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# Spatio-temporal variability of particulate matter in the key part of Gansu Province, Western China☆

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ABSTRACT

To investigate the spatial and temporal behaviors of particulate matter in Lanzhou, Jinchang and Jiayuguan during 2014, the hourly concentrations of PM2.5 and PM10 were collected from the Ministry of Environmental Protection (MEP) in this study. The analysis indicated that the mean annual PM10 (PM2.5) concentrations during 2014 were 115 ± 52 μg/m$^3$ (57 ± 28 μg/m$^3$), 104 ± 75 μg/m$^3$ (38 ± 22 μg/m$^3$) and 114 ± 72 μg/m$^3$ (32 ± 17 μg/m$^3$) in Lanzhou, Jinchang and Jiayuguan, respectively, all of which exceeded the Chinese national ambient air quality II standards for PM. Higher values for both PM fractions were generally observed in spring and winter, and lower concentrations were found in summer and autumn. Besides, the trend of seasonal variation of particulate matter (PM) in each city monitoring site is consistent with the average of the corresponding cities. Anthropogenic activities along with the boundary layer height and wind scale contributed to diurnal variations in PM that varied bimodally (Lanzhou and Jinchang) or unimodally (Jiayuguan). With the arrival of dust events, the PM10 concentrations changed dramatically, and the PM10 concentrations during dust storm events were, respectively, 19, 43 and 17 times higher than the levels before dust events in Lanzhou, Jinchang and Jiayuguan. The ratios (PM2.5/PM10) were lowest, while the correlations were highest, indicating that dust events contributed more coarse than fine particles, and the sources of PM are similar during dust storms. The relationships between local meteorological parameters and PM concentrations suggest a clear association between the highest PM concentrations, with $T \le 7$ °C, and strong winds (3–4 scale). However, the effect of relative humidity is complicated, with more PM10 and PM2.5 exceedances being registered with a relative humidity of less than 40% and 40–60% in Lanzhou, while higher exceedances in Jinchang appeared at a relative humidity of 80–100%.

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## 1. Introduction

In recent decades, rapidly expanding economic development has resulted in tremendous increases in energy consumption, air pollutant emissions and the occurrence of air pollution worldwide (Chan and Yao, 2008; Li et al., 2013; Zhao et al., 2013). As is known, air pollutants, particularly PM (mainly including PM10 and PM2.5: PM with an aerodynamic diameter less than 10 μm and 2.5 μm, respectively) have significant health effects (Chien et al., 2012; Caiazzo et al., 2013). High concentrations of PM will increase the risk of respiratory and cardiovascular systems in the elderly and reduce the survival rates in newborn which are well established in Tianjin, Taiwan and Hong Kong (Yu et al., 2013; Chen et al., 2015; Li et al., 2015). Compared with PM10, PM2.5 is more harmful due to its smaller size and long atmospheric lifetime. Studies have demonstrated that a 10 μg/m$^3$ increase in the previous day's PM was associated with from a 0.3%–1.2% excess risk in all mortality for PM2.5, with an equivalent **0.2%–1.0%** excess risk for PM10 in China (Middleton et al., 2008; Janssen et al., 2013; Yu et al., 2013; Pascal et al., 2014).

PM is the primary air pollutant in most Chinese cities (MEP, 2012a). In relation to PM10, the data began to release in 2000

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(Chen et al., 2015), and the related research has studied by a few years (Hoffmann et al., 2008; Wang et al., 2009; Zhu et al., 2011). However, PM2.5 has been gradually focused in recent years, the data were partly available at the start of 2012. Anthropogenic activity, including industrial development, combustion and traffic emissions are dominant factors for the spatial and temporal (including diurnal, weekly and seasonal) variation of PM (DeGaetano, 2004; Zhao et al., 2009; Elbayoumi et al., 2013; Ferm and Sjöberg, 2015; Eeftens et al., 2015). In addition, natural factors (particularly dust events, which break out frequently during the spring in northern China) also have important effects on the spatial-temporal variation of PM (Hoffmann et al., 2008; Shen et al., 2009; Feng and Wang, 2012; Jugder et al., 2014; Liu et al., 2014).

At present, studies on the impact of anthropogenic and natural factors on atmospheric PM are mainly focused on a single city or seasons with higher levels of PM (Chu et al., 2012; Jugder et al., 2014; Cui et al., 2015; Gao et al., 2015; Wang et al., 2015; Zheng et al., 2015; Qiu et al., 2016; Tian et al., 2016), whereas only a very limited number of studies have studied the large-scale annual variance of PM (Cao et al., 2005; Hu et al., 2014; Xie et al., 2015; Zhao et al., 2016). Lanzhou, Jinchang and Jiayuguan, located in the key parts of the Chinese government's "The Silk Road Economic Belt", are the most economically developed cities in Gansu Province (Fig. 1). As a result of the government-initiated development strategy, preferential policies and expanding investment will further aggravate the human impact on the atmospheric quality in these areas. In addition, due to their relationship to the Kumtag Desert, Badain Jaran Desert and Tengger Desert, respectively, from west to east (Wang et al., 2005a, 2006; Guan et al., 2013, Fig. 1), these three cities frequently experience dust storms in spring. In this study, the hourly concentrations of PM2.5, PM10 and meteorological data were measured in Lanzhou, Jinchang and Jiayuguan during 2014, revealing the spatial and temporal variations of PM and the main factors affecting them. Then, a massive dust storm, that occurred from April 23 to 27 of 2014, was selected to provide a comprehensive analysis of changes in the PM concentration before, during and after a dust storm in relation to influencing mechanisms. This is the first attempt at characterizing regional PM2.5 pollution using ground-measurement data with hourly time resolution across northwest China.

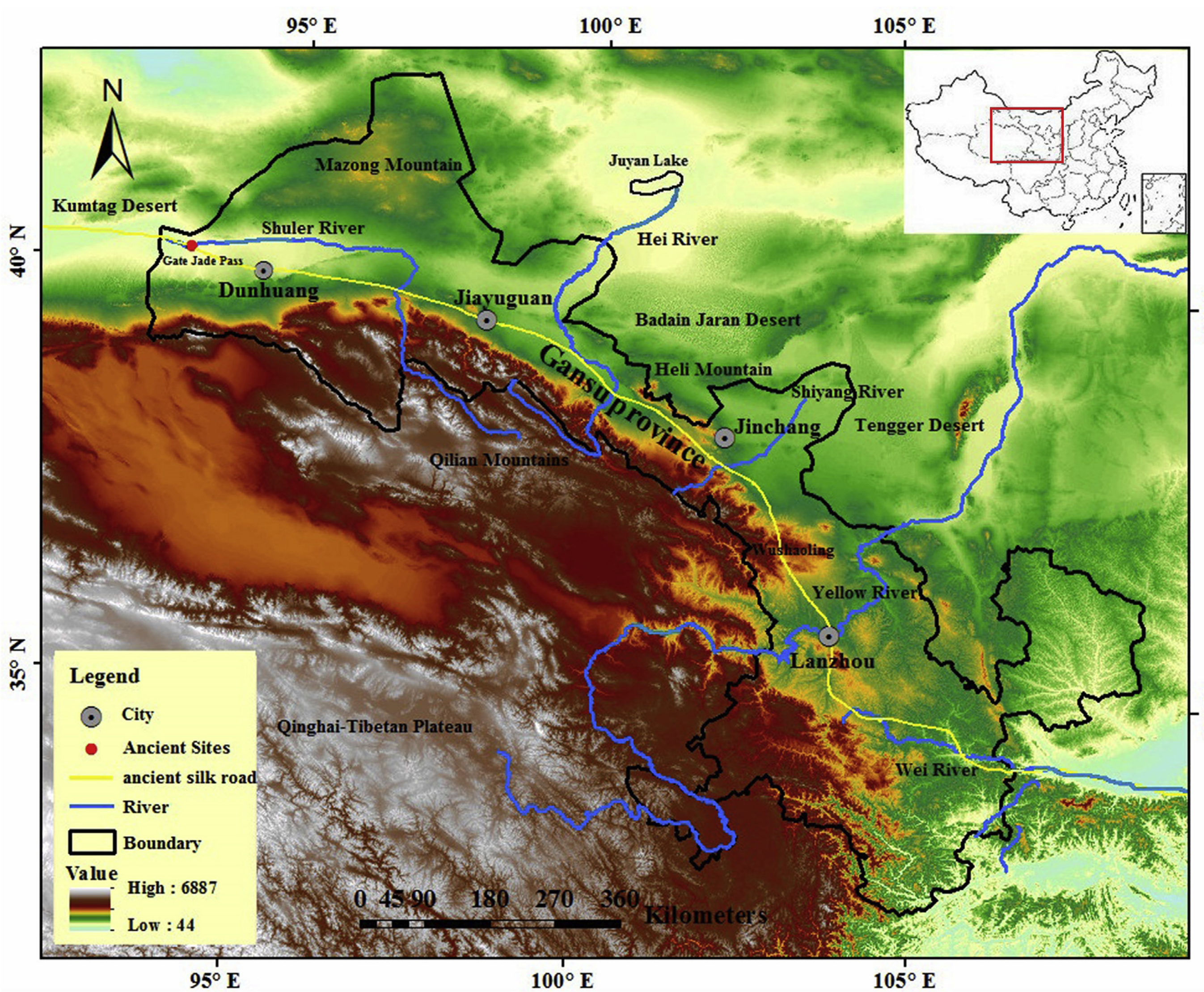


**Fig. 1.** Location of the three cities selected in this study. The Hexi corridor starts at Wushaoling in the east and ends at Gate Jade Pass in the west, running between the Qilian Mountains, Mazong Mountains, Heli Mountains, Tengger Desert and Badain Jaran Desert. The yellow line represents the Ancient Silk Road. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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