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Relationships between meteorological parameters and criteria air pollutants in three megacities in China

Hongliang Zhang [a], Yungang Wang [b,*], Jianlin Hu [c], Qi Ying [d], Xiao-Ming Hu [e]

[a] Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA
[b] Environmental Resources Management (ERM), Walnut Creek, CA 94597, USA
[c] Department of Civil and Environmental Engineering, University of California, Davis, CA 95616, USA
[d] Zachry Department of Civil Engineering, Texas A&M University, College Station, TX 77843, USA
[e] Center for Analysis and Prediction of Storms, and School of Meteorology, University of Oklahoma, Norman, OK 73072, USA

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ABSTRACT

Meteorological conditions play a crucial role in ambient air pollution by affecting both directly and indirectly the emissions, transport, formation, and deposition of air pollutants. In this study, the relationships between meteorological parameters and ambient air pollutants concentrations in three megacities in China, Beijing, Shanghai, and Guangzhou were investigated. A systematic analysis of air pollutants including $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3 and meteorological parameters including temperature, wind speed (WS), wind direction (WD) and relative humanity (RH) was conducted for a continuous period of 12 months from March 2013 to February 2014. The results show that all three cities experienced severe air quality problems. Clear seasonal trends were observed for $PM_{2.5}$, PM_{10}, CO, SO_2 and NO_2 with the maximum concentrations in the winter and the minimum in the summer, while O_3 exhibited an opposite trend. Substantially different correlations between air pollutants and meteorological parameters were observed among these three cities. WS reversely correlated with air pollutants, and temperature positively correlated with O_3. Easterly wind led to the highest $PM_{2.5}$ concentrations in Beijing, westerly wind led to high $PM_{2.5}$ concentrations in Shanghai, while northern wind blew air parcels with the highest $PM_{2.5}$ concentrations to Guangzhou. In Beijing, days of top 10% $PM_{2.5}$, PM_{10}, CO, and NO_2 concentrations were with higher RH compared to days of bottom 10% concentrations, and SO_2 and O_3 showed no distinct RH dependencies. In Guangzhou, days of top 10% $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2 and O_3 concentrations were with lower RH compared to days of bottom 10% concentrations. Shanghai showed less fluctuation in RH between top and bottom 10%. These results confirm the important role of meteorological parameters in air pollution formation with large variations in different seasons and geological areas. These findings can be utilized to improve the understanding of the mechanisms that produce air pollution, enhance the forecast accuracy of the air pollution under different meteorological conditions, and provide effective measures for mitigating the pollution.

1. Introduction

China holds rich culture and incredible history. Its large cities are transforming into cosmopolitan metropolises attracting enormous tourism, business development, and global integration. However, China's economic performance and growth over the last several decades can be overshadowed by the amount of air pollution the Chinese people inhale every day. In every major urban area across China, concentrations of air pollutants greatly exceed standards recommended by the World Health Organization (WHO).

Globally, 7 million deaths in 2012 were attributable to air pollution, which becomes the world's largest single environmental health risk accounting for one in eight of total global deaths (World Health Organization, 2014). In China, between 350,000 and 500,000 people die prematurely each year as a result of outdoor air pollution, and it has become the fourth biggest threat to the health of Chinese people after heart disease, dietary risk and smoking (Chen et al., 2013a). The China's Huai River policy, which provides free winter heating via the provision of coal for boilers in cities north of the Huai River but denies heat to the south, leads to a reduction in life expectancies of 5.5 years (95% CI: 0.8, 10.2) in the north owing to an increased incidence of cardiorespiratory mortality (Chen et al., 2013b).

* Corresponding author.
E-mail address: carl.wang@erm.com (Y. Wang).

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Previous air quality studies conducted in China mainly focus on the sources, the physical characteristics, and chemical composition of air pollutants (Cao et al., 2014; Wang et al., 2013a; Xue et al., 2014; Yuan et al., 2014). Several case studies have shown that meteorological conditions affect ambient air pollution in China in numerous ways. For example, Tian et al. (2014) reported that the air quality was the worst in spring, and became better in summer, subsequently tended to be more serious in autumn and winter in Beijing. Xu et al. (2011a) found that trace gas concentrations were strongly dependent on wind, and O_3 mixing ratio showed clear dependencies on temperature and relative humidity in North China Plain (NCP) region. Previous studies suggested that variation of the synoptic patterns modulated pollutant concentrations and likely provided the primary driving force for the day-to-day variations in the NCP regional pollution (Chen et al., 2008; Wang et al., 2009; Wei et al., 2011; Zhang et al., 2012a). Southerly/Southwesterly surface wind was found more likely to contribute to severe air pollution in the NCP (Wang et al., 2010, 2013b; Xu et al., 2011b). Results from Wang et al. (2015) showed that aerosol-radiation interactions played an important role in the haze episode in the NCP region. However, the knowledge gap between meteorological parameters and their impacts on concentrations of air pollutants remains wide.

In this study, a systematic analysis is presented to investigate the relationships of six criteria air pollutants ($PM_{2.5}$, PM_{10}, CO, SO_2, NO_2 and O_3) with meteorological parameters (wind direction, wind speed, temperature, and relative humidity) in three megacities based on a 12-month record of observations in 2013–2014. The goal is to unfold these vital relationships that can be utilized to improve the understanding of the mechanisms that produce air pollution, enhance the forecast accuracy of the air pollution under different meteorological conditions, and provide effective

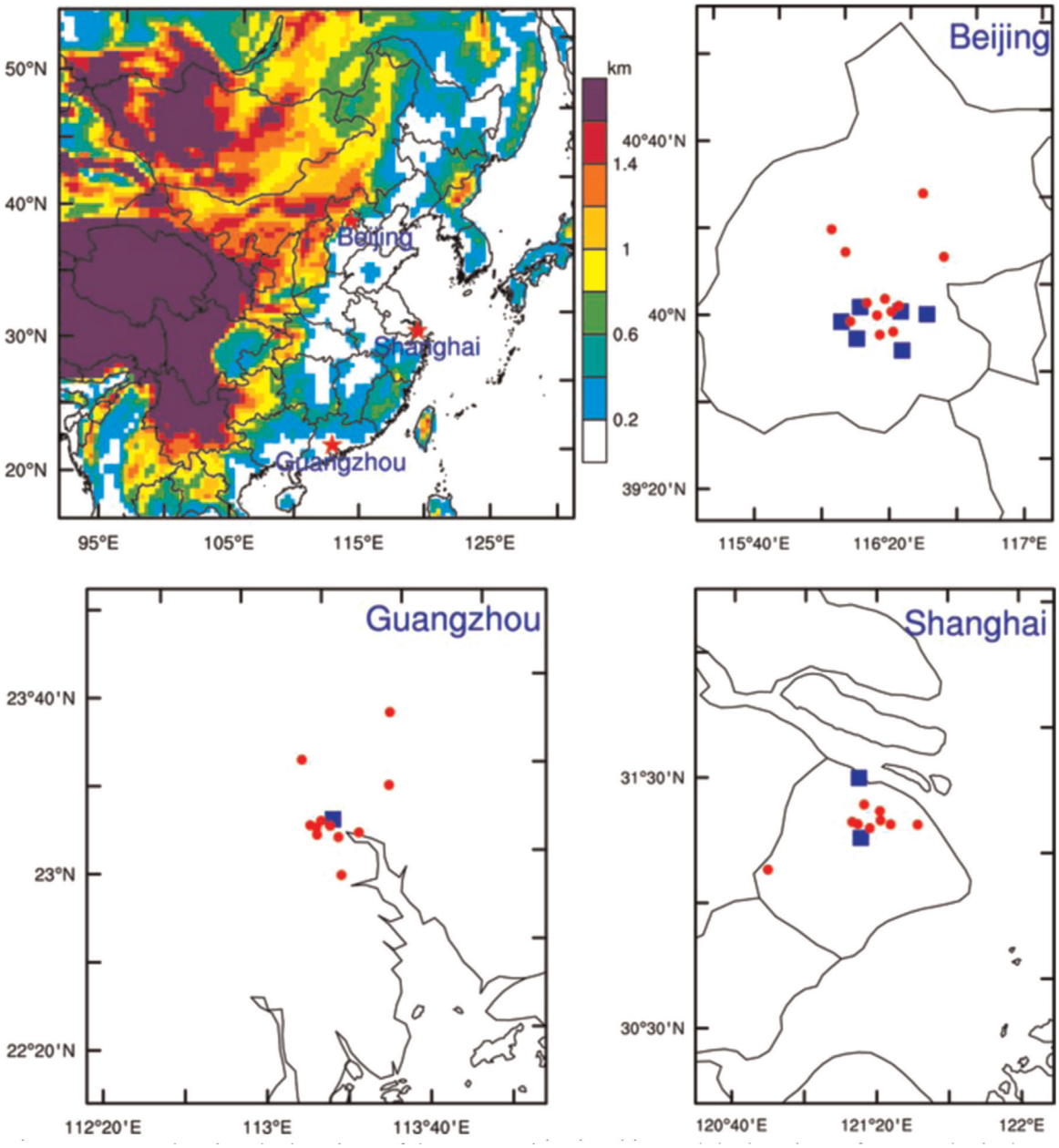

Fig. 1. Maps showing the locations of three megacities in China and the locations of meteorological (blue squares) and air quality (red circles) stations in each city. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)