Aspects of the Quality of Data from the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) Site Broadband Radiation Sensors

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A systematic evaluation of the performance of broadband radiometers at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site is needed to estimate the uncertainties of the irradiance observations. Here, net radiation observed with the net radiometer in the energy balance Bowen ratio (EBBR) station at the central facility is compared with the net radiation computed as the sum of component irradiances recorded by nearby pyranometers and pyrgeometers. In addition, data obtained from the central facility pyranometers, pyrgeometers, and pyrheliometers are examined for April 1994, when intensive operations periods were being carried out.

The data used in this study are from central facility radiometers in a solar and infrared observation station (SIROS), an EBBR station, the so-called "BSRN" set of upward pointing radiometers (where BSRN previously implied Baseline Surface Radiation Network), and a set of radiometers pointed down at the 25-m level of a 60-m tower. The 25-m radiometers view a wheat field. The SIROS, BSRN, and EBBR radiometers are all located in a pasture and are positioned within 25 m of each other; the upward pointing radiometers are at a height of about 1.5 m above the local surface, the net radiometer is at a height of 2.3 m, and the downward pointing SIROS pyranometer and pyrgeometer are at a height near 9.5 m. All of the upward pointing pyranometers and pyrgeometers are ventilated, but the net radiometer and the downward pointing radiometers are unventilated.

The uncertainties of readings from net radiometers are known to be substantial at times and differ considerably for varying radiometer designs (e.g., Field et al. 1992; Halldin and Lindroth 1992). The absolute uncertainties of net radiometer readings might optimistically be viewed as being no better than about ±10 W m^{-2} or ±5%, whichever is larger, for any particular half-hour irradiance average. In this paper, suggested uncertainty values correspond to the range for confidence levels of 90-95% for averaged readings. For pyranometers subjected to the broadband outdoor radiometer calibration (BORCAL) procedure by the National Renewable Energy Laboratory (NREL), the uncertainty of individual readings is reported to be typically about 3% (Wells et al. 1993). Pyranometer data reported here and by the Atmospheric Radiation Measurement (ARM) experiment center are all computed with calibration coefficients generated from BORCALs. Recent comparisons, however, of BORCALs sensitivity coefficients to those produced originally with integrating spheres by the manufacturer, Eppley Laboratory, Inc., suggest that the NREL BORCAL procedures result in irradiance values that are approximately 3% larger on average than those that would be obtained with the Eppley coefficients.[a] For pyrgeometers, past experiences have shown that irradiance estimates using factory sensitivity coefficients have typical uncertainties of about ±20 W m^{-2}. By careful comparison of pyrgeometers and subsequent adjustment of calibration coefficients, however, agreement within 5 10Wm^{-2} for any group of pyrgeometers appears to be possible;[b] NOAA/SRRB has carried out such comparisons for the pyrgeometers used in this study. All pyrgeometer data reported by the ARM experiment center are currently derived with the Eppley factory calibrations.

Net Radiation

Differences between 30-min averages of EBBR net radiometer (Rn) values and values computed as

(a) J. DeLuisi, National Oceanic and Atmospheric Administration (NOAA), Surface Radiation Research Branch (SRRB), Private communication.
(b) J. DeLuisi, National Oceanic and Atmospheric Administration, Surface Radiation Research Branch, Private communication.

the component sum from the SIROS data are shown in Figure 1 for the months of December 1994, January 1995, and February 1995. With the pyrgeometer factory (Eppley) calibrations, the nighttime differences increase from near zero to about 15 W m^{-2} as the net radiation decreases from zero to about 80 W m^{-2}. The differences are displaced by about 15 W m^{-2} for all net radiation values when the NOAA/SRRB calibration coefficients are used for the pyrgeometers. We hypothesize that the nighttime trend evident for both sets of data indicates that the longwave sensitivity of the EBBR net radiometer is slightly different than the sensitivity of the pyrgeometers. For the positive values of net radiation in Figure 1, most of the differences would probably be made larger on average by approximately 3% of the values on the horizontal scale if the Eppley sensitivity coefficients had been used rather than the BORCAL coefficients for the pyranometers.

Condensation and frost are known to occur on the radiometer domes, particularly on the upper dome of the EBBR net radiometer when exposed to cloudless nighttime skies. Condensation on the domes of the upward pointing pyrgeometers and pyranometers is less likely because they are ventilated. When frost or condensation at night was visually seen only on the EBBR radiometer domes, the EBBR net radiation was sometimes as much as 50 W m^{-2} larger (less negative) than the SIROS pyrgeometer estimates made with the Eppley calibration factors. Such large discrepancies disappeared after the condensation or frost evaporated from the domes. We suggest that condensation or frost on the EBBR net radiometer dome is considerably warmer than the sky and thus causes overestimates of downward longwave radiation. Further analyses have indicated that largest overestimates of nighttime values from the EBBR net radiometer during December 1994 through February 1995 tended to occur when the relative humidity was high, when condensation was particularly likely. Some of these cases can be seen in the upper left-hand corner of Figure 1.

Recent analyses indicate that readings from the EBBR net radiometer during the afternoon at the central facility during December 1994 through February 1995 were sometimes suppressed by as much as 100 W m^{-2}. By visual inspection, condensation was seen on the interior of the EBBR domes; this condensation could have shaded the sensing element slightly from direct-beam solar radiation. Cloudless skies and southerly winds seemed to be correlated with this situation. The reduced values for the data points seen in the lower right-hand corner of Figure 1

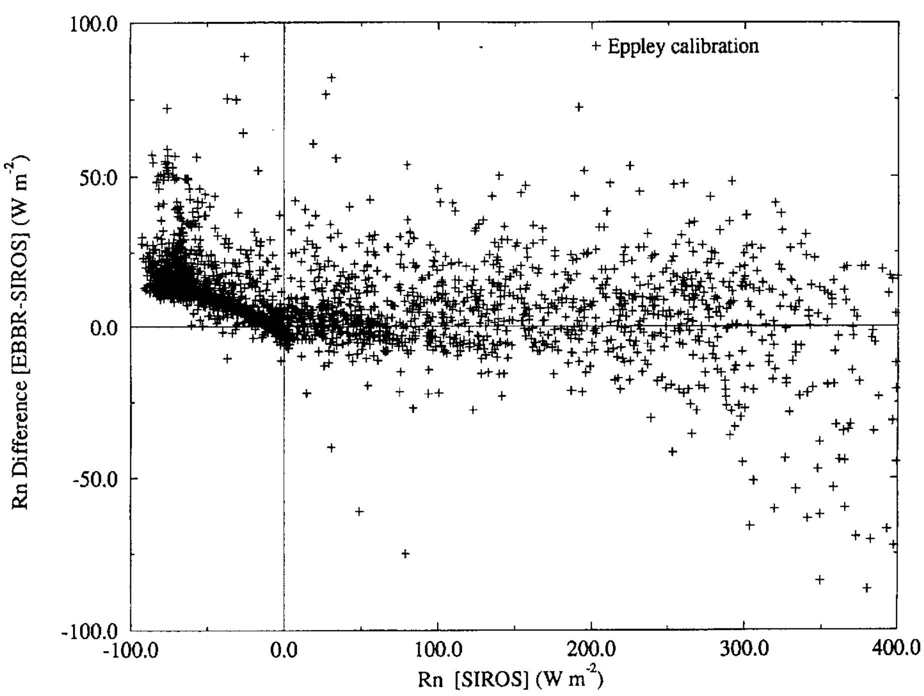

Figure 1. Differences between 30-min-average net radiation estimates from the central facility EBBR and SIROS during December 1994, January 1995, and February 1995 versus the SIROS net radiation values. The SIROS net radiation estimates were computed with the Eppley factory calibration coefficients.

might have been caused by this condensation problem. We suspect that the source of the condensation might be eliminated by an improved seal around the net radiometer domes and more frequent change of desiccant in a tube leading to the dome air, but further investigation is needed.

Replacement of the domes on the EBBR net radiometers could cause a change of as much as 3% in its sensitivity, according to the manufacturer. A rather large change was seen when the domes were replaced on December 2, 1994, after which the nighttime Rn difference dropped on average from about 30 W m^{-2} to 15 W m^{-2} when the net irradiance was near 80 W m^{-2}. Other instances of dome changes will be studied to characterize more thoroughly the effects of dome replacement on the EBBR net radiometer readings.

The effects of using SIROS net radiation estimates for the calculation of sensible and latent heat fluxes can be evaluated by replacing the EBBR net radiation values with SIROS-derived values in the energy balance equation. Figure 2 shows a case study, in which the Eppley coefficients were used with the pyrgeometer data. Our analyses suggest that the latent heat fluxes, on average, appear to be mostly unaffected by use of the SIROS net radiation values, but the sensible heat fluxes are substantially altered at times, somewhat in proportion to the changes in the net radiation values used.

April 1994 Data

A set of graphs displaying daily broadband radiation data obtained at the central facility in April 1994 can be obtained from M. Wesely at mlwesely@anl.gov or J. Tichler of Brookhaven National Laboratory at tichler@met.das.bnl.gov. Figure 3 shows the types of data addressed. Observations of diffuse and direct-beam solar irradiances with the central facility SIROS were not made during this month. Because the BSRN global solar irradiance (K⇓) computed as the sum of direct and diffuse components agreed well on April 18 with the BSRN and SIROS K⇓ observed directly with unshaded pyranometers, the BSRN pyranometer used to observe the diffuse irradiance was apparently shaded quite well on this day. Such comparisons on other days indicate that the shading disk was improperly positioned for periods of several hours on April 6, 23, and 24.

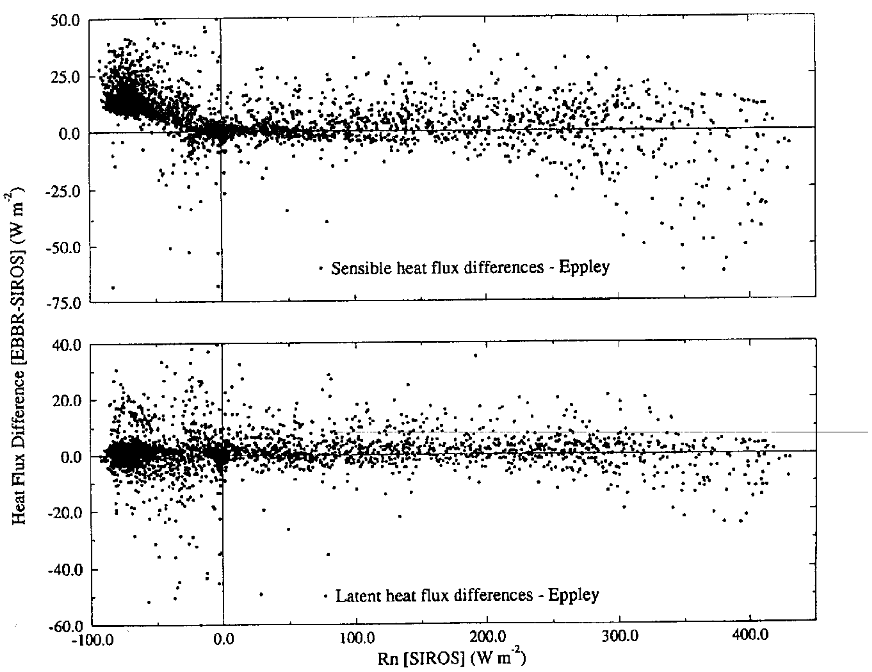

Figure 2. Differences between 30-min-average surface flux estimates from the EBBR and recalculated fluxes using the SIR0S net radiation values (with the Eppley factory calibration coefficients) for (a) sensible heat flux and (b) latent heat flux for December 1994, January 1995, and February 1995.

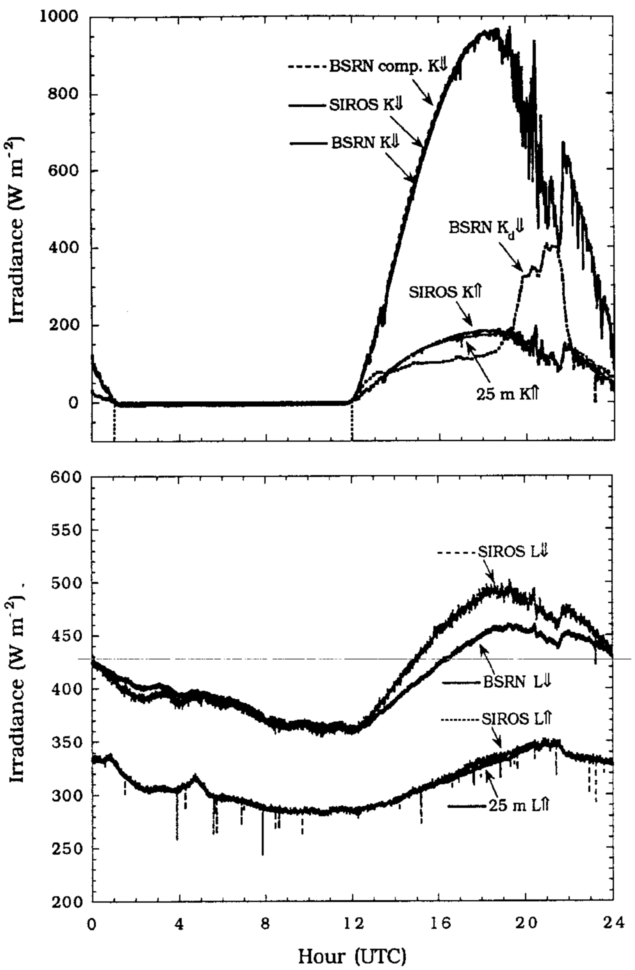

Figure 3. Irradiance observations made with pyranometers, pyrgeometers, and a pyrheliometer during April 18, 1994, where "K" indicates solar radiation, "L" longwave radiation, the downward pointing arrow to downwelling radiation, the upward pointing arrow to upwelling radiation, "comp." to the component sum of diffuse plus direct-beam irradiance on a horizontal surface, and the subscript "d" to diffuse solar radiation seen with a shaded pyranometer.

"Spikes " can be seen in Figure 3 on several of the SIROS data streams. All SIROS data streams from the central facility except for the upwelling longwave irradiance exhibited this problem. It was eliminated on September 20, 1994, by moving an electric cattle fence surrounding the SIROS instruments to a greater distance from the instrumentation. These spikes also occurred at the two Ashton and Ringwood extended facility SIROSs in operation in April 1994 and continued until the electric fences there were relocated in September 1994. From the dates of the SIROS installations to the dates when the electric fences were moved, spikes on the SIROS data were common whenever the fence was activated. In general, the spikes tended to bias the SIROS readings low by a 0.2 1.5 W m^{-2} for 30-min averages for all affected sensors except the SIROS pyrheliometer, for which the reduction could be as large as 10 W m^{-2}. For 5-min averages, the reductions could be 3-4 times larger.

Calculations show that the observations of diffuse solar irradiance with the BSRN shaded pyranometer are 4-8% larger than comparable, midday values from the BSRN and SIROS unshaded pyranometers on overcast days in April 1994. The cause of this discrepancy is unknown, but we recommend that users of the data multiply the diffuse readings by 0.94. The upward pointing SIROS pyrgeometer read about 2% larger on average than the BSRN pyrgeometer, and the two upward pointing hemispherical solar sensors appear to give mean values within 1% of each other. Table 1 lists surface albedos computed for days selected for consistently overcast skies and for cloudless skies between 1600 and 2000 hr (UTC). The albedos for overcast conditions do not appear to have changed significantly from day to day and were about the same for the two fields. For cloudless conditions, the albedos might have decreased slightly during the month, with the wheat field having a perceptibly smaller albedo than the pasture.

Table 1. Computed values of surface albedo at two locations at the central facility during April 1994.

Day of Month	Pasture	Wheat
Overcast		
5	0.186	0.201
9	0.205	0.202
11	0.147	0.185
22	0.196	0.199
Cloudless		
3	0.222	0.214
6	0.203	0.182
15	0.191	0.175
16	0.194	0.174
17	0.194	0.184
26	0.187	0.165

Acknowledgments

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