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Significant Improvements in Pyranometer Nighttime Offsets Using High-Flow DC Ventilation

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I. Abstract

Accurate solar radiation measurements using pyranometers are required for understanding radiative impacts on the Earth's energy budget and in solar energy applications.

Ventilators of pyranometers, which are used to keep the domes clean and dry, also affect instrument thermal offset accuracy.

For single-black-detector pyranometers with ventilators, high-flow-rate (50-CFM and higher), 12-V DC fans lower the offsets, lower the scatter, and improve the predictability of nighttime offsets compared to operating with lower-flow-rate (35-CFM), 120-V AC fans.

Black-and-white pyranometers, which are used to measure diffuse horizontal irradiance, sometimes show minor improvement with DC fan ventilation, but their offsets are always small, usually no more than 1 W/m², whether AC- or DC-ventilated [1].

II. Method

- Pyranometers with single black detectors often underestimate downwelling global or diffuse solar irradiance unless offset corrections are applied. Offsets arise from outer dome cooling to the sky above the instrument (Figure 6) and partial cooling of the inner dome and thermopile hot junction, resulting in an underestimated solar irradiance signal. Converting from low-flow-rate AC fans to high-flow-rate DC fans leads to lower and more predictable nighttime offsets.
- Thermal offsets were examined for several manufacturers' pyranometers as a function of the instrument net infrared measured by an Eppley Model Precision Infrared Radiometer (PIR) that was shaded and ventilated with a 35-CFM, 120-V AC fan. Of the tested pyranometers, the Eppley Precision Spectral Pyranometer (PSP) had the largest offset, followed by the Kipp & Zonen CM11, and then the CM22, which had very little offset. Black-and-white pyranometers have offsets typically no larger than approximately 1 W/m² [2], [3] (Figure 4).
- Table 1 indicates the locations where studies were performed that provide data regarding thermal offset behaviors. Results of four of the studies are summarized in figures 2 through 5. Testing at the National Renewable Energy Laboratory (NREL) Solar Radiation Research Laboratory (SRRL) showed ventilator output flow rates are lower than fan manufacturers' specified free airflows (typically 35 CFM for AC fans, 50–80 CFM for DC fans) because of the size of the opening around the radiometer domes [4].

Table 1. Pyranometer Testing and Locations

Pyranometer Model /Figure	Manufacturer & Type	Ventilation	Location
PSP/Figure 2	Eppley—Single black detector	• 120 V AC, 35 CFM • 12 V DC, 50 CFM	• ARM Program • Barrow, AK • 71.3230 N, 156.6114 W
Five PSPs/ Figure 1 and Figure 3	Eppley—Single black detector	• Two 120 V AC, 35 CFM • Three 12 V DC, 50 CFM	• NREL SRRL • Golden, CO • 39.7424 N, 105.1786 W
SR75 and 8-48/Figure 4	• Spectra-Sun—Single black detector • Eppley—Black and white	• 120 V AC, 35 CFM • 12 V DC, 80 CFM	• SURFRAD • Goodwin Creek, MS • 34.2550 N, 89.8736 W
PSP/ Figure 5	Eppley—Single black detector	• 12 V DC, 50 CFM • 120 V AC, 35 CFM	• University of Oregon • Eugene, OR • 44.0467 N, 123.0742 W
Two CM11s and Two CM22s	Kipp & Zonen—Single black detector	• None • 12 V DC, 100 CFM	• NOAA • Boulder, CO • 39.9911 N, 105.2607 W

Figure 1. Test setup at NREL's SRRL consisted of five Eppley PSPs installed in Model VEN ventilators along with thermopile and housing temperature measurements. Net infrared is measured from a colocated PIR. Nighttime data were collected using two AC fans and three DC fans during January and February 2014.

III. Pyranometer and Ventilator Fan Test Results

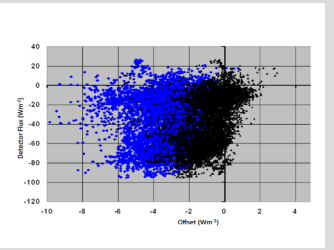


Figure 2. The 2006–2009 North Slope of Alaska Pyranometer Infrared Loss Study and Evaluation of Heated Ventilators in the Arctic testing at Barrow, AK, shows the pyranometer offset on the X-axis and 35-CFM, 120-V AC ventilated Eppley PIR instrument net infrared on the Y-axis. Blue nighttime measurement points are for the PSP pyranometer, with 35-CFM, 120-V AC ventilation; and black points are for ventilation using a 50-CFM, 12-V DC fan in the same ventilator, showing that the DC fan produces a lower offset (www.arm.gov/campaigns/nsa2006PYIRloss).

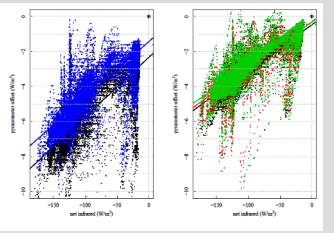


Figure 3. Offset measurements were conducted at NREL's SRRL in Golden, CO, (Figure1) for 32 days beginning in January 2014. Offsets for two PSPs ventilated using 35-CFM, 120-V AC fans are plotted on the left. Offsets for three PSPs ventilated with 50-CFM, 12-V DC fans are plotted on the right for the same period showing lower offsets, less scatter, fewer extreme values, and better linearity.

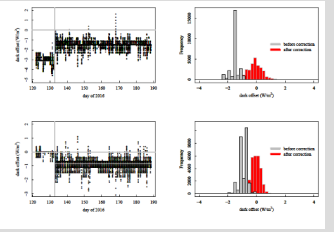


Figure 4. Plots from the Surface Radiation Budget (SURFRAD) site in Goodwin Creek, MS, show SpectraSun pyranometer dark offsets before and after switching to DC ventilation. Top right: The gray histogram is for the offsets after Day 133 before the correction; the red histogram is for the offsets after Day 133 after correction. Bottom left: Plot of Eppley Model 8-48 (black-and-white) pyranometer dark offsets before and after switching to DC ventilation. The offsets are larger than they were with AC ventilation, although offsets are always small for black-and-white pyranometers. Bottom right: Similar to the top right figure, these histograms are for the Eppley Model 8-48 pyranometer data after Day 133. In the post-correction histogram (red), 95% of the points are within 0.6 W/m².

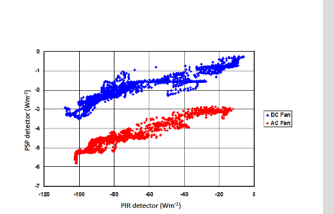
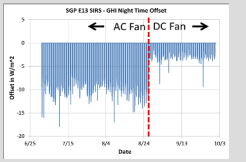


Figure 5. Offsets for the same Pacific Northwest National Laboratory PSP plotted for four days in a DC fan ventilator (blue) and then switched to an AC fan ventilator (red) for three days at the University of Oregon. For both periods, the offset behavior with instrument net infrared readings was linear. A significant increase in the offset occurred when switched from DC to AC ventilation. Humidity and clouds on these nights limited the range of instrument net infrared readings.

IV. Results of DC Fan Deployment at ARM Program SGP SIRS Sites

- Transition to the higher-flow 12-V DC fans in ventilators consistently resulted in the reduction of PSP thermal offset responses (ARM Program ECO-00991).
- Average change in nighttime thermal offset for PSPs from the 18 sites was from -7.0 W/m² prior to the fan change to -2.3 W/m² after the fan change.



Daily Difference in Nighttime PSP Offsets

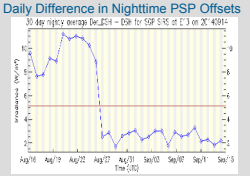
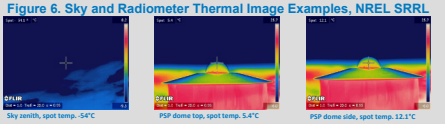


Figure 6. Sky and Radiometer Thermal Image Examples, NREL SRRL



V. Summary

- Radiometer thermal offset effects can result in greater data uncertainty if corrections are not applied.
- Figure 4 (top row, left) shows that offsets were reduced by approximately one-half for the SpectraSun pyranometer; and it indicates that the offsets, at least at night, are predictable and removable to approximately 1.1 W/m² (top row, right). For the Eppley 8-48 black-and-white pyranometer, the small inherent offset might be slightly better or slightly worse with DC ventilation; but it was predictable to 0.6 W/m² (Figure 4, bottom row).
- Figure 5 provides an example of the effect of ventilation with AC fans compared to DC fans. The same pyranometer was ventilated on seven consecutive days, and only the fan type was changed (from DC to AC).
- Offsets for the unventilated Kipp & Zonen CM11 and CM21 pyranometers tested at the National Oceanic and Atmospheric Administration (NOAA), Boulder, site (test plots not shown) were similar and predictable. The offsets improved significantly when the Kipp & Zonen CVF3 DC ventilators were added.
- Changing from AC fans to higher-flow DC fans in PSP ventilators at the ARM Program Solar Infrared Radiation Station (SIRS) radiometry sites (Section IV) resulted in reducing PSP thermal offsets.
- Other commercial pyranometers should be tested; however, the focus was on those available for study. Most effort to date has focused on diffuse irradiance. Global irradiance offsets need to have more emphasis. An important outcome of future research will be to clarify under what circumstances nighttime data can be used to predict daytime offsets.
- These studies provide insight toward obtaining accurate solar radiation measurements. Manufacturers and researchers continue to improve designs of pyranometers and ventilators, which should assist in acquiring accurate solar radiation data with low uncertainty.

References

1. J. Michalsky, M. Kutchenreiter, and C. Long, "Significant Improvements in Pyranometer Nighttime Offsets Using High-Flow, DC Ventilation," *Journal of Atmospheric and Oceanic Technology* (2017), 10.1175/JTECH-D-16-0224.1.

2. J.J. Michalsky et al. "Results from the First ARM Diffuse Horizontal Shortwave Irradiance Comparison," *Journal of Geophysical Research* 108: 4108 (2003), doi:10.1029/2002JD002825, D3.

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4. M. Kutchenreiter, P. Gotseff, A. Habte, I. Reda, M. Sengupta, A. Andreas, and M. Anderberg, "Evaluation of DC Ventilator Fans Proposed for Pyranometer Measurements in the ARM Program" (paper presented at the ASR Science Team Meeting, 2014).

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