Use of spectral irradiances measured at surface to retrieve aerosol optical parameters

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Abstract

This study presents a method to retrieve key aerosol optical parameters such as aerosol optical thickness and single scattering albedo using spectral direct and diffuse irradiances measured at surface by taking into account the cosine error correction factors in detail. The proposed method is applied to observed spectral irradiance data at Hedo observation site of SKYNET network. We found very good agreement for aerosol optical thickness and reasonable agreement for single scattering albedo with results from sky radiometer.

Keywords: Aerosol optical thickness, single scattering albedo, cosine error correction factor

1. Introduction

Aerosols are known to play important roles on atmospheric heat budget and climate change through their direct and indirect effects. Due to the importance of aerosols on climate change study, they have received considerable interests in the recent years. As a result, aerosols are being monitored by several space- and ground- based remote sensing approaches. Aerosol optical parameters obtained from ground-based remote sensing methods are widely used to validate results from several satellites as well as numerical model simulations. Among several ground-based remote sensing networks in the world, SKYNET network has monitoring sites in different parts of the Asia. Sky radiometer, which measures aerosol optical and physical characteristics, is the key instrument of this network. In order to validate aerosol optical parameters obtained from sky radiometer, a new radiometer that can measure spectral diffuse, direct, and global irradiances is installed at some key SKYNET sites. This study is dedicated to develop algorithm for such newly developed radiometer.

2. Data

We used irradiances measured by spectral radiometer (MS-700) with automated shadow band (Manufacturer: EKO Co., Ltd., Japan). The measurement sequence starts with a measurement made at nadir, i.e., total horizontal irradiances. The band is then rotated so that three measurements are made in seqence; the middle one blocks the sun and other two block strips of sky 9^0 either side. Such side measurements are used to correct diffuse irradiance by taking into account the excess sky blocked by the band when the sun-blocking measurements are made. Direct irradiances can be obtained from measured direct and diffuse irradiances. The spectral range of this instrument is from 301.1 nm to 1147.7 nm with resolution of 3.3nm.Along with such measured spectral irradiances, we used other data such as ozone concentration from TOMS, spectral surface reflectance from MODIS, precipitable water content (PWC) from microwave radiometer in our algorithm. Aerosol optical parameters obtained from sky radiometer were used to compare our retrieved results.

3. Description of an algorithm

Fig. 1 shows a simple flow chart for the retrieval of aerosol optical thickness and single scattering albedo using spectral irradiances measured by MS-700. For our retrieval, we carefully selected the wavelengths at which absorptions by atmospheric constituents such as ozone, water vapor etc. are negligible. The selected wavelengths are 400nm, 500nm, 675nm, 870nm, and1020nm.The cosine error correction factors for direct irradiances at certain zenith and azimuth angles, which were provided by the company, were extrapolated/interpolated to zenith angle ranging from 0 to 90^0 and azimuth angle ranging from 0 to 360^0 at the step of 0.5^0. One can calculate the solar position from given latitude, longitude, and observation time, and apply such interpolated/extrapolated data to correct spectral direct irradiances measured by MS-700. After correcting MS-700 measured direct irradiances, Beer-Lambert law was used to calculate total optical thickness. By subtracting Rayleigh optical thickness and ozone optical thickness from the total optical thickness, aerosol optical thickness (AOT) was calculated.

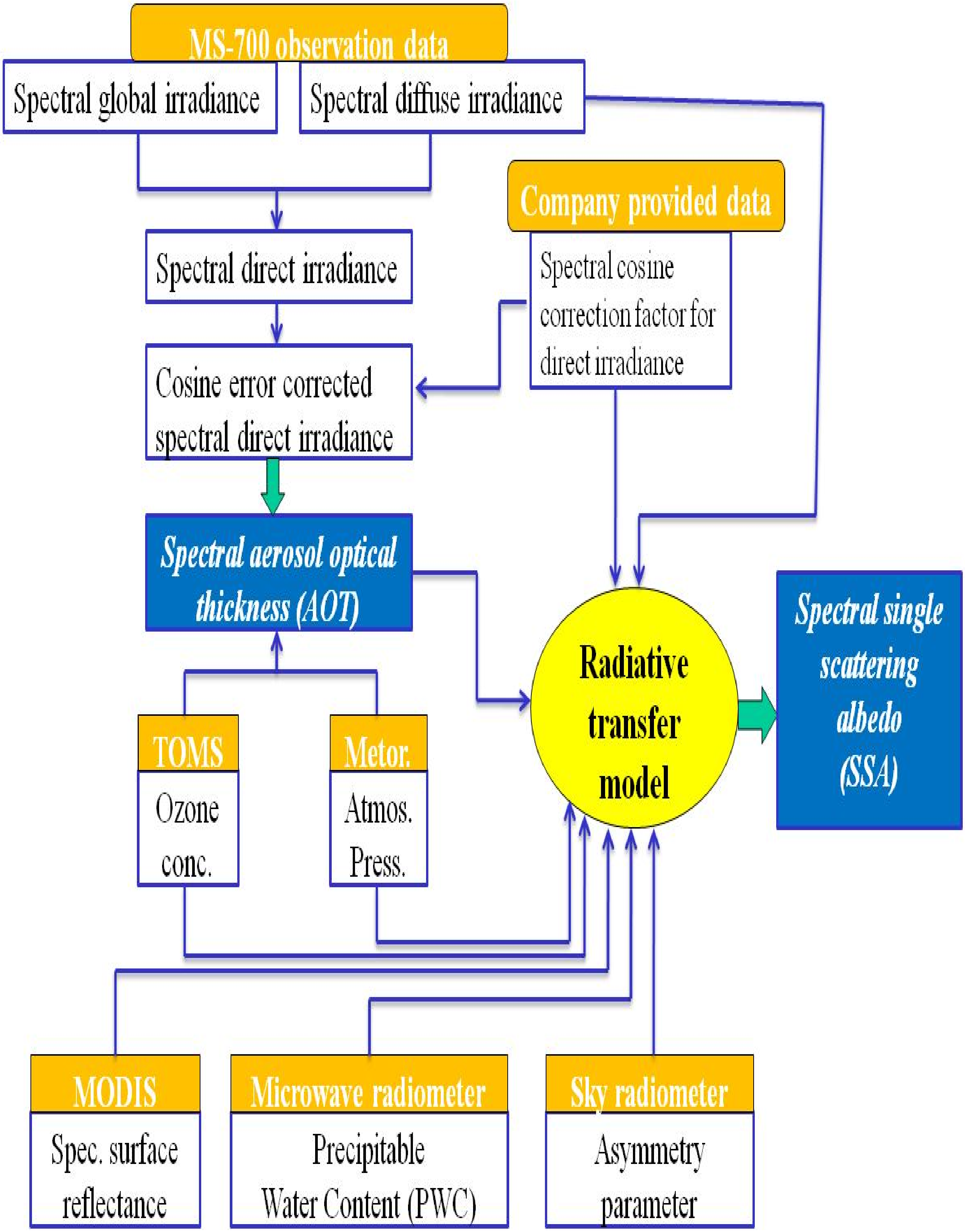

Fig. 1. A simple flow chart showing the retrieval method of aerosol optical thickness and single scattering albedo using spectral irradiances measured by MS-700.

Single scattering albedo(SSA) is the key optical parameter of aerosol. We used radiative transfer (RT) model to estimate SSA. In our method, at first AOT from MS-700, asymmetry parameter from sky radiometer, PWC from microwave radiometer, ozone concentration from TOMS, spectral surface reflectances from MODIS and 31 SSA values ranging from 0.7 to 1.0 at an interval of 0.01 were inputted in RT model to estimate radiances at different directions (zenith angle: 0 to 90^0 and azimuth angle: 0 to 360^0). Therefore, we calculated 31 sets of radiance data at different directions. Such modeled radiances were converted to MS-700 equivalent radiances by applying fine gridded cosine error correction factors for direct irradiances as described above. MS-700 equivalent radiances are defined as such radiances whose integration over the full zenith and azimuth angles should give diffuse irradance equivalent to that measured by MS-700. By integrating MS-700 equivalent radiances at different directions for each value of SSA, we obtained 31 values of MS-700 equivalent diffuse irradiances. One can directly compare such 31 values of MS-700 equivalent diffuse irradiances with directly measured MS-700 diffuse irradiance

to find the most plausible value of SSA. This method can give correct SSA if measured diffuse irradiance by MS-700 is highly qualitative. On the other hand, one may estimate 31 values of MS-700 equivalent diffuse/global ratio or diffuse/direct ratio and compare with respective measured component to find the most plausible value of SSA. The latter method is more suitable if the calibration constant of the instrument is not very accurate.

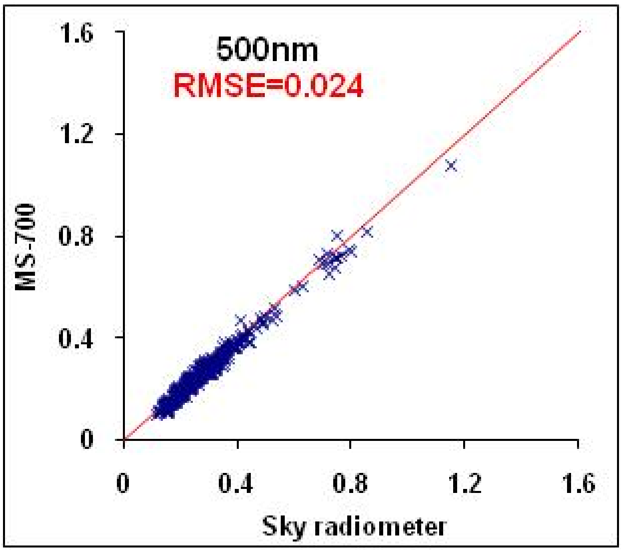

Fig. 2. Comparison of aerosol optical thickness (AOT) at 500nm obtained from MS-700 and sky radiometer.

4. Results and discussion

We applied the above-mentioned algorithm to data measured by MS-700 at Hedo observatory of SKYNET network. We used data observed in the spring season (March, April, and May) of 2009. As an example of retrieved AOTs from MS-700 instrument, we show comparison of MS-700 result with that of sky radiometer at 500nm in Fig. 2. For comparison, we selected Level 2.0 data of sky radiometer, which were analyzed using SKYRAD.pack software[1)] and cloud screening algorithm [2)]. As shown in Fig. 2, the values of AOTs retrieved from MS-700 agreed quite well with sky radiometer at 500nm by falling data around 1:1 line. The RMSE for data shown in Fig. 2 is 0.024. Though the results for other wavelengths are not shown here, the values of RMSE for the wavelengths of 400nm, 675nm, 870nm, and 1020nm were 0.055, 0.021, 0.020 and 0.026, respectively. Those retrieved results with will be further improved by performing sensitivity studies with different solar spectrum data and technique of picking out solar spectrum data at the wavelengths of our interest.

We retrieved SSA values by applying the first method described in section 3 i.e. we compared measured diffuse irradiance with 31 values of modeled MS-700 equivalent diffuse irradiances.

This is because we verified the calibration constant of MS-700 provided by company by performing closure experiment with standard grating sun photometer (GER-2600). Fig. 3 shows the Comparison of MS-700 measured diffuse irradiance and MS-700 equivalent modeled diffuse irradiance at the wavelength of 500nm.

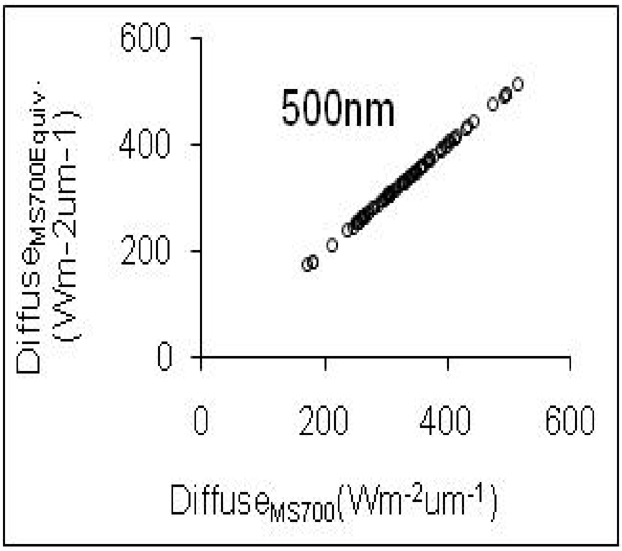

Fig. 3. Comparison of MS-700 measured diffuse irradiance and MS-700 equivalent modeled diffuse irradiance at the wavelength of 500nm.

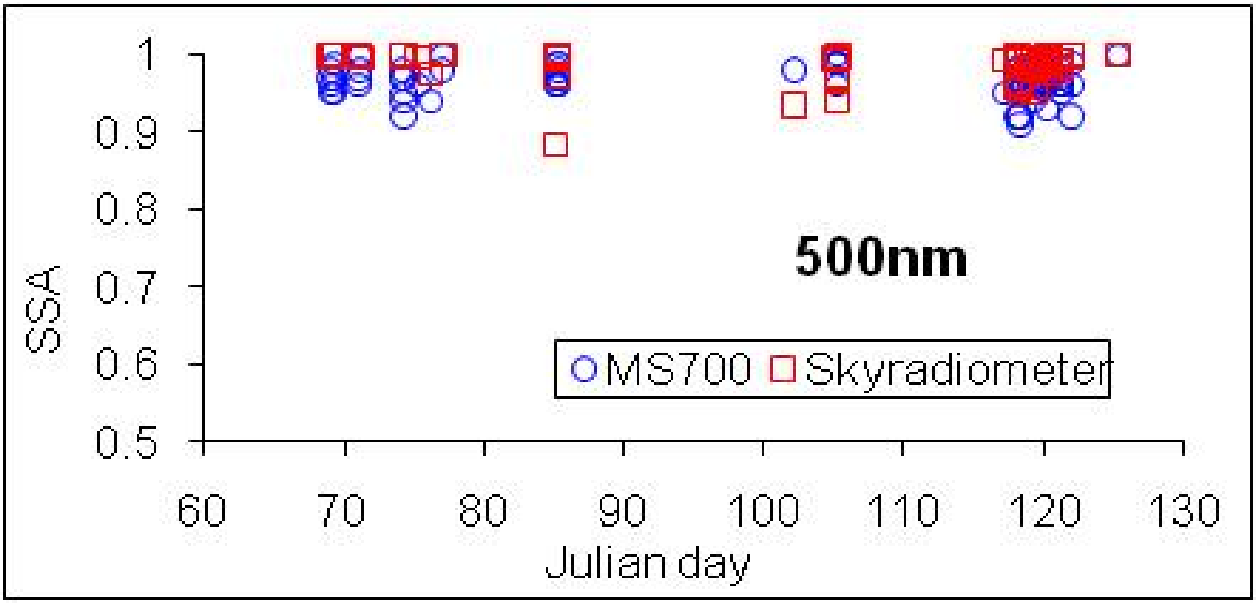

Fig. 4. Time series of SSA values at 500nm retrieved from MS-700 and sky radiometer

Fig. 4 shows the time series of SSA values at 500nm retrieved from MS-700 and sky radiometer. As shown in Fig. 4, the values of SSA at 500nm agreed reasonably. For other wavelengths (not shown here), SSA also agreed reasonably. However, there were some large distinct differences at some observation point at those wavelengths. Based on our sensitivity study, it was observed that retrieved SSA values from data of both MS-700 as well as sky radiometer depend on a number of input parameters. As a part of validating retrieved SSAs from both MS-700 and sky radiometer, spectral SSAs from each instrument as well as other necessary parameters were inputted in a radiative transfer model to estimate broad band diffuse fluxes(0.315-2.8μm), which were then compared with directly measured data. For MS-700 data, the relationship was *Modeled flux=1.05*Measured flux* with R^2=0.983. For sky radiometer data , For sky radiometer data, the relationship was *Modeled flux=1.08*Measured flux* with R^2=0.924. Similarly, the values of RMSE between modeled and measured fluxes for MS-700 and sky radiometer data were 8.15Wm^{-2} and 14.47Wm^{-2}, respectively.

Acknowledgements

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