not change; it is still 18 m or approximately 3.7 m above the average canopy height. The orientation of the wind speed and direction sensor did change and it is now facing west on a boom 15 ft out from the tower. The date of the wind speed and direction sensor change was July 16, 2002 at 18:44 GMT. Both the orientation and the height of the T/RH probe changed. It is now 19.25 m above the surface or 4.95 m above the average canopy height and is facing northeast. The date of the T/RH probe change was July 15, 2002 at 22:36 GMT.

7.1.3 Specifications

Wind speed at 10 m, Precision: 0.01 m/s; Uncertainty: ± 1% for 2.5 to 30 m/s.

Wind direction at 10 m, Precision: 0.1°; Uncertainty: ± 5°.

Air temperature at 2 m, Precision: 0.01°C; Uncertainty: a function of wind speed.

Relative humidity at 2 m, Precision: 0.1% RH; Uncertainty: ± 2.06% RH (0% to 90% RH), ± 3.04% RH (90% to 100% RH).

Barometric pressure at 1 m, Precision: 0.01 kPa; Uncertainty: ± 0.035 kPa.

Precipitation, Precision: 0.254 mm; Uncertainty: ± 0.254 mm (unknown during strong winds and for snow).

Snow depth, Precision: 0.1 mm, ± 10 mm plus any offset error. Snow Depth sensors were removed from service in August 2002 (see "Overall Uncertainties for Primary Quantities Measured").

Data Acquisition Errors

The Campbell Scientific CR10 A/D converter accuracy is ± 0.2 % of full-scale range. The time base accuracy is ± 1 min per month, or about 23 ppm. The Site Data System checks the time-of-day clock once per day and corrects the SMOS clock if it is off by more than a minute.

Wind Speed

The NIST calibration uncertainty is specified as ± 1% for wind speeds from the sensor threshold to 30 m/s. The conversion error is negligible. The schedule of routine maintenance and sensor verification is designed to eliminate any long-term stability error.

The sensor threshold is specified as 1 m/s. The following estimates of the range of underestimation caused by the threshold assume a normal distribution of wind speeds about the mean. When the true wind speed is 1.0 m/s, the winds will be below the threshold 50% of the time. This will result in an underestimate of 0.5 m/s. When the true wind speed is 1.5 m/s, assuming the standard deviation will be between 0.25 and 1.00 m/s, the winds will be below the threshold between 2 and 31% of the time. This will result in an underestimate between 0.02 and 0.23 m/s. When the true wind speed is 2.0 m/s with a range of standard deviations between 0.25 and 1.00 m/s, the winds will be below the threshold between 0 and 16% of the time. This will result in an underestimate between zero and 0.12 m/s.

If the reported wind speed is 0.5 m/s, an underestimate of 0.5 is probable. This would bias the measurement by -0.5. If the reported wind speed is 1.0 m/s, an underestimate of 0.19 to 0.30 m/s is possible. If the reported wind speed is 1.5 m/s, an underestimate of 0.02 to 0.20 m/s is possible. If the reported wind speed is 2.0 m/s, an underestimate of 0 to 0.10 m/s is possible.

The uncertainty range with 95% confidence is approximately:

± 1%	for a reported wind speed from 2.5 to 30.0 m/s
-0.12 to +0.02 m/s	for a reported wind speed of 2.0 m/s
-0.22 to +0.00 m/s	for a reported wind speed of 1.5 m/s
-0.31 to -0.20 m/s	for a reported wind speed of 1.0 m/s
-0.51 to -0.49 m/s	for a reported wind speed of 0.5 m/s

Wind Direction

The sensor accuracy is specified as ± 3°. The A/D conversion accuracy is equivalent to ± 0.7° over a temperature range of 0° to 40°C for a period of one year. I have estimated sensor alignment to true north to be accurate within ± 3°. The uncertainty with 95% confidence is, therefore, approximately ± 5°.

Temperature

The accuracy of the temperature measurement is specified as ± 0.4°C. Included in this accuracy are sensor interchangeability, bridge resistor precision, and polynomial curve fitting errors. The long-term stability is not known. The radiation error of the naturally aspirated multi-plate radiation shield used for all stations, except for the central facilities SMOS, is specified as ± 0.4°C root mean square (rms) at 3 m/s, ± 0.7°C rms at 2 m/s, and ± 1.5°C rms at 1 m/s.

The uncertainty with 95% confidence of temperature sensors in naturally aspirated radiation shields is approximately:

± 0.45 C	when the wind speed is 6 m/s or greater
± 0.89 C	when the wind speed is 3 m/s
± 1.46 C	when the wind speed is 2 m/s
± 3.07 C	when the wind speed is 1 m/s

The radiation error of the aspirated radiation shield used at the Central Facility is specified as ± 0.2°C rms. The uncertainty with 95% confidence of temperature sensors in this radiation shield is, therefore, ± 0.57°C.

Relative Humidity

The accuracy of the sensor is specified as ± 2% RH for 0 to 90% RH, and ± 3% RH for 90 to 100% RH. Errors considered in this accuracy are calibration uncertainty, repeatability, hysteresis, temperature dependence, and long-term stability over a period of one year. The A/D conversion accuracy is equivalent to ± 0.5% RH.

The uncertainty with at least 95% confidence is, therefore,

± 2.06 % RH, 0 to 90 % RH
± 3.04 % RH, 90 to 100 % RH

Barometric Pressure

The manufacturer's technical data contains an uncertainty analysis. Errors included in their analysis are linearity, hysteresis, calibration uncertainty, repeatability, temperature dependence, and long-term stability over a period of one year. Because the sensor has a digital output, no conversion error occurs in the Campbell data logger.

The specified uncertainty with 95% confidence is +/-0.035 kPa.

Precipitation

The tipping-bucket rain gauge produces a pulse output. The data logger counts the pulses for the period of integration. The uncertainty is, therefore, a minimum of one full bucket or 0.254 mm. For rain rates less than 75 mm per hour with light to moderate winds, the collection efficiency of the gauge is 99% to 100%.

During heavy rain or strong, gusty winds, the collection efficiency is reduced. Manufacturers have not attempted to specify accuracies for these conditions.

Although Alter shields are used to increase the efficiency of snow collection, the efficiency of collection is variable and usually well below 100%. Furthermore, the heater does not melt snow at temperatures below -10°C. Thus, the data user should use the water-equivalent estimates for snowfall with a great deal of skepticism. At best, the readings are only a rough indicator that snow occurred, for temperatures above -10°C. If snow occurred at -10°C or below and the temperature increased to above -10°C hours later, then some melting would occur and an incorrect time of precipitation would be reported.

Snow Depth

The sensor has a digital output, therefore, there is no conversion error. The snow depth is determined by subtracting the measurement from the height of the sensor. An error in the latter will result in a bias error. Since this height is manually entered into the data logger program, the bias error could be large. The sensor accuracy is specified as ± 10 mm.

7.2 Theory of Operation

Each of the primary measurements of wind speed, wind direction, air temperature, RH, barometric pressure, and rainfall are intended to represent self-standing data streams that can be used independently or in combinations. The theory of operation of each of these sensors is similar to that for sensors typically used in other conventional surface meteorological stations. Some details can be found under *System Configuration and Measurement Methods* but further, greatly detailed description of theory of operation is not considered necessary for effective use of the data for these rather common types of measurements. The instrument mentor or the manufacturer can be contacted for further information.

7.3 Calibration

7.3.1 Theory

The SMOSs are not calibrated as systems. The sensors and the data logger (which includes the analog-to-digital converter) are calibrated separately. All systems are installed using components that have a current calibration. The sensor calibrations are checked every six months in the field by SGP site operations personnel by comparison to calibrated references. Any sensor that fails a field check is returned to the manufacturer for recalibration. The Wind Monitors are returned to the manufacturer for recalibration after two years of use per manufacturer suggestion and given adequate funding. Therefore, it is possible that in some years the wind monitors are not sent back to the manufacturer for the 2-year recalibration and preventative maintenance. Overall, this should not lead to a problem, as the sensors rarely go out of calibration and are checked every 6 months.

7.3.2 Procedures

Wind speed calibration is checked by rotating the propeller shaft at a series of fixed rpm's using an R. M. Young Model 18810 Anemometer Drive. The reported wind speeds are compared to a table of expected values and tolerances. If the reported wind speeds are outside the tolerances for any rate of rotation, the sensor is replaced by one with a current calibration.

Wind direction calibration is checked by using a vane angle fixture, R. M. Young Model 18212, to position the vane at a series of angles. The reported wind directions are compared to the expected values. If any direction is in error by more than 5 degrees, the sensor is replaced by one with a current calibration.

Air temperature and RH calibrations are checked by comparison with a reference Vaisala Model HMI31 Digital RH and Temperature Meter and HMP35 Probe. If the reported temperature and RH vary by more than the sensor uncertainty from the reference, the probe is replaced by one with a current calibration.

Barometric pressure calibration is checked by comparison with a reference Vaisala PA-11 Barometer. If the reported pressure varies by more than the sensor uncertainty from the reference, the sensor is replaced by one with a current calibration.

Precipitation calibration is checked by allowing 500 ml of water to pass slowly through the sensor. If the reported number of tips varies by more than one from the expected value, the rain gauge is replaced by one with a current calibration.

Snow depth calibration is checked by placing an object with a known height under the sensor. If the reported depth varies by more than the sensor uncertainty of 10 mm from the known height, the offset in the data logger program is adjusted to produce the correct height. If adjustment of the offset does not produce the correct height within 10 mm, the sensor is replaced by one with a current calibration.

7.3.3 History

Calibration checks of SMOS sensors are conducted every six months in the field. Because the data flow is interrupted and the 10-m tower must be lowered for these checks, a data quality report (DQR) is usually issued to note the loss of data. A list of field calibration checks and/or sensor replacements follows.

SMOS E1, Larned, KS

Data available beginning on 5 SEP 1995
Field calibration check on 3 OCT 1995
T-RH probe replaced on 29 NOV 1995 (PIF No. P951207.5)
Field calibration check on 18 APR 1996
Rain gauge replaced on 24 JUL 1996
Field calibration check on 30 OCT 1996 (PIF No. P961210.1)
Field calibration check on 30 APR 1997 (DQR No. D970718.2)

Wind monitor replaced on 6 AUG 1997 for 2-year factory PM and calibration
Failed barometer replaced on 20 AUG 1997
Field calibration check on 29 OCT 1997 (DQR No. D971112.1)
Field calibration check on 29 APR 1998 (DQR No. D980601.1
Field calibration check on 24 NOV 1998
Field calibration check on 13 APR 1999
T-RH probe replaced on 6 JUL 1999
Field calibration check on 29 SEP 1999
Field calibration check on 25 APR 2000
Field calibration check on 24 OCT 2000
Wind monitor replaced on 13 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 24 APR 2001
T-RH probe replaced 17 JUL 2001
Field calibration check on 6 NOV 2001
Field calibration check on 21 MAY 2002
Field calibration check on 5 NOV 2002
Field calibration check on 6 MAY 2003
Field calibration check on 21 OCT 2003
Field calibration check & T-RH probe replaced on 20 APR 2004
Field calibration check on 19 OCT 2004
Field calibration check on 5 APR 2005

SMOS E3, LeRoy, KS

Data available beginning on 12 DEC 1995
Field calibration check on 1 MAY 1996 (PIF No. P960523.2)
Field calibration check on 14 NOV 1996 (PIF No. P961210.5)
Field calibration check on 16 APR 1997 (DQR No. D970718.3)
Wind monitor replaced on 6 AUG 1997 for 2-year factory PM and calibration
Field calibration check on 15 OCT 1997 (DQR No. D971112.2)
Field calibration check on 13 MAY 1998 (DQR No. D990601.6
Field calibration check on 11 NOV 1998
Field calibration check on 31 MAR 1999 (not wind sensor)
Field calibration on wind sensor 12 MAY 1999
Field calibration check on 8 DEC 1999
Field calibration check on 10 MAY 2000
T-RH probe replaced on 7 JUL 2000
Field calibration check on 27 SEP 2000
Wind monitor replaced on 14 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 11 APR 2001
Field calibration check on 24 OCT 2001
Field calibration check on 8 MAY 2002
T-RH probe replaced on 25 SEP 2002
Field calibration check on 20 NOV 2002
Field calibration check on 23 APR 2003
Field calibration check on 5 NOV 2003

Field calibration check on 7 APR 2004
Field calibration check on 6 OCT 2004
Field calibration check on 20 APR 2005

SMOS E4, Plevna, KS

Data available beginning on 30 MAR 1995
Wind speed calibration corrected on 18 APR 1995
Field calibration check on 3 OCT 1995
Field calibration check on 18 APR 1996
Field calibration check on 31 OCT 1996 (PIF No. P961210.7)
Field calibration check on 30 APR 1997 (DQR No. D970718.4)
Field calibration check on 30 OCT 1997 (DQR No. D971112.3)
Field calibration check on 29 APR 1998 (DQR No. D9780601.7)
Field calibration check on 24 NOV 1998
Field calibration check on 14 APR 1999
T-RH probe replaced on 12 MAY 1999
Field calibration check on 29 SEP 1999
Wind monitor replaced on 12 APR 2000 for 2-year factory PM and calibration
Field calibration check on 26 APR 2000
Failed barometer replaced 1 AUG 2000
Field calibration check on 8 NOV 2000
Field calibration check on 25 APR 2001
Field calibration check on 7 NOV 2001
Field calibration check on 22 MAY 2002
Field calibration check on 6 NOV 2002
Field calibration check on 7 MAY 2003
Field calibration check on 22 OCT 2003
T-RH probe replaced on 22 OCT 2003
Field calibration check & T-Rh probe replaced on 21 APR 2004
T-RH probe replaced 6 MAY 2004
Field calibration check on 20 OCT 2004
Field calibration check on 6 APR 2005

SMOS E5, Halstead, KS

Data available beginning on 20 JUN 1996
Field calibration check on 31 OCT 1996 (PIF No. P961210.8)
Field calibration check on 1 MAY 1997 (DQR No. D970718.5)
Field calibration check on 30 OCT 1997 (DQR No. D971112.5)
Field calibration check on 30 APR 1998 (DQR No. D980601.2)
Field calibration check on 25 NOV 1998
Field calibration check on 14 APR 1999
Field calibration check on 30 SEP 1999
Wind monitor replaced on 12 APR 2000 for 2-year factory PM and calibration
Field calibration check on 25 APR 2000

Field calibration check on 8 NOV 2000
Field calibration check on 25 APR 2001
Field calibration check on 7 NOV 2001
Field calibration check on 22 MAY 2002
Field calibration check on 6 NOV 2002
Field calibration check on 7 MAY 2003
Field calibration check on 21 OCT 2003
Field calibration check on 21 APR 2004
T-RH probe replaced 14 JUL 2004
Field calibration check on 20 OCT 2004
Field calibration check on 6 APR 2005

SMOS E6, Towanda, KS

Data available beginning on 21 DEC 1995
Wind Monitor replaced on 3 APR 1996 (PIF No. P960523.5)
Field calibration check on 1 MAY 1996 (PIF No. P960523.4)
Field calibration check on 14 NOV 1996 (PIF No. P961210.11)
Field calibration check on 29 APR 1997 (DQR No. D970718.6)
Field calibration check on 14 OCT 1997 (DQR No. D971112.7)
Last field calibration check revealed that the barometer had drifted out of tolerance. It was replaced on 24 NOV 1997.
Field calibration check on 13 MAY 1998 (DQR No. D980601.8)
Field calibration check on 12 NOV 1998
Field calibration check on 1 APR 1999 (no wind sensor check)
Field calibration check on wind sensors only 12 May 1999
Field calibration check on 8 DEC 1999
Wind monitor replaced on 29 MAR 2000 for 2-year factory PM and calibration
Field calibration check on 10 MAY 2000
Field calibration check on 28 SEP 2000
Wind monitor replaced on 15 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 12 APR 2001
Field calibration check on 23 OCT 2001
T-RH probe replaced on 24 APR 2002
Field calibration check on 8 MAY 2002
T-RH probe replaced on 4 JUN 2002
Field calibration check on 21 NOV 2002
Field calibration check on 24 APR 2003
T-RH probe replaced on 11 SEP 2003
T-RH probe replaced on 15 SEP 2003
Field calibration check on 6 NOV 2003
Field calibration check on 8 APR 2004
Barometer replaced on 24 SEP 2004
Field calibration check on 17 OCT 2004
Field calibration check on 21 APR 2005

SMOS E7, Elk Falls, KS

Data available beginning on 24 FEB 1995
Field calibration check and T-RH probe replaced on 9 MAR 1995
Wind monitor ground repaired on 22 MAR 1995
T-RH probe replaced on 17 MAY 1995 (PIF No. P950814.1)
Field calibration check on 4 OCT 1995 (PIF No. P951009.2)
Field calibration check on 2 MAY 1996 (PIF No. P960523.6)
Field calibration check on 13 NOV 1996 (PIF No. P961210.19)
T-RH probe replaced on 4 FEB 1997
Field calibration check on 16 APR 1997 T-RH probe replaced (DQR No. D970718.7)
Field calibration check on 16 OCT 1997 (DQR No. D971112.8)
Field calibration check on 12 MAY 1998 (DQR No. D980601.9)
Field calibration check on 11 NOV 1998
T-RH probe replaced on 8 JUN 1999
T-RH probe replaced on 6 JUL 1999
Field calibration check on 30 MAR 1999
Field calibration check on 7 DEC 1999
Field calibration check on 9 MAY 2000
Field calibration check on 26 SEP 2000
Wind monitor replaced on 5 DEC 2000 for 2-year factory PM and calibration
Wind monitor replaced on 13 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 10 APR 2001
Field calibration check on 25 OCT 2001
Field calibration check on 7 MAY 2002
T-RH probe replaced on 6 JUN 2002
Field calibration check on 19 NOV 2002
Barometer replaced on 22 NOV 2002
Field calibration check on 22 APR 2003
Field calibration check on 4 NOV 2003
Field calibration check on 6 APR 2004
T-RH probe replaced 13 JUL 2004
Field calibration check on 5 OCT 2004
Field calibration check on 19 APR 2005

SMOS E8, Coldwater, KS

Data available beginning on 28 JUL 1993
Field calibration check on 3 NOV 1993
Field calibration check on 15 JUN 1994
Field calibration check on 16 NOV 1994 (PIF No. P941128.4)
Field calibration check and wind monitor replaced on 19 APR 1995 (PIF No. P950509.7)
Field calibration check on 2 OCT 1995 (PIF No. P951009.5)
Field calibration check and T-RH probe replaced on 17 APR 1996 (PIF No. P960523.7)
Field calibration check on 30 OCT 1996 (PIF No. P961210.12)
Field calibration check on 29 APR 1997 (DQR No. D970718.8)

Wind monitor replaced on 5 AUG 1997 for 2-year factory PM and calibration
Wind monitor wires corrected 30 SEP 1997 due to install error 5 AUG 1997
Field calibration check on 29 OCT 1997, rain gauge replaced(DQR No. D971112.9)
T/RH probe had drifted out of tolerance. It was replaced on 24 NOV 1997.
Field calibration check on 28 APR 1998 (DQR No. D980601.10)
Field calibration check on 23 NOV 1998
T/RH probe had drifted out of tolerance. It was replaced on 30 MAR 1999
Field calibration check on 27 APR 1999
Field calibration check on 28 SEP 1999
Field calibration check on 25 APR 2000
T-RH probe replaced on 23 MAY 2000
Field calibration check on 24 OCT 2000
Wind monitor replaced on 5 DEC 2000 for 2-year factory PM and calibration
T-RH probe replaced on 10 APR 2001
Field calibration check on 24 APR 2001
Field calibration check on 6 NOV 2001
Wind monitor replaced on 12 MAR 2002
Field calibration check on 21 MAY 2002
Field calibration check on 5 NOV 2002
Field calibration check on 20 MAY 2003
Field calibration check on 21 OCT 2003
Field calibration check & T-RH probe replaced on 20 APR 2004
Field calibration check on 19 OCT 2004
T-RH probe replaced on 25 JAN 2005
T-RH probe replaced on 8 FEB 2005
Field calibration check on 5 APR 2005

SMOS E9, Ashton, KS

Data available beginning on 1 JUL 1993
Field calibration check on 1 NOV 1993
Field calibration check on 13 JUN 1994
Field calibration check on 14 NOV 1994 (PIF No. P941128.5)
Field calibration check and wind monitor replaced on 18 APR 1995 (PIF No. P950509.8)
Field calibration check and T-RH probe replaced on 5 OCT 1995 (PIF No. P951009.4)
Field calibration check on 30 APR 1996 (PIF No. P960523.9)
Field calibration check on 15 NOV 1996 (PIF No. P961210.13)
Field calibration check and wind monitor replaced on 1 MAY 1997 (DQR No. D970718.9)
Field calibration check on 16 OCT 1997 (DQR No. D971112.11)
Field calibration check on 14 MAY 1998 (DQR No. D980601.3)
Field calibration check on 12 NOV 1998
Field calibration check on 1 APR 1999
T-RH probe replaced on 13 MAY 1999
Field calibration check on 9 DEC 1999
Field calibration check on 11 MAY 2000
T-RH probe replaced on 25 MAY 2000

Field calibration check on 26 SEP 2000
Wind monitor replaced on 5 DEC 2000 for 2-year factory PM and calibration
T-RH probe replaced on 27 FEB 2001
T-RH probe replaced on 13 MAR 2001
Field calibration check on 10 APR 2001
Field calibration check on 23 OCT 2001
T-RH probe replaced on 28 MAR 2002
Field calibration check on 9 MAY 2002
Field calibration check on 19 NOV 2002
T-RH probe replaced on 7 FEB 2003
Field calibration check on 24 APR 2003
Field calibration check on 4 NOV 2003
Field calibration check on 6 APR 2004
Field calibration check on 5 OCT 2004
Field calibration check on 9 APR 2005

SMOS E11, Byron, OK

Data available beginning on 28 JUN 1995
T-RH probe replaced on 22 AUG 1995 (PIF No. P950828.4)
Field calibration check on 17 OCT 1995 (PIF No. P951101.11)
T-RH probe wiring repaired on 31 OCT 1995 (PIF No. P951103.1)
T-RH probe replaced on 12 DEC 1995 (PIF No. P951219.1)
Field calibration check on 16 APR 1996 (PIF No. P960523.10)
Field calibration check on 29 OCT 1996 (PIF No. P961210.14)
Field calibration check on 29 APR 1997 (DQR No. D970718.10)
Wind monitor replaced on 5 AUG 1997 for 2-year factory PM and calibration
Field calibration check on 28 OCT 1997 (DQR No. D971112.12)
Field calibration check on 5 MAY 1998 (DQR No. D980601.4)
Field calibration check on 3 DEC 1998
Field calibration check on 20 APR 1999
Field calibration check on 5 OCT 1999
T-RH probe replaced on 13 JAN 2000
T-RH probe had drifted out of tolerance. Probe replaced on 24 MAR 2000
Field calibration check on 18 APR 2000
T-RH probe replaced on 6 JUN 2000
T-RH probe replaced on 25 JUL 2000
Field calibration check on 17 OCT 2000
Wind monitor replaced on 6 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 17 APR 2001
Field calibration check on 2 OCT 2001
Field calibration check on 14 MAY 2002
Rain gauge replaced on 17 MAY 2002
T-RH probe replaced on 25 JUN 2002
Field calibration check on 12 NOV 2002
Field calibration check on 29 APR 2003

Field calibration check on 14 OCT 2003
Field calibration check & T-RH probe replaced on 13 APR 2004
T-RH probe replaced 13 JUL 2004
Barometer replaced on 20 JUL 2004
Field calibration check on 26 OCT 2004
Field calibration check on 12 APR 2005

SMOS E13, Central Facility, Lamont, OK

Data available beginning on 1 JUL 1993
Instrument replaced due to lightning damage on 10 MAY 1993
Field calibration check on 26 OCT 1993 (PIF No. P931101.6)
T-RH probe replaced on 6 MAY 1994
Field calibration check on 17 JUN 1994
Field calibration check on 18 NOV 1994 (PIF No. P941128.1)
T-RH multi-plate radiation shield replaced by aspirated shield on 14 APR 1995
Field calibration check on 5 MAY 1995 (PIF No. P950509.3)
T-RH probe replaced on 30 JUN 1995 (PIF No. P950707.4)
Wind monitor and rain gauge replaced on 18 JUL 1995
Field calibration check on 6 OCT 1995 (PIF No. P951009.6)
Field calibration check on 3 MAY 1996 (PIF No. P96052313)
Field calibration check on 18 NOV 1996 (PIF No. P961210.15)
T-RH probe replaced on 30 JAN 1997
T-RH probe replaced on 14 MAR 1997
T-RH probe replaced on 9 APR 1997
Field calibration check on 20 APR 1997 (DQR No. D970721.3)
T-RH probe replaced on 14 MAY 1997
Wind monitor replaced on 1 AUG 1997 for 2-year factory PM and calibration
Field calibration check and Wind monitor replaced on 10 OCT 1997 (DQR No. D971112.13)
Field calibration check on 7 MAY 1998 (DQR No. D980601.11)
Field calibration check on 4 DEC 1998
Field calibration check on 9 APR 1999
Field calibration check on 7 OCT 1999
Field calibration check on 4 MAY 2000
Field calibration check on 19 OCT 2000
Wind monitor replaced on 8 MAR 2001 for 2-year factory PM and calibration
Field calibration check on 20 APR 2001
Field calibration check on 4 OCT 2001
Field calibration check on 16 MAY 2002
T-RH probe replaced on 14 JUN 2002
Field calibration check on 14 NOV 2002
Field calibration check on 1 MAY 2003
Field calibration check on 16 OCT 2003
Field calibration check on 15 APR 2004
T-RH probe replaced on 27 MAY 2004
Field calibration check on 28 OCT 2004

Field calibration check on 15 APR 2005

SMOS E15, Ringwood, OK

Data available beginning on 13 JUL 1993
Field calibration check on 2 NOV 1993
Field calibration check on 14 JUN 1994
Field calibration check on 21 NOV 1994 (PIF No. P941128.2)
Field calibration check and Wind monitor replaced on 24 APR 1995 (PIF No. P950509.4)
T-RH probe replaced on 31 JUL 1995 (PIF No. P950808.1)
Field calibration check on 10 OCT 1995 (PIF No. P951101.5)
Field calibration check on 23 APR 1996 (PIF No. P960523.14)
T-RH probe replaced on 7 MAY 1996 (PIF No. P960523.16)
T-RH probe replaced on 15 AUG 1996
Field calibration check on 5 NOV 1996 (PIF No. P961210.16)
Field calibration check on 22 APR 1997 (DQR No. D970718.11)
Wind monitor replaced on 6 MAY 1997 for 2-year factory PM and recalibration
Field calibration check on 7 OCT 1997 (DQR No. D971112.14)
T-RH probe replaced on 24 FEB 1998 (DQR No. D980401.5)
Field calibration check on 5 MAY 1998 (DQR No. D980601.5)
T-RH probe replaced on 20 OCT 1998
Field calibration check on 3 DEC 1998
Field calibration check on 20 APR 1999
Field calibration check on 5 OCT 1999
Field calibration check on 18 APR 2000
T-RH probe replaced on 13 JUN 2000
Field calibration check on 17 OCT 2000
Wind monitor replaced on 12 DEC 2000 for 2-year factory PM and calibration
Field calibration check on 17 APR 2001
Field calibration check on 2 OCT 2001
Wind speed sensor replaced 27 NOV 2001
Field calibration checks on 14 MAY 2002
Wind Monitor replaced on 11 JUN 2002
Field calibration check on 12 NOV 2002
Field calibration check on 29 APR 2003
Field calibration check on 14 OCT 2003
Field calibration check & T-RH probe replaced on 13 APR 2004
Field calibration check on 26 OCT 2004
Field calibration check on 12 APR 2005

SMOS E20, Meeker, OK

Data available beginning 8 JUL 1993
T-RH probe replaced on 10 JUN 1993 (PIF No. P930602.2)
Wind Monitor replaced on 8 JUL 1993
Field calibration check on 28 OCT 1993

Field calibration check on 9 JUN 1994
Field calibration check on 25 NOV 1994 (PIF No. P951128.3)
Field calibration check on 27 APR 1995 (PIF No. P950509.6)
T-RH probe replaced on 11 MAY 1995
Field calibration check on 13 OCT 1995 (PIF No. P951101.8)
T-RH probe replaced on 26 OCT 1995 (PIF No. P951101.8)
Field calibration check and Wind monitor replaced on 10 APR 1996 (PIF No. P960523.17)
T-RH probe replaced on 20 JUN 1996
T-RH probe replaced on 15 AUG 1996
Field calibration check on 23 OCT 1996 (PIF No. P961210.18)
Field calibration check on 9 APR 1997 (DQR No. D970718.12)
Field calibration on wind sensors 21 MAY 1997
Field calibration check on 22 OCT 1997 (DQR No. D980407.1)
Field calibration check on 20 MAY 1998 (DQR No. D980601.12)
Field calibration check on 20 NOV 1998
Field calibration check on 7 APR 1999
T-RH probe replaced on 8 SEP 1999
Field calibration check on 15 DEC 1999
T-RH probe had drifted out of tolerance. It was replaced on 12 JAN 2000.
Wind monitor replaced on 22 MAR 2000 for 2-year factory PM and calibration
Field calibration check on 17 MAY 2000
Wind monitor replaced on 28 JUN 2000
Field calibration check on 4 OCT 2000
Field calibration check on 4 APR 2001
Field calibration check on 17 OCT 2001
Wind monitor replaced on 23 JAN 2002
Wind monitor replaced on 17 APR 2002
Field calibration check on 1 MAY 2002
T-RH probe replaced on 12 SEP 2002
Field calibration check on 26 NOV 2002
Field calibration check on 16 APR 2003
Field calibration check on 29 OCT 2003
Field calibration check on 28 APR 2004
Field calibration check on 29 SEP 2004
T-RH probe replaced on 8 DEC 2004
T-RH probe replaced on 2 FEB 2005
Field calibration check on 27 APR 2005

SMOS E21, Okmulgee, OK

Data available beginning on 25 AUG 1999
T-RH probe replaced on 27 JUL 1999
Field calibration check on 10 AUG 1999
T-RH probe replaced 5 OCT 1999
T-RH probe replaced on 2 NOV 1999
Barometer replaced on 30 NOV 1999

Field calibration check on 14 DEC 1999
Barometer replaced on 19 APR 2000
Field calibration check on 17 MAY 2000
T-RH probe replaced 26 on JUL 2000
Wind monitor orientation corrected on 17 AUG 2000
Fine tune wind monitor orientation 20 SEP 2000
Field calibration check on 4 OCT 2000
Field calibration check on 3 APR 2001
Rain gauge replaced on 18 SEP 2001
Field calibration check on 11 DEC 2001
Barometer replaced on 17 APR 2002
Field calibration check on 1 MAY 2002(not wind speed and direction)
Field calibration check of wind speed and direction 7 AUG 2002
Field calibration check on 26 NOV 2002
T-RH probe replaced on 5 Mar 2003
Field calibration check on 16 APR 2003
Field calibration check on 29 OCT 2003
Field calibration check on 28 APR 2004
Barometer replaced 23 JUN 2004
Barometer replaced on 26 OCT 2004
Field calibration check on 8 NOV 2004
T-RH probe replaced on 17 DEC 2004
T-RH probe replaced on 18 JAN 2005
Field calibration check on 26 APR 2005

SMOS E24, Cyril, OK

Data available beginning 27 AUG 1995
Field calibration check on 12 OCT 1995 (PIF No. P951101.9)
Field calibration check on 24 APR 1996 (PIF No. P960523.18)
Field calibration check on 7 NOV 1996 (PIF No. P961210.20)
T-RH probe replaced on 11 FEB 1997
Field calibration check on 23 APR 1997 (DQR No. D970718.13)
Field calibration check and Wind monitor replaced on 21 OCT 1997 (DQR No. D980407.2)
T-RH probe replaced on 10 FEB 1998 (DQR No. D980401.6)
T-RH probe replaced on 10 MAR 1998 (DQR No. D980401.6)
Field calibration check on 19 MAY 1998 (DQR No. D980601.13)
T-RH probe replaced on 3 NOV 1998
Field calibration check on 19 NOV 1998
T-RH probe replaced on 17 DEC 1998
Field calibration check on 23 MAR 1999
Field calibration check on 16 DEC 1999
Field calibration check on 7 MAR 2000
Field calibration check on 18 MAY 2000
Field calibration check on 5 OCT 2000
Wind monitor replaced on 14 DEC 2000 for 2-year factory PM and calibration

Field calibration check on 5 APR 2001
T-RH probe replaced 23 AUG 2001
Field calibration check on 16 OCT 2001
Field calibration check on 2 MAY 2002
T-RH probe replaced on 14 JUN 2002
T/RH probe replaced on 17 OCT 2002
Field calibration check on 27 NOV 2002
T/RH probe replaced on 27 NOV 2002
Field calibration check on 17 APR 2003
Field calibration check on 30 OCT 2003
Field calibration check on 29 APR 2004
Field calibration check on 30 SEP 2004
T-RH probe replaced on 9 DEC 2004
Field calibration check on 28 APR 2005

SMOS E25, Seminole, OK

Data available beginning on 16 DEC 1996
Field calibration check on 9 APR 1997 (DQR No. D970718.14)
Field calibration check on wind sensors only 21 MAY 1997
Field calibration check on 22 OCT 1997 (DQR No. D980407.3)
T/RH probe had drifted out of tolerance. It was replaced on 3 DEC 1997.
Replacement T/RH probe not functioning properly. It was replaced on 16 DEC 1997.
Field calibration check on 20 MAY 1998 (DQR No. D980601.14)
T-RH probe replaced on 21 OCT 1998
Field calibration check on 13 JAN 1999
Field calibration check on 25 MAR 1999
Field calibration check on 15 DEC 1999
Field calibration check on 17 MAY 2000
Field calibration check on 4 OCT 2000
Wind monitor replaced on 13 DEC 2000 for 2-year factory PM and calibration
T-RH probe replaced on 10 JAN 2001.
Field calibration check on 4 APR 2001
Field calibration check on 17 OCT 2001
Site removed 08 APR 2002 - last data collection at 15:00 GMT

SMOS E27, Earlsboro OK

Data available beginning on 2 MAY 2003 (no rain gage)
Rain gage installed 5 MAY 2003
Field calibration check on 15 MAY 2003
Field calibration check on 29 OCT 2003
Field calibration check on 28 APR 2004
Field calibration check on 27 SEP 2004
T-RH probe replaced on 8 DEC 2004
Field calibration check on 27 APR 2005

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance Documentation

See http://www.ops.sgp.arm.gov/pm_proc/smospm.htm.

7.4.3 Software Documentation

See http://science.arm.gov/tool/dod/showdod.php?Inst=smos.

7.4.4 Additional Documentation

7.5 Glossary

Barometric pressure - Local station pressure measured at the SMOS station at a height of 1 m.

Precipitation - All forms of water meteors.

Relative humidity - Percentage of saturated vapor pressure at the specified temperature.

Vector-averaged wind speed - Wind speed computed as the vector sum of the orthogonal u and v components, which are computed for each one-second sample of wind speed and direction. The wind directions reported by the SMOS are determined from the vector-averaged winds.

Wind Monitor - Trade name for R. M. Young propeller anemometer and wind vane.

Also see the ARM Glossary.

7.6 Acronyms

A/D: analog-to-digital converter
ARM: Atmospheric Radiation Measurement (Program)
DQA: Data Quality Assessment
RH: relative humidity
RMSE: root-mean-square error
SGP: Southern Great Plains
SMOS: Surface Meteorological Observation System
T/RH: Temperature/Relative Humidity

Also see the ARM Acronyms and Abbreviations.

7.7 Citable References

This section is not applicable to this instrument.