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Photosynthetically Active Radiation (PAR) Instrument Handbook

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August 2025

ARM

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Acronyms and Abbreviations

A/C	alternating current
ARM	Atmospheric Radiation Measurement
BNF	Bankhead National Forest
IRT	infrared thermometer
LBNL	Lawrence Berkeley National Laboratory
METWXT	WXT520/530 meteorological instrument system
PAR	photosynthetically active radiation (400-700-nm wavelength)
PPFD	photosynthetic photon flux density (μmol m^{-2} s^{-1})
RH	relative humidity

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1.0 Mentor Contact Information

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2.0 Instrument Description

Three photosynthetically active radiation (PAR) measurement instruments were deployed at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) User Facility's Bankhead National Forest (BNF) observatory, installed on three different instrument towers within the forest. Each of the three instruments comprises an enclosure at the base of the tower, containing a datalogger and internal humidity sensor, connected to external PAR sensors mounted at various heights and vertical orientations on the same tower. PAR sensors measure radiation reaching the sensor with wavelengths from 400-700 nm, per unit area, per unit time, or the photosynthetic photon flux density (PPFD, μmol photons m^{-2} s^{-1}). On the 43-meter tower of BNF supplemental site S10, sensors are located 43 m, 22 m, 10 m, and 5 m from ground level. Downwelling radiation is measured with upward-facing sensors at all heights, and upwelling radiation is measured with downward-facing sensors at 43 m and 5 m. On the two 10-m towers of BNF supplemental sites S13 and S14, upwelling radiation is measured at 8 m and 2 m, and downwelling radiation is measured at 8 m.

Table 1. PAR System deployments.

Dates	Tower
2025-03-20 to present	S10
2025-05-13 to present	S13
2025-05-28 to present	S14

2.1 Technical Specification

The hardware used in each PAR instrument includes a datalogger (CR1000X, Campbell Scientific, USA), a backup battery power supply (PS200, Campbell Scientific, USA) with A/C adapter connected to external line A/C power, and an internal humidity sensor (CS210, Campbell Scientific, USA), inside an enclosure (Figures 1 and 2). PAR sensors are wired from the datalogger differential voltage measurement channels to connectors on the enclosure for easy replacement. PAR sensors (LI-190R, LI-COR Inc., USA) are connected to the exterior of the enclosure and cables are run up the tower to booms extending horizontally 2-3 m from the vertical structure (Figures 3 and 4). Sensors were mounted to the ends of the booms and leveled to point either directly upwards to measure downwelling radiation, or directly downwards to measure upwelling radiation.

PAR sensor (LI-190R) specifications, according to the manufacturer (LI-COR Inc.):

Calibration:	± 5% traceable to U.S. National Institute of Standards and Technology
Sensitivity:	Typically 5 μA to 10 μA per 1,000 μmol s-1 m-2
Linearity:	Maximum deviation of 1% up to 10,000 μmol m^{-2} s^{-1}
Response time:	< 1 μs
Temperature Dependence:	± 0.15% per °C maximum
Cosine Correction:	Cosine corrected up to 82° angle of incidence
Azimuth:	< ± 1% error over 360° at a 45° elevation
Tilt:	No error induced from orientation
Operating Temperature Range:	−40 °C to 65 °C
Relative Humidity Range:	0% to 100% RH, non-condensing
Detector:	High-stability silicon photovoltaic detector (blue enhanced)
Size:	2.36 cm diameter × 3.63 cm (0.93” × 1.43”)
Weight:	24 g head; 60 g base/cable (2 m) with screws

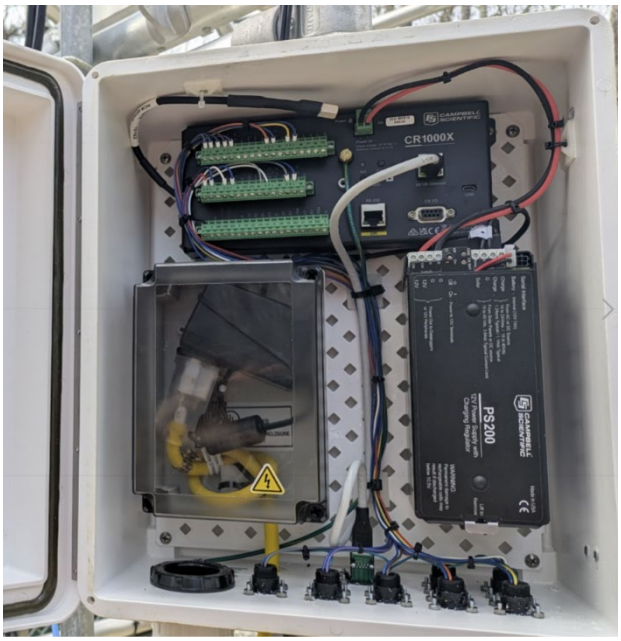

Figure 1. View of inside of enclosure for PAR instrument mounted on S10 tower and measuring 6 PAR sensors, with connectors visible at the bottom of the image.

Figure 2. View of the interior of one of the identical enclosures housing PAR instruments mounted on S13 and S14 towers. The uppermost datalogger is dedicated to the PAR instrument, and is wired to three PAR sensor connectors shown at the bottom of the image. The other two loggers in the enclosure share the power supply and are used in the WXT520/530 meteorological instrument system (METWXT) and infrared thermometer (IRT) instruments co-located on each of the towers.

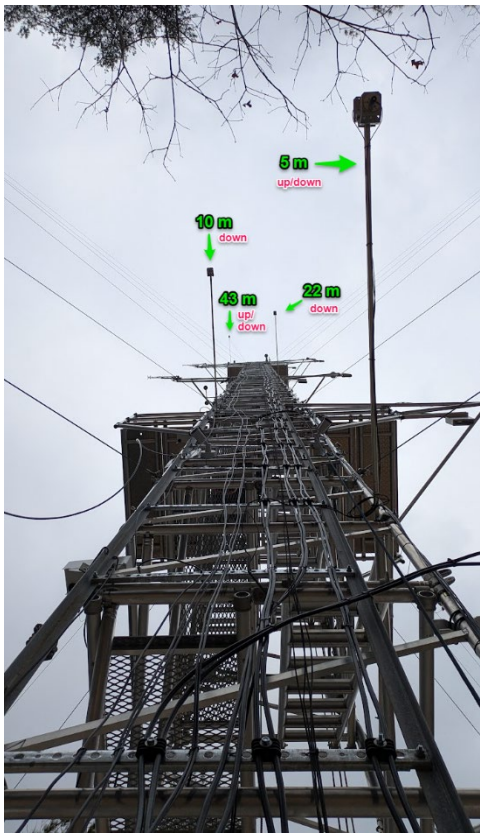

Figure 3. Upward view of S10 tower showing locations of PAR sensors off the most southward-facing "D" face of the tower frame.

Figure 4. Side view of S13 tower showing position of PAR sensor booms at 2 m and 8 m. The 8 m boom extends away from the camera.

2.2 Instrument/Measurement Theory

According to the manufacturer (LI-COR Inc.), “The LI-190R uses a high-quality silicon photodiode and glass optical filter to create uniform sensitivity to light between 400 nm to 700 nm, which closely corresponds to light used by most plants. A newly designed optical filter tailors the spectral response to an unprecedented performance standard. Furthermore, the new filter is unaffected by environmental factors such as heat or humidity. The filter blocks light with wavelengths beyond 700 nm, which is critical for measurements under vegetation where the ratio of infrared to visible light may be high.”

3.0 Data

3.1 Data Description

Measurements of PAR, relative humidity, and battery voltage are collected by the datalogger every 10 s. Every 1 minute, an average and standard deviation is stored in the output data table for each sensor, as well as the minimum battery voltage measured.

3.2 Data Quality and Uncertainty

Uncertainty for PAR measurements is ± 5%.

3.3 QC Bit Definitions

QC definition for all qc variables corresponding to primary variables:
flag_method = "bit";
bit_1_description = "Value is equal to missing_value -9999."; 1
bit_2_description = "Value is less than the valid_min."; 2
bit_3_description = "Value is greater than the valid_max."; 4

Table 2. Values used for valid_min and valid_max for each measurement type.

Measurement	Valid_min	Valid_max
PAR	-10 µmol m^{-2} s^{-1}	3000 µmol m^{-2} s^{-1}
relative humidity	0%	100%
battery voltage	0 V	17.5 V

3.4 Examples of Data

Example of headers and three rows of data (limited to three decimal places) from the PAR instrument on the S10 tower:

JUL,TIMESTAMP,BATT_VOLT_MIN,BATT_VOLT_MIN_QC,PANEL_TEMP_AVG,PANEL_TEMP_AVG_QC,PANEL_TEMP_STDDEV,PANEL_TEMP_STDDEV_QC,RH_AVG,RH_AVG_QC,RH_STDDEV,RH_STDDEV_QC,PAR_1_40M_DWELL_AVG,PAR_1_40M_DWELL_AVG_QC,PAR_1_40M_DWELL_STD,PAR_1_40M_DWELL_STD_QC,PAR_2_40M_UWELL_AVG,PAR_2_40M_UWELL_AVG_QC,PAR_2_40M_UWELL_STD,PAR_2_40M_UWELL_STD_QC,PAR_3_20M_DWELL_AVG,PAR_3_20M_DWELL_AVG_QC,PAR_3_20M_DWELL_STD,PAR_3_20M_DWELL_STD_QC,PAR_4_10M_DWELL_AVG,PAR_4_10M_DWELL_AVG_QC,PAR_4_10M_DWELL_STD,PAR_4_10M_DWELL_STD_QC,PAR_5_4M_DWELL_AVG,PAR_5_4M_DWELL_AVG_QC,PAR_5_4M_DWELL_STD,PAR_5_4M_DWELL_STD_QC,PAR_6_4M_UWELL_AVG,PAR_6_4M_UWELL_AVG_QC,PAR_6_4M_UWELL_STD,PAR_6_4M_UWELL_STD_QC

2460754.5,3/20/2025 0:00,13.29,0,23.454,0,0.006,0,44.248,0,0.020,0,7.299,0,0.314,0,0.547,0,0.030,0,6.404,0,0.319,0,5.058,0,0.219,0,4.051,0,0.215,0,0.509,0,0.021,0

2460754.501,3/20/2025 0:01,13.28,0,23.435,0,0.005,0,44.278,0,0.018,0,6.266,0,0.279,0,0.473,0,0.021,0,5.432,0,0.242,0,4.360,0,0.163,0,3.469,0,0.152,0,0.441,0,0.020,0

2460754.501,3/20/2025 0:02,13.36,0,23.417,0,0.005,0,44.318,0,0.007,0,5.357,0,0.234,0,0.398,0,0.023,0,4.672,0,0.186,0,3.738,0,0.165,0,3.008,0,0.108,0,0.387,0,0.019,0

4.0 Maintenance Plan

Humidity inside the enclosure is monitored with the humidity sensor to avoid the presence of liquid water by condensation, which could damage electrical components. When humidity inside the enclosure exceeds 80%, the desiccant packs inside the enclosure should be replaced with fresh packs.

Routine maintenance of PAR sensors should include checking for obstructions (material such as dust, litter, or bird droppings), cleaning, and sensor leveling as needed.

5.0 Calibration Plan

On a periodic basis (approximately annually), mentors replace PAR sensors with recently calibrated sensors and perform calibrations of previously deployed sensors at LBNL for re-deployment. Sensors are cycled in this way to maintain continuous measurements and updated calibration coefficients. When sensors are replaced, updated calibration coefficients are entered into the datalogger program, with logger program version history stored. Calibration is conducted by comparing paired measurements of natural sunlight against a set of 10 reference sensors, while installed on a shared, machine-leveled surface over a clear-sky day. The calibration procedure is described in detail in an upcoming manuscript that will be added to future versions of this instrument handbook.

6.0 User Notes and Known Issues

When electrical storms are in the immediate vicinity of the tower, sometimes electrical activity interferes with the low-voltage, passive PAR sensors, creating short periods of time with artificially noisy measurements. A code is used to define these time periods and flag the PAR data as "suspect" in data quality reports for each data set, based on a test for incidence of PAR measurements <-10 µmol m 2 s-1, with a one-hour buffer time window. This test is largely effective at identifying periods affected by electrical storms, but is not 100% accurate. Therefore, users are directed to look for these events and be cautious about using data that may be affected by lightning.

7.0 Frequently Asked Questions

Why does PAR appear "noisy" at times?

- Shadows by objects such as trees or clouds overhead can cause large short-term fluctuations in PAR measurements, and high standard deviations of measurements within each 1-minute averaging interval.
- Measurement noise can also be associated with lightning strikes around the tower. These events will often include negative values for PAR that do not occur in the absence of electrical interference (see section 6.0 above).

8.0 Citable References

PAR calibration procedure manuscript in preparation. To be added.

9.0 Version History

Version 1.0, August 2025

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