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Toward characterization of the aerosol optical properties over Loess Plateau of Northwestern China

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ABSTRACT

Aerosol optical properties were obtained from a CIMEL sunphotometer of the Aerosol Robotic Network at the Semi-Arid Climate and Environment Observatory of Lanzhou University (SACOL). SACOL is located over the Loess Plateau of the Northwestern China. The observed data are analyzed for the period of August 2006–October 2008. We find that aerosol optical depths (AODs) have a pronounced annual cycle, with a maximum dust aerosol loading during the spring. The 2-year average values of AOD, Ångström exponent (α), and water vapor path (WVP) along with their standard deviation (in parenthesis) are 0.35 (0.21), 0.93 (0.34), and 0.77 cm (0.52 cm), respectively. The probability distributions of these quantities all have one modal value, which are 0.3, 1.1, and 0.5 cm, respectively. There is a notable feature in the relationship between daily averaged AOD and Ångström exponent: a wide range of α corresponding to moderate to low aerosol optical depths (<0.8). There is no significant correlation between daily averaged WVP and AOD. However the daily averaged Ångström exponent and WVP show a significant positive correlation, indicating that the smaller aerosol particles present when the WVP is large. Variations of the retrieved aerosol volume size distributions are mainly associated with the changes in the concentration of the coarse aerosol fraction. The geometric mean radii for the fine and coarse aerosols are 0.18 μm ($\pm$0.03 μm), and 2.53 μm ($\pm$0.25 μm), respectively. The spectral dependences of the single scattering albedos are different between the dusty and non-dusty conditions. In the presence of dust, the SSAs increase slightly with wavelength. When dust is not a major component, the corresponding values decrease with wavelength.

1. Introduction

Aerosol particles, as important constituents of the earth atmosphere, play an important role in the global and regional climate by scattering and absorbing solar radiation [1–6]. Mineral dust is a major part of natural aerosols in the atmosphere [7], and has a great effect on the radiation budget and hydrologic cycle of the Earth's system [8,9]. Mineral dust can also cause changes in cloud properties, such as the number concentration and size of cloud droplets, which can alter both cloud albedo and cloud lifetime [5,10]. However, these dust radiative forcing and their climatic effects still contain considerable uncertainties due to the lack of understanding to aerosol properties and their spatial and temporal distributions [11].

East Asia is one of the major source regions of mineral dust aerosols in the world [12,13]. Every year, deserts in Eastern Asia produce a large amount of mineral dust particles that become entrained in the atmosphere [14]. They can be transported over thousands of kilometers by

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the westerlies [15–17]. Fully accounting for aerosol effects on climate requires extensive measurements of aerosol optical, microphysical and chemical properties, and their spatial and temporal distributions.

In recent years, many investigations and field experiments have focused on the optical properties of dust aerosols in the East Asian region surrounding China [4,12,18–22]. These studies are vital to understand the characteristics and variations of dust aerosols in East Asian so that we can evaluate more accurately the effect of mineral dust aerosols on global and regional climate change in the future. However, there have been very few studies examining the atmospheric aerosol properties over Northwestern China where is a major source region of dust aerosols.

This work is mainly to examine the aerosol optical properties obtained at the Semi-Arid Climate and Environment Observatory of Lanzhou University (SACOL) which is located over the Loess Plateau of Northwestern China (see Fig. 1). We investigate seasonal and interannual variabilities of aerosol optical depth and its spectral behavior. We also present the characteristics of volume size distribution, single scattering albedo, asymmetry parameter, and complex refractive index as well.

2. Site and measurements

An automatic sun and sky scanning radiometer (CIMEL Sunphotometer) was set up at SACOL (latitude: 35.946° N, longitude: 104.133°E, and elevation: 1970 m) from August 2006. It is one of the Aerosol Robotic Network (AERONET) sites over Loess Plateau in Northwestern China. SACOL is a rural site and located on the top of Tsuiying Mountain, which is about 50 km southeast of Lanzhou city at the southern bank of Yellow River [22]. In addition, this site is situated at the south edge of the Tengger Desert, which is a typical dust activity center in Northwest China (Fig. 1). The detailed descriptions of the instrument and data acquisition procedures were given by Huang et al. [22].

The CIMEL sun/sky radiometer makes measurements of the direct sun and diffuse sky radiances within the spectral range 340–1020 nm [23]. The automatic tracking sun and sky scanning radiometer makes direct sun measurements with a 1.2 full field of view at every 15 min in eight spectral channels at 340, 380, 440, 500, 675, 870, 940, and 1020 nm (nominal wavelengths). Seven of the eight bands are used to acquire aerosol optical depth data. The eighth band at 940 nm is used to retrieve total precipitable water content in centimeters. The instrument's calibration is carried out at the pristine Mauna Loa Observatory (MLO; latitude: 19°53′N, longitude: 15 5°57′W, elevation: 3400 m) once per year. The calibration coefficients of aerosol optical depth measurements were based on an intercomparsion with a reference instrument that was calibrated using Langley plots from data collected. Radiance measurements were calibrated using a two meters integrating sphere at NASA Goddard Space Flight Center [23].

Holben et al. [23] and Eck et al. [24] presented that the total uncertainty in aerosol optical depth (AOD) for a field instrument is about 0.01–0.02. The details of water vapor path (WVP) retrieval procedure and errors involved can be found in [25]. The retrieved precipitable water vapor path is consistent with radiosonde and microwave radiometer measurements within ~10%. The accuracy of the aerosol particle size distributions and single scattering albedos has been studied in detail by [26]. Retrieval errors in $dV/d\ln R$ typically do not exceed 15–35% (depending on aerosol type) for each particle radius bin within the 0.1–7 μm range. The errors for very small particles (r~0.05–0.1 μm) and very large particle (r~7–15 μm) may be as large as 35–100% for given particle radius bin. However, no significant shifts in the positions of mode radii or changes in the shape of size distributions are expected. Single

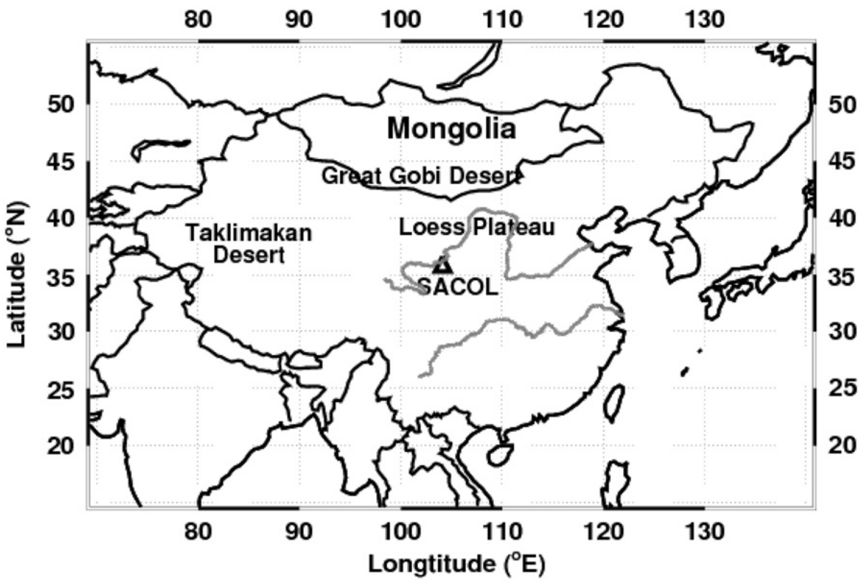

Fig. 1. Location of the SACOL observatory over China.