Direct-to-Diffuse UV solar irradiance ratio for a UV rotating shadowband spectrograph (UV-RSS) and a UV multi-filter rotating shadow-band radiometer (UV-MFRSR)

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UV-MFRSR [Harrison et al., 1994]

QuickTime™ and a decompressor are needed to see this picture.

Abstract: Two spectroradiometers that measure direct and diffuse UV solar irradiance are located at the Table Mountain Test Facility, 8 km north of Boulder, CO. The UV- Rotating Shadowband Spectrograph (UV-RSS) measures diffuse and direct solar irradiance from 290 – 400 nm. The UV Multi-Filter Rotating Shadowband Radiometer (UV-MFRSR) measures diffuse and direct solar irradiance in seven 2-nm wide bands, i.e. 300, 305, 311, 317, 325, and 368 nm. The purpose of the work is to compare radiative transfer model calculations (TUV) with the results from the UV-Rotating Shadowband Spectroradiometer (UV-RSS) and the UV-MFRSR to estimate direct-to-diffuse solar irradiance ratios (DDR) that are used to evaluate the possibility of retrieving aerosol single scattering albedo (SSA) under a variety of atmospheric conditions: large and small aerosol loading, large and small surface albedo. For the radiative transfer calculations, total ozone measurements are obtained from a collocated Brewer spectrophotometer from the NEUBrew Network.

UV-RSS [Kiedron et al., 2001]

Motivation: The NEUBREW network (NOAA-EPA UV Network) was designed to investigate factors affecting surface UV solar irradiance. The network deployed Brewer spectrophotometers at six sites across the continental U.S. The sites were chosen to coincide with networks that provide aerosol and cloud properties. The six sites are located in proximity with the USDA Monitoring Network [Bigelow et al., 1996], the NOAA SURFRAD Network, and with several AERONET sites. UV index from the Brewer spectrophotometers for four of the six sites are compared to the NCEP UV forecast and are shown in the plots to the right. Clockwise from the top left is Boulder, CO, Bondville, IL, Houston, TX, and Raleigh, NC. Typically, at the "dirtier" sites the UV forecast is high with respect to the measurements. The UV forecast considers forecasted ozone and clouds, ground albedo, surface elevation, and aerosol properties for the calculations [C. Long et al., 1996].

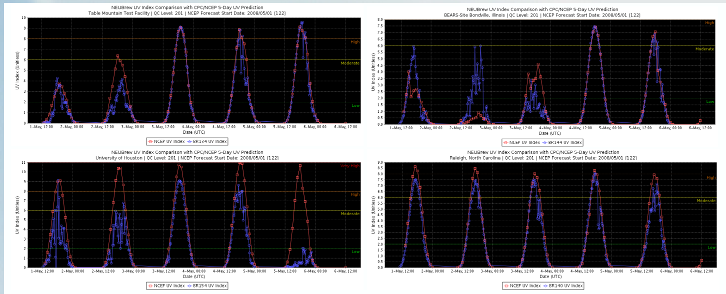

Figure 1: http://www.esrl.noaa.gov/gmd/grad/neubrew/

Methodology:

Aerosol single scattering albedo (ω) is the ratio of the aerosol scattering coefficient to total aerosol extinction coefficient and is an indicator of the absorbing properties of the aerosols. The single scattering albedo can be retrieved by using a radiative transfer code that is constrained using measured Direct-to-Diffuse solar irradiance (DDR) and measured aerosol optical properties, spectral surface albedo, and total Ozone. The radiative transfer code is the TUV4.1 model developed by Madronich [1993]. The RT model is iterated with ω until the measured DDR converges to the modeled DDR.

Measurements and TUV model inputs:

- DDR (Direct/Diffuse solar irradiance ratio) is measured with the UV-RSS spectrograph (300 - 400nm) and UV-MFRSR (300-nm, 305-nm, 311-nm, 317-nm, 325-nm, 332-nm, 368-nm; FWHM = nominal 2-nm).
- Surface Albedo measured with a UVB Broadband radiometer on a tower 25 ft high (Figure 2), and with a UV-MFRSR in six wavelength channels. Measurements are in general agreement with UV spectral studies of Feister et al. [1995]. Check against TSI images.
- Aerosol Optical Depth (τ) - measured with a UV-MFRSR (332-nm, 368-nm), SURFRAD vis-MFRSR(415-nm, 500-nm, 614-nm, 670-nm, 868-nm), checked with AERONET sunphotometer (340-nm, 380-nm, 440-nm, 500-nm, 655-nm) [Harrison et al., 1994; Augustine et al., 2008].
- Angstrom Coefficient (α)- USDA UV-MFRSR and vis-MFRSR
- Asymmetry Parameter (g) - AERONET at 340-nm, g is typically larger in the UV than the visible [Holben et al., 1998; Fiebig et al., 2006].
- Single scattering albedo (ω) - Checked against AERONET, where UV ω is typically smaller than in visible [Holben et al., 1998].
- Total Ozone - Brewer spectrophotometer*, OMI, NOAA Dobson spectrophotometer (Figure 3).

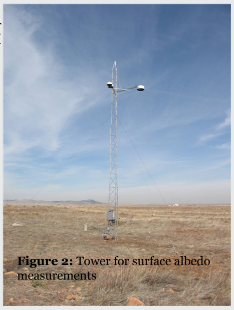

Figure 2: Tower for surface albedo measurements

Comparison of DDR from UV-MFRSR and UV-RSS:

The accuracy of the measured DDR is one of the parameters that influences the ability to retrieve the aerosol single scattering albedo. At Table Mountain outside Boulder, CO we can compare two instruments that simultaneously measure the direct and diffuse spectral solar irradiance. Figure 3 gives the DDR for the two instruments and is typical of results. Figure 4 gives the percent difference between the UV-MFRSR/UV-RSS. In this case, the DDR is different by approximately 5% for the 7 channels. More interesting are the differences with SZA. Each instrument has been corrected for angular response errors, but the signature of the angular response of the UV-MFRSR (Figure 5) is evident in figure 5 indicating the correction could be improved.

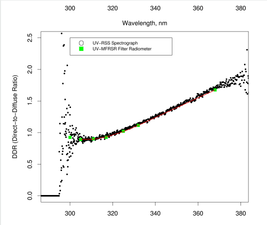

Figure 3. Diffuse to Direct Ratio (DDR) of the UV-RSS and UV-MFRSR as a function of wavelength on July 13, 2005. The plot above is the percent difference of the UV-MFRSR from the UV-RSR.

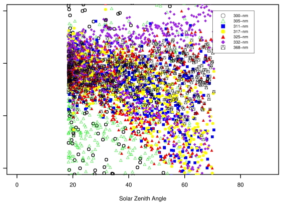

Figure 4. Percent difference between the UV-MFRSR relative to the UV-RSS on July 13, 2006 as a function of solar zenith angle.

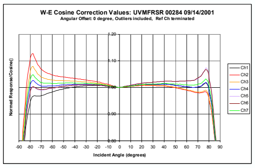

Figure 5: Angular response corrections for the UV-MFRSR (channels 1-7, 300, 305, 311, 317, 325, 332, 368-nm, respectively)

TUV Sensitivity studies:

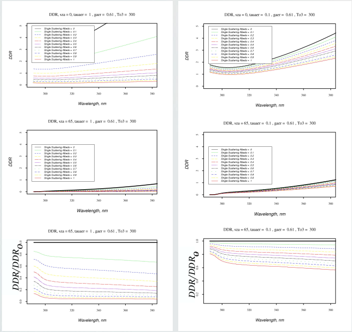

Figure 6: TUV4.1 calculations of Direct-to-Diffuse irradiance. Bottom two graphs are the same as the two graphs above at SZA=65° except relative to DDR with no aerosol. For a SZA=0, DDR/DDRo looks the same as for SZA=65.

Results: Radiative transfer calculations were performed to determine the sensitivity of DDR as function of wavelength for different input parameters. Figure 6 shows the RT results of DDR as a function of ω for two different aerosol optical depths. The sensitivity studies indicate that it is difficult to accurately retrieve ω for AOD below 0.2, which is consistent with other studies [Petters et al., 2003; Bais et al, 2005; Krotkov et al., 2005]. At large SZA's, ω is more difficult to retrieve due to reduced signal/noise and increasesd angular response uncertainties. Figure 8 shows that for λ=332-nm at SZA=21, a change of 0.05 in DDR results in approximately 0.06 change in ω at τ(aer) = 0.2.

We calculated aerosol single scattering albedo for May 16 using UV-RSS data. Results for SZA=21 is shown below in Figure 7. The results give an ω value of 0.84 to 0.91 for the wavelength region from 305 - 368 nm. This is consistent with AERONET measurements for the BAO-Boulder site of 0.93 at 550-nm [Holben et al., 1998].

UV-RSS ω for May 16, 2007, SZA = 21:
AOD is 0.37 at 332-nm from UV-MFRSR, asymmetry parameter is set at 0.71 which is increased 0.03 above 550-nm from AERONET, surface albedo varies from 0.02 - 0.034 for 300 - 368 nm, total ozone is 315 DU, and the Angstrom coefficient is set at 1.1 from SURFRAD MFRSR and UV-MFRSR AOD measurements, and surface elevation is 1.67 km.

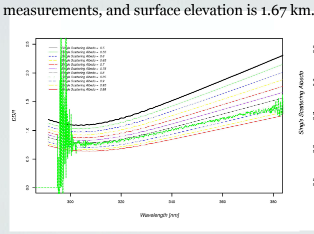

Figure 7: UV-RSS single scattering albedo

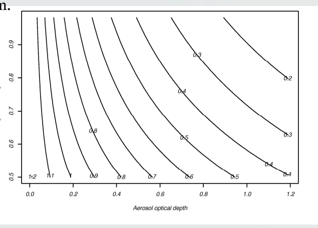

Figure 8: UV-RSS DDR contours at 332 nm

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Future

- Compute single scattering albedo (ω) for a range of atmospheric conditions and solar zenith angles at the Table Mountain site. Table Mountain is not the best site given that aerosol optical depths are generally less than 0.2. Largest τ is typically in the summer. Extend study to sites with aerosol optical depths above 0.2.
- Reduce uncertainty in UV-MFRSR and UV-RSS DDR by improving the angular response corrections as a function of τ.
- Compute the uncertainty caused by the field of view for the diffuse and direct solar irradiance measurements. If the field of view is too large, the direct is overestimated and the diffuse is underestimated giving a DDR value too large. This effect would be the same for the UV-RSS and the UV-MFRSR given the shadow-banding is the same.
- The direct solar irradiance is very sensitive to the aerosol optical depth (τ) with less influence on the diffuse solar irradiance. Comparing the direct solar irradiance transmittance to the modeled solar irradiance transmitance has the advantage of checking the accuracy of the aerosol optical depth. Using the transmittance has the advantage of avoiding uncertainty in the extraterrestrial flux [Michalsky et al., 2008].