DOE/SC-ARM-TR-143

AmeriFlux Measurement Component (AMC) Instrument Handbook

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Acronyms and Abbreviations

AC	alternating current
AMC	AmeriFlux Measurement Component
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement Climate Research Facility
ASCII	American Standard Code for Information Interchange
cm	centimeter
DC	direct current
DOE	U.S. Department of Energy
ft	foot
g	gram
LBNL	Lawrence Berkeley National Laboratory
mA	milliamperes
nm	nanometer
NSA	North Slope of Alaska
PAR	photosynthetically active radiation
QA	quality assurance
QC	quality control
VAC	volts, alternating current
VDC	volts, direct current
VWC	volumetric water content

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AmeriFlux Measurement Component (AMC)

2.0 Contacts

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For CS655 Soil Volumetric Water Content/Temperature Sensors and CS210 Relative Humidity/Air Temperature Sensors:

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For PQS-1 Photosynthetically Active Radiation (PAR) Sensors

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3.0 Instrument Description

An AMC system was installed at the U.S. Department of Energy (DOE)'s Atmospheric Radiation Measurement (ARM) Climate Research Facility North Slope of Alaska (NSA) Barrow site, also known as NSA C1 at the ARM Data Archive, in August 2012. A second AMC system was installed at the third ARM Mobile Facility deployment at Oliktok Point, also known as NSA M1.

This in situ system consists of 12 combination soil temperature and volumetric water content (VWC) reflectometers and one set of upwelling and downwelling photosynthetically active radiation (PAR) sensors, all deployed within the fetch of the Eddy Correlation Flux Measurement System. Soil temperature and VWC sensors placed at two depths (10 and 30 cm below the vegetation layer) at six locations (or microsites) allow soil property inhomogeneity to be monitored across a landscape.

The soil VWC and temperature sensors used at NSA C1 are the Campbell Scientific CS650L and the sensors at NSA M1 use the Campbell Scientific CS655. The two sensors are nearly identical in function, and vendor specifications are based on the CS650 unless otherwise stated.

4.0 Measurements Taken

Near-real-time plots at various time scales are available for the AMC system at the NSA C1 site via the ARM Data Quality Explorer plot browser at http://plot.dmf.arm.gov/plotbrowser/.

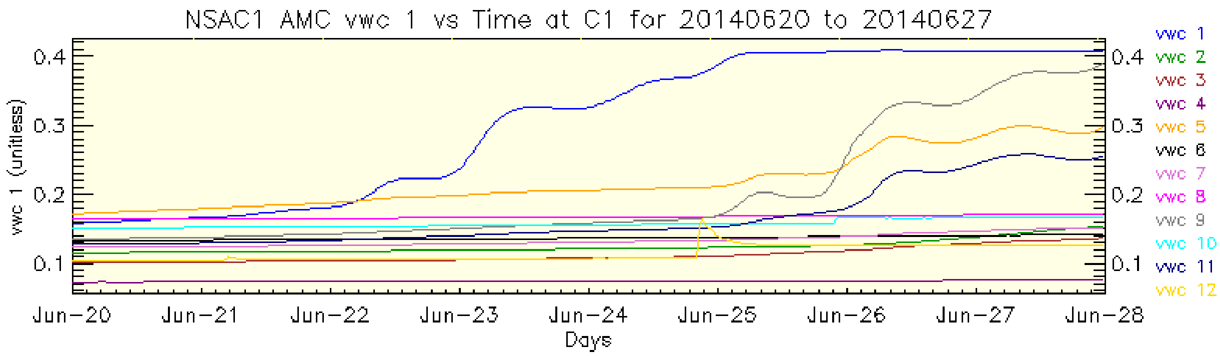

Figure 1. Sample plot showing VWC for all 12 sensors for 1 week of data.

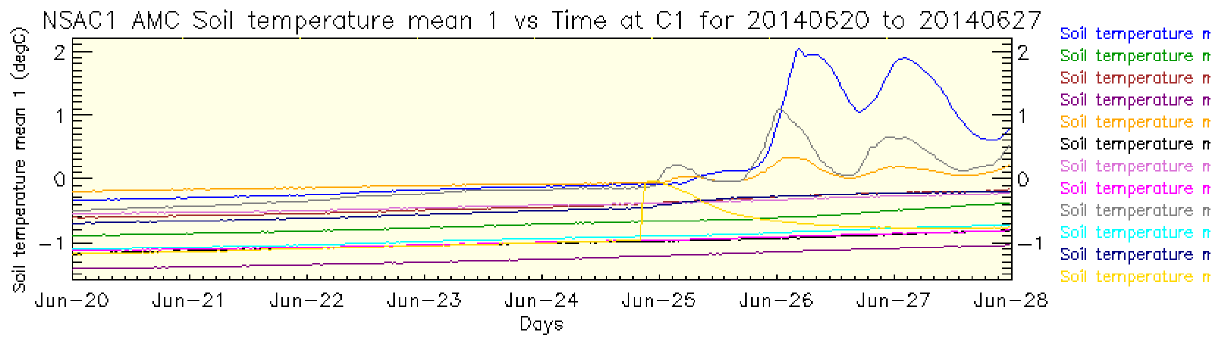

Figure 2. Sample plot showing soil temperature for all 12 sensors for 1 week of data.

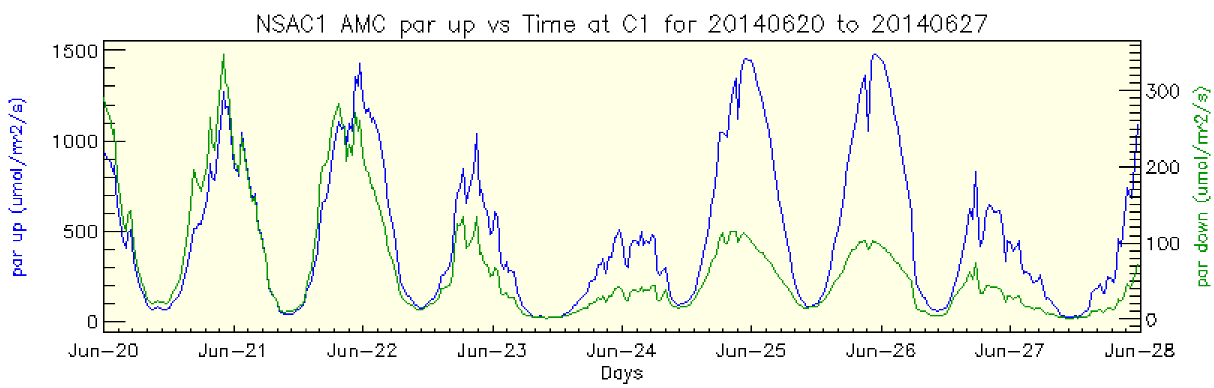

Figure 3. Sample plot showing PAR sensors for 1 week of data. The term "par_up" refers to the upward facing, downwelling radiation, while "par_down" is the downward facing, upwelling radiation.

Data also are available at research.dmf.arm.gov in netCDF format.

5.0 Links to Definitions and Relevant Information

The datastream specification described below is based on the Data Object Description developed for the M1 datastream.

5.1 Data Object Description

- qc_standars_version: 1.0
- sampling_interval: 5 minutes
- averaging_interval: 30 minutes
- averaging_interval_comment: The time assigned to each data point indicates the end of any period of averaging of the geophysical data
- sensor_height: Sensor heights above base altitude
- par: photosynthetically active radiation
- VWC: soil volumetric water content

5.2 Data Ordering

5.2.1 Primary Variables

30 minutes:

- vwc_1
- vwc_2
- vwc_3
- vwc_4
- vwc_5
- vwc_6
- vwc_7
- vwc_8
- vwc_9
- vwc_10
- vwc_11
- vwc_12
- soil_temp_1
- soil_temp_2

- soil_temp_3
- soil_temp_4
- soil_temp_5
- soil_temp_6
- soil_temp_7
- soil_temp_8
- soil_temp_9
- soil_temp_10
- soil_temp_11
- soil_temp_12
- par_up
- par_down.

5.2.2 Secondary/Underlying Variables Body Text

30 minutes:

- base_time
- time_offset
- time
- lat
- lon
- alt.

5.2.3 Diagnostic Variables

30 minutes

- logger_volt
- logger_panel_temp
- logger_enclosure_rh.

5.3 Data Plots

See Section 5.0 for time series of measurements of primary variables at NSA C1.

6.0 Data Quality

The b1 file contains data-quality flags for all variables. The variable statuses (i.e., bit values) are listed below:

- 0×0 = value is within specified range
- 0×1 = value is equal to “missing_value”
- 0×2 = value is less than “valid_min”
- 0×4 = value is greater than “valid_max”
- 0×8 = value failed the “valid_data” check

Standard deviations on the half-hour averages are reported for all primary variables (Section 6.2.1), as well as quality control (QC) on the standard deviations. Standard deviations that are ≥20% of the signal are considered large and will lead to questions about the 30-minute mean.

6.1 Instrument Mentor Monthly Summary

In addition to the ARM automated data-quality assessment system, the Lawrence Berkeley National Laboratory (LBNL) team produces a parallel automated data visualization and quality-checking system, which includes an automated data-quality checking routine that runs the following checks.

- Visual quality QC frequency: daily to weekly
- QC delay: 1 to 3 days
- QC type: Instrument mentor routinely views graphic displays of time series plots of daily, weekly, monthly, yearly, and total time scales. E-mails will be sent to the mentor and relevant parties for data-quality breaches.

6.2 Calibration Database

Current available calibration values are documented in the Calibration Database.

6.2.1 Calibration for PQS-1 PAR Sensors

Table 1. Calibration performed by the AmeriFlux QA/QC Laboratory for NSA M1 sensors.

Date	ARM Site	Sensor Number	Sensor Name	Calibration Coefficient ($\mu V\ \mu mol^{-1}\ m^2\ s$)
09/27/2013	NSA M1	130957	par_up	5.48
09/27/2013	NSA M1	130958	par_down	5.68

Table 2. Calibration performed by the Kipp & Zonen for NSA C1 sensors.

Date	ARM Site	Sensor Number	Sensor Name	Calibration Coefficient (µV µmol^{-1} m^2 s)
12/08/2012	NSA C1	100109	par_down	4.5
12/08/2012	NSA C1	100110	par_up	4.96

7.0 Technical Specification

The specification of each instrument is summarized based on the specification sheets provided by vendors, tests performed at LBNL, and calibrations performed by the AmeriFlux QA/QC Laboratory.

7.1 Units

- Logger battery voltage: volts
- Logger panel temperature: degrees Celsius
- Logger enclosure relative humidity: %
- Volumetric water content: (m^3/m^3) or %
- Soil temperature: degrees Celsius
- PAR sensors: µmol m^{-2} s^{-1}

7.2 Range

7.2.1 PS200 Logger Power Supply/Charge Regulator

7.2.1.1 Input

- AC input voltage: 14 to 24 VAC root mean square
- DC input voltage: 15 to 40 VDC

7.2.1.2 Output

- Measured output voltage: 13.84 ±0.01 VDC

7.2.2 CS210 Logger Enclosure Relative Humidity

- Measurement range: 0 to 100% noncondensing
- Operating temperature: 0°C to 50°C

7.2.3 CS650/CS655 Volumetric Water Content and Temperature

- VWC range: 5% to 50%

- Operational temperature range: −10 to +70°C

7.2.4 PQS-1 PAR Sensors

- Spectral range: (400 to 700) ±4 nm
- Operating temperature: −30°C to +70°C
- Relative humidity: 0% to 100%
- Typical values: 0 μmol m^{-2} s^{-1} to 2000 μmol m^{-2} s^{-1}

7.3 Accuracy

7.3.1 CS650/CS655 Volumetric Water Content

7.3.1.1 Vendor Specification

Accuracy according to Campbell Scientific: ±3% VWC typical in mineral soils where solution the electrical conductivity is ≤10 dS/m. Accuracy specifications are based on Campbell Scientific laboratory measurements in a series of solutions with dielectric permittivity ranging from 1 to 81 and solution electrical conductivities ranging from 0 to 3 dS/m.

7.3.1.2 LBNL Tests

Accuracy according to LBNL test of CS650L sensors: ±5% based on comparison of average of 12 sensors with gravimetric water content of subsamples of measured soils.

7.3.2 CS650/CS655 Temperature

Accuracy: ±0.5°C for probe body buried in soil.

7.3.3 PQS-1 PAR

Accuracy: N/A (there is currently no International Organization for Standardization standard).

7.4 Repeatability

7.4.1 CS650/CS655 Volumetric Water Content

- Precision: <0.05%.

Precision is determined for the CS650 by taking repeated measurements in the same material. The precision of the CS650 is better than 0.05% VWC and 0.01 dS/m electrical conductivity.

7.4.2 CS650/CS655 Temperature

Precision: ±0.02°C.

7.4.3 PQS-1 PAR

Precision reported from calibration performed by AmeriFlux QA/QC Laboratory on September 27, 2013. This number can change slightly with each calibration.

- 1 standard deviation = 0.1 µV μmol^{-1} m^2 s.

7.5 Sensitivity

7.5.1 CS650/655 Volumetric Water Content and Temperature

We assume that the sensitivity is limited to the precision of each of the sensors; see Sections 7.4.1 and 7.4.2.

7.5.2 PAR

- Sensitivity: 4 to 10 µV μmol^{-1} m^2 s
- Sensitivity change over 1 year: <2%
- Temperature dependence: <−0.1%/°C
- Non-linearity: <1%

7.6 Uncertainty

See Sections 7.3 on accuracy and 7.4 on precision for instrument uncertainty.

Uncertainties in 30-minute-averaged measurements are based on the standard deviation of 1-minute measurements during each half hour.

7.7 Input Voltage

- CR1000 and CS650/CS655 sensors run off of the PS200 power supply output at 13.84 VDC.
- CS210 RH/temperature sensor uses the 5V output port at the CR1000.
- CS650/CS655 sensors use the SDI-12 interface, and can accept 6 to 18 VDC.
- PQS-1 PAR sensors are passive devices and require no input voltage.

7.8 Input Current

- CS210: <0.5 mA
- CS650/CS655: 45 mA at 12 VDC, 135 µA quiescent at 12 VDC

- PQS-1: <0.03 µA at peak sunlight

The entire system draws <100 mA at any given time.

7.9 Input Values

NA

7.10 Output Values

See Section 7.2 for the range of values output by each sensor type.

8.0 Instrument System Functional Diagram

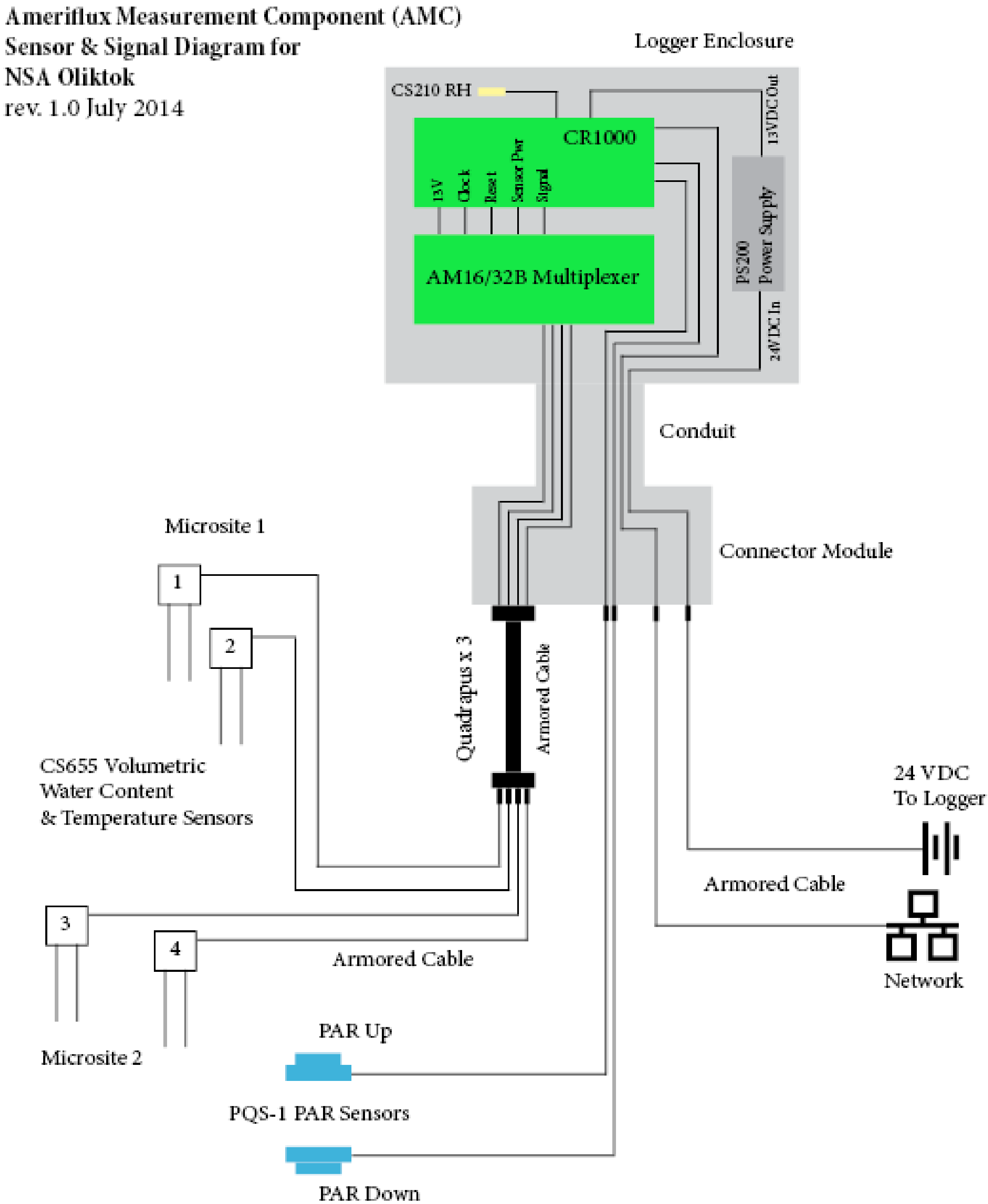

Figure 4. Signal diagram for AMC at NSA AMF3. Note that only 4 of 12 sensors are drawn, and only 1 of 3 “Quadrapus” cable adapters is drawn. The Quadrapus takes three CS655 cables with four-pin connectors and combines them to one 9-pin connector.

8.1 Instrument Wiring Diagrams

Table 3. CS655 VWC/temperature sensors.

CS655			Quadrapus				Connector Module		Logger Box	
Sensor Number	4-Pin Female		4-Pin Male		9-Pin Female		9-Pin Male Through-Wall		AM16/32B	
	Pin	Color	Pin	Color	Pin	Color	Pin	Color	CH	Function
1	1	Red	1	Red	1	Red	1	Red	1H	12 V
	2	Green	2	White	2	Green	2	Green	1L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
2	1	Red	1	Red	3	Red	3	Red	2H	12 V
	2	Green	2	White	4	Green	4	Green	2L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
3	1	Red	1	Red	5	Red	5	Red	3H	12 V
	2	Green	2	White	6	Green	6	Green	3L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
4	1	Red	1	Red	7	Red	7	Red	4H	12 V
	2	Green	2	White	8	Green	8	Green	4L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
5	1	Red	1	Red	1	Red	1	Red	5H	12 V
	2	Green	2	White	2	Green	2	Green	5L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
6	1	Red	1	Red	3	Red	3	Red	6H	12 V
	2	Green	2	White	4	Green	4	Green	6L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
7	1	Red	1	Red	5	Red	5	Red	7H	12 V
	2	Green	2	White	6	Green	6	Green	7L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
8	1	Red	1	Red	7	Red	7	Red	8H	12 V
	2	Green	2	White	8	Green	8	Green	8L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
9	1	Red	1	Red	1	Red	1	Red	9H	12 V
	2	Green	2	White	2	Green	2	Green	9L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
10	1	Red	1	Red	3	Red	3	Red	10H	12 V
	2	Green	2	White	4	Green	4	Green	10L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
11	1	Red	1	Red	5	Red	5	Red	11H	12 V
	2	Green	2	White	6	Green	6	Green	11L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground
12	1	Red	1	Red	7	Red	7	Red	12H	12 V
	2	Green	2	White	8	Green	8	Green	12L	Signal
	4	Black/Orange/ Shielded	4	Black	9	Black	9	Black	GND	Ground

Table 4. PQS-1 PAR sensors.

PQS-1			Connector Module		Logger Box	
	4-Pin Male		4-Pin Female Through-Wall		CR1000	
Sensor Number	PIN	Color	PIN	Color	CH	Function
130957	1	Red	1	Red	5H	Diff (+)
	2	Blue	2	Green	5L	Diff (-)
	4	Black	4	Black	G	Ground
130958	1	Red	1	Red	6H	Diff (+)
	2	Blue	2	Green	6L	Diff (-)
	4	Black	4	Black	G	Ground

Table 5. CS210 enclosure relative humidity sensor.

CS210	Logger Box	
In Logger Enclosure	CR1000	
Color	CH	Function
White	SE1	RH Signal
Clear	G	Ground
Black	5V	Power

Table 6. AM16/32B multiplexer.

Data Logger + Multiplexer Interface				
AM16/32B		CR1000		
CH	Function	Color	CH	Function
12 V	Multiplexer Power	Red	12 V	Power
G	Ground	Black	G	Ground
RES	Reset	Ground	C2	Reset For Multiplexer
CLK	Clock	White	C3	Clock For Multiplexer
COM ODD H	Sensor Power	Red	SW12	Switched 12 V
COM ODD L	Signal	White	C1	Control Port
COM G	Ground	Black	G	Ground

Table 7. System power.

System Power			Connector Module		Logger Box	
	4-Pin Female		4-Pin Male Through-Wall		PS200	
Power Supply	Pin	Color	Pin	Color	CH	Function
	1	NA	1	Red	CHG	24 VDC
	4	NA	4	Black	GND	Ground

9.0 Instrument/Measurement Theory

9.1 CS650/CS655 Water Content Reflectometer Method of Measuring Volumetric Water Content

Descriptions of this method were taken from Campbell Scientific *CS650 and CS655 Water Content Reflectometers Instruction Manual*.[1]

9.1.1 Description of Measurement Method

For the water content measurement, a differential emitter-coupled logic oscillator on the circuit board is connected to the two parallel stainless steel rods. The differentially driven rods form an open-ended transmission line in which the wave propagation velocity depends on the dielectric permittivity of the media surrounding the rods. An emitter-coupled logic oscillator state change is triggered by the return of a reflected signal from the end of one of the rods. The fundamental principle for the CS650 water content measurement is that the velocity of electromagnetic wave propagation along the probe rods depends on the dielectric permittivity of the material surrounding the rods. As water content increases, the propagation velocity decreases because of increasing dielectric permittivity. Therefore, the two-way travel time of the rod signal depends on water content; hence, the name water content reflectometer. Digital circuitry scales the high-speed oscillator output to an appropriate frequency for measurement by an onboard microprocessor. Increases in oscillation period resulting from signal attenuation are corrected using an electrical conductivity measurement. A calibration equation converts period and electrical conductivity to bulk dielectric permittivity. The Topp equation is used to convert from permittivity to VWC.

9.1.2 The Topp Equation

The relationship between dielectric permittivity and VWC in mineral soils was described by Topp et al. (1980) in an empirical fashion using a third-degree polynomial. With θ_v the VWC and Ka the bulk dielectric permittivity of the soil, the equation presented by Topp et al. is:

$$\theta_v = -5.3 \times 10^{-2} + 2.923 \times 10^{-2} K_a - 5.53 \times 10^{-4} K_a^2 + 4.33 \times 10^{-6} K_a^3$$

It has been shown in numerous research efforts that this equation works well in most mineral soils, so a soil-specific calibration of the CS650 probe is usually not necessary. If a soil-specific calibration is desired, the user can generate an equation relating K_a to θ_v following the methods described in Section 8 in the Campbell Scientific *CS650 and CS655 Water Content Reflectometers Instruction Manual*.

[1] Available at http://s.campbellsci.com/documents/au/manuals/cs650.pdf.

9.1.3 Electrical Conductivity

9.1.3.1 Soil Electrical Conductivity

The quality of soil water measurements, which apply electromagnetic fields to wave guides, is affected by soil electrical conductivity. The propagation of electromagnetic fields in the configuration of the CS650 instrument is predominantly affected by changing dielectric permittivity in response to changing water content, but it is also affected by electrical conductivity. Free ions in soil solution provide electrical conduction paths that result in attenuation of the signal applied to the waveguides. This attenuation reduces both the amplitude of the high-frequency signal on the probe rods and the bandwidth. The attenuation reduces oscillation frequency at a given water content because it takes longer to reach the oscillator trip threshold.

It is important to distinguish between soil bulk electrical conductivity and soil solution electrical conductivity. Soil solution electrical conductivity refers to the conductivity of the solution phase of soil. Soil solution electrical conductivity, $\sigma_{solution}$, can be determined in the laboratory using extraction methods to separate the solution from the solid and then measuring the electrical conductivity of the extracted solution.

The relationship between solution and bulk electrical conductivity can be described as follows (Rhoades et al. 1976):

$$\sigma_{bulk} = \sigma_{solution}\, \theta_V T + \sigma_{solid}$$

where σ_{bulk} is the electrical conductivity of the bulk soil, $\sigma_{solution}$ is the soil solution, σ_{solid} is the solid constituents, θ_v is the VWC, and T is a soil-specific transmission coefficient intended to account for the tortuosity of the flow path as water content changes. Rhoades et al. (1989) published a form of this equation that accounts for both mobile and immobile water. This publication also discusses soil properties such as clay content and compaction related to operation of the CS650 instrument. The above equation is presented here to show the relationship between soil solution electrical conductivity and soil bulk electrical conductivity.

Most expressions of soil electrical conductivity are given in terms of solution conductivity or electrical conductivity from extract because it is constant for a soil. Bulk electrical conductivity increases with water content so comparison of the electrical conductivity of different soils must be at the same water content.

The calibration equation in the CS650 firmware corrects the oscillation frequency for the effects of $\sigma_{solution}$ up to 3 dS/m for the CS650 instrument and up to 10 dS/m for the CS655 instrument. This is equivalent to σ_{bulk} values of approximately 0.8 dS/m and 2.7 dS/m, respectively. If σ_{bulk} exceeds these limits, the CS650 probe will return 99999 for dielectric permittivity and VWC. The measured period average and voltage ratio values will continue to be reported even if the bulk electrical conductivity is outside the operational range of the probe.

9.1.3.2 Temperature Correction of Soil Electrical Conductivity

The value reported by the CS650 is bulk electrical conductivity. This value is temperature dependent, changing by 2% per degree Celsius. To compensate for the effect of temperature, electrical conductivity readings may be converted to a standard temperature, such as 25°C, using the following equation:

$$EC_{25} = EC_T \div (1 + 0.023 \times (T_{soil} - 25)$$

where EC_{25} is the σ_{bulk} value at 25°C and EC_T is the σ_{bulk} value at soil temperature T_{soil} (°C).

9.2 PQS-1 PAR Quantum Sensor

Irradiance is calculated using the output voltage values from the sensor.

$$E = U/S$$

where irradiance E (µmol/m^2/s) is the ratio of output voltage U (µV) read by the data logger and sensitivity S (µV/µmol/m^2/s) determined by the calibration of each sensor.

10.0 Setup and Operation of Instrument

10.1 Logger Mount Assembly at NSA C1

The data logger mount assembly at NSA C1 is made of aluminum strut to house the stainless steel data logger box for the CR1000. The mount assembly is placed on a wooden pallet. Because of the weight of the data logger box and mount assembly combined, it was decided that anchoring the mount into the ground was not necessary. All CS650L sensor cables, PAR sensors, and power/Ethernet cables connect to the logger box. The PAR sensor horizontal arm is mounted on one of the vertical legs of the mount assembly.

10.2 Tripod at AMF3

The CR1000 data logger is housed in a modified enclosure that has a separate attached connector module. Modified areas are sealed with silicone glue. The logger and connector module are mounted vertically on the main mast of the tripod. The tripod legs are anchored to the permafrost level, which is <30 cm below the surface. The PAR sensor horizontal arm is mounted near the top of the main mast of the tripod.

10.3 Cable Armoring

10.3.1 NSA C1

Pairs of CS650L 150-ft cables were housed in 50-ft sections of ballistic nylon. Because the armor is shorter than the cable length, adjacent sections overlap by 1 to 3 ft.

10.3.2 NSA AMF3

Each 50-ft sensor cable is wrapped in stainless steel cable armor and sealed with electrical tape at each end.

10.4 CS650/CS655 Sensor Installation

The sensors are installed horizontally, parallel to the earth surface, and underground. There are two sensors at each microsite, and a single pit is dug to place sensors at two depths. Pits 40 cm long by 15 cm wide by 33 cm deep are cut, and the earth is removed with care to maintain the shape and depth. The deeper sensor prongs are inserted horizontally along the long axis of the pit into the wall of the pit. Soil is replaced over the sensor until the depth of the shallower sensor is installed in the same way.

10.5 PQS-1 PAR Sensor Installation

Upward-facing and downward-facing sensors are identical models. Each sensor is mounted to an aluminum block that is mounted to the horizontal arm, which in turn is mounted to the tripod (AMF3) or logger mount assembly (NSA C1). The sensor cables are strain relieved with zip ties or clamps along the arm all the way to the logger box.

The sensor arm is pointed directly south and in a location that is at least 10 times the distance of the height of the nearest obstruction. The level bubble for the upward-facing sensor is used to level both sensors.

11.0 Software

11.1 LoggerNet

Supplied by Campbell Scientific, LoggerNet is the main software used for control and communication of the CR1000 data logger. LoggerNet runs on a Microsoft Windows-based operating system, and is configured to collect data from the logger at regular intervals and save it on the local machine. Applications within LoggerNet that frequently are used include:

- *Connect*: This application is used to connect to the logger, and view real-time data tables and plots.
- *Program*: The loggers are programmed using CRBasic code, and the codes are edited using the CRBasic Editor.
- *Device Configurator*: This application is used to set the Internet Protocol address of the logger for use with the NL120 Ethernet adapter so that a wired connection can be made between the computer and data logger.

A single instance of LoggerNet can manage connections and configurations for multiple loggers in the field. This is the case for the AMC loggers at each of the sites, where other Campbell Scientific systems are managed in the field alongside the AMC system.

11.2 CR1000 Program

Written in CRBasic (based on Visual Basic), the script is uploaded and compiled on the CR1000 itself. The script is used to read and control the input/output ports on the logger, perform calculations such as averaging and other statistics, and to produce American Standard Code for Information Interchange (ASCII)-format data files at specified intervals. The CR1000 programs used at each of the sites are available by contacting the instrument mentor.

12.0 Calibration

12.1 CS650/CS655 Volumetric Water Content and Temperature

This description is excerpted from the Campbell Scientific *CS650 and CS655 Water Content Reflectometers Instruction Manual*.

The Topp equation underestimates the water content of some organic, volcanic, and finely textured soils. In addition, porous media with porosities greater than 0.5 or bulk densities greater than 1.55 g/cm^3 may require a media-specific calibration equation.

No user-defined calibration was performed, and the calibration determined by Campbell Scientific is used.

12.2 PQS-1 PAR

See Section 6.6.1 for current PQS-1 calibration values. The calibration for these sensors will be performed every year by the AmeriFlux QA/QC Laboratory.

13.0 Maintenance

13.1 CS650/CS655 Volumetric Water Content and Temperature

As stated in the *CS650 and CS655 Water Content Reflectometers Instruction Manual*, the instruments do not require periodic maintenance.

13.2 PQS-1 PAR Sensors

The sensor output will be biased low if the dome is not clean. The sensor domes should be cleaned only with water or water with mild detergent *once per month by ARM onsite staff during the warm season* at NSA.

13.3 Cables

One of the CS650L sensor cables at NSA C1 appeared to have been chewed on by an animal. Sensor cables may need to be repaired should the cable armor be compromised either by animals or by human error in cable armoring.

14.0 Safety

No safety hazards are associated with the operation of this instrument. All subsystems operate at low current (<100 mA) and low voltage (<30 VDC).

15.0 Citable References

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