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Aerosol optical properties during firework, biomass burning and dust episodes in Beijing

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HIGHLIGHTS

- Aerosol optical properties were presented during different pollution episodes.
- The relationships of AOD and α were different for various aerosol types in Beijing.
- The SSA increased when pollution episodes happened with maximum occurred in dust days.

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ABSTRACT

In order to characterize the aerosol optical properties during different pollution episodes that occurred in Beijing, the aerosol loading, scattering, and size distributions are presented using solar and sky radiance measurements from 2001 to 2010 in this paper. A much higher aerosol loading than the background level was observed during the pollution episodes. The average aerosol optical depth (AOD) is largest during dust episodes coupled with the lowest Ångström exponent (α), while higher AOD and lower α were more correlated with firework and biomass burning days. The total mean AOD at 440, 675, 870 and 1020 nm were 0.24, 0.49, 0.64 and 1.38 in the clean, firework display, biomass burning and dust days, respectively. The mean α for dust days was 0.51 and exceeded 1.1 for the remaining episodes. The size distribution of the dusty periods was dominated by the coarse mode, but the coarse mode was similar magnitude to the fine mode during the firework and biomass burning days. The volume concentration of the coarse mode during the dust days increased by a magnitude of more than 2–8 times that derived in the other three aerosol conditions, suggesting that dust is the major contributor of coarse mode particles in Beijing. The single scattering albedo (SSA) values also increased during the pollution episodes. The overall mean SSA at the four wavelengths were 0.865, 0.911, 0.922 and 0.931 in clean, firework display, biomass burning, and dust days in Beijing, respectively. However, in the blue spectral range, the dust aerosols exhibited pronounced absorption.

1. Introduction

Aerosol radiative forcing is of considerable uncertainty in the changes of climate system (IPCC, 2001). The effects of aerosols are closely related to their size distribution and physical characteristics, including optical properties. Aerosol pollution plays an important role in global climate change, as well as in adverse effects on human health (Andreae, 1991; Koe et al., 2001). In particular, Beijing, the capital of China, has been facing serious particulate pollution (He et al., 2001). According to the results of former studies, PM_{10} was reported to be the major air pollutant and $PM_{2.5}$ was also elevated in the Beijing urban atmosphere (Zhao et al., 2009; Chan and Yao, 2008). Several main pollutants include: mineral dust (dust storms in spring), biomass burning (in summer and autumn), coal combustion for heating (in winter), and vehicle emissions throughout the entire year (Song et al., 2007; Q.Q., Wang et al., 2007; Y., Wang et al., 2007; Li et al., 2008a; Ge et al., 2009).

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Gobi and deserts over northwest China are one of principal dust source regions in East Asia. Intense frontal activities in spring provide a mechanism for the injection of substantial materials into the lower and middle troposphere. In spring, the dust uplifted from Asian arid areas can be transported to large part of northern China, Korea, Japan and even the west of America across the North Pacific Ocean (Chuang, 1992; Zhang et al., 1993; Chun et al., 2001; Husar et al., 2001), and typically invade Beijing in March and April (Liu et al., 1981; Gao et al., 2002). The characteristics of dust aerosols in terms of their transport, physical, chemical, and optical properties have been widely studied (Tanré et al., 2001; Zhang et al., 1993, 1998; Maring et al., 2003; Kim et al., 2005; Mori et al., 2003). Biomass burning has attracted much interest in recent years for its impact on climate change, regional air pollution, and human health. For example, winter wheat straw burning became frequent from south to north accompanying the extension of pollutants in June, leading to the degradation of regional air quality over Beijing (Li et al., 2008a). For the smoke particles generated from biomass burning, approximately 80–90% of their volume is in the accumulation mode. Accumulation mode particles have been shown to have three principal components: particulate organic material (POM carbon with the associated organic matter such as H, N, and O), black carbon, and trace inorganic species (Reid et al., 2005). Some previous investigations have focused on the air quality, chemical composition, mixing state, and optical properties of biomass burning particles (Eck et al., 1999; Graham et al., 2002; Q.Q., Wang et al., 2007; Y., Wang et al., 2007; Li et al., 2008a; Bi et al., 2011). Additionally, it has drawn attention that intensive firework events for the Chinese New Year (CNY) celebrations releases pollutants, like ozone, sulfur dioxide, carbon dioxide, carbon monoxide, and suspended particles with trace metals and organic compounds (Liu et al., 1997; Attri et al., 2001; Ravindra et al., 2003; Steinhauser et al., 2008; Vecchi et al., 2008), especially in the fine mode (Li et al., 2008b). The air pollution during the CNY's firework events is evidently influenced by meteorological condition (Li et al., 2006). Meanwhile, other studies have investigated the aerosol physical, chemical and related properties in clear, dusty, foggy and hazy days in Beijing (Wang et al., 2006; Sun et al., 2006; Yu et al., 2011). Though these studies dedicated to each pollution episode were few in number, overall studies on aerosol optical properties during severe pollution episodes in Beijing occurred frequently are rather limited.

This study presents the aerosol optical depth, scattering and other aerosol optical properties for the dust, firework and biomass burning episodes occurring in Beijing using the Aerosol Robotic Network (AERONET) data from 2001 to 2010. Correlations between

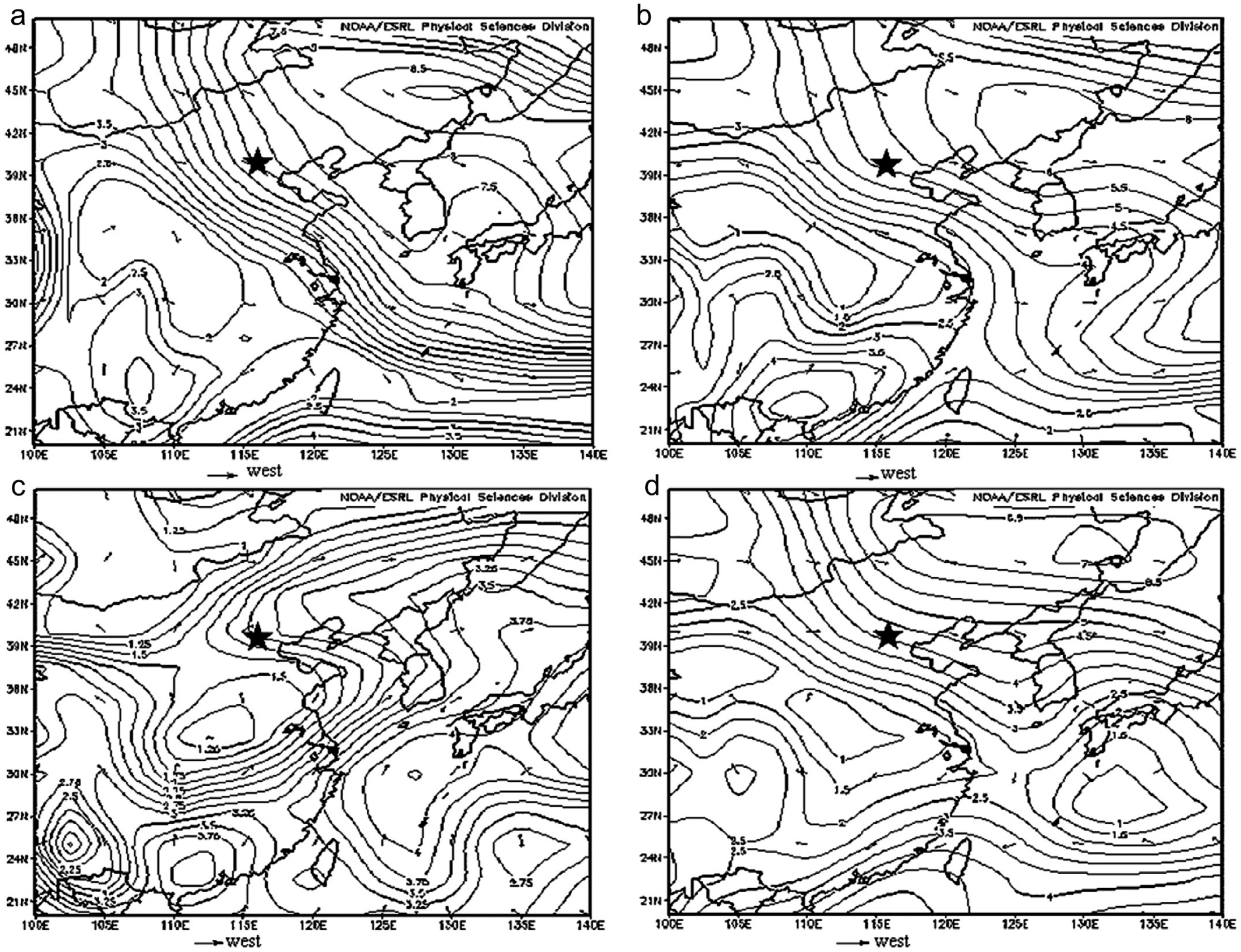

Fig. 1. Spatial distribution of the East Asia seasonal-averaged 850 hPa wind vectors derived from the NCEP reanalysis data for the observation period (2001–2010): (a) Winter, (b) Spring, (c) Summer, and (d) Autumn; ★is the location of Beijing.