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Research on aerosol profiles and parameterization scheme in Southeast China

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HIGHLIGHTS

- The horizontal and vertical distributions of CALIOP extinction data were highly accurate in Southeast China.
- Multi-time scale CALIOP aerosol profiles were analyzed.
- The Elterman profile is significantly lower than the CALIOP profiles in Southeast China.
- Two sections exponential fitting was used in the aerosol profile parameterization scheme.

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ABSTRACT

The vertical distribution of the aerosol extinction coefficient serves as a basis for evaluating aerosol radiative forcing and air quality modeling. In this study, MODIS AOD data and ground-based lidar extinction coefficients were employed to verify 6 years (2009–2014) aerosol extinction data obtained via CALIOP for Southeast China. The objective was mainly to provide the parameterization scheme of annual and seasonal aerosol extinction profiles. The results showed that the horizontal and vertical distributions of CALIOP extinction data were highly accurate in Southeast China. The annual average AOD below 2 km accounted for 64% of the total layer, with larger proportions observed in winter (80%) and autumn (80%) and lower proportions observed in summer (70%) and spring (59%). The AOD was maximum in the spring (0.58), followed by the autumn and winter (0.44), and reached a minimum in the summer (0.40). The near-surface extinction coefficient increased from summer, spring, autumn and winter, in that order. The Elterman profile is obviously lower than the profiles observed by CALIOP in Southeast China. The annual average and seasonal aerosol profiles showed an exponential distribution, and could be divided into two sections. Two sections exponential fitting was used in the parameterization scheme. In the first section, the aerosol scale height reached 2200 m with a maximum (3,500 m) in summer and a minimum (1,230 m) in winter, which meant that the aerosol extinction decrease with height slower in summer, but more rapidly in winter. In second section, the aerosol scale height was maximum in spring, which meant that the higher aerosol diffused in spring.

1. Introduction

Aerosols correspond to a polyphase system constituted of solid-state and liquid-state particles of size 10^{-3} μm–20 μm suspended in the global atmosphere. They influence the earth's energy budget and alter global climate by scattering and absorbing solar short-wave and global long-wave radiation (Coakley et al., 1983). Although aerosols play an important role in changing global and regional climate, the complicated nature of their global spatial

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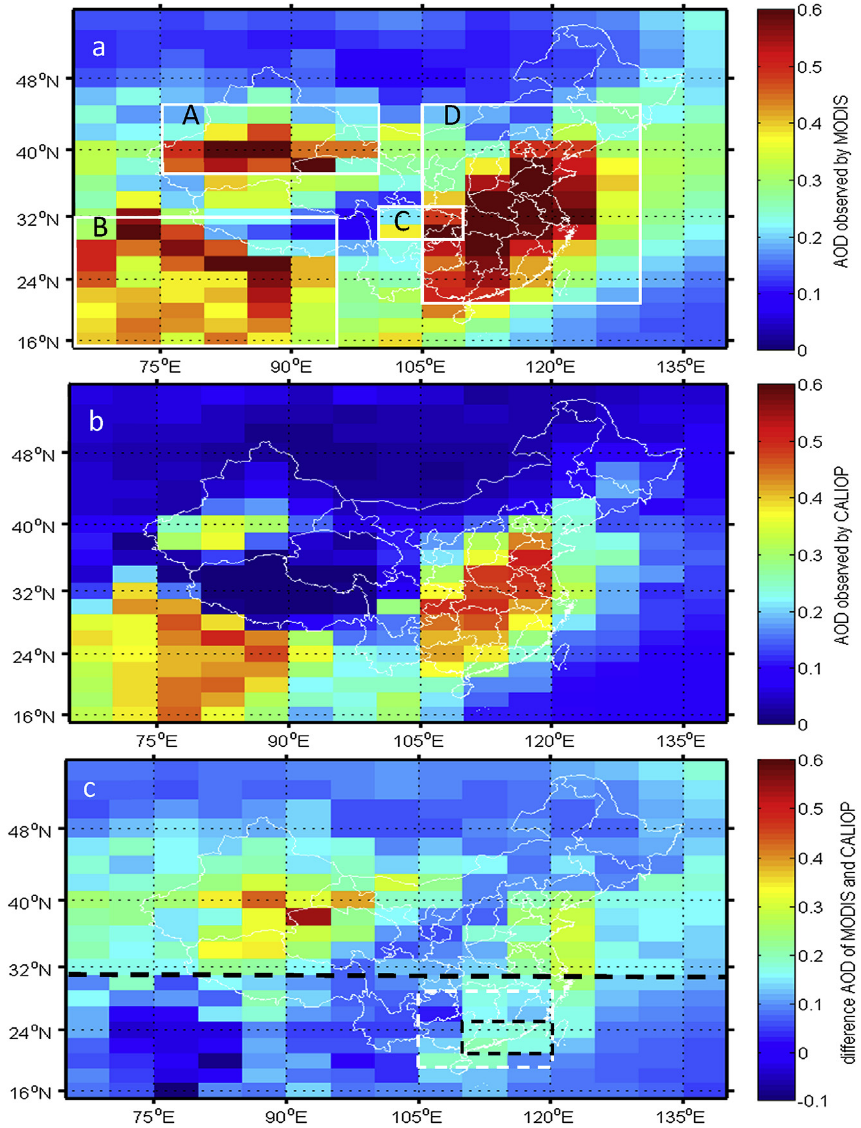

Fig. 1. The horizontal distribution of multi-year averaged (2009–2014) AOD data obtained for China. (Fig. 1a corresponds to MODIS AOD data; Zones A–D are indicated by the boxes labeled A–D: Zone A corresponds to the Tarim Basin and Taklimakan desert, Zone B corresponds to the Tibetan Plateau and southern region of Himalayas, Zone C corresponds to the Sichuan Basin and Zone D corresponds to the large area formed by the North China Plain, the Middle-Lower Yangtze plains and Southern China. Fig. 1b shows CALIOP AOD data for the daytime. Fig. 1c shows the difference in MODIS and CALIOP AOD values; the white dash line encloses the Southeast China region, and the black dash line encloses the Guangdong province region).

distribution as well as physical and chemical changes creates difficulty in estimating aerosol radiative forcing (Luo et al., 1998). Available research shows that the uncertainty of direct radiative forcing might result from a failure to consider changes in the aerosol's vertical distribution (Gunnar, 2009). According to the IPCC's Fourth Assessment Report (IPCC-2007), direct aerosol radiative forcing as estimated by model simulations is significantly less than direct radiative forcing estimated based on observational data, with the former only half of the latter. Therefore, the acquisition of accurate aerosol extinction profiles is of great significance for performing quantitative estimation of direct radiative forcing.

In addition to ground-based observation, satellite-based remote sensing is an important means to acquire an aerosol's optical characteristics. Internationally, satellite-borne sensors, such as AVHRR, TOMS, OMI, MODIS and MISR (Dobber et al., 2006; Gao and Washington, 2009; Martonchik et al., 1998; Remer et al., 2005; Zhang et al., 2015; Zhao et al., 2006) have made great progress in studying the influence of the horizontal distribution of aerosols on climate. MODIS and MISR provide global AOD inversion data, with an inversion accuracy which is greater than on land for oceans showing less uncertainty in terms of surface albedo (Kahn et al., 2005). OMI is the successor to TOMS and GOME, acquiring an aerosol absorption index from the spectrum ratio at 342.5 nm and 388 nm (Satheesh et al., 2009). However the aforementioned satellite-borne sensors are very limited for the purposes of studying an aerosol's vertical distribution characteristics. The Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) is the world's only onboard active polarization lidar detector (Winker et al., 2010). It is capable of probing the vertical distribution of clouds and aerosols remotely (Mishra and Shibata, 2012a; Winker et al., 2007), and thus is useful for studying aerosol radiation effects.

Some work (Bibi et al., 2015; Solanki and Singh, 2014) has already been performed to quantitatively verify CALIOP's backscattering coefficient and aerosol radiative characteristics. CALIOP