ARESE II Spectral and Broadband Shortwave Absolution Calibrations

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Introduction

In the first Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE), care was given to the characterization and calibration of each instrument, but each absolute calibration was performed independently using whatever standard was available to each investigator. Kiedron et al. (1999), for example, have demonstrated that there may be significant variability in spectral calibration sources. The lack of redundancy also cast some doubt on the measurements made for this experiment.

In the ARESE II there is an attempt to improve both situations by having calibrations of absolute irradiance performed before and after the flight portion of the experiment for the broadband and the spectral instruments using the same standards for broadband measurements and the same spectral lamps for spectral calibrations. Further, there are three systems measuring broadband and three systems measuring spectral irradiance mounted on the aircraft looking in the nadir and looking in the zenith with multiple systems at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site looking up from the surface.

In this paper, we discuss the systems that we have deployed for the spectral and for the broadband calibrations and some of the initial data.

Spectral Calibration

The spectral instruments used in ARESE II are the National Aeronautics and Space Administration (NASA) Ames Research Center's solar spectral flux radiometer (SSFR) spectrometer, the Colorado State University's scanning spectral polarimeter (SSP) spectrometer, and the University of California San Diego's total direct diffuse radiometer (TDDR) interference filter photometer. These instruments measure spectral irradiance using different techniques. Each instrument is characterized for angular response and wavelength response by the individual institution before and/or after the ARESE II.

The spectral irradiance standard for this experiment was established using six National Institute of Standards and Technology (NIST) lamps purchased for the ARM Program by the National Renewable

Energy Laboratory (NREL). The measurements were performed using the NREL Optronic OL750 spectrometer with an integrating sphere receiver that measures spectral irradiance between 280 and 2400 nm using three different gratings, silicon and PbS detectors, and five order-sorting filters. Standard practices recommended by NIST were followed in aligning and operating the lamps.

The average responsivity of the six lamps was used to set the calibration scale. Figure 1 indicates that the six lamps vary within approximately ± 2% of this scale. The 'T' and 'W' in the legend indicate measurements taken on two different days (Tuesday or Wednesday). It is interesting to note that the differences are offsets that are nearly constant with wavelength, indicating some problem with geometry rather than color temperature control. We suggest that the problem was with the NIST procedure because the repeatability of the protocol that we followed appears to be a factor of four better (see Figure 1 for our Tuesday and Wednesday measurements of lamp 404).

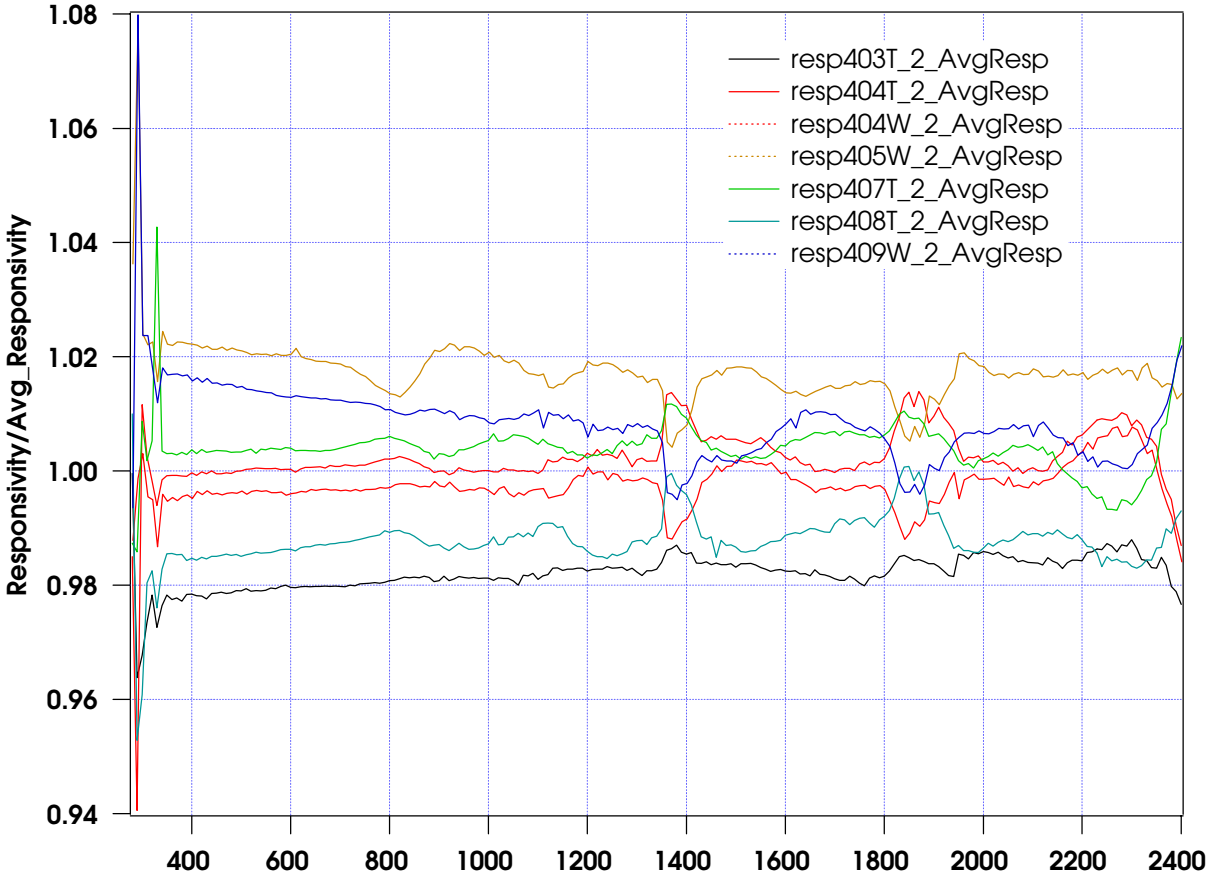

Figure 1. Ratio of six lamp responsivities to their average. One lamp run was repeated on two days (404) with closely matched results. The offsets are almost constant with wavelength and likely associated with the NIST calibrations.

Figure 2 contains plots of the output of the lamps used in the calibration of the ARESE II spectral instruments. In particular, we recommend that calibrations performed at the Ponca City, Oklahoma, airport using lamps GS937, GS938, and GS939 are the most dependable calibrations. At least two of these three lamps were used for each spectral instrument calibration.

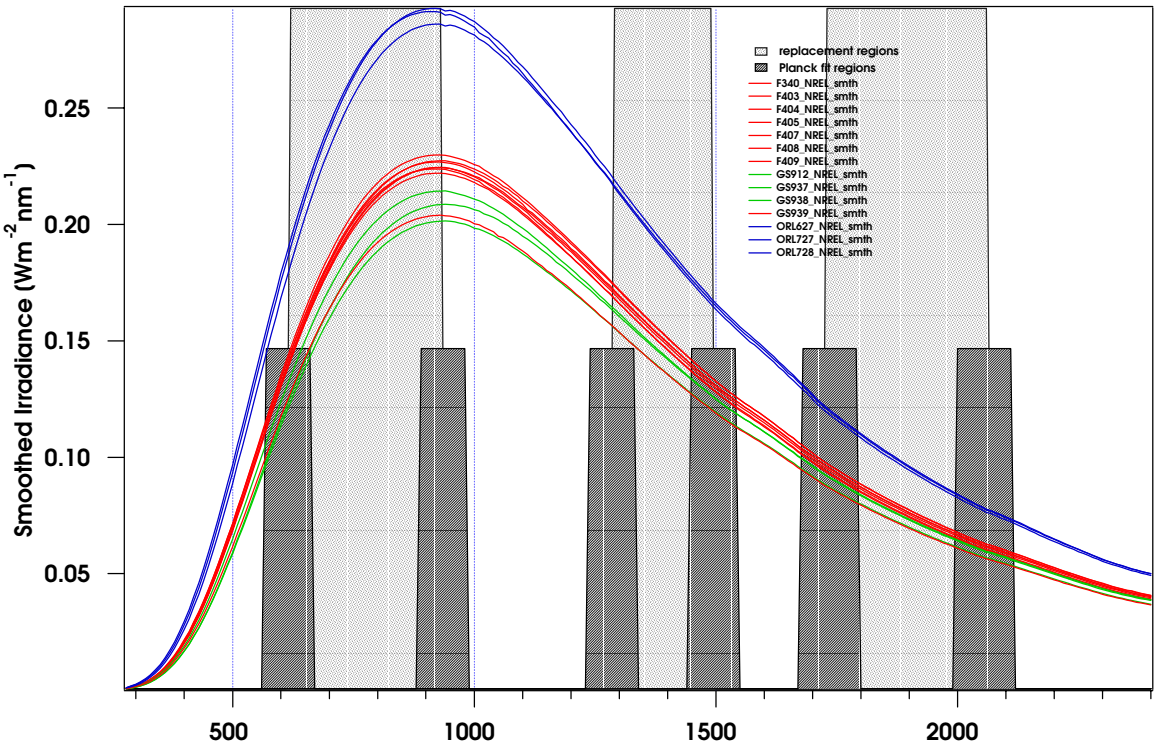

Figure 2. Spectral irradiance of lamps used for ARESE II spectral calibration. Lamp outputs have been smoothed through the apparent discontinuities in Figure 1 using a blackbody function to smooth. GS937, GS938, and GS939 1000W FEL lamps were the primary sources in the spectral calibrations.

Broadband Calibration

The broadband calibration system follows the Baseline Surface Radiation Network (BSRN) recommendation for the measurement of shortwave radiation. An Eppley AHF absolute cavity radiometer to measure direct normal irradiance is the anchor for this type of calibration with its tie to the World Radiation Reference. An Eppley normal incidence pyrheliometer (NIP) is used to measure direct when the cavity is either not operating or the cavity is in the calibration phase of its operation. We used an Eppley 8-48 and an Eppley precision spectral pyranometer (PSP) under the tracking balls of a Sci-Tec Model 2AP tracker to measure the diffuse. The 8-48 is our primary source of diffuse horizontal irradiance with the PSP as backup. In addition, an Eppley precision infrared radiometer (PIR) is shaded to provide data that is used for the correction of the PSP offset. The total horizontal irradiance is the sum of the normal component of the cavity measurement and the 8-48 diffuse horizontal irradiance, if they are available; otherwise, the other measurements are substituted when required.

Figure 3 contains plots of the data used for the initial calibration of the shortwave irradiance instruments. Before and after solar noon, the skies had considerable cirrus cloud cover. The nearly two-hour period centered at solar noon, 12:43 local time, was largely devoid of cloud cover with diffuse horizontal irradiance near or below 100 W/m^2. One-minute averages of 30 2-sec samples yielded standard deviations of between 0 and 2 W/m^2 indicating the level of stability that is required for a calibration. In Figure 3, the PSP diffuse is lower than the 8-48 diffuse because no corrections for offset have yet been applied to these data.

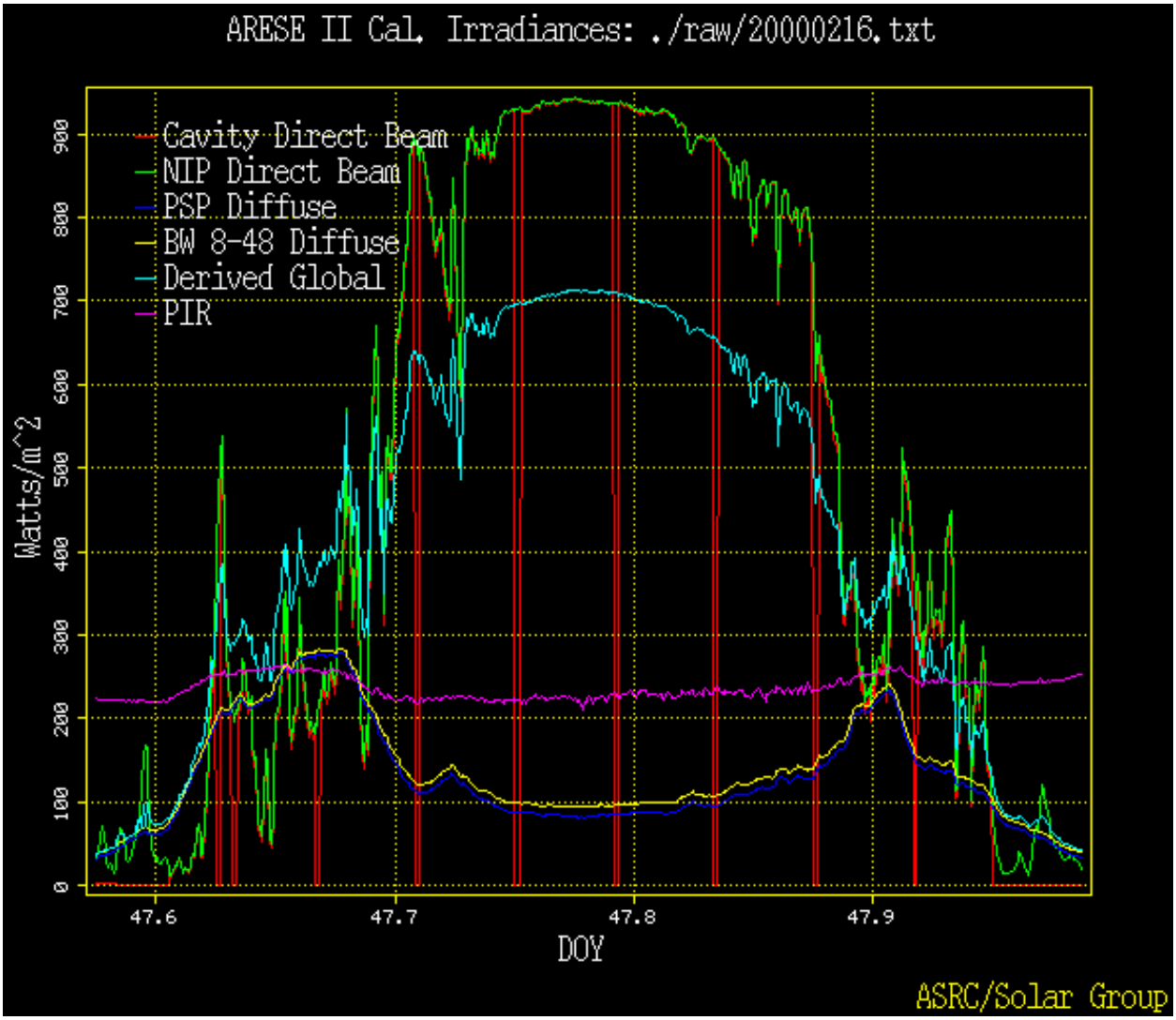

Figure 3. Broadband shortwave irradiance data for February 16, 2000. To calibrate ARESE II pyranometers, total horizontal irradiance data near solar noon are used. The light blue total horizontal irradiance data are sums of the vertical component of the direct measured with the Eppley AHF cavity radiometer and the diffuse horizontal irradiance measured with the Eppley 8-48. The Eppley NIP is substituted for the cavity during its internal calibration (dips in red).

Reference

Kiedron, P. W., J. J. Michalsky, J. L. Berndt, and L. C. Harrison, 1999: Comparison of spectral irradiance standards used to calibrate shortwave radiometers and spectroradiometers. *App. Opt.*, **38**, 2432-2439.