

SolarSIM-D2

Performance Results @ NREL 17th - 21st November, 2014

SolarSIM: Solar Spectral Irradiance Meter

- Direct spectral and irradiance monitoring for PV and meteorological applications
- The SolarSIM-D2 uses silicon photodiodes integrated with bandpass interference filters to monitor discrete sections of the solar spectrum
- The SolarSIM-D2's software uses the photodiode measurements to reconstructs the complete solar spectrum
- Designed for prolonged outdoor use
- Cheaper, lower-power, more
 rugged than a spectroradiometer





Purpose of Testing

- To test and calibrate the SolarSIM-D2 against NREL's
- Spectroradiometer (secondary standard)
- Pyrheliometer (ISO first class)
- Absolute cavity radiometer (primary standard)
- To collaborate with Keith Emery on the efficacy of the SolarSIM-D2



Test Set up





Located at the NREL Outdoor Test Facility:

- Two SolarSIM-D2s mounted on a Solsys 2 tracker (left photo) adjacent to Keith Emery's Primary Photovoltaic Reference Cell Calibration test bed (right photo):
 - A: ASDi FieldSpec3 spectroradiometer (secondary standard)
 - B: Eppley Absolute Cavity Radiometer (primary standard)
 - C: Licor Spectroradiometer (secondary standard)
 - D: Isotype sensors (4 of)

Located at the NREL Solar Radiation Resource Laboratory (100m higher in elevation - not shown):

- PGS 100 Spectroradiometer (secondary standard)
- Eko 710/712 Spectroradiometer (WISER system)
- CH1 Pyrheliometer (secondary standard)



NREL Campus





SolarSIM-D2 Performance – Clear Sky



SolarSIM-D2 produces accurate spectra

- 1. Wavelength ranges: PG\$100: 350 1080 nm. Licor: 350 1100 nm. WISER: 350 1650 nm. ASDi: 350 2400nm. SSIM: 280 4000nm.
- 2. Acceptance angle vary from ±1 ±2.5° between the different devices. Slope angles vary between 0.5° 1.7°.
- 3. SolarSIM-D2 spectral model has 1 nm spectral resolution, compared to 3 10nm (FWHM) for the spectroradiometers.
- 4. * Geometric, pressure corrected airmass.



SolarSIM-D2 Performance – Clear Sky



SolarSIM-D2 produces accurate spectra even at high air mass

- 1. Wavelength ranges: PGS100: 350 1080 nm. Licor: 350 1100 nm. WISER: 350 1650 nm. ASDi: 350 2400nm. SSIM: 280 4000nm.
- 2. Acceptance angle vary from ±1 ±2.5° between the different devices. Slope angles vary between 0.5° 1.7°.
- 3. SolarSIM-D2 spectral model has 1 nm spectral resolution, compared to 3 10nm (FWHM) for the spectroradiometers.
- 4. * Geometric, pressure corrected airmass.



SolarSIM-D2 Performance – Cloudy Sky



SolarSIM-D2 produces accurate spectra under cirrus cloud

- 1. Wavelength ranges: PGS100: 350 1080 nm. WISER: 350 1650 nm. SSIM: 280 4000nm.
- 2. Acceptance angle vary from $\pm 1 \pm 2.5^{\circ}$ between the different devices. Slope angles vary between $0.5^{\circ} 1.0^{\circ}$.
- 3. SolarSIM-D2 spectral model has 1 nm spectral resolution, compared to 3 10nm (FWHM) for the spectroradiometers.
- 4. The SolarSIM-D2 was located 200m apart from the PGS100 and WISER spectroradiometers.



SolarSIM-D2 Performance – Cloudy Sky



SolarSIM-D2 produces accurate spectra under moderate cloud

- 1. Wavelength ranges: PG\$100: 350 1080 nm. WISER: 350 1650 nm. SSIM: 280 4000nm.
- 2. Acceptance angle vary from $\pm 1 \pm 2.5^{\circ}$ between the different devices. Slope angles vary between $0.5^{\circ} 1.0^{\circ}$.
- 3. SolarSIM-D2 spectral model has 1 nm spectral resolution, compared to 3 10nm (FWHM) for the spectroradiometers.
- 4. The SolarSIM-D2 was located 200m apart from the PGS100 and WISER spectroradiometers.



SolarSIM-D2 Performance – Cloudy Sky



SolarSIM-D2 produces accurate spectra under heavy cloud

- 1. Wavelength ranges: WISER: 350 1650 nm. SSIM: 280 4000nm.
- 2. Acceptance angles are $\pm 2.5^{\circ}$ for both instruments. Slope angles are 1.0° .
- 3. SolarSIM-D2 spectral model has 1 nm spectral resolution, compared to 3 10nm (FWHM) for the spectroradiometers.
- 4. The SolarSIM-D2 was located 200m apart from the WISER spectroradiometer.



SolarSIM-D2 Performance – Clear DNI



The integral of the SolarSIM-D2 spectra provides accurate DNI data

- 1. The CH1 NIP is located 100m above the SolarSIM-D2 at the NREL Solar Radiation Resource Laboratory. This accounts for the discrepancy from 15:45 onwards as the SolarSIM-D2 experiences sunset before the CH1 NIP. At 15:45 the elevation angle is 9.0° (AM6.37).
- 2. The NREL CH1 NIP has the same field of view as the SolarSIM-D2: 1.0° slope angle and ±2.5° acceptance angle.
- 3. NREL CH1 NIP calibration date: 19th May 2014.



SolarSIM-D2 Performance – Cloudy DNI



SolarSIM-D2 provides accurate DNI data even on cloudy days

- The drop in the SolarSIM-D2 DNI in the morning is due to NREL staff walking in front of and shadowing the SSIM during morning set-up. 1.
- The discrepancy from 4pm onwards is due to the CH1 NIP being located 100 m above the SolarSIM-D2 at the SRRL, leading to the SSIM experiencing sunset earlier.
- The temporal resolution of the CH1 is 60s. The temporal resolution of the SolarSIM-D2 is 1s. This accounts for the higher temporal resolution 3. **Spectrafy** (sharper peaks) evident in the SolarSIM-D2 DNI data.

SolarSIM-D2 Performance – DNI



SolarSIM-D2 DNI data matches NREL's Secondary Standard ACR

- 1. The SolarSIM-D2 was tested side-by-side with the NREL Absolute Cavity Radiometer at the NREL Outdoor Test Facility. The uncertainty of the NREL ACR is ± 0.37%.
- 2. The NREL Absolute Cavity Radiometer (Eppley ID#23734) is a secondary standard as defined by the World Meteorological Organisation. As such it undergoes calibration every 5 years at the WMO International Pyrheliometer Comparison in Davos Switzerland against the six World Standard Group pyrheliometers.
- ACR data was acquired manually. Gaps between clusters of data points represent periods of unsuitable atmospheric conditions.
 The acceptance angle and slope angle of the ACR match those of the SolarSIM-D2.
 - Spectrafy[™]



Reliability of SolarSIM-D2 Spectra



No sign of performance degradation to date

- 1. The data shows two comparisons of SolarSIM101 and SolarSIM102 measured four months apart.
- 2. SolarSIM101 remained on-sun for the duration of the four month test period, in addition to the two months prior.
- 3. SolarSIM102 (one of the two reference SolarSIMs calibrated at NREL) was stored indoors for the duration of the test period and was only taken outside in order to perform the two comparative measurements.



Reliability of SolarSIM-D2 DNI – 6 months



SSIM cumulative DNI within 0.5% of Eppley NIP over 12 months

- The data was measured at the University of Ottawa Solar Test Site in Ottawa, Canada. The SolarSIM-D2 and Eppley NIP were cleaned once per week during the test period.
- 2. The data has been filtered to remove days where the two instruments were on-sun for differing lengths of time.
- 3. The SolarSIM-D2 and the NIP shed snow at different rates, which is not been filtered out of the data.
- 4. The acceptance angle of the Eppley pyrheliometer is $\pm 2.9^{\circ}$ compared to $\pm 2.5^{\circ}$ for the SolarSIM-D2.







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