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Particulate matter and gaseous pollutions in three megacities over China: Situation and implication

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HIGHLIGHTS

- In the study period, 37%, 21% and 7% of the PM2.5, and 20%, 6% and 1% of the PM10 over 3 megacities exceeded NAAQS Grade II.
- SO_2, CO, and O_3 mass concentrations are all below the Grade-II standards.
- Compared to a decade ago, gaseous pollutants decrese significantly, with SO_2 decreasing around 70%, NO_2 decreasing 30% and CO decreasing above 40%.
- O_3 is high in summer and low in winter, which is quite distinct from that of other gases pollutant and PM pollutions

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ABSTRACT

Lately released particular matter (PM) and gaseous pollutants (SO_2, NO_2, CO, and O_3) data observed in three mega cities (Beijing, Shanghai, and Guangzhou) over China from April 2014 to March 2015 are employed to analyze the current situation of air pollutions. Meteorological data during the same time period are also used to explain the variations of air pollutants. Annual averaged PM2.5 and PM10 mass concentrations shows that the highest magnitude and strongest seasonal variations occurring in Beijing and lowest magnitude and weakest seasonal variations in Guangzhou. During the study period, 37%, 21% and 7% of the PM2.5, and 20%, 6% and 1% of the PM10 mass concentration exceeded the National Ambient Air Quality Standard (NAAQS) Grade II. Large differences in the ratios of PM2.5 to PM10 between the episode and non-episodes days are found in Beijing (0.22), which is almost twice as in Shanghai (0.12) due to less episode days in the latter. Compared to Beijing and Shanghai, no episode days were found in spring and summer in Guangzhou, the episode days occur only from mid-fall to winter. NO_2 concentrations shows a marked increase during the late fall to wintertime over all three cities, which is consistent with the seasonal variations of PM concentrations. SO_2 concentrations show a slight increase during the wintertime and CO also shows an increase in winter due to emissions by vehicle cold start. SO_2 and CO concentrations during the study period are below the Grade-II standards but NO_2 concentrations exceed the Grade-II standards from late to winter. Compared to the concentrations of decade ago, SO_2 decreases around 70%, NO_2 decreases around 25%, and CO decreases around 45%. O_3 shows a strong seasonal variation, with relatively high magnitude in summer and low in winter, which is quite distinct from the seasonal variations of other gases pollutant and PM pollutions. The impact of meteorological conditions, such as precipitation, wind speed, relative humidity, and temperature, on PM and gaseous concentrations are also examined.

1. Introduction

With the rapid development of economy and the higher population density, China's pollutants emission in the past few decades has increased to a considerable extent that led to serious air pollution problems. The particulate matter (PM) concentrations and gaseous pollutants in China have increased significantly in urban areas, especially in the most populated and industrialized regions, such as the Beijing-Tianjin-Hebei (BTH), the Yangtze River

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Delta (YRD), and the Pearl River Delta (PRD). For example, annual average concentrations of particles with aerodynamic diameter equal to or less than 2.5 μm (PM2.5) were observed over 100 μg/m^3 in Beijing (He et al., 2001) and 60 μg/m^3 in Shanghai (Ye et al., 2003), greatly exceeding the World Health Organization (WHO) guideline value of 10 μg/m^3 (WHO, 2005). An increasing trend in the severity and frequency of PM pollution in more recent years has been observed (Deng et al., 2008; Li et al., 2011; Zhang et al., 2008; Zhao et al., 2013).

Many previous studies have monitored and analyzed the basic characteristics in some urban areas in China (He et al., 2001; Ye et al., 2003; Tie et al., 2009; Wang et al., 2012; Zhang et al., 2012, 2013; Zhao et al., 2013; Sun et al., 2014; Guo et al., 2014; Huang et al., 2014) during the decades. In recent years, a series of laws, regulations, and standards have been formulated and promulgated in order to reduce air pollutant emissions and improve air quality across cities. Starting from March 2012, the Chinese Ministry of Environmental Protection (CMEP) has released the official revisions of the ambient air quality index (AQI), as well as seven pollutants including $PM_{2.5}$, PM_{10}, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), 1 h peak ozone (O_3), and 8 h peak O_3, covering more than 100 major cities. In this study, we make use of the lately released observation data to study both particulate matter and gaseous pollutants in China, which is beneficial to improving our understanding of issues like emission sources, their formation mechanisms, and possible causes of air quality degradation. Compared to most previous studies, the CMEP dataset used in this study covers more monitoring sites for a city, and thus better representing the air quality condition in the city. Also, the data provides continuous monitoring on air pollutants, which allow us to explore the seasonal and inter-annual variabilities.

We focus on three mega cities in China including Beijing, Shanghai and the Guangzhou. Beijing is located in BTH region and is the capital and the center of politics, economics and culture in China. Heavy industries are gradually being replaced by other less polluting industries such as financial and other service industries, and high-technology manufacturing. Shanghai is located in YRD region and is the economic center of eastern China and its

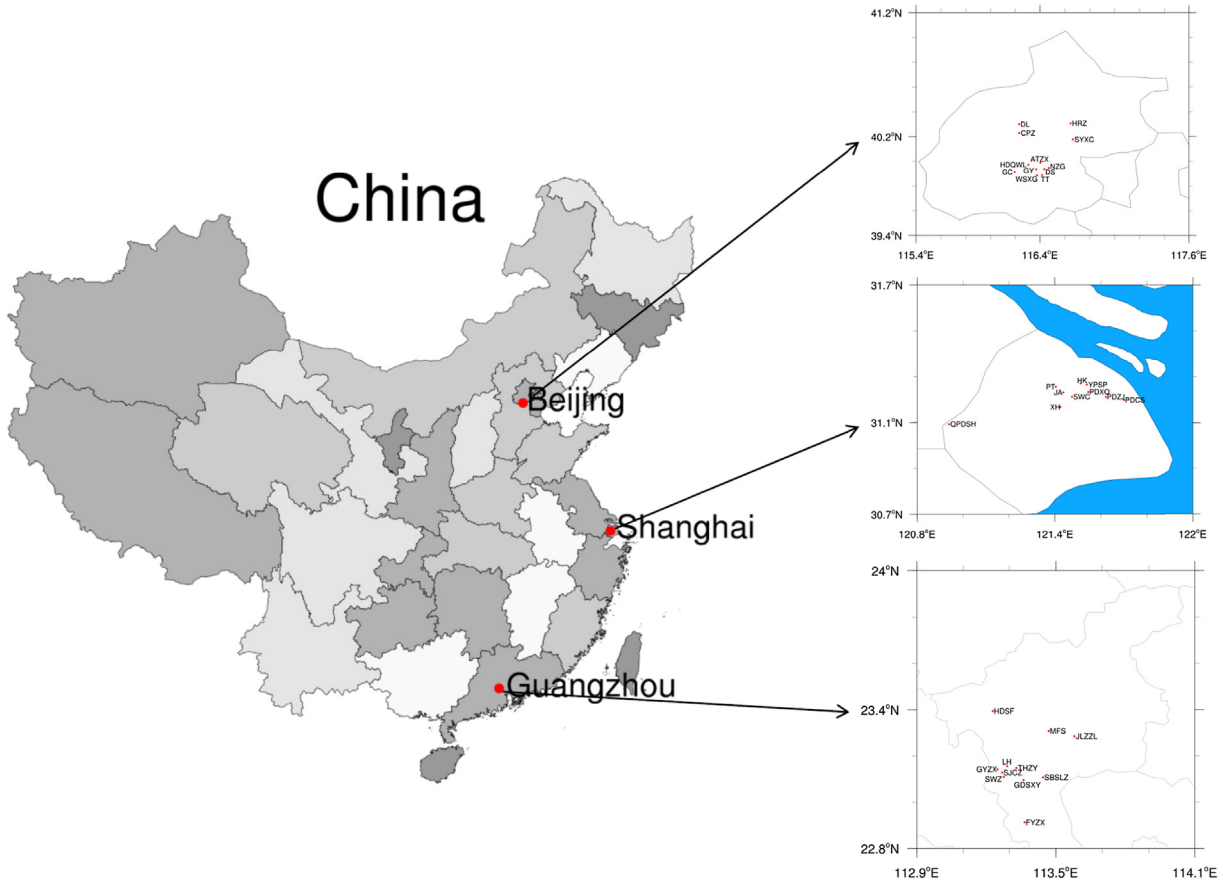

Fig. 1. Locations of the monitoring sites in Beijing, Shanghai, and Guangzhou.

Table 1
Annual mean and seasonal mean of PM2.5 and PM10 mass concentrations (μg/m^3) and their standard deviation (in brackets) in Beijing, Shanghai, and Guangzhou.

		Annual	Spring	Summer	Autumn	Winter
PM2.5	Beijing	76.9 (61.4)	76.3 (49.0)	58.4 (37.5)	90.8 (76.9)	80.8 (67.8)
	Shanghai	53.7 (33.6)	57.9 (30.8)	42.4 (23.1)	42.5 (25.1)	74.2 (41.7)
	Guangzhou	43.6 (21.0)	35.7 (13.2)	33.4 (15.3)	48.0 (18.8)	57.2 (25.0)
PM10	Beijing	115.2 (71.2)	132.4 (64.0)	88.2 (39.3)	127.2 (85.3)	111.3 (77.2)
	Shanghai	77.0 (42.9)	83.1 (44.8)	59.5 (29.1)	64.4 (27.8)	104.1 (51.4)
	Guangzhou	64.1 (27.4)	53.3 (19.0)	52.4 (19.5)	69.6 (24.6)	81.1 (33.3)