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Precipitation Meteorological Instruments (PRECIPMET) Handbook

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ARM

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
DOE	U.S. Department of Energy
DQAR	Data Quality Assessment Report
DQR	Data Quality Report
IF	intermediate facility
MET	surface meteorological instrumentation
PARS2	laser disdrometer
PRECIPMET	precipitation meteorological instruments
PTU	pan and tilt unit
QC	quality checks
RC	resistor-capacitor
RWP	radar wind profiler
SGP	Southern Great Plains
TBRG	tipping bucket rain gauge

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1.0 General Overview

The PRECIPMET surface meteorology instrument system provides temperature, relative humidity, pressure, wind speed and direction, and precipitation data relevant to the precipitation network instruments: laser disdrometer (PARS2) and radar wind profiler (RWP). The PRECIPMET is installed at the intermediate facilities (IF) of the U.S. Department of Energy (DOE)'s Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) atmospheric observatory. The instrument system consists of a Vaisala WXT520 weather transmitter and a 12"-diameter Novalynx tipping bucket rain gauge (TBRG). The WXT520 is mounted on top of the control building at a height of approximately 4 meters. The tipping bucket is mounted on a pole level with the surrounding fencing (approximately 2 meters) to prevent physical interference with the gauge.

2.0 Contacts

2.1 Mentor

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2.2 Vendor/Instrument Developer

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3.0 Deployment Location and History

The PRECIPMET instruments are installed at sites where no surface meteorological data are collected. Their measurements are intended to be used as reference data for the co-located precipitation network instruments (PARS2 and RWP).

Table 1. Deployment location and history.

Parent Facility	Site	Start Date	End Date
SGP	I8	03/30/2017	present
SGP	I9	03/30/2017	present
SGP	I10	03/30/2017	present

4.0 Near-Real-Time Data

Near-real-time data can be found here: precipmet

5.0 Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

All variables in the PRECIPMET data files are level b1, indicating quality flags are applied to the data. All data are functions of time at 1-minute intervals. Uncertainty stated is defined by the manufacturer.

Table 2. PRECIPMET primary variables and uncertainty.

Data File Variable	Description	Unit	Uncertainty
temp_mean	Air temperature	°C	± 0.3°C at 20°C (see manual for extended temperature uncertainty graph)
rh_mean	Relative humidity	%	± 3% (from 0% to 90%) ± 5% (from 90% to 100%)
atmos_pressure	Atmospheric pressure	kPa	± 0.05 kPa from 0°C to 30°C
wspd_arith_mean	Wind speed, arithmetic mean	m/s	± 3% at 10 m/s

Data File Variable	Description	Unit	Uncertainty
wspd_vec_mean	Wind speed, vector mean	m/s	± 3% at 10 m/s
wdir_vec_mean	Wind direction, vector mean	degree	± 3°
wxt520_precip_rate_mean	WXT mean precipitation rate	mm/hr	± 5% (not including errors induced by wind)
wxt520_cumul_precip	WXT cumulative precipitation	mm	± 5% (not including errors induced by wind)
tbrg_precip_total	Tipping bucket rain gauge (TBRG) precipitation total	mm	± 1% at 1 to 3 in/hr ± 3% at 0 to 6 in/hr
tbrg_precip_total_corr	TBRG precipitation total, corrected	mm	Undefined; lab-measured correction

5.1.2 Secondary/Site-Specific Variables

Not applicable.

5.1.3 Diagnostic Variables

Diagnostic variables are recorded in the data files to help identify potential sensor problems.

Table 3. PRECIPMET diagnostic variables.

Data File Variable	Description	Unit
temp_std	Temperature standard deviation	°C
rh_std	Relative humidity standard deviation	%
wdir_vec_std	Wind direction, vector mean standard deviation	degrees
logger_volts	Logger voltage	V
logger_temp	Logger temperature	°C

5.1.4 Data Quality Flags

Data quality flag variables contain bit-packed representations of quality checks (QC) performed on the data. Each data quality flag variable is the primary data file variable name prepended with “qc”. The bit- packing representation, also described in the file header metadata, is as follows:

qc_bit_comment = "The QC field values are a bit-packed representation of true/false values for the tests that may have been performed. A QC value of zero means that none of the tests performed on the value failed." ;
:qc_bit_1_description = "Value is equal to missing_value." ;
:qc_bit_1_assessment = "Bad" ;
:qc_bit_2_description = "Value is less than the valid_min." ;
:qc_bit_2_assessment = "Bad" ;
:qc_bit_3_description = "Value is greater than the valid_max." ;
:qc_bit_3_assessment = "Bad" ;
:qc_bit_4_description = "Difference between current and previous values exceeds valid_delta." ;
:qc_bit_4_assessment = "Indeterminate" ;

Table 4. PRECIPMET QC variables and limits.

Data File Variable	Minimum	Maximum	Delta
qc_temp_mean	-40°C	50°C	20°C
qc_rh_mean	-2 %	104 %	30 %
qc_atmos_pressure	80 kPa	110 kPa	1 kPa
qc_wspd_arith_mean	0 m/s	60 m/s	20 m/s
qc_wspd_vec_mean	0 m/s	60 m/s	20 m/s
qc_wdir_vec_mean	0°	360°	n/a
qc_wxt520_precip_rate_mean	0 mm/hr	200 mm/hr	n/a
qc_wxt520_cumul_precip	0 mm	100 mm	n/a
qc_tbrg_precip_total	0 mm	10 mm	n/a
qc_logger_volt	10 V	15 V	5 V
qc_logger_temp	-25°C	50°C	10°C

5.1.5 Dimension Variables

All PRECIPMET variables are dimensioned by time at 1-minute intervals.

5.2 Annotated Examples

Not applicable.

5.3 User Notes and Known Problems

Wind measurements occasionally drop out in times of snow due to transducer blockage.

There is evidence that the sensor under-reports very light rain when compared with nearby precipitation instruments. The manufacturer confirms that this is due to sensor mechanics. The sensor plate requires precipitation to be falling at terminal velocity to register, and light rain often does not reach terminal velocity.

5.4 Frequently Asked Questions

Q: Should the PRECIPMET be used for surface meteorological studies?

A: No. Primary support for surface meteorological data resides in the surface meteorological instrumentation (MET) datastream, though these instruments are not currently installed at IFs. The PRECIPMET data are intended to be used specifically for hyper-local meteorological data relevant to the precipitation network instruments. The siting of instruments may not be ideal and depends on physical limitations of each specific site.

Q: Which precipitation measurement in this datastream is most reliable?

A: The tipping bucket rain gauge will provide the most reliable precipitation data due to its mechanical tipping catchment. The WXT520 relies on an acoustic measurement principle that has been unreliable in light precipitation events.

6.0 Data Quality

6.1 Data Quality Health and Status

Information regarding data quality and instrument status can be found at http://dq.arm.gov.

6.2 Data Reviews by Instrument Mentor

The instrument mentor performs routine data checks to diagnose potential problems. If a problem is found, appropriate actions are taken to mitigate the issue, such as initiating instrument maintenance and filing of a Data Quality Report (DQR).

6.3 Data Assessments by Site Scientist/Data Quality Office

In addition to data reviews by the instrument mentor, the ARM Data Quality Office submits weekly Data Quality Assessment Reports (DQAR). DQARs are used as a tool to identify potential instrument and data flow problems, and to inform applicable personnel about the general quality of the data. These assessments include visual inspection of the data, and comparison with co-located instrument systems that measure similar variables.

6.4 Value-Added Products and Quality Measurement Experiments

ARM produces a number of value-added products (VAP) by performing additional analyses and processing on existing data products. More information about historical and existing VAPs can be found at https://dis.arm.gov/data/vaps.

7.0 Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Vaisala WXT520 weather transmitter

Novalynx 260-2500E-12 tipping bucket rain gauge

Campbell Scientific CR1000 data logger

7.1.2 System Configuration and Measurement Methods

The WXT520 sensor is mounted on top of a control building at an approximate height of 4 meters from the ground (see Figure 1). Due to site limitations, the mounting does not necessarily adhere to the manufacturer installation recommendations. Since the data are intended as reference for similarly mounted precipitation instrumentation, the effects are considered negligible.

The tipping bucket rain gauge is installed at the north-western corner of each IF to minimize physical interference from surrounding structures and situate it on the side of prevailing winds. The gauge is mounted within the chain link security fencing on a pole at a height of approximately 2 meters so that the top of the gauge funnel is level with the top rail of the fencing (see Figure 1).

Figure 1. PRECIPMET installation at IF.

7.1.3 Specifications

All instrument specifications are as stated by the respective manufacturer in the operation manuals.

WXT520 Specifications:

Temperature:
- Range (operation): -52°C to 60°C
- Range (storage): -60°C to 70°C
- Resolution: 0.1°C

Relative humidity:
- Range: 0% to 100%
- Resolution: 0.1 %

Pressure:
- Range: 600 hPa to 1100 hPa
- Resolution: 0.1 hPa

Wind speed:
- Range: 0 m/s to 60 m/s
- Resolution: 0.1 m/s
- Response time: 0.25 s

Wind direction:
- Range: 0° to 360°
- Resolution: 1°
- Response time: 0.25 s

Precipitation accumulation:
- Collection area: 60 cm^2
- Resolution: 0.01 mm

Precipitation intensity:
- Range: 0 to 200 mm/hr
- Response time: running one min average in 10s steps

Tipping Bucket Specifications:

Precipitation accumulation:
- Collection diameter: 12 inches
- Calibration: 1 tip = 0.01 inch of precipitation

7.2 Theory of Operation

7.2.1 WXT520

Pressure, temperature, and relative humidity measurements use a pan and tilt unit (PTU) module that contains Vaisala proprietary sensors. The PTU includes a capacitive silicon sensor, a capacitive ceramic sensor, and a capacitive thin film polymer sensor for measurement of pressure, temperature, and humidity, respectively. According to the manufacturer's manual, the measurement is based on an advanced resistor-capacitor (RC) oscillator, and capacitance of two reference capacitors is continuously measured. Temperature dependency of the pressure and humidity measurements is accounted for in the microprocessor.

Wind measurements use equally spaced ultrasonic transducers (in the same horizontal plane), and measure the transit time between each to determine speed and direction. According to the manufacturer's manual, the formula for calculating transit time is:

$$V_w = 0.5 \text{ x } L \text{ x } (1/t_f - 1/t_r)$$

Where:

V_w = wind speed

L = distance between two transducers

t_f = forward transit time

t_r = reverse transit time

Precipitation measurements use a steel cover and piezoelectric sensor to detect precipitation impact proportional to drop volume, which is then translated to rain amount. Filtering techniques attempt to eliminate noise from non-precipitation sources. Precipitation is operated in time mode; messages are sent at the designated output time (1 minute).

For the WXT520s that have heating enabled, the heating elements below the precipitation sensor and inside the ultrasonic transducers activate when the ambient temperature reaches 4°C.

7.2.2 Tipping Bucket Rain Gauge

The tipping bucket rain gauge uses a 12"-diameter catchment funnel that directs precipitation into the tipping bucket mechanism. This mechanism tips once the bucket fills with 0.254 mm of precipitation. A magnetic reed switch records a pulse output with each bucket tip. A thermostatic heater melts frozen precipitation that is then directed into the bucket.

7.3 Calibration

7.3.1 Theory

7.3.1.1 WXT520

The manufacturer provides no suggestion for a routine calibration interval, apart from replacing the PTU module every two years. Since this instrument is used as supplemental data to the precipitation network, is not research-grade by standard (larger uncertainties). The current calibration schedule is annual; wind data are verified to read zero, and replacement of the PTU module is performed.

7.3.1.2 Tipping Bucket Rain Gauge

The manufacturer provides no suggestion for a routine calibration interval, apart from frequent periodic maintenance allowing for less frequent calibration. The current calibration schedule is twice a year; a known amount of water is passed through the rain gauge and the number of tips are recorded. If the tip count is off, the bucket is adjusted and checked until the correct number of tips is achieved.

In addition to the field calibration, a laboratory-driven dynamic calibration is performed once annually in an effort to mitigate the underestimation of precipitation at high rain rates. First, pump output is measured at a series of known target precipitation rates. Then the gauge is calibrated using the same target rates from the pump calibration by measuring actual gauge output. These results are scatter-plotted (“real” pump versus “actual” gauge) and a best-fit equation is determined. The result is a correction equation (second-order polynomial) that is applied to the raw precipitation data and stored in the tbrg_precip_total_corr variable.

7.3.2 Procedures

Wind speed verification: A bag is placed over the ultrasonic transducers and the speed is verified to be 0 m/s. If this is not the case, the instrument will be replaced and sent to the manufacturer for evaluation.

PTU module replacement: The sensor is uninstalled from the control building mount. The old PTU module is removed using the fixing screws to open the sensor and access the module. The new module is inserted and the fixing screws reset. The sensor is reinstalled to the control building mount for operation.

Tipping bucket static calibration: Every 6 months, 500 mL of water is passed through the gauge and the number of tips are recorded. If the number of tips is not within 5% of the expected outcome, the tip screws are adjusted and the calibration is repeated until it is operating within the accepted uncertainty.

Tipping bucket dynamic calibration: Once a year, two calibrations are run: calibration of the pump, and calibration of the rain gauge. The pump calibration takes target (simulated) precipitation rates and measures actual pump output. The gauge calibration takes the same target precipitation rates from the pump calibration and measures actual gauge output. After both the pump and gauge calibrations are run for a series of target rates, the “real” (pump) and “actual” (gauge) rates are scatter-plotted (real versus actual). A regression line is fitted to the plotted data, and the equation of best-fit (second-order polynomial, intercept at 0) is determined. The best-fit equation is then used to correct the data within the logger program when the corresponding rain gauge is installed.

7.3.3 History

Please contact the instrument mentor for details regarding calibration records.

7.4 Operation and Maintenance

7.4.1 User Manual

In addition to the manufacturers' manuals, ARM maintains instrument user manuals for internal operational use. These manuals contain information specific to instrument installation and configuration, and are generally of no value to data users.

7.4.2 Routine and Corrective Maintenance Documentation

Preventative visual checks of the instrument and live data are performed daily. If a problem is noted, steps are taken to correct the issue. Any performed maintenance is documented using internal reporting forms. If data quality has been compromised, a DQR will be filed and supplied to the user with their order.

7.4.3 Software Documentation

Not applicable.

7.4.4 Additional Documentation

Vaisala WXT520 Weather Transmitter Manual

7.5 Glossary

ARM Glossary

7.6 Citable References

Vaisala. 2012. *USER'S GUIDE: Vaisala Weather Transmitter WXT520.* Helsinki, Finland: Vaisala Oyj.