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Column-integrated aerosol optical and physical properties at a regional background atmosphere in North China Plain

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HIGHLIGHTS

- We show temporal aerosol optical property over regional background atmosphere of North China.
- High AOD in spring indicates dust events can affect the regional background atmosphere of North China.
- Angstrom exponent analysis indicates mixed aerosol is the dominant type in Xinglong.

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ABSTRACT

The AERONET level 2.0 data at Xinglong station from February 2006 to July 2011 were used to characterize the aerosol optical and physical properties, including temporal variability, aerosol absorption, classification and properties under dust and haze conditions. The annual mean aerosol optical depth (AOD) and extinction Angstrom exponent (EAE) are 0.28 ± 0.30 and 1.07 ± 0.38, respectively. The seasonal variations of AOD_{440nm} are higher in spring (0.40 ± 0.3) and summer (0.40 ± 0.42) than in autumn (0.20 ± 0.22) and winter (0.19 ± 0.21). The EAE is low in spring (0.96 ± 0.43) and high in summer (1.22 ± 0.38). The EAE is ~1.25 with an absorption Angstrom exponent (AAE) of ~1.0–1.5 in Xinglong, which indicates that the dominant type is mixed aerosol (accounting for 88.2% at AAE > 1.0). Almost all of the dust observations occurred in spring. The volume concentrations of both fine and coarse mode particles increase with increasing AOD. In spring, the increase of coarse particles is greater than that of fine aerosols; however, the reverse phenomenon is observed for other seasons. The high AOD at Xinglong could be associated with the growth of fine mode aerosols and addition of coarse mode particles. This background station is not only impacted by dust aerosols from northwest China and south Mongolia but also influenced by long-range transportation of anthropogenic aerosols from south urban and industrialized regions. The mean AOD was 1.49 on the dust day, while AOD was 1.10 on the haze day. The mean EAEs were 0.09 and 1.43 on dust and haze days, respectively.

1. Introduction

Atmospheric aerosol is an important component of the radiative force affecting the climate. Aerosols can absorb or scatter radiation and directly affect the earth-atmosphere radiative balance (Charlson et al., 1992). Furthermore, aerosol particles can serve as cloud condensation nuclei (CCN) and indirectly modify the microphysical characters, optical properties and precipitation of clouds (Twomey et al., 1984). The highly temporal variation and spatial inhomogeneity make it difficult to accurately measure aerosol properties and thereby to study the climate effect of aerosols (Holben et al., 1998). Ground-base and satellite remote-sensing are two important methods to detect aerosol optical and physical properties. Long-term monitoring of aerosols from the ground and

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space is absolutely required for our further understanding of aerosol climate effects (Kaufman et al., 2002).

Much progress has been made during recent years in ground based remote sensing of aerosol optical properties in China. Tens of Aerosol Robotic Network stations have been established in China and the data are widely used to characterize aerosol optical properties, to validate satellite aerosol products and to study aerosol direct radiative forcing (Li et al., 2007, 2011). However, these aerosol studies mainly focused on cities and polluted regions of China, such as the Yangtze Delta region (Pan et al., 2010) and the Beijing–Tianjin–Hebei area (Xia et al., 2007a). Analysis of aerosol properties in background regions is still required that can provide a comparison to nearby cities and polluted regions. Pan et al. (2010) studied aerosol optical properties at the Longfengshan regional background station in Northeast China and revealed that the annual mean aerosol optical depth (AOD) at 440 nm was ∼0.3–0.4. The minimum values (0.10–0.20) of the annual mean AOD at 500 nm were observed in Qinghai-Tibetan Plateau (Wang et al., 2008). Che et al. (2009) analyzed aerosol optical properties and their relationship with aerosol compositions over three regional background stations in China, i.e., Lin'an (LA) in the Yangtze Delta region, Shangdianzi (SDZ) in the North China Plain and Longfengshan (LFS) in the Northeast China. It was revealed that monthly AOD at 440 nm ranged from 0.26 in November at SDZ to 1.29 in September at LA. The results clearly showed that the background level aerosol loading was very high in eastern China and was even close to AOD values in urban stations, indicating that aerosol pollution was regional in nature.

North China Plain (NCP; 34.5–41°N, 114–120°E) is one of heavily populated region across the world. Rapid increase of anthropogenic activities has resulted in an increase of aerosol loading in this region (Luo et al., 2002). Aerosol properties in Beijing have been extensively researched (Fan et al., 2006; Xia et al., 2007a; Xie et al., 2008; Li et al., 2010). A distinct seasonal variation of aerosol optical properties and dramatic variation of AOD as a consequence of change in synoptic system were found (Li et al., 2007, 2011). SDZ is a regional background station located in NCP. It was found that AOD at 440 nm ranged from 0.26 in November to 0.91 in June. AOD at SDZ was close to AOD in suburban regions of NCP even it was widely suggested being a background stations (Che et al., 2009; Li et al., 2007). Xinglong (XL) is another background station in NCP where a CIMEL sunphotometer was installed in 2006 (Fig. 1). XL is located at the top of a mountain (970 m a.s.l) and is about 100 km away from Beijing to the northwest. It is far away from anthropogenic emission sources. Given the fact the elevation of XL is much higher than that of SDZ (293 m a.s.l), so it should be a better place than SDZ to record the background aerosol loading in NCP. The objective and major findings of this study are to reveal distinct seasonal variation of column-integrated aerosol optical and physical properties at background region of NCP based on detailed analysis of multiyear AErosol RObotic NETwork (AERONET) data, which is significant for our understanding of the background level of aerosol loading in NCP and further understanding of effects of anthropogenic and natural emissions on aerosol loading and aerosol optical properties. Furthermore, it is significant for comprehension of regional direct and indirect climate effect by anthropogenic and natural aerosol particles in North China Plain.

This study first examines the optical and properties of aerosols in XL using AERONET data including the aerosol optical depth (AOD), extinction Angstrom exponent (EAE), single scattering albedo (SSA), asymmetric parameter (ASYM), total amount of precipitable water (TPW) and aerosol volume size distributions. Next, major aerosol types are classified by using the EAE and absorption Angstrom exponent (AAE). Third, a graphical method is used to identify the growth of fine particles and the addition of coarse particles. Finally, this study analyzes the aerosol characteristics and potential sources of aerosol particles on dust and haze days by using data from Ozone Monitoring Instrument (OMI), Moderate

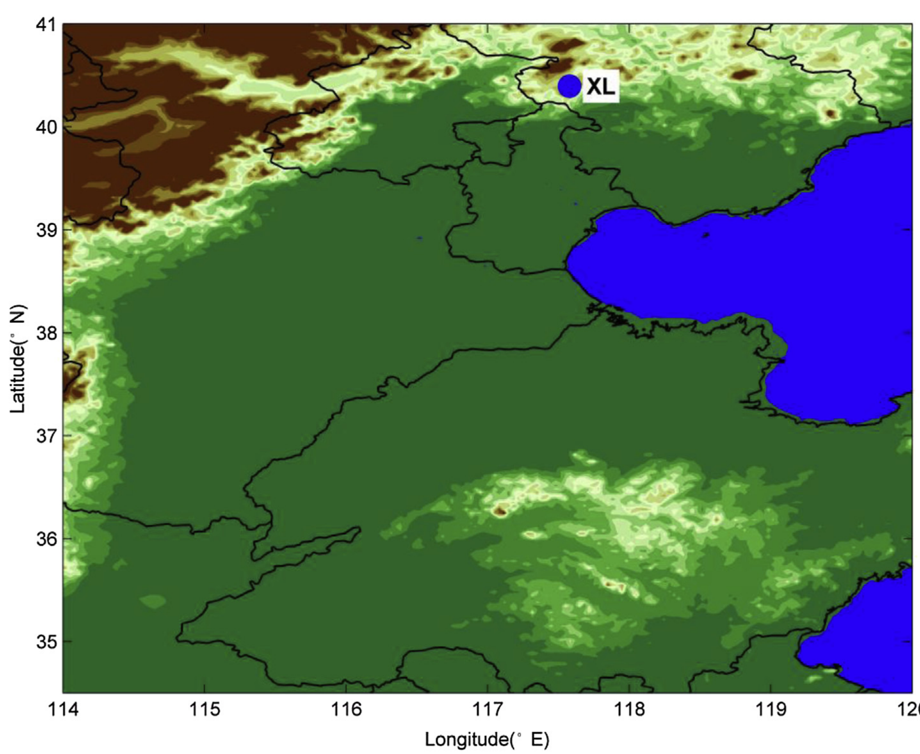

Fig. 1. Topography of North China Plain (NCP) and the XL station (the blue circle). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)