# Broadband and Spectral Flux Measurements During the ARESE and ARM-UAV Spring 1996 Campaigns

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## Introduction

We present data collected over a 3-week period at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site from three remote ground stations located along the main flight tracks of the ARM 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 measured the downwelling component of the atmospheric shortwave radiation field from 0.224 to 3.91 microns and 0.68 to 3.3 microns, respectively; whereas the TDDR covered 7 spectral channels (approximately 10 nm bandpass) in the solar spectrum: 0.500, 0.862, 1.064, 1.250, 1.501, 1.650, and 1.750 microns. Data from these surface instruments will be used in conjunction with the aircraft measurements to characterize the atmospheric column absorption between the surface and various atmospheric levels. Absolute and relative comparisons of the total solar broadband instruments are made with pyranometers located in close proximity to the RAMS measurements. Moreover, total and aerosol optical depths are determined via the rotating shadow bands of the TDDRs in varying clear sky conditions.

## Absolute Flux Determination

Raw data (V) is converted to absolute fluxes (W/m$^2$) via the dark signal measurements in the field and the experimentally derived calibration constants. After initial conversion, the angular response of the broadband detectors and TDDR are incorporated into the measurements to provide the true downwelling component of the incident radiation. This improvement to the data is accomplished by estimating the direct and diffuse components of the radiation field (via a TDDR shadow ring analysis) and correcting these components appropriately. The direct component is scaled using the experimentally measured angular response corresponding to the known sun/instrument angle and the diffuse component is scaled using a weighted average of the angular response function over the entire hemisphere.

A sample of the TSBR and FSBR data from October 11 and 15, 1995, is shown in the top panel of Figure 1; TDDR data (500- and 1501-nm channels) are presented in Figure 2. All the instruments acquired data at a rate of approximately 9 Hz during all operation periods. The narrowband fluxes presented in Figure 2 are the result of a shadow ring analysis used in determining the total and diffuse portions of the downwelling flux.

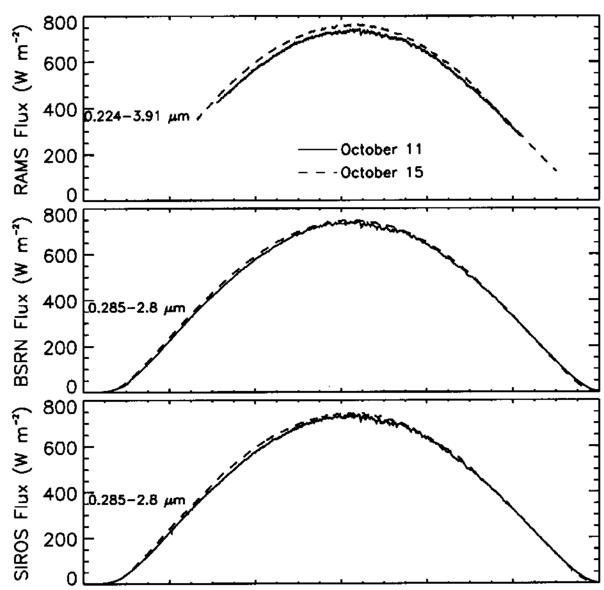


**Figure 1**. RAMS, BSRN, and SIROS downwelling fluxes on October 11 and 15, 1995.

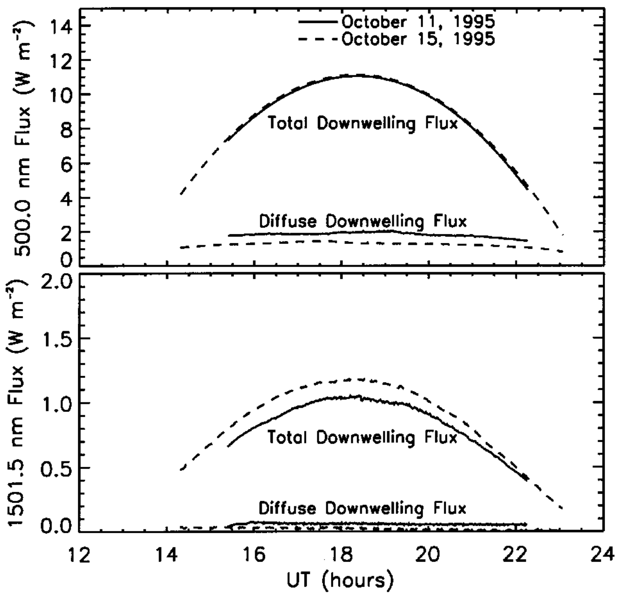


**Figure 2**. TDDR 500 and 1501 nm data on October 11 and 15, 1995.

## October 11 Versus October 15

Despite the fact that clear conditions existed on both October 11 and 15, the atmosphere during October 11 was considerably more optically thick than that on October 15. A comparison of water vapor soundings taken at 3-hour intervals during these days demonstrates this fact. Sounding taken at 17:30 Universal Time (UT) on each day indicate the peak relative humidity at about 70% on October 11 and about 40% on October 15, at altitudes of roughly 3 and 4 km, respectively. Maximum solar zenith angles at the Central Facility in Lamont, Oklahoma, of 43.63 and 45.13 degrees imply that the top-of-atmosphere (TOA) downwelling component of the total solar flux is about 2.6% (~35 W/m$^2$) greater on October 11 than that on October 15. RAMS measurements on these days verify the significant absorption in the total and near-infrared broadband channels (top panel of Figure 1) such that the surface flux is about 30-40 W/m$^2$ less on October 11 relative to that on October 15; hence an additional 70 W/m$^2$ is absorbed. Similar Solar and Infrared Observing System (SIROS) and Baseline Surface Radiation Network (BSRN) measurements (middle and bottom panels of Figure 1) indicate less day-to-day variation (10-20 W/m$^2$) in the peak fluxes on these days, thus indicating an additional absorption of only 50 W/m$^2$.

TDDR data measured and analyzed on these days support the relative optical thicknesses discussed above. Referring to Figure 2, the diffuse component of conservative scattering 500-nm channel is definitely larger on the optically thick day and the total downwelling fluxes are roughly equal. Consequently, the optical depth is greater on October 11. The 1501.5-nm channel, located on a water vapor band, shows a significant decrease in signal associated with the additional water vapor content indicating absorption in this band. The larger diffuse signal also indicates an increase in scattering on October 11 at 1501.5 nm. Furthermore, using the shadow ring analysis to interpret the TDDR data, the optical depths determined on each of these days show that the optical depths are significantly greater on October 11 than on October 15.

## Data Validation

Model calculations made on various days during ARESE are used to validate RAMS measurements during this period. An initial calculation of upwelling and downwelling fluxes on October 11 and 15, 1995, are presented in Figure 3. The total solar broadband flux is calculated versus altitude at local solar noon using the narrowband adding/doubling method (Kiehl and Briegleb, private communication) with an appropriate aerosol layer. The total downwelling broadband flux on October 11 starts out greater than that on October 15 due to the greater solar zenith angle at local noon, but this effect is

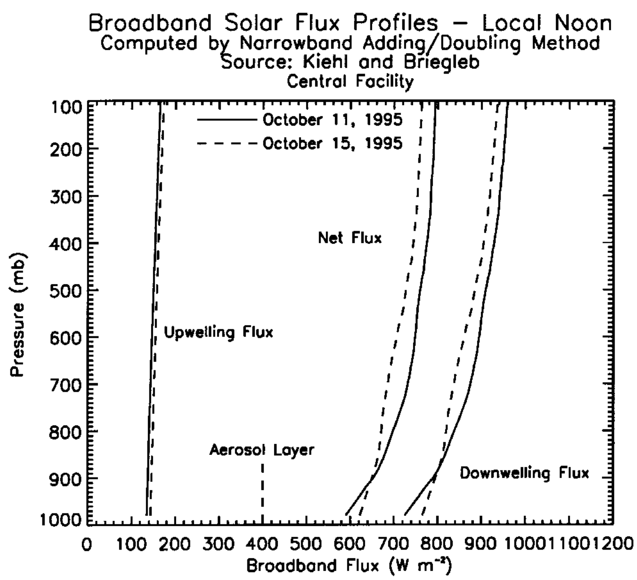


**Figure 3**. Model calculations (Kiehl and Briegleb, private communication) at local noon on October 11 and 15, 1995.

reversed at the surface due to the variations in the atmosphere during the two days. The difference of about 30 $W/m^2$ compares favorably with the RAMS measurements made on these days (see Figure 1).

# Conclusions

The RAMS broadband and spectral measurements made on October 11 and 15, 1995, are consistent with each other in that the more optically thick day (October 11) shows an enhanced amount of absorption throughout the day. The magnitude of this extra absorption is consistent with model calculations at local solar noon on each day. Similar BSRN and SIROS measurements made on these days also indicate an added absorption on October 11, but about 20 $W/m^2$ less than the total amount of 70 $W/m^2$ measured by the RAMS instruments.