Ventilator Improvements for Reducing Radiometer Frost, Snow, and Ice Accumulation

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ABSTRACT

- The Atmospheric Radiation Measurement (ARM) program provides high-quality radiometric data traceable to the International System of Units through the World Radiometric Reference.
- The National Renewable Energy Laboratory (NREL) and ARM, through the Radiometer Calibration Facility at the Southern Great Plains site, provide broadband radiometer calibrations (BORCAL) and longwave calibration of radiometers deployed in the Sky Radiation (SKYRAD), Ground Radiation (GNDRAD), and Solar Infrared Radiation Station (SIRS) instrument platforms. Both NREL and ARM continue to improve radiometric measurements through the introduction of new methods and system modifications to reduce uncertainty in calibrations and field measurements.
- This poster presents a review of testing performed under ENG0003807, with the objective of improving the reduction of frost, ice, and snow accumulation on radiometers mounted in Eppley model VEN ventilators.
- The model VEN ventilator is used with Eppley pyranometers and pyrgeometers at ARM program SIRS and SKYRAD sites for downwelling broadband shortwave and longwave radiometric measurements and at GNDRAD sites located in cold-climate regions for upwelling longwave and broadband shortwave measurements.
- As part of ENG0003807, testing is being performed at NREL with modified sun shields used on Eppley VEN ventilators and at the ARM program AMF3 Oliktok (OLI) site with increased voltage to ventilator heater coils, heating pads under sun shields, and modified ventilator sun shields. The results will show the performance of each test scenario and a recommendation for deployment.

OVERVIEW

- Arctic weather conditions have intermittently resulted in accumulations of frost, ice, and snow on Eppley Precision Spectral Pyranometer (PSP), Precision Infrared Radiometer (PIR), and 8-48 (diffuse pyranometer) radiometer domes and sun shields at the ARM program OLI and Barrow, North Slope of Alaska (NSA, known officially as Utqiaġvik), sites. The frost and ice accumulations on the SKYRAD radiometer domes is sometimes thick, requiring additional cleaning. As an example of conditions at OLI, during January 2018, air temperatures were as low as approximately -30ºC and relative humidity ranged from approximately 70% to 100%.
- Low-wattage heater coils are used in the OLI and NSA SKYRAD and GNDRAD ventilators. The heater coils have sometimes not been sufficient to prevent temporary ice and frost accumulation on SKYRAD domes. The SKYRAD frost and ice dome accumulation events have been more frequent at OLI than at NSA. Normal incidence pyrheliometer windows typically do not have frost and ice accumulations as often as the domed radiometers.
- Testing at OLI primarily included the use of sun shields with modified openings on the Eppley VEN ventilators, application of heating pads on the bottoms of sun shields, and increasing ventilator heating coil voltage. Highlights of actions and observations are provided below.
- Modified sun shields were tested at NREL's Solar Radiation Research Laboratory (SRRL). Standard Eppley PSP/PIR and 8-48 sun shields were modified at NREL's instrument machine shop. The sun shield modifications included three types of beveling and widening of the circular opening edges. In addition, the machine shop made 3-D-printed cooling caps to use for the sun shield testing. Summarized information is provided below.

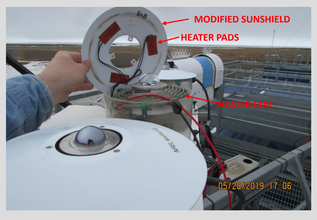
OLIKTOK SKYRAD
Highlights of Observations and Actions
• January 2018: Reports of recurring frost and ice on radiometer domes, mainly 8-48 diffuse and global PSP
• 3/3/18: Sun shield with 1/8-inch enlarged opening installed on PIR1. Heater pads installed on bottom of PSP sun shield. PIR1 dome frost reduction improvement reported. PSP dome frost reduction reported and top of sun shield accumulates less frost and snow.
• 4/14/18: 8-48 diffuse sun shield raised slightly. Heater coil replaced
• 5/6/18: Sun shield with 1/8-inch enlarged opening installed on 8-48 diffuse, and heater pads attached to bottom of sun shield (power-off initially). 8/17/18: Sunon fan (higher flow) installed in diffuse ventilator
• 10/8/18: New support plate with holes beneath ventilator positions installed on solar tracker
• 11/8/18: New adjustable power supply for heater coils in all four ventilators installed. Voltage to heaters coils increased from 48 to 58 VDC. 12/10/18: Improvement in dome frost reduction reported
• 1/18/19: Significant snow and ice event reported. PIR2 ventilator top opening blocked by snow. PIR1 less affected. 8-48 diffuse dome has frost. 1/24/19: 8-48 diffuse heater pads turned on
• 2/10/19: Sunshield with 1/8-inch enlarged opening installed on PIR2.

PSP 3/1/18: Frost on dome and sun shield prior to installing heater pads on bottom of sun shield.

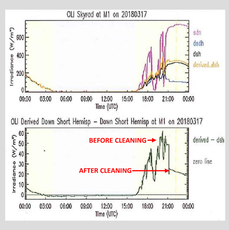
PSP 3/7/18: Heater pad installation significantly reduces frost, snow on PSP dome and sun shield. Snow is on top of PIR and 8-48 sun shields.

PIR2 3/8/18: Standard sun shield. Frost on dome. Frost and snow on sun shield.

PIR1 3/8/18: Modified sun shield with widened opening. No frost on dome. Frost and snow on sun shield.



8-48 5/28/19: Heater coil, heater pad on bottom of sun shield, modified sun shield opening.



3/17/18: Derived global horizontal minus global horizontal difference prior to cleaning 8-48, 21:00 UTC.

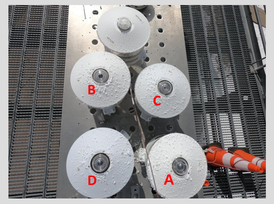
NREL SOLAR RADIATION RESEARCH LABORATORY
Modified Sun Shield Test Equipment
Ventilator model: Eppley VEN
Radiometers:
Eppley model PSP pyranometer (global horizontal shortwave hemispheric irradiance)
Eppley model 8-48 pyranometer (diffuse shortwave hemispheric irradiance)
Eppley model PIR pyrgeometer (downwelling longwave hemispheric irradiance)
Fan: Sunon model GF8025181-0000U-SC9, 80 x 80 mm
Power supply: Altech PS6012, 12.04 VDC output
Data logger: CR1000
Sun shields: Eppley sun shields for VEN ventilators
A. Standard sun shield for PSP/PIR, 2.36-inch opening
B. Modified PSP/PIR sun shield; opening beveled 45 degrees on bottom
C. Modified PSP/PIR sun shield; opening enlarged 1/16-inch and beveled 45 degrees on bottom
D. Modified PSP/PIR sun shield; Opening enlarged 1/8-inch and beveled 45 degrees on bottom
A. Standard sun shield for 8-48; 3.28-inch opening
B. Modified 8-48 sun shield; opening beveled 45 degrees on bottom
C. Modified 8-48 sun shield; opening enlarged 1/16-inch and beveled 45 degrees on bottom
D. Modified 8-48 sun shield; opening enlarged 1/8-inch and beveled 45 degrees on bottom

Standard PSP sun shield opening (left). Modified PSP sun shield with 1/16-inch widening and beveled edge (middle). Modified 8-48 sun shield image showing beveled edge (right).

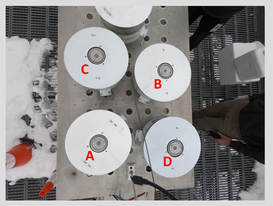
Modified Sun Shield Output Velocity Test				
Ventilator	Fan	RPM	Sun shield	Meters/second*
V1	F1	5217	PSP/PIR, modified opening, enlarged 1/8 inch	4.1
V2	F2	5228	PSP/PIR, modified opening, enlarged 1/16 inch	3.8
V3	F3	5220	PSP/PIR, modified opening, bevel only	3.1
V4	F4	5211	PSP/PIR, standard sun shield	2.3

*Indoor velocity test, 4.6 inches above sun shield openings. Screens not used on fan intakes.

PSP, 8-48, and PIR Testing with Modified Sun Shields on NREL SRRL Deck			
Date, test type	Radiometers	Sunshield type	Dome-clearing comments
2/27/19 Ambient conditions	4 PSPs	A: standard	Cleared frost after C
		B: beveled opening	Cleared frost first
		C: widened1/16-in.,beveled	Cleared frost soon after B
		D: widened 1/8-in., beveled	Cleared frost after C
5/9/19 Cooling cap test	4 PSPs	A: standard	Cleared dew after B
		B: beveled opening	Cleared dew soon after C
		C: widened 1/16-in., beveled	Cleared dew first
		D: widened 1/8-in., beveled	Cleared dew after B
5/10/19 Cooling cap test	4 8-48s	A: standard	Cleared dew after B and C
		B: beveled opening	Totally clear first
		C: widened 1/16-in., beveled	Cleared dew fastest
		D: widened 1/8-in., beveled	Cleared dew after B and C
5/12/19 Water spray tests	4 PIRs	A: standard	Cleared after D
		B: beveled opening	B, C cleared before A, D
		C: widened 1/16-in., beveled	C, B cleared before A, D
		D: widened 1/8-in., beveled	Cleared after B, C

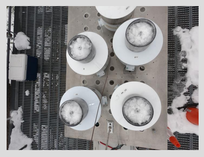


2/27/19, 11:27 MST: "B" modified sun shield first to clear ambient morning frost on PSP dome.

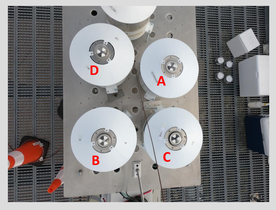


5/9/19, 2:14 MST: "C" modified sun shield first to clear dew in cooling cap test on PSP dome.

2/22/19: Test installation at SRRL with GoPro camera and light during snowfall period.



5/9/19: Image of 3-D-printed cooling caps on PSP domes for dew clearing test.



5/10/19, 5:15 MST: "B" and "C" modified sun shields exhibited quickest 8-48 dome dew-clearing times in cooling cap tests.

5/12/19 17:45 MST: "B" and "C" modified sun shields averaged quickest PIR dome drying in water spray tests.

Summary

- Observations made by OLI station operators and reviews of images indicate that installation of the modified sun shields reduced the amount of frost, ice, and snow on the radiometer domes.
- Testing of heating pads on the PSP and 8-48 radiometer sun shield bottoms at OLI resulted in an improvement in reducing frost and ice formation on the domes and reduced the accumulation of snow on sun shield openings. Increasing the ventilator heating coil voltage to 58 VDC for all four ventilators helped to reduce frost formation on radiometer domes.
- Testing of PSP/PIR and 8-48 sun shields with different opening modifications was performed on the radiometry measurement deck at the SRRL. Modifications included (1) beveling the bottom edge of the opening, (2) beveling and widening the opening 1/16 inch, and (3) beveling and widening the opening 1/8 inch.
- Tests of the modified sun shields during winter conditions and after winter using cooling caps indicated that the bevel-only and 1/16-inch widened/beveled sun shields cleared dome frost and dew faster than the 1/8-inch widened/beveled and standard sun shields for both PSPs and 8-48s.
- Results of water spray tests with modified sun shields for PIRs indicated that the bevel-only and 1/16-inch widened/beveled sun shields cleared water droplets from domes faster than the 1/8-inch widened/beveled and standard sun shields.
- Testing of the modified sun shields indicated that the modification of the 1/8-inch widening provided the largest output flow velocity increase, but the best dome-clearing performance was achieved with the bevel-only and 1/16-inch widened/beveled modifications. This is attributed to the output airstream being directed more effectively to the dome glass surface.
- Characterization of the use of the heater coils and sun shield heater pads might be recommended to determine the potential effect on radiometer responsivity and if there is a need to include them during BORCAL calibrations.
- Implementation recommendations for OLI include: obtain new modified sun shields from the manufacturer and attach heater pads to the bottoms of the sun shields. Select the modification style based on the results of comparisons at SRRL. For NSA, obtain new modified sun shields and consider the possible use of heater pads under the sun shields. New power supplies have been installed at both OLI and NSA and allowed increasing the heater coil voltage, with 58 V being used presently.

Acknowledgement

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