Ground Station Radiation Measurements During the Atmospheric Radiation Measurement Enhanced Shortwave Experiment Campaign

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We present data from three remote ground stations located along the main flight tracks of the Atmospheric Radiation Measurement Enhanced Shortwave Experiment (ARESE). Each ground station consisted of three hemispherical field-of-view instruments: a total solar broadband radiometer (TSBR), fractional solar broadband radiometer (FSBR), and a total-direct-diffuse radiometer (TDDR). This radiation measurement system (RAMS) was identical to that aboard the aircraft used for measuring the upwelling and downwelling fluxes during the ARESE mission. The TSBR and FSBR instruments on the RAMS stations measured the downwelling component of the atmospheric radiation field from 0.26 to 4.0 µm and 0.695 to 2.9 µm, respectively, whereas the TDDR covered 7 spectral channels in the solar spectrum 0.500, 0.86, 1.05, 1.250, 1.50, 1.65, and 1.75 µm, with each channel having a bandpass of roughly .01 µm.

Ground-based spectral data was acquired during the ARESE campaign in the period between October 11 and November 1, 1995, in conjunction with aircraft measurements using identical instruments. RAMS measurement systems were located at the central facility (cloud and radiation testbed [CART] site) in Lamont, OK, as well as remote facilities at Ringwood and Byron, OK, for the purpose of covering both the primary northern and southern flight tracks of the mission. The three sites chosen were also outfitted with ARM solar and infrared radiation observation stations (SIROS) platforms consisting of a variety of multifilter rotating shadowband radiometers (MFRSR), pyrgeometers, pyranometers, and pyrheliometers, that measured both narrowband and broadband direct and hemispherical radiation.

During each day of operation, data were acquired through a semi-portable acquisition system with a laptop PC providing real-time display of the raw signals. A typical checklist of operations included

- setup: unpacking from overnight storage
- warmup: typically 15-20 minutes
- dark signal startup measurement: data acquisition with instrument covers in place (high and low gain for TDDR instruments)
- flux measurements: TDDR gain initially set at high and manually change to low depending on daily atmospheric conditions
- dark signal shutdown measurement: data acquisition with instrument covers in place (high and low gain for TDDR instruments)
- shutdown: conventional data to floppy disk and pack system for overnight storage

After daily operation, data were transferred to floppy disk for quick-look analysis and archiving.

The TSBR's and FSBR's were carefully calibrated in order to characterize the detector's degree of equivalence of electrical and optical heating. The instrumental response is calibrated in the laboratory and the field using NIST traceable standards and standard detectors. Accuracies of 1% are typical with linearities within 0.1%. Zenith angular or "cosine" and azimuthal angular response of the instruments are tested in the laboratory using a well collimated beam of light at various angles. Selection of proper diffuser materials eliminates most of the cosine response imperfections yielding response accuracy of 0.5%.

Analysis of the signals is accomplished first by evaluating the dark signal for the given detector. During the ARESE period the dark signal was measured both during the startup and shutdown periods on each day. Analyses for all days of operation and for all ground stations indicate a deviation corresponding to less than 5 W m^2 with the deviation for a given day typically less than 2 W m^2 per instrument. Finally, radiances are calculated from the measured signal via the relation:

$$F = C * (S - D) \quad (1)$$

where, F is the flux (W m^2), C is the derived calibration constant (W m^2 V^{-1}), S is the signal (V), and D is the dark signal (V).

To test the ability of the broadband radiometers in accurately recording variations in the atmospheric conditions, data were compared on two clear sky days; October 11 being characterized by having much larger optical depths than on October 15. Measured results from the RAMS station at Lamont are presented in Figure 1 and show a decrease of about 30 W m^2 in the peak radiance for the more optically thick day (October 11) despite the higher sun angle (43.63 vs. 45.13°) corresponding to about a 35 W m^2 increase in the exoatmospheric constant over this bandpass. Similar measurements from the SIROS Downwelling Shortwave Hemispherical Irradiance, Ventilated Pyranometers indicate little to no variation between these two measurement periods.

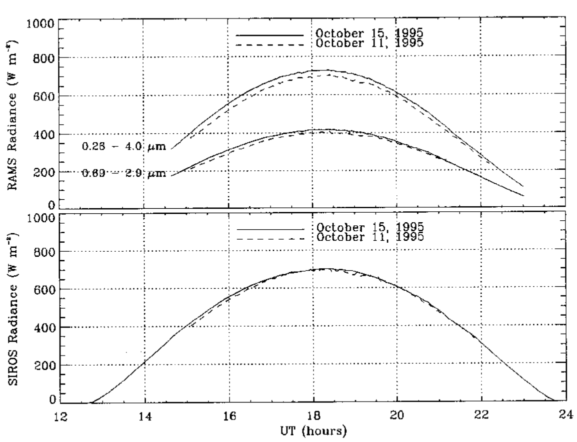

Figure 1. RAMS vs. SIROS on October 11 and 15, 1995.

For the TDDR, determination of the direct solar and diffuse components of the radiation field is achieved by incorporating an oscillating shadow ring in front of the optical aperture of the hemispherical field-of-view radiometer. In this fashion, at some point during the oscillation cycle, the ring will project a shadow that will exclude the solar beam from the field of view of the radiometer; only the scattered or diffuse component, F_D, of the total radiation will reach the aperture of the optical system. On the other hand, when the oscillating ring is out of the field of view of the radiometer, the total hemispherical radiation field, F_τ, is detected. From the values of F_D and F_τ, the direct solar beam, F_s, is obtained. The value of F_s, in conjunction with the exoatmospheric value of this parameter (which can be determined using a Langley method with ground data, via direct measurements of high flying aircraft, or with model calculations), are used in evaluating optical depths at the wavelengths corresponding to the spectral channels.

Conversion of the raw signal to meaningful units of each of the TDDR channels is identical to that of the broadbands in that there exists an offset and scaling factor (for each gain setting). The procedure used in determining the direct solar component from one dip region consists of finding the inflection points on each wing of the dip and using these values to approximate the forward scattering component of the radiation field. In this manner, the direct solar beam, uncontaminated by any forward scattering component is determined. A sample of a complete analysis of the seven spectral channels of the RAMS station at Lamont on October 17 is shown in Figure 2.

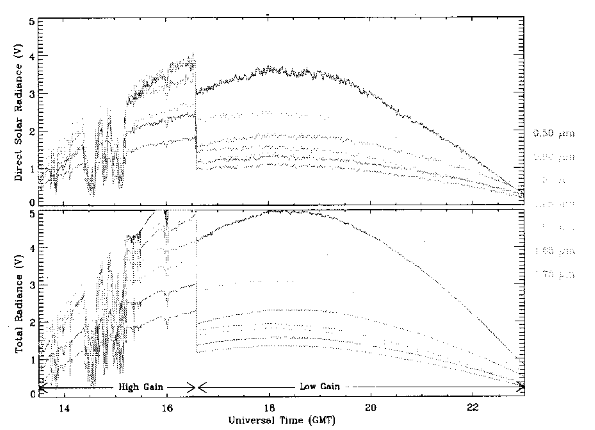

Figure 2. TDDR total and direct components - October 17 (Lamont).