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Measuring Broadband IR Irradiance in the Direct Solar Beam

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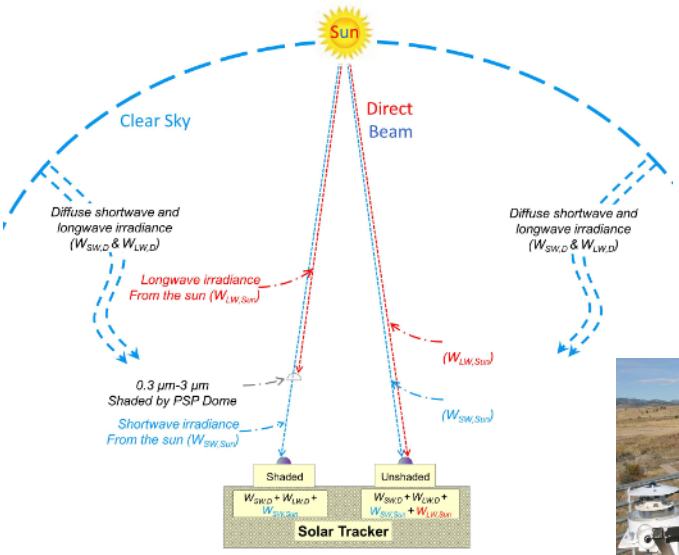
Abstract: **Solar and atmospheric science radiometers, e.g. pyranometers, pyrheliometers, and photovoltaic cells are calibrated with traceability to a consensus reference, which is maintained by Absolute Cavity Radiometers (ACRs). The ACR is an open cavity with no window, developed to measure extended broadband direct solar irradiance beyond the ultraviolet and infrared bands below and above 0.2 µm and 50 µm, respectively. On the other hand, pyranometers and pyrheliometers are developed to measure broadband shortwave irradiance from approximately 0.3 µm to 3 µm, while the present photovoltaic cells are limited to approximately 0.3 µm to 1 µm. The broadband mismatch of ACR versus such radiometers causes discrepancy in radiometers' calibration methods that has not been discussed or addressed in the solar and atmospheric science literature. Pyrgeometers are also used for solar and atmospheric science applications and are calibrated with traceability to consensus reference, yet are calibrated during nighttime only, because no consensus reference has yet been established for the daytime longwave irradiance. This poster shows a method to measure the broadband IR irradiance in the direct solar beam from 3 µm to 50 µm, as a first step that might be used to help develop calibration methods to address the mismatch between broadband ACR and shortwave radiometers, and the lack of a daytime reference for pyrgeometers. The irradiance was measured from sunrise to sunset for 5 days when the sun disk was cloudless; the irradiance varied from approximately 1 Wm^{-2} to 16 Wm^{-2} for solar zenith angle from 80° to 16° respectively; estimated uncertainty is 1.5 Wm^{-2}.**



Direct LW = [Unshaded] – [Shaded]
= $[W_{SW,D} + W_{LW,D} + W_{SW,Sun} + W_{LW,Sun}] - [W_{SW,D} + W_{LW,D} + W_{SW,Sun}]$
= $W_{LW,Sun}$

Figure 1. Illustration of sensed irradiance by unshaded and shaded pyrgeometers

Pyrgeometer Measurement Equation:

$$W = K_0 + K_1 * V_{tp} + K_2 * W_r + K_3 * (W_d - W_r)$$

where,
- W is the calculated atmospheric longwave irradiance, in Wm^{-2}
- K_0, K_1, K_2, and K_3 are the calibration coefficients
- V_{tp} is the thermopile output voltage, in µV
- W_r is the receiver irradiance, in W m^{-2} = σ * (T_c + 0.0007074 * V_{tp})^4, where T_c is the case temperature, in Kelvin, and σ is Stefan-Boltzmann constant = 5.6704*10^{-8} W m^{-2} K^{-4}
- W_d is the dome irradiance, in Wm^{-2} = σ * T_d^4, where T_d is the dome temperature, in Kelvin.

Measurement Equations of IR irradiance from the Sun:

The IR irradiance in the sun beam equals $W_{LW,sun}$,

$$W_{LW,Sun} = W_u - W_s$$

where W_u is the measured IR irradiance using the unshaded PIR, and W_s is the measured IR irradiance using the shaded PIR

And the IR direct normal irradiance from the sun equals W_{DNLW},

$$W_{DNLW} = \frac{W_{LW,Sun}}{\cos z}$$

where z is the solar zenith angle

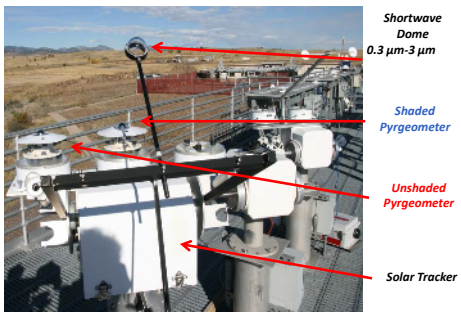


Figure 2. Unshaded and shaded pyrgeometers at NREL/SRRL
Photo by Mark Kutchenreiter, NREL

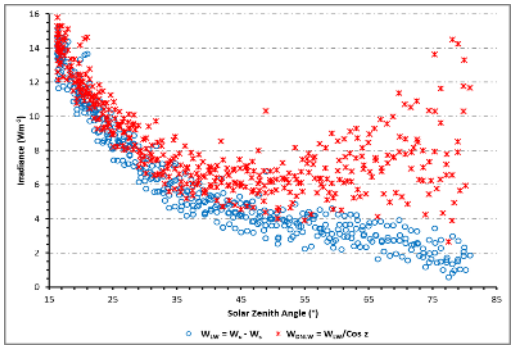


Figure 3. Measured longwave irradiance from the sun versus zenith angle for five clear sky days at NREL/SRRL

Conclusion and Future Work:

- ***IR irradiance from the sun: measured with expanded uncertainty of 1.5 Wm^{-2}***
- ***Compared to model calculation with agreement with the estimated expanded uncertainty of 1.5W/m^2***
- ***Preliminary step contributes to establishing consensus world reference for the direct-beam IR irradiance***
- ***A pyrheliometer fitted with solar blind coated silicon windows has been proposed to measure direct-beam longwave irradiance from the sun. Its initial results were presented at the 14th BSRN Scientific Review and Workshop***
- ***Once refined and consensus reference is established, it might be used to correct for the spectral mismatch that results from calibrating shortwave radiometers using an unwindowed absolute cavity radiometer, and to develop calibration method to calibrate pyrgeometers during daylight time, instead of present nighttime calibration***
- ***Next step, replicate this setup using matched pairs of other commercially available pyrgeometer models. As different models have slightly different spectral transmission characteristics, the spectral distribution of direct-beam longwave irradiance can be studied in more detail. Also, perform this measurement at other geographical locations.***

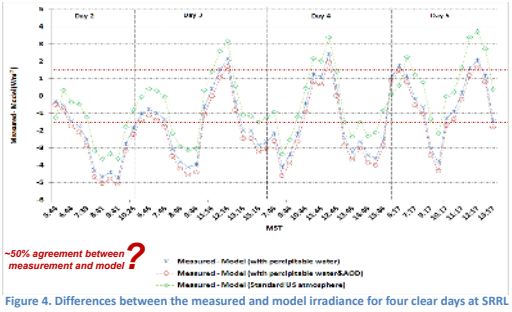


Figure 4. Differences between the measured and model irradiance for four clear days at SRRL

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