Operation of a Multi-Filter Rotating Shadowband Radiometer at Clark Atlanta University

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Introduction

The multi-filter rotating shadowband radiometer (MFRSR) measures the optical thickness of the atmosphere in six wavelength intervals (FWHM of 10 nm) to estimate optical extinction due to atmospheric ozone, haze and water vapor. The Earth System Science System (ESSP) is installing a new MFRSR on the roof of the Research Center for Science and Technology (RCST) at Clark Atlanta University (CAU) to conduct optical extinction studies in urban Atlanta. The magnitude of the optical extinction can serve as a measure of atmospheric concentrations of ozone and water vapor and as an indication of fluctuations in the overall concentration of atmospheric aerosols.

Objectives

The objectives of this work are to: (1) install and operate the MFRSR on the roof of the RCST, (2) produce Langley plots for each detection wavelength, and (3) use the MFRSR as an absolute reference for calibration of the ESSP's 2nd-generation LED sun photometers. Due to a shadowband programming problem, the direct normal beam was not able to be measured, and no Langley analyses could be performed.

The Instrument

The MFRSR measures the direct normal, diffuse horizontal, and total horizontal solar irradiances in six spectral bands: 415, 500, 610, 665, 862, and 940 nm. The instrument also provides a broadband (350-1000 nm)[1] measure of these radiation components. The sensors associated with each of the wavelength bands are all located in a small canister capped by a level, upward-looking Lambertian diffuser. Radiation that strikes the diffuser is directed towards the sensors. The sensors consist of a single silicon photodetector for measuring broadband radiation, and a set of photodiode detectors behind interference filters for measuring spectral irradiances. The diffuser is shaded at periodic intervals by a rotating shadowband. During these intervals the total horizontal diffuse radiation is measured for each wavelength, as well as the broadband channel. The shadowband is then moved so the diffuser is fully exposed to the sky. The total horizontal downward radiation is then measured. The difference between the total horizontal and diffuse radiation gives the downward component of the direct beam solar irradiance; from this quantity the direct beam solar irradiance is calculated.[2,3]

Theory

A Langley analysis is used to derive the vertical column depths of ozone, aerosols and water vapor. The direct solar beam as it passes through the atmosphere is attenuated according to Beer's law:

$I = I_o \exp(-? \sec(??)$

where I_o and I represent monochromatic radiances before and after attenuation by the atmosphere, ? is the monochromatic extinction of the atmosphere, ? is the zenith angle, and sec(?? is the relative optical or air mass. Taking the logarithm of each side gives the equation of a line:

$\ln(I) = \ln(I_o) - ? \sec(??$

The slope ? of the line gives the optical thickness of the atmosphere, and the intercept $\ln(I_o)$ is a measure of the extra-terrestrial radiance.

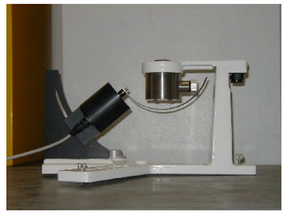
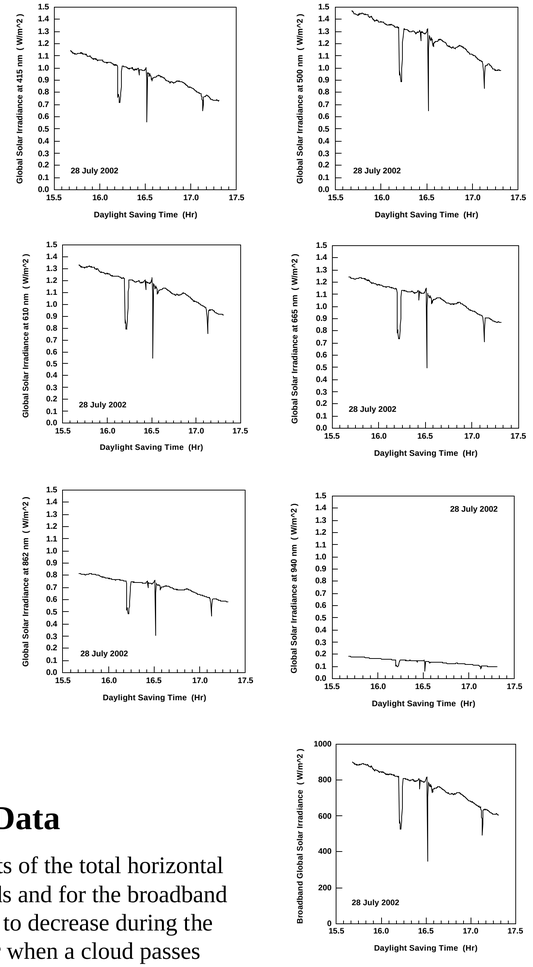


Figure 1. MFRSR.

Figure 2. Alisa Holley operating MFRSR.



Data

Figures 3-9 to the right are time series plots of the total horizontal irradiance for each of the six spectral bands and for the broadband sensor. The intensity in each band is seen to decrease during the afternoon hours. Dips in the signals occur when a cloud passes between the sun and the MFRSR. The signals generally track well, but small differences are found among them. The pointing direction of the MFRSR was changed during data acquisition, but this did not affect the measurements because the shadowband was not rotating.

Conclusion and Plans for Future Work

The MFRSR is now able to acquire total horizontal irradiance data, but is not quite ready to collect diffuse and direct-beam data. Materials have been purchased to construct a permanent mounting platform for the instrument, and an operation manual has been written. The next steps are to mount the instrument on the roof of the RCST and to fix the shadowband rotation problem.

[1]Harrison, L., et al., Appl. Optics 33 (1994) 5118-5125. [2]http://www.arm.gov/docs/instruments/static/mfrsr.html. [3]http://www.ess.uci.edu/~cmclinden/link/rsr.html.

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