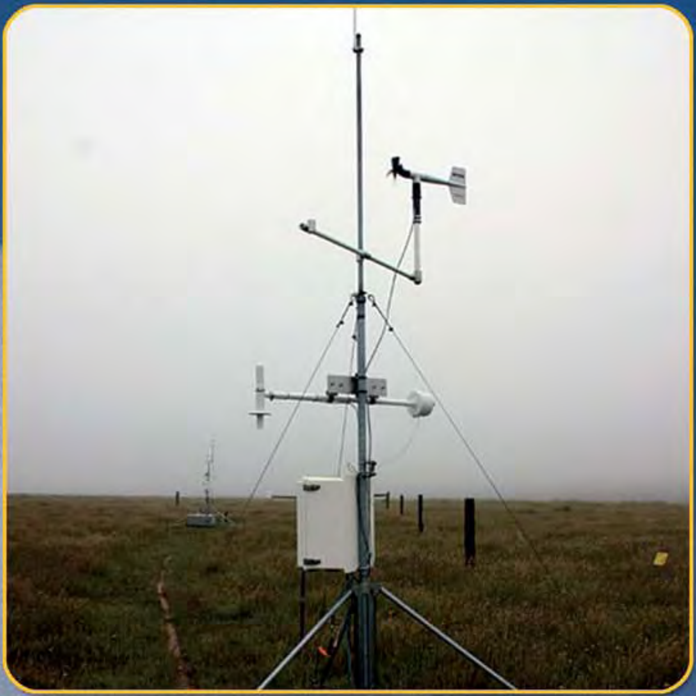
ARM Mobile Facility Surface Meteorology Handbook



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Atmospheric Radiation Measurement

Climate Research Facility

U.S. Department of Energy

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ARM Mobile Facility Surface Meteorology (MET) Handbook

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Contents

Tables

1. General Overview

The Atmospheric Radiation Measurement (ARM) Mobile Facility Surface Meteorology station (MET) uses mainly conventional in situ sensors to obtain 1-min statistics of surface wind speed, wind direction, air temperature, relative humidity (RH), barometric pressure, and rainrate. Additional sensors may be added to or removed from the base set of sensors depending upon the deployment location, climate regime, or programmatic needs. In addition, sensor types may change depending upon the climate regime of the deployment. These changes/additions are noted in Section 3.

2. Contacts

2.1 Mentor

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2.2 Instrument Developer

Data Logger
Campbell Scientific Inc.
815 W. 1800 N.
Logan, UT 84321
Phone: 801-753-2342
Fax: 801-750-9540
Web page: http://www.campbellsci.com

Wind Monitor & Aspirated Radiation Shield
R.M. Young Company
2801 Aero Park Drive
Traverse City, MI 49686
Phone: 231-946-3980
Fax: 231-946-4772
Web page: http://www.youngusa.com/

Temperature-Relative Humidity (T-RH) Probe, Digital Barometer & Present Weather Detector
Vaisala
100 Commerce Way
Woburn, MA 01801-1068
Phone: 617-933-4500
Fax: 617-933-8029
Web page: http://www.vaisala.com

Rain Gauge
Optical Scientific, Inc.
205 Perry Parkway, Suite 14
Gaithsburg, MD 20877-2141
Phone: 301-948-6070
Fax: 301-948-4674

3. Deployment Locations and History

Table 1 shows the locations of the MET and sensors used.

Table 1. Locations and Sensors

Location	Start Date	End Date	Sensors
Point Reyes, CA	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	01/05/2006		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)	01/05/2006		HMP-45D T/RH probe, 05106 Wind Monitor, PTB-220 Barometer, 815 and 115 Optical Rain Gauge

4. Near-Real-Time Data Plots

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

- http://www.arm.gov/sites/amf/niamey/nimdataplots.stm

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

- Point Reyes, California, Primary Variables
- Niamey, Niger, Primary Variables
- Niger Ancillary Site (Bizamboubou, Niger) Primary Variables

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

- Point Reyes, California, Diagnostic Variables
- Niamey, Niger, Diagnostic Variables
- Niger Ancillary Site (Bizamboubou, Niger) Diagnostic Variables

5.1.4 Data Quality Flags

- Point Reyes, California, Quality Control Variables
- Niamey, Niger, Quality Control Variables
- Niger Ancillary Site (Bizamboubou, Niger) Quality Control Variables

5.1.5 Dimension Variables

- Point Reyes, California, Dimension Variables
- Niamey, Niger, Dimension Variables
- Niger Ancillary Site (Bizamboubou, Niger) Dimension Variables

5.2 Annotated Examples

This section is not applicable to this instrument.

5.3 User Notes and Known Problems

Incorrectly Listed Units for Vapor Pressure in Data Object Design

The Data Object Design incorrectly listed the units of hPa for Vapor Pressure. When the new collection system was installed at each site (see Table 1), the units were actually reported in kPa.

Naming Convention of the Wind Monitor During the Point Reyes Deployment

The program was adapted from the Tropical Western Pacific (TWP) MET system. These surface meteorology systems have two wind monitors. Therefore, the naming convention of the two wind monitors (upper and lower) was kept during this deployment. All wind variables that are preceded with an "up" are where the data from the single wind monitor were stored. All wind variables that are preceded with a "lo" were filled with -9999 indicating that the data are missing. In subsequent deployments, the program was changed to reflect that there is only one wind sensor.

5.4 Frequently Asked Questions

This section is not applicable to this instrument.

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 Instrument Mentor (Michael Ritsche) performs a number of tasks to ensure the quality of MET data. Data quality control (QC) procedures for this system are considered **mature**.

- **QC frequency**: Weekly
- **QC delay**: Real-time; weekly
- **QC type**: Min/max/delta flags; graphical plots; mentor reviews
- **Inputs**: Collected data
- **Outputs**: Monthly Mentor Reports, DQR, BCR, ECO, PIF, DQPR (as needed)
- **Reference**: None

Standard MET data are subject to several levels of QC and quality assurance. When the data are collected, each variable has various automated QC checks that look for values outside defined max/min/delta. Any variable outside these parameters is flagged in the QC variable. The mentor receives weekly reports, called Data Quality Assessment Reports (DQARs), from the DQ Office and reviews them for problems. Any problems listed in the weekly DQARs are checked and spot checks are also performed to verify that the DQARs are accurate.

6.3 Data Assessments by Site Scientist/Data Quality Office

The ARM Data Quality Office uses the Data Quality Assessment 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 DQ Problem reports tool to initiate and track the problem resolution process. Weekly reports are sent to the mentor describing errors noticed, quality flags that were tripped, and any other issues that the DQ office feels might affect data quality.

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 (VAPs). Despite extensive instrumentation deployed at the ARM Climate Research Facility (ACRF) 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 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.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Wind speed and direction sensors: A propeller anemometer and wind vane, R. M. Young Model 05106 Wind Monitor.

Temperature and relative humidity sensor: Platinum RTD and RH, Vaisala Model HMP45D T-RH Probe.

Barometric pressure sensor: Digital barometer, Vaisala Model PTB220.

Precipitation: Optical precipitation gauge, Optical Scientific, Inc. Model ORG-115-DA MiniOrg or ORG-815-DA MiniOrg.

Data logger: Campbell Scientific, Inc. Model CR23X.

7.1.2 System Configuration and Measurement Methods

The MET sensors are mounted on a 3-m mast, except for the Optical Rain Gauge.

The wind monitor propeller anemometer produces a magnetically controlled AC output whose frequencies are 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 3 m.

The T-RH probe 4-lead, platinum resistance thermometer 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. The T-RH probe is mounted in a naturally aspirated R. M. Young Model 41002 Gill Multi-plate Radiation Shield at a height of 2 m.

The barometric pressure sensor uses a silicon capacitive pressure sensor and is housed in an enclosure along with the data logger.

The optical precipitation gauge detects scintillation of an infrared beam caused by liquid water in the path. It is located near the tower. The following equations are used to convert the voltage signal to a rainrate.

For the ORG-815:

$$\text{Rainrate (mm/hr)} = (25*(V^{1.87}) - 0.15$$

For the ORG-115:

$$\text{Rainrate (mm/hr)} = (20*(V^{2}) - 0.05$$

The CR23X data logger measures each input once per second except for barometric pressure, which is measured once per minute, and logs 1-min averaged data. Vapor pressure is computed from the air temperature and RH. The data logger produces 1-min averages, minimums, maximums, and standard deviations of wind speed, air temperature, RH, and rainrate. It also produces 1-min vector-averaged wind speed and direction, a 1-min standard deviation of the wind direction computed by an algorithm, 1-min averages and standard deviations of vapor pressure, and a reading of the barometric pressure, logger panel temperature, and the internal supply voltage.

7.1.3 Specifications

Wind speed at 3 m: Precision: 0.01 m/s; Uncertainty: +/- 2%.

Wind direction at 3 m: Precision: 0.1 deg; Uncertainty: +/- 5 deg.

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 hPa; Uncertainty: +/- 0.15 hPa.

Precipitation: Precision: 0.1 mm/hr; Uncertainty: +/- 0.1 mm/hr.

Overall Uncertainties for Primary Quantities Measured

All MET uncertainty analyses are based on manufacturer's specifications. Manufacturers specify accuracies in several ways. Some give absolute range of error, some give uncertainties as defined above, while others give root mean square (rms) errors.

Data Acquisition Errors

The Campbell Scientific, Inc CR23X datalogger Analog to Digital converter (A-D) converter accuracy is +/- 0.025% FSR for 0 - 40°C, +/- 0.05% FSR - 25° to 50°C, +/- 0.075% FSR - 40° to 80°C. The clock accuracy is +/- 1 min per month - 25° to 50°C, +/- 2 min per month - 40° to 80°C. The LoggerNet software checks the clock of the logger once per day and adjusts it if it is off by more than 2 s. The computer continuously maintains time synchronization with a global positioning system (GPS)-based time reference using the NTPD protocol. The GPS-based reference is local to each site.

Wind Speed

The propeller of the wind monitor is accurate to +/- 2%. 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.

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. Sensor alignment to true north has been estimated 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 is specified as +/- 0.4°C 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

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

Error Source	Imprecision
Linearity	+/- 0.10 hPa
Hysteresis	+/- 0.03 hPa
Repeatability	+/- 0.03 hPa
Calibration Uncertainty	+/- 0.15 hPa
Temperature Dependence	+/- 0.1 hPa
Long-term Stability	+/- 0.1 hPa
Accuracy at + 20°C	+/- 0.20 hPa
Total Accuracy	**+/- 0.25 hPa**

Precipitation/Rainfall Rate

The Optical Rain Gauge has an uncertainty of +/- 0.1 mm/hr. The ORG always has a voltage level output. Programming allows the datalogger to disregard voltage values less than the threshold recommended by the manufacturer (85 mV). Since the ORG is sampled at 1Hz and the data are averaged to a minute, it is possible that rainrates as small as 0.002 mm/hr can be reported (0.1 mm/hr divided by 60 s).

7.2 Theory of Operation

Each of the primary measurements of wind speed, wind direction, air temperature, RH, barometric pressure, and rate of rainfall are intended to represent self-standing datastreams 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 in Section 7.1.2 but a 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 manufacturers can be contacted for further information.

7.3 Calibration

7.3.1 Theory

The MET is not calibrated as a system. The sensors and the data logger (which includes the A-D converter) are calibrated separately. All systems are installed using components that have a current calibration. Site personnel check the sensor and data logger calibrations in the field by comparison to calibrated references. Any sensor or data logger 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.

7.3.2 Procedures

Wind speed calibration is checked by rotating the propeller shaft at a series of fixed rpms 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 five degrees, one with a current calibration replaces the sensor. Air temperature and RH calibrations are checked by comparison with a reference Vaisala Model HMI31 Digital Relative Humidity and Temperature Meter and HMP35 Probe and a YSI 4600 Precision Thermometer. If the reported temperature and RH vary by more than the sensor uncertainty from the reference, one with a current calibration replaces the probe.

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, one with a current calibration replaces the sensor.

The data loggers are sent back to the manufacturer every two years for calibration checks on the internal clock, A-D converters, and the internal multiplexers. Removed units are replaced by loggers with a current calibration.

7.3.3 History

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 the following links:

- http://www.twppo.lanl.gov/internal/pages/operations_mobile_niger.html

7.4.3 Software Documentation

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

7.4.4 Additional Documentation

- http://www.twppo.lanl.gov/internal/pages/operations.html.

7.5 Glossary

Barometric pressure – Local station pressure measured at the 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 that are computed for each 1-s sample of wind speed and direction. The wind directions reported by the AMF 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

ARM	Atmospheric Radiation Measurement (Program)
A-D	Analog to Digital converter
DQAR	Data Quality Assessment Reports
DQ HandS	Data Quality Health and Status
GPS	global positioning system
MET	ARM Mobile Facility Surface Meteorology station
RH	relative humidity
rms	root mean square
RMSE	root-mean-square error
T-RH	temperature-relative humidity
TWP	Tropical Western Pacific
QC	quality control
QME	Quality Measurement Experiment

Also see the ARM Acronyms and Abbreviations.

7.7 Citable References

None.