Optical Characteristics of the Yellow Sand from Ground-Based Solar Radiation Measurements near the Yellow Sea

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1. Introduction

Together with molecular scattering and absorption due to the atmospheric gases, aerosols give direct impact on the amount of solar radiation reaching the earth's surface. Consequently aerosols play an important role in modulating the earth's climate through the energy conversion circuit existing between radiation energy available at the surface and the atmospheric circulation. On the other hand, most aerosols, whether naturally or anthropogenically originated, are transported from the source region to the deposition area, leading to interactions with biosphere, hydrosphere, cryosphere and even with atmosphere. Furthermore, the aerosols also affect the quality of remotely sensed geophysical parameters such as ocean color, sea surface temperature, surface albedo because the radiation interferes with aerosol while photon is traveling the atmosphere. Therefore, in order to assess the impact of aerosol on the environment, in particular geochemical cycle and its influences on the quantitative measurement of surface and atmospheric remote sensing parameters, it is essential to determine and examine the amount of aerosols within the atmospheric column, optical and chemical properties, and their spatial and temporal variations.

Here we provide some results of the aerosol optical characteristics from spectral extinction and diffuse sky radiation measurements near the Yellow Sea. Optical properties obtained in this study can provide valuable information to the verification and development of satellite aerosol remote sensing as well as ocean color remote sensing over East Asia.

2. Ground Measurements and Analysis

The direct and diffuse solar radiation measurements were carried out at the background atmosphere monitoring site (36.517°N, 126.317°E) in Anmyon Do which is located on the west coast of the Korean peninsular. The observation site and its geographical environment are shown in Figure 1. Among the experiment data measured from 10 March 1998 to 15 August 1998, four days (March 16, 17, April 19, and 28) of measurements are analyzed in order to emphasize optical properties of Yellow Sand whose event took place on April 19 and 28. Other two days represent base aerosol.

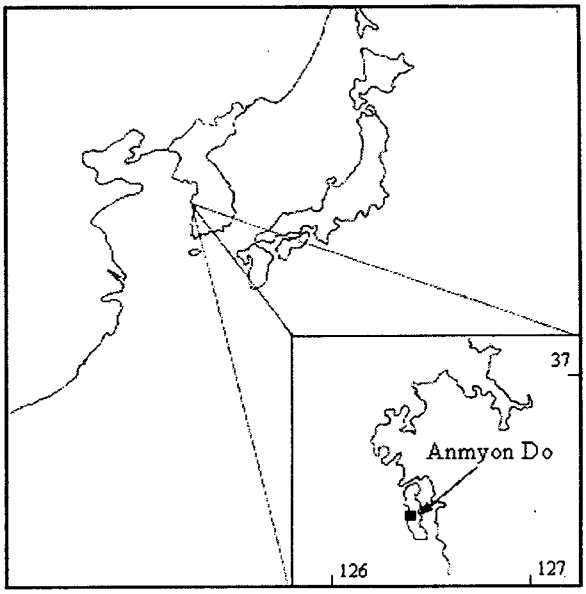

Figure 1: Geographical location of the observation site (Anmyon Do). The inset is the enlarged area map showing details of surroundings

2.1 Sun Photometer Data

Spectral direct solar irradiance has been measured using PREDE sun photometer (PSF-100) at four wavelengths λ=0.368. 0.500, 0.675, and 0.778 µm. The aerosol optical thickness $\tau_{a\lambda}$ has been determined by subtracting optical thickness by Rayleigh scattering ($\tau_{m\lambda}$) and by ozone absorption ($\tau_{o\lambda}$), i.e.:

$$\tau_{a\lambda} = \frac{\ln(F_{o\lambda} / F_{\lambda})}{m} - \tau_{m\lambda} - \tau_{o\lambda} \quad (1)$$

where $F_{o\lambda}$ is the direct solar radiation assumed to be at the top of the atmosphere and F_{λ} is the measured direct solar irradiance at the ground. Relative optical air mass m is obtained by the inverse of cosine of the solar zenith angle. Optical thickness of by Rayleigh scattering is calculated using a formula by Hansen and Travis (1974), i.e.:

$$\tau_{m\lambda} = (0.008569\,\lambda^{-4}\,(1+0.0113\,\lambda^{-2}+0.00013\,\lambda^{-4}))p/p_o \quad (2)$$

where p is atmospheric surface pressure and p_o is the standard atmospheric pressure of 1013.25mb. For the calculation of ozone optical thickness, we use column ozone amount estimated by Nimbus 7 Total Ozone Mapping Spectrometer (TOMS). In order to reduce the inconsistency between the sun photometer and sky radiometer and examine calibration performance we compared output readings of direct solar radiation by two instruments. Figure 2 shows the slopes are in good agreement between two instruments, suggesting optical properties obtained from two instruments should be very consistent with each other.

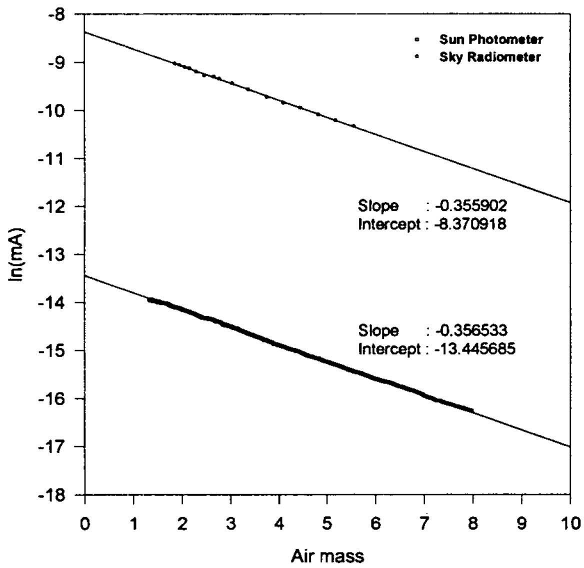

Figure 2: Comparison of the readouts of sun photometer and sky radiometer for direct solar irradiance in March 16, 1998

2.2 Sky Radiometer Data

The PREDE sky radiometer (POM-01L) was used for measuring sky radiance in the solar aureole region at the wavelength of 315, 400, 500, 675, 870, 940, and 1020 nm. The solar aureole measurements were performed as follows: the sky radiances in the almucantar were measured every 20 min, starting from direct solar radiation, and then diffuse radiation with scattering angles from 0° to 60°.

The measured sky radiance data are analyzed by applying the inversion scheme developed by Nakajima et al. (1995) for the retrieval of optical thickness, volume spectra and phase function of the aerosol. The inversion method includes a radiative transfer algorithm to account for multiple scattering and it has been successfully used for various aerosol retrieval studies (Nakajima et al., 1995, Dalu et al., 1995). As inputs for the retrieval model, we used ground albedo of 0.1 and refractive index of 1.55-0.01*i* for the yellow sand and 1.50-0.01*i* for the base aerosol.

3. Results

3.1 Aerosol Optical Thickness

Aerosol optical thickness at 500 nm for the 4 observation days is presented in Figure 3. On March 16, nearly constant τ_a a little larger than 0.2 is noticed. Dominant wind direction was south-westerly. On the following day (March 17), even though there is larger scattering in the morning, the optical thickness has been decreased with time. Wind measurements at the site suggests the idea of why there is such a trend. In the morning of March 17, dominant wind direction was east and north-easterly with which inland aerosol can be transported to the site. Major wind direction was changed into north-westerly in the afternoon so that marine type aerosol can be placed on the observation site. Even though there is daily variation of optical thickness of base aerosol largely depending on predominant wind direction, the optical thickness is in general smaller than 0.4. On both April 19 and 28, yellow sand aerosols are observed (Korean Meteorological Administration, 1998). It has been reported that heavy yellow sand event is observed from April 18 to 21 whereas mild yellow sand event is observed for a relatively short period in April 28. It is found that the optical thickness is increased during the yellow sand event, reaching to the value from 0.5 to 1.4 that is much larger than the base value of 0.1 to 0.4. It is observed that the typical magnitude of yellow sand optical thickness is around 0.8.

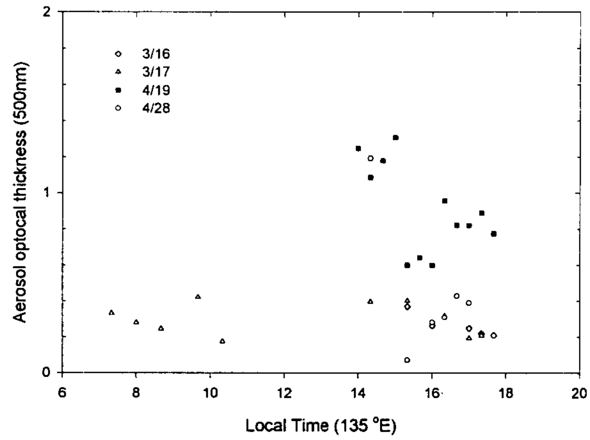

Figure 3: Scatterplot of the instantaneous aerosol optical thickness at 500 nm.

3.2 Aerosol Volume Spectrum

Figure 4 shows the columnar aerosol volume spectra obtained from the sky radiation measurements. The assumed refractive index of aerosol is 1.55-0.01i for the yellow sand events independently of the wavelength. The obtained spectral distributions of base aerosol indicate a tri-modal pattern, showing modes at 0.08, 0.4, and 3 μm. The mode at 0.08 μm can be related to the background aerosol particles, and the mode at 0.4 μm and 3 μm of base aerosol can be related to sea salt particles since they are the sizes of typical maritime aerosols (d'Almeida et al., 1991). By contrast the spectra in the yellow sand events of 19 and 28 April show significant increase of large particles ranging from 1 to 3 μm, with a new peak at around 2 μm. This peak around 2 μm found in the yellow sand cases is very consistent with the spectrum of near-ground aerosols measured from the Anderson sampler (given in Figure 5). Plots are drawn at the center diameter of 0.3-0.5, 0.5-0.82, 0.82-1.35, 1.35-2.23, 2.23-3.67, 3.67-6.06, 6.06-10, 10-25 μm from the left, thus the volume distribution shape in the ground sampler measurements matches to that obtained from sky radiation measurements.

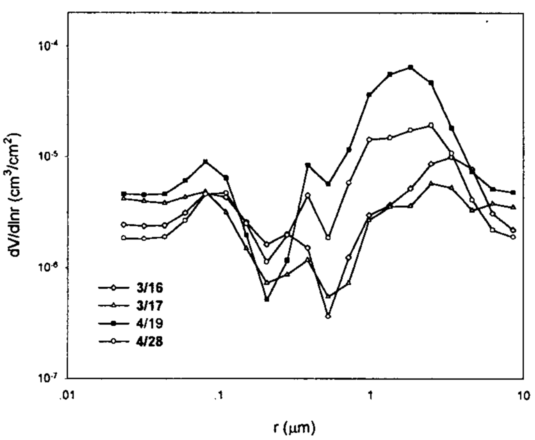

Figure 4: Aerosol volume spectra. April 19 and 28 correspond to the yellow sand events.

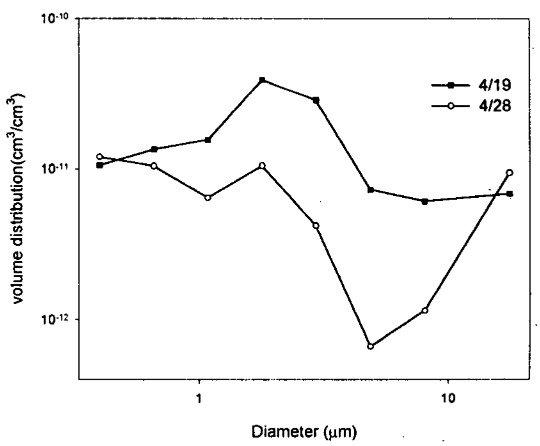

Figure 5: Volume spectra of near-ground aerosols measured by Anderson sampler in April 19 and 28.

3.3 Aerosol Phase Function

One of the important optical properties of aerosol is single scattering phase function. We retrieved aerosol phase function using Nakajima et al. (1995) retrieval algorithm and present results in Figure 6. Considering that April 19 and 28 are days showing the yellow sand events, there is much increased scattering throughout all scattering angles, compared with phase functions of background aerosol (March 16 and 17). Local minima are shown around 120 scattering angle. It is of interest that spectral dependence of the phase function is much weaker for yellow sand events (April 19, and 28).

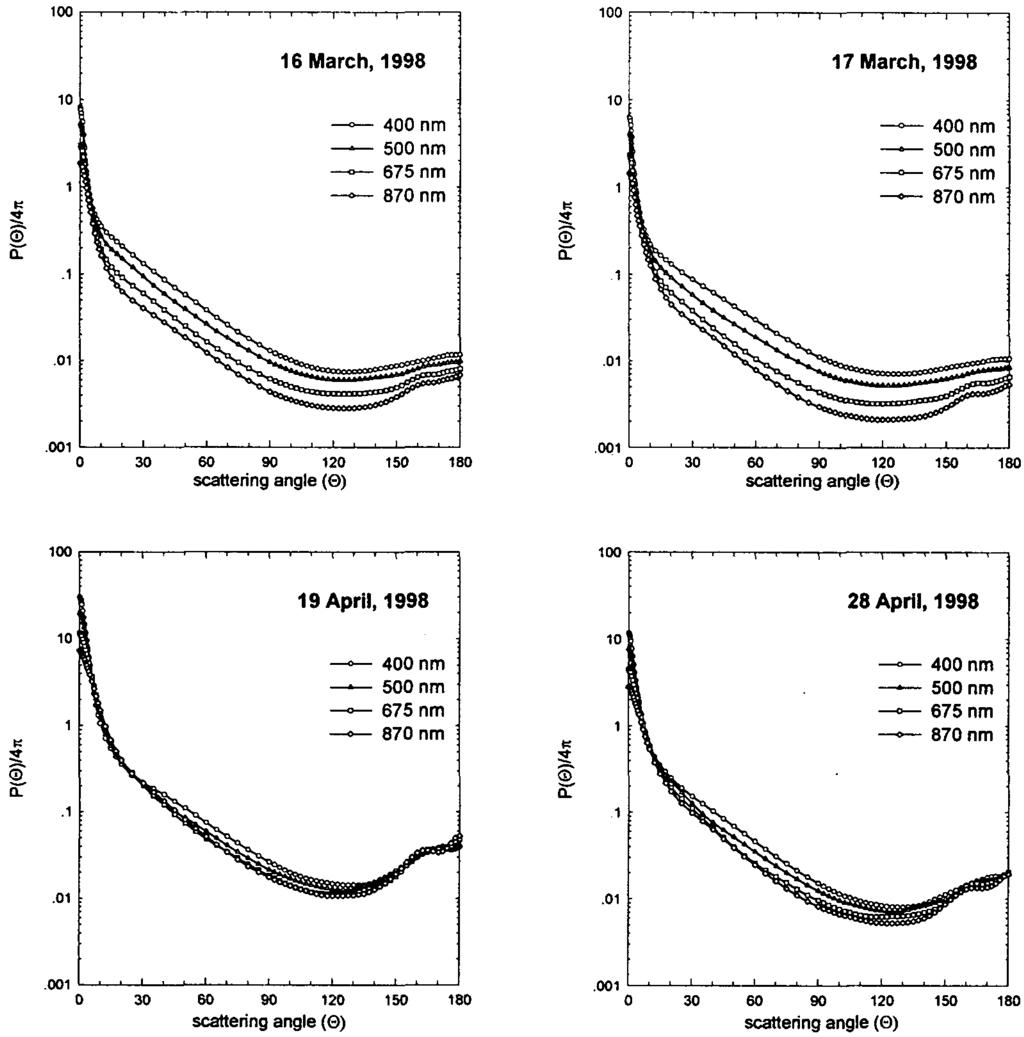

Figure 6: Aerosol phase functions for four days.

4. Acknowledgments

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