DOE/SC-ARM/TR-086

ARM Surface Meteorology Systems Handbook

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

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Tables

1. General Overview

The ARM Surface Meteorology Networks consists mainly of conventional *in situ* sensors that obtain a defined "core" set of measurements. The core set of measurements is: Barometric Pressure (kPa), Temperature (°C), Relative Humidity (%), Arithmetic Averaged Wind Speed (m/s), Vector Averaged Wind Speed (m/s), Vector Averaged Wind Direction (deg). The sensors that collect the core variables are mounted at the standard heights defined for each variable: Winds: 10 meters, Temperature and Relative Humidity: 2 meters, Barometric Pressure: 1 meter.

Depending upon the geographical location different models and types of sensors may be used to measure the core variables due to the conditions experienced at those locations. Most sites have additional sensors that measure other variables that are unique to that site or are well suited for the climate of the location but not at others. The following table lists the variables and the sensors by site.

Table 1. Caption

	Barometer	**Temp**	**Relative Humidity**	**Wind Speed**	**Wind Direction**	**Visibility & Present Weather**	**Liquid Precip**	**Frozen Precip**	**Temp & Dew Point**
SGP Met	Vaisala PTB220	Vaisala HMP45C	Vaisala HMP45C	RM Young 05103	RM Young 05103	N/A	NovaLynx TBRG	N/A	N/A
NSA Met	Vaisala PTB220	Vaisala HMT337	Vaisala HMT337	Vaisala Ultrasonic WS525	Vaisala Ultrasonic WS425	Vaisala FD12P PWS	Vaisala FD12P PWS	Vaisala FD12P PWS	TSL 1088 CMH
TWP Met	Vaisala PTB220	Vaisala HMP45D	Vaisala HMP45D	RM Young 05106	RM Young 05106	N/A	Optical Sci ORG 815 & RIMCO 7499 TBRG	N/A	N/A
AMF Met	Vaisala PTB220	Vaisala HMP45D	Vaisala HMP45D	RM Young 05106	RM Young 05106	Vaisala PWD22	Vaisala PWD22 & Optical Sci ORG 815	Vaisala PWD22	N/A

Additionally, the North Slope of Alaska surface meteorology systems are collected from towers. The tower at Barrow has 4 levels and the tower at Atqasuk has 2 levels. Two additional data streams are created using the sensors on the different levels of the towers. The datastreams are arrays with the first value for each variable being the lowest level. The following table describes the variables in the tower data streams.

Table 2. Caption

	Temp	**RH**	**WS**	**WD**
NSATWRC1	2, 10, 20 40m	2, 10, 20, 40m	2, 10, 20, 40m	2, 10, 20, 40m
NSATWRC2	2m & 5m	2m & 5m	N/A in Met data	N/A in Met data

2. Contacts

2.1 Mentor

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2.2 Instrument Manfacturer

Data loggers (CR10, CR10X, CR1000, CR23X, CR3000)
Campbell Scientific Inc.
815 W. 1800 N.
Logan, UT 84321
Phone: (801) 753-2342
Fax: (801) 750-9540
Website: http://www.campbellsci.com

Aspirated 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
Website: http://www.youngusa.com/

Present Weather Sensor (PWS), Present Weather Detector (PWD), Ultrasonic Wind Sensor, Barometer and Temperature/Relative Humidity Probe,
Vaisala
100 Commerce Way
Woburn, MA 01801-1068
Phone: (617) 933-4500
Fax: (617) 933-8029
Website: http://www.vaisala.com

Tipping Bucket Raingauge for Southern Great Plains (SGP TBRG)
NovaLynx Corporation
PO Box 240
Grass Valley, CA 95945-0240
Phone: (530) 823-7185
USA Toll Free: (800) 321-3577
Fax: (530) 823-8997
Web: http://www.novalynx.com

Optical Raingauge (ORG)
Optical Scientific, Inc.
205 Perry Parkway, Suite 14
Gaithsburg, MD 20877-2141
Phone: 301-948-6070
Fax: 301-948-4674

Tipping Bucket Raingauge for Tropical Western Pacific sites (TWP TBRG)
McVan Instruments
58 Geddes Street
PO Box 298, Mulgrave
Victoria, Australia, 3170
Phone: (+61-3) 9582-7333
Fax: (+61-3) 9560-1164
Web page: http://www.mcvan.com

Chilled-Mirror Hygrometer for the North Slope of Alaska (NSA CMH)
Technical Services Laboratory, Inc.
95 Ready Ave.
Fort Walton Beach, FL 32548
Phone: 850-243-3722

Fiber Driver
Allied Telesys
19800 North Creek Parkway, Suite 200
Bothell, WA 98011
Phone: 425-487-8880
Fax: 425-489-9191
Toll-free: 1-800-424-6596 (US only)
Web page: http://alliedtelesyn.com

3. Deployment Locations and History

Table 3. SGP Deployment History

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

Table 3. (cont'd)

Location	Date Installed	Date Removed	Status
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	Decommisioned
E27-Earlsboro, OK	2002/05/02		Operational

Table 4. TWP Deployment History

Location	Date Installed	Date LoggerNet Upgrade	Date Removed	Status
TWP C1 Manus	10/1996	08/2004		Operational
TWP C2 Nauru	11/1998	07/2004		Operational
TWP C3 Darwin	04/2002	05/2004		Operational

Table 5 contains the additional column of "Date LoggerNet Upgrade". On this date major changes to the way the data were collected were made which included adding new variables and removing others.

Table 5. NSA Deployment History

Location	Date Installed	Date LoggerNet Upgrade	Date T/RH and Ultrasonic Upgrade	Date Removed	Status
NSA C1 Barrow, AK	03/1998	10/2003	09/2008		Operational
NSA C2 Atqasuk, AK	07/2000	10/2003	09/2008		Operational

Table 6 contains two additional columns of "Date LoggerNet Upgrade" and "Date T/RH and Ultrasonic Upgrade". Major changes to the way the data were collected, which included adding new variables and removing others, occurred on these dates. In the case of the Date of LoggerNet Upgrade, some sensors were removed altogether. At NSAC1 the Optical Raingauge was removed and one that measured every minute replaced the CMH that measured once every 15 minutes. At NSAC2 the ultrasonic snow depth sensor was removed.

Table 6. AMF1 Deployment Locations and History

Location	Start Date	End Date	Sensors Deployed
Pt. Reyes, Ca (PYE M1)	02/01/2005	09/15/2005	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge
Niamey, Niger (NIM M1)	01/05/2006	01/07/2007	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge, PWD-22 Present Weather Detector
Niger Ancillary Site (Bazimboubou, Niger) (NIM S1)	01/05/2006	12/08/2006	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge,
Hasselbach, Germany (FKB M1)	04/02/2007	01/01/2008	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge, PWD-22 Present Weather Detector
Shouxian, China (HFE M1)	05/2008	12/2008	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge, PWD-22 Present Weather Detector
China Ancillary Site (Taihu, China) (HFE S1)	05/2008	12/2008	HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge,
Graciosa, Azores	05/2009		HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge, PWD-22 Present Weather Detector

Table 6 contains the additional column for “Sensors Deployed”. This is a result of the fact that the AMF has an ancillary site that is deployable in case the main site does not have an optimal location. The ancillary site typically does not have all the same sensors and so the variables are different. Additionally, given the climate of the region certain sensors may not be useful. For example, the ORG should not be used for frozen precipitation measurements and will be removed from the instrument list during arctic deployments.

4. Near-Real-Time Data Plots

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

http://www.arm.gov/data/data_plots.stm

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

The following links lead to tables that list the information for the primary variables, their long names, units, measurement level and interval and resolution. Primary Variables are different than the “Core” variables in that they are all the variables measured at the given location from all the meteorological

system sensors. For example, the SGP MET "Core" variables are Barometric Pressure (kPa), Temperature (˚C), Relative Humidity (%), Arithmetic Averaged Wind Speed (m/s), Vector Averaged Wind Speed (m/s), Vector Averaged Wind Direction (deg). The SGP Primary Variables also contain the precipitation measured form the tipping bucket raingage and a corrected precipitation measurement and the calculated vapor pressure.

- SGP MET Primary Variables
- NSA MET Primary Variables
- NSA TWR C1 Primary Variables
- NSA TWR C2 Primary Variables
- TWP MET Prmary Variables
- AMF MET Primary Variables
  - Point Reyes, California
  - Niamey, Niger
  - Niger Ancillary Site (Bizamboubou, Niger)
  - Hasselback, Germany
  - Shouxian China,
  - China Ancillary Site (Taihu, China)
  - Graciosa, Azores

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 the ARM surface meteorology systems.

5.1.3 Diagnostic Variables

Diagnostic variables are typically variables that don't have a scientific value but instead allow for determination of the proper function of the sensors and system components. For example, Battery Voltage, Error Codes and standard deviations of the Primary Variables are contained in these tables.

- SGP MET Diagnostic Variables
- NSA MET Diagnostic Variables
- NSA TWR C1 Diagnostic Variables
- NSA TWR C2 Diagnostic Variables
- TWP MET Diagnostic Variables
- AMF MET Diagnostic Variables
  - Point Reyes, California
  - Niamey, Niger
  - Niger Ancillary Site (Bizamboubou, Niger)
  - Hasselback, Germany
  - Shouxian China
  - China Ancillary Site (Taihu, China)
  - Graciosa, Azores

5.1.4 Data Quality Flags

Data Quality Flags are additional variables inserted into the datastream during routine collection and ingest. These variables are a flag to assist in the checking the quality of the data collected. The following tables lis the maximum, minimum and delta values for each variable that will cause the QC variable to be set.

- SGP MET Data Quality Flags
- NSA MET Data Quality Flags
- NSA TWR C1 Data Quality Flags
- NSA TWR C2 Data Quality Flags
- TWP MET Data Quality Flags
- AMF MET Data Quality Flags
  - Point Reyes, California
  - Niamey, Niger
  - Niger Ancillary Site (Bizamboubou, Niger)
  - Hasselback, Germany

- Shouxian China
- China Ancillary Site (Taihu, China)
- Graciosa, Azores

5.1.5 Dimension Variables

The dimension variables are the same for all datastreams regardless of site.

Table 7. Dimension Variables

Variable	Measurement Interval	Unit
base_time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
time_offset	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
lat	1 min	degrees
lon	1 min	degrees
alt	1 min	meters above sea level

NOTE: lat/lon/alt refers to the ground where the instrument is sited, NOT the height of the sensor. The Dimension Variables are not separated out by site since these are common to all locations.

5.2 Annotated Examples

None.

5.3 User Notes and Known Problems

This section contains detailed information about known problems and issues with the sensors or system that may be of importance to the end data user. Examples of data during problems and data plots are sometimes included in order to better explain the problem. In most cases, the known problems are cases of poor data that occur due to routine maintenance, self-cleaning by sensors, etc that affect the data quality.

- SGP MET User Notes and Known Problems
- NSA MET & TWR User Notes and Known Problems
- TWP MET User Notes and Known Problems
- AMF MET User Notes and Known Problems

5.4 Frequently Asked Questions

- SGP MET FAQs
- NSA MET & TWR FAQs

- TWP MET FAQs
- AMF MET FAQs

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

The Data Quality Office sends out weekly reports on each system on a weekly basis. These reports are viewed by the mentor. Any issues requiring mentor intervention or actions are handled at this time. Mentor Reports that include the Data Quality Office reports and spot chekcing of all systems are created monthly.

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 Atmospheric Radiation Measurement (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 to fill unmet measurement needs, but 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. Instead, a QME adds value to the input data streams 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 at http://www.arm.gov/data/vaps.stm.

7. Instrument Details

The following detailed information about the instrument can be viewed by clicking on the appropiate link for each indivisual system.

7.1.1 Detailed Description

7.1.1.1 List of Components

7.1.1.2 System Configuration and Measurement Methods

7.1.1.3 Specifications

7.1.2 Theory of Operation

7.1.3 Calibration

7.1.3.1 Theory

7.1.3.2 Procedures

- SGP MET Instrument Details
- NSA MET & TWR Instrument Details
- TWP MET Instument Details
- AMF MET Instrument Details

7.2 Operation and Maintenance

7.2.1 User Manual

Users can click on the following links in order to view the very detailed Users Manual for each system. These users manual contain information wuch as wiring diagrams, calibration procedures, daily and weekly checks. Examples of the program that resides on the data logger and set up procedures are also located here.

- SGP MET Users Manual
- NSA MET & TWR Users Manual
- TWP MET Users Manual
- AMF MET Users Manual

7.2.2 Software Documentation

ARM netCDF file header descriptions may be found for each of the systems can be found by following the links below

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

http://science.arm.gov/tool/dod/showdod.php?Inst=NSAMET
http://science.arm.gov/tool/dod/showdod.php?Inst=NSATWR
http://science.arm.gov/tool/dod/showdod.php?Inst=TWPMET
http://science.arm.gov/tool/dod/showdod.php?Inst=AMFMET

7.2.3 Additional Documentation

This section is not applicable to this instrument.

7.3 Glossary

Barometric pressure: Local station pressure measured at station at a height of 1 m.

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 that are computed for each sample of wind speed and direction. The wind directions reported are determined from the vector-averaged winds.

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

See the ARM Glossary at http://www.arm.gov/about/glossary.stm.

7.4 Acronyms

AC	alternating current
A/D	Analog to Digital converter
CMH	chilled mirror hygrometer
DQA	Data Quality Assessment
DQO	Data Quality Office
NIST	National Institute of Standards and Technology
QME	Quality Measurement Experiment
RH	Relative Humidity
rms	root mean square
SGP	Southern Great Plains
T/RH	temperature/relative humidity (sensor)
VAP	value-added product
TBRG	tipping bucket rain gage
ORG	optical rain gage
PWD	Present Weather Detector
PWS	Present Weather Sensor

Also see the ARM Acronyms and Abbreviations at http://www.arm.gov/about/acronyms.stm.

7.5 Citable References

None.