Results of the Second Diffuse Horizontal Irradiance IOP

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Introduction

The largest uncertainty in the measurement of total horizontal shortwave irradiance is not in the measurement of the, often dominant, direct normal component, but in the measurement of the diffuse horizontal irradiance. This measurement may include all of the radiation received on cloudy days or as little as 10% of the radiation received on clear days with the sun high in the sky. Improving the measurement uncertainty associated with diffuse horizontal irradiance measurements has been the goal of the First Diffuse and now the Second Diffuse Intensive Operational Periods (IOPs). A desired outcome of this effort is a working standard to establish the lowest possible uncertainty that we can hope for without the development of absolute standards for this quantity. This standard will be established using the most consistent instruments of the IOPs. Results from the second IOP will be discussed here including our efforts to ferret out the best instruments and the best offset-corrections for both clear and cloudy sky measurements.

Setting and Instrumentation

The measurements were made over a 12-day period from October 6-17, 2003. All data were taken on top of the Atmospheric Radiation Measurement (ARM) Radiation Calibration Facility at the Southern Great Plains (SGP) central facility near Lamont, Oklahoma. The latitude is 36.61° N, 97.49° W, at an altitude of 317 m. The days varied from extremely clear to totally overcast with partly cloudy and hazy conditions as well. The instrument list included three Kipp and Zonen (KZ) CM22s with one standard and two modified versions, one KZ CM11, two KZ CM21s with different ventilations systems, an Eppley prototype flat-plate pyranometer, two Eppley 8-48s from two different institutions with different calibration types, a standard Eppley precision spectral pyranometer (PSP), two modified Eppley PSPs with dome and case temperature measurements, a Yankee prototype, a EKO standard instrument, and a Carter-Scott Design standard pyrnaometer. All were mounted on KZ 2AP-GD or Brusag trackers that shaded the pyranometers all day long. One tracker started tracking after sunrise and stopped tracking before sunset (Figure 1); however, this had minimal impact on the study.

Offsets

On one very clear day, all instruments were calibrated using a shade/unshade technique, in which the difference in measured voltages for these two shadings is compared to a direct beam irradiance measurement that is multiplied by the cosine of the solar zenith angle to get the direct component normal to the plane of incidence. This is arguably the best calibration technique, but more importantly, it was applied uniformly to all instruments. The measurements were repeated over a two-hour period during which the sun varied within 1°° of 45° solar zenith angle (SZA).

All instruments were tested for offsets using the night data plotted versus the thermopile-only signal from a collocated Eppley PIR (denoted “net pir”). Figure 1 shows 4 of the 15 instruments. The red linear least-squares fits are forced through zero according to the technique suggested in Dutton et al. (2001) for Eppley PSPs only. The black fits follow the points, with some going naturally through zero as one would expect for a net infrared signal of zero. The standard PSP was corrected using the Dutton et al. (2001) method, the two PSPs equipped with dome and case thermistors were corrected with the Haeffelin et al. (2001) method and 12 others were corrected using the black fits. Caps were placed over the pyranometers during the mid afternoon to determine whether the predicted offset based on the night data was correctly predicted. Twelve of the fifteen offsets were within 1 W/m^2; two did poorly in this regard, and we were unable to cap one of the instruments since the dome diameter was larger than our cap diameter.

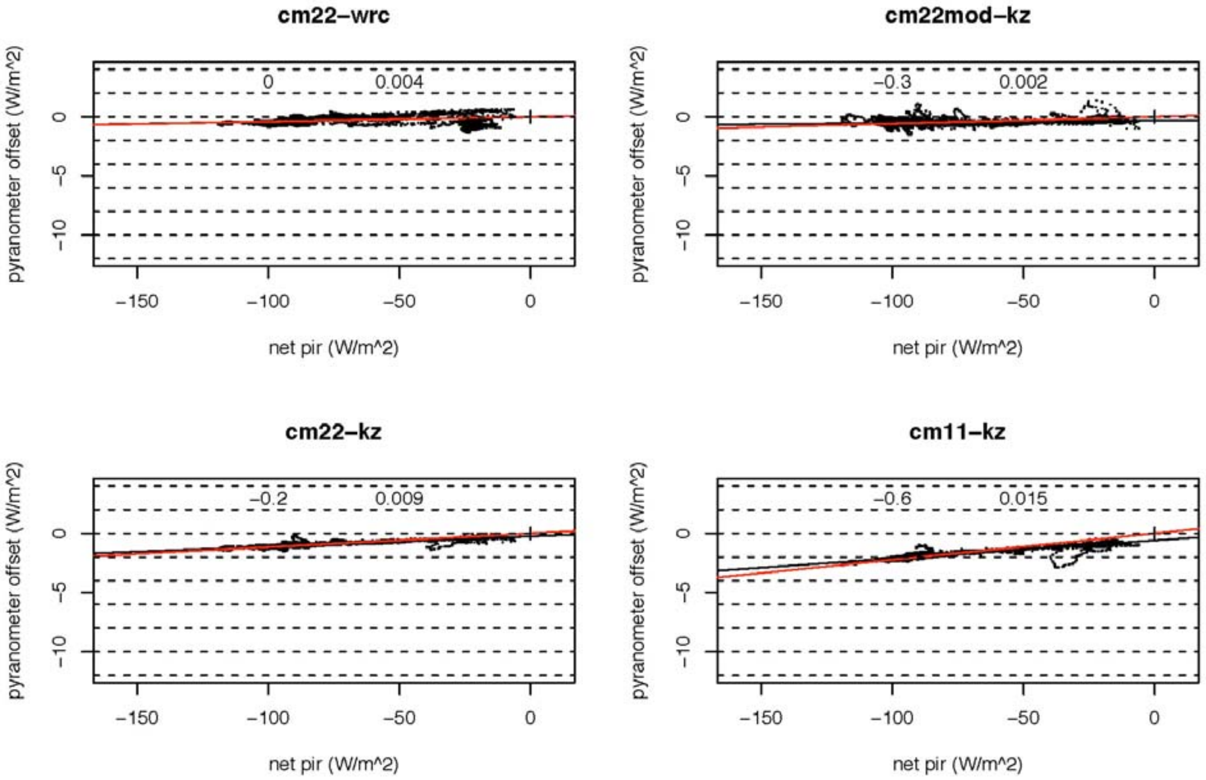

Figure 1. The offsets of four instruments at night versus the net pir measurement. For these four pyranometers the black line linear least squares fit was used to predict the offset for both day and night conditions. Capping experiments during the day validated the predictions for most of the instruments.

Results

Figure 2 is an over-plot of the eight instruments listed. This was a very clear day with no visible clouds above 5° of elevation. The spread is only about +/-1 W/m^2. We would be finished if the other seven pyranometers were not presenting data as well. The rest of the story is to explain why instruments vary from this majority and explain whether there is any physical justification for eliminating them just because they do not agree with this majority.

For example, in Figure 3, the Dutton et al. 2001-corrected PSP falls below the majority, shows more noise, and is not nearly a constant fractional offset. On this basis we can eliminate it as a candidate for the standard group. These arguments plus poor offset behavior can be used to eliminate several of the other pyranometers. The exceptions are the three instruments that read high in Figure 4. Two are Eppley 8-48s and the other is the YES prototype. The three instruments have cosine responses that exceed the normalized cosine response at large angles of incidence compared with the majority that generally have cosine responses that underestimate the normalized cosine response. This effect, tested for isotropic and Rayleigh conditions for instruments shade/unshade-calibrated at 45°, explained less than 0.5% of the 3%-5% differences.

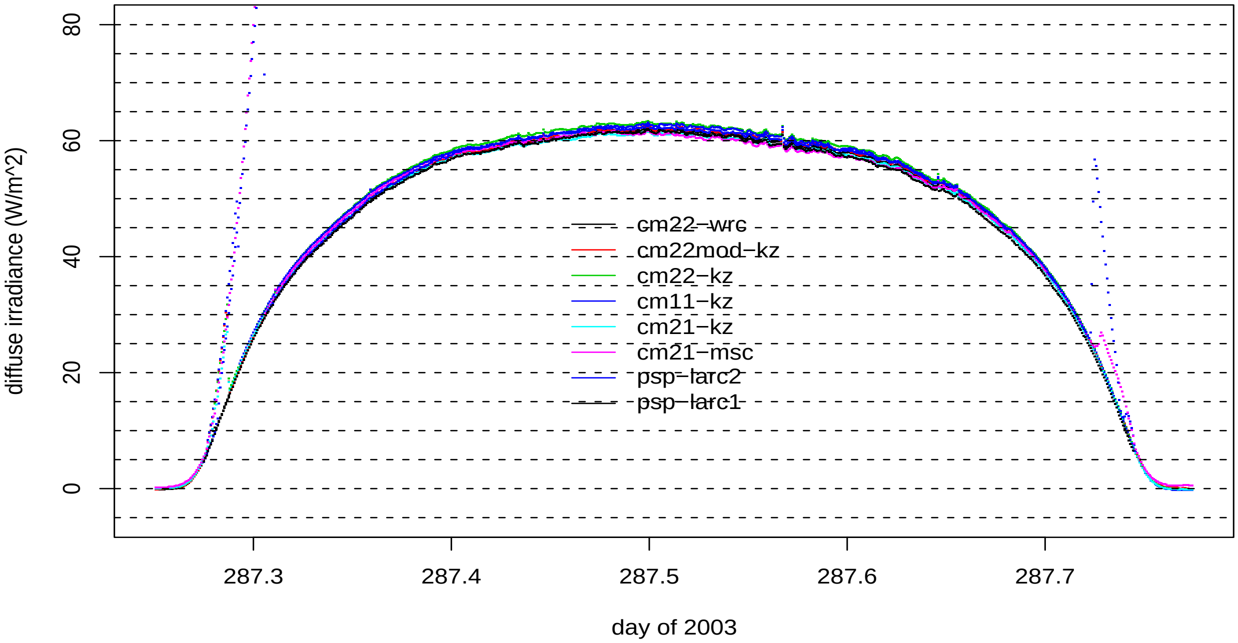

Figure 2. Over-plot of eight instruments that are corrected for offset and have a common shade/unshade calibration applied. One tracker started late and ended early in the day exposing pyranometers to direct sun at times.

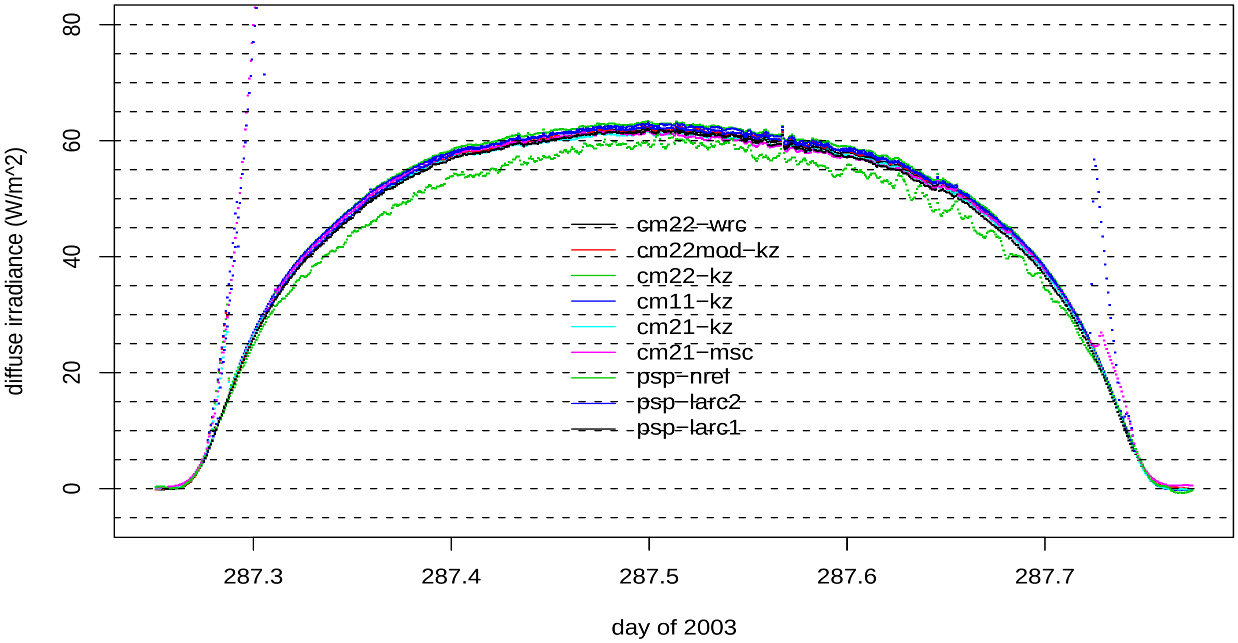

Figure 3. The PSP corrected with Dutton et al. (2001) technique falls below the group, and the bias is not a constant fraction. Furthermore, the offset correction of this instrument on cloudy days is inadequate.

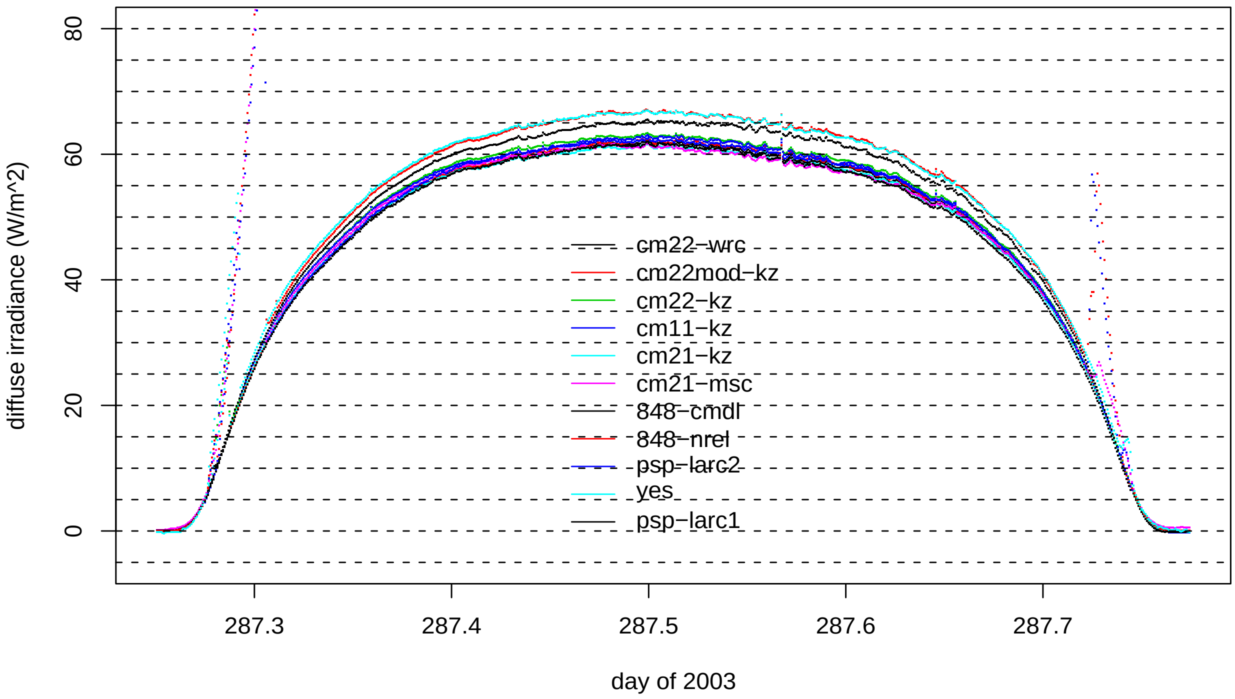

Figure 4. The 848-cmdl, 848-nrel, and YES prototype read high relative to the majority of instruments.

For the 8-48s the working hypothesis is tied to the spectral reflectivity of the white paint on the alternate sectors of the receiver. If it is not constant with wavelength, the response will change according to the spectral distribution of the incident light, which for clear skies and cloudy skies is quite different. We are investigating early reports that the white paint does not reflect as well in the near-infrared than it does in the visible spectrum. We have no clear explanation as yet of why the YES prototype reads as high as it does.

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