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Review

Aerosol pollution in China: Present and future impact on environment

Xuexi Tie[a], Junji Cao[b,*]

[a] National Center for Atmospheric Research, Boulder, CO, USA
[b] SKLLQG, Institute of Earth Environment, Chinese Academy of Sciences, No. 10 Fenghui South Road, High-Tech Zone, Xi'an 710075, China

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ABSTRACT

With its dense population, rapid economic growth and dramatic rate of urbanization, China is experiencing extreme air pollution problems. This is particularly the case in Central-Eastern China (CEC), where the two major cities of Beijing and Tianjin are located, in the Yangtze-River Delta (YRD) with the city of Shanghai, and in the Pearl-River Delta (PRD) with the mega-city of Guangzhou. Space observations show that the atmospheric aerosol load in these three regions is considerably higher than, for example, in the urbanized regions of Europe and North America. The high aerosol concentrations in these regions have raised many environmental problems, such as impact on human health, visibility, and climate changes. In this paper, several crucial issues regarding aerosol pollution in these highly populated regions (CEC, YRD, and PRD) are discussed, including (1) when the aerosol load starts to rapidly increase in these regions; (2) how the high aerosol concentrations affects the environment; and (3) what the potential consequences are under possible low aerosol load in these regions. Discussion on these crucial issues might lead to some insight for better understanding of the characterizations of aerosol pollution due to the rapid economical development in China.

Contents

1. Introduction

Rapidly increasing urbanization will be a major environmental driving force in the 21st century, affecting air quality on all scales — local, regional, and global. According to recent United Nations estimates, the number of mega cities (with more than 10 million inhabitants) has increased from 1 in 1950 to 19 in 2000, and is expected to reach 23 by 2015. In eastern coast China, there is a concentration of many large cities; including four mega cities (see Fig. 1). Such dense urbanization has important effects on atmospheric environment. Satellite observations have revealed much higher aerosol pollution in eastern China than in eastern US (Tie et al., 2006). Such high aerosol pollution has primarily resulted from human activities. According to statistics of the International Energy Agency, the energy consumption in China has increased more than 300% from 1973 to 2002. The use of coal during 2003 amounted to 1502 TG (10^{12} g) in China and 976 TG in the US. By contrast, the use of crude oil was 234 TG in China and 864 TG in the US. The use

* Corresponding author. Tel.: +86 29 88326488; fax: +86 29 88320456.
E-mail address: cao@loess.llqg.ac.cn (J. Cao).

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Fig. 1. The distribution of large cities in China. The small red dots represent cities with population of more than 1 million, and the bigger orange dots show the locations of mega cities with population of more than 10 million. The blue circles indicate the CEC, YRD, and PRD regions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

of coal is known to produce more SO_2 and aerosol particles than oil fuel. As a result, extensive coal burning results in very heavy aerosol pollution in eastern coast China (Cao et al., 2003a, b; Deng et al., 2008; Sun et al., 2004; Wu, Tie, & Deng, 2006; Wu et al., 2005; Zhang et al., 2006).

High aerosol pollution causes wide-ranging consequences for human health, cultivated and natural ecosystems, visibility, weather, radiative forcing, and tropospheric oxidation (self-cleaning) capacity (Tie et al., 2005). For climatic effects, aerosol leads to direct radiative forcing because it scatters (Charlson, Lovelock, Andreae, & Warren, 1987; Charlson et al., 1992; Tegen, Koch, Lacis, & Sato, 2000) and absorbs (Jacobson, 2001; Ramanathan, Crutzen, & Kiehl, 2001; Ramanathan & Vogelmann, 1997) solar radiation in the atmosphere. Aerosol also alters the formation and precipitation efficiency of liquid water, ice, and mixed-phase clouds (Charlson et al., 1987), thereby causing indirect radiative forcing associated with these changes in cloud properties. In addition to climate and weather, aerosol has important impacts on human health. The Chinese Academy on Environmental Planning blamed air pollution for 411,000 premature deaths in China in 2003, primarily from lung and heart diseases. Tie, Wu, and Brasseur (2009) analyzed a 52-year history of surface measurements of haze data in the PRD region, to show that the dramatic increase in the occurrence of aerosol pollution events between 1954 and 2006 was followed by significant enhancement of the incidence of lung cancer. High aerosol concentration often produces low visibility. According to Deng et al. (2008), the occurrence of low visibility days increased dramatically after 1975 due to high aerosol concentration in the PRD region.

In this paper, we will focus on the discussion of characterization of aerosol pollution in eastern coast China, including the three fast developing areas (CEC, YRD, and PRD). Several crucial issues regarding the impact of aerosol pollution on environment in these regions will also be discussed in order to better understand the pollution control strategy and to improve the aerosol pollution in this region.

2. Present aerosol pollution in China

2.1. Characterizations of aerosol pollution

There are two major kinds of aerosol pollution in China: (1) anthropogenic aerosol pollution and (2) mineral dust aerosol pollution. According to Guinot et al. (2006), the anthropogenic aerosol particles in Beijing region were dominated by organic matter (52%) and sulfate particles (28%), followed by nitrate (9%), ammonium (8%) and soot (3%) particles. These particles are generally small (radius less than 0.5 μm). As will be discussed in the following sections, these small particles play a dominant role in causing low visibility and affecting human health. Because these small particles are mainly produced by anthropogenic emissions (traffic, industrial, biomass burning, etc.), their high concentrations are generally correlated to the major cities (see Fig. 2(a)), such as the CEC, YRD, and PRD regions shown in Fig. 1. The sizes of mineral dust particles are relatively large (radius greater than 0.5 μm) compared to anthropogenic particles (Zhang, Han, Cheng, & Tao, 2009). There are several distinguishing characters between the small anthropogenic particles and the large mineral dust particles. (a) There are very strong seasonal variations for mineral dust particles compared to anthropogenic particles. According to Zhang et al. (2006), mineral dust events occur mainly in spring, while anthropogenic aerosol pollution exists in all seasons. (b) The spatial distributions are very different between mineral dust and anthropogenic aerosols. As shown in Fig. 2(b), the highest dust concentrations are located in the Gobi Desert and the dust gets transported to northern China with western prevailing winds during spring. As a result, the dust pollutions have important envi-