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Analysis of patterns in the concentrations of atmospheric greenhouse gases measured in two typical urban clusters in China

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ABSTRACT

China is the largest emitter of greenhouse gases, and urban clusters play an essential role in China's carbon emissions because of the country's unbalanced economic development. In this paper, the discrete air sample measurements of atmospheric CO_2, CH_4, and CO during the period between 2007 and 2013 from Shangdianzi (SDZ) station in Jing-Jin-Ji (JJJ) region and Linan (LAN) station in Yangtze River Delta (YRD) region, respectively, are presented and characterized. By backward trajectory cluster analysis, the low background CO_2 mole fraction and similar long-term trends with Waliguan global station (WLG) were observed at SDZ because most of the air masses originate mostly from remote clean terrestrial areas in the north with limited information of anthropogenic emissions. But the background CH_4 and CO are influenced mainly by ruminants and rice field emission from the surrounding regions and urban cluster emission in the JJJ region, which lead to the higher CH_4 and CO in summer at SDZ. Whereas, the CO_2, CH_4 and CO background values observed at LAN are higher by the combined effects of long-distance atmospheric transportation from Northern and Central China and urban clusters emission from the YRD region. The observed polluted data at SDZ and LAN are all strongly affected by regional and local anthropogenic emissions, which lead to the higher GHGs concentrations compared to the background data. However, because the air mass transportation from the north is weak in winter and no winter heating is required and vegetation photosynthesis is still stronger in the south of China, the CO_2 concentration at LAN is lower than that at SDZ in autumn and winter. The polluted CO value at SDZ is found considerably higher than that at LAN, especially in spring and winter. By analyzing the correlations of observed regional enhanced values of CO_2, CH_4 and CO at the two stations, we find the significant correlation between them, which means they may share the common-source of anthropogenic emissions from the regional fossil fuel and biomass burning in cold season. Moreover, the high coal-consumption proportion with the low CO_2 emissions factors, and much biomass burning with low combustion efficiency in JJJ region lead to the higher slope values of $\triangle CO_2$ and $\triangle CO$ in spring and winter at SDZ and considerably higher than that at LAN. The results can provide a further understanding of regional/local features of atmospheric GHGs under the influence of human activities in the urban clusters in China.

1. Introduction

Carbon dioxide (CO_2) and methane (CH_4) are the two most important anthropogenic greenhouse gases (GHGs) in the atmosphere. These gases contribute approximately 65% and 17% of total radiative forcing from long-lived greenhouse gases, respectively. Global atmospheric CO_2 concentrations reached 143% of pre-industrial level in 2014, primarily because of emissions from the combustion of fossil fuels (90%) and cement production (10%). Atmospheric CH_4 reached 254% of its pre-industrial level in 2014 (Liu, 2015; WMO, 2014, 2015). CH_4 is driven mainly by reaction with hydroxyl radical (OH) and emissions from sources such as wetlands, fossil fuel and biomass burning, as well as by atmospheric transport. Carbon monoxide (CO) is not a greenhouse gas, but its most prominent sources are closely associated with primary emissions from the incomplete combustion of fossil fuels and biomass. Therefore, CO is a good indicator of anthropogenic pollution (Gamnitzer et al., 2006; Levin and Karstens, 2007; Turnbull et al., 2006).

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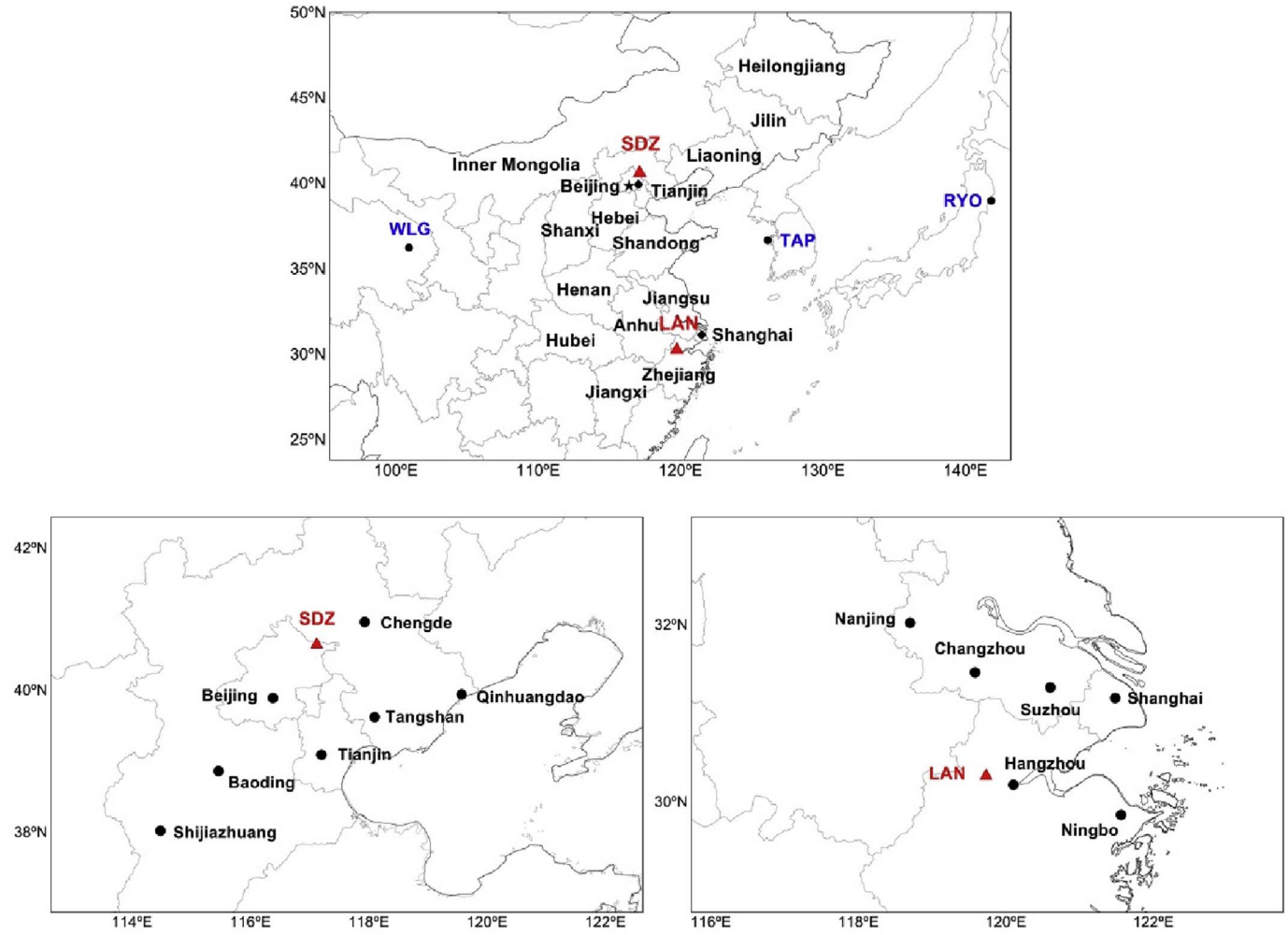

Fig. 1. Map of study region, showing the locations of SDZ and LAN stations (red triangles), main provinces and cities. (The areas are 218331 km^2, 213018 km^2, and the population densities are 4.93, 7.41 $10^3/km^2$ in JJJ and YRD, respectively.). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

China, with its fast-growing economy, is the largest emitter of GHGs (Boden et al., 2010; Gregg et al., 2008). However, the characteristics and the level of GHGs emissions vary among different regions. Cities play an essential role in China's carbon emissions; more specifically, 85% of China's direct carbon emissions are from cities (Liu, 2015). Therefore, observing atmospheric CO_2 and CH_4 concentrations in combination with the characteristics of the natural and socio-economic environment in different regions can yield important information on regional GHGs sources and sinks.

Previous studies have mostly focused on long-term observations of atmospheric greenhouse gases and related gases from Waliguan (WLG) global background station (Zhang et al., 2011, Zhang and Zhou, 2013, 2013; Zhou et al., 2004a, 2004b, 2005). Few studies have been published based on the observations from regional stations because of insufficient data and the complex distribution of multiple sources and sinks, especially in the economically developed urban areas (Fang et al., 2013, 2014; Liu et al., 2009, 2014; Pu et al., 2014).

The Jing-Jin-Ji region (JJJ region) encompasses Beijing and Tianjin, as well as eight other cities and more than 80 counties in Hebei province (Fig. 1), is located in the North China Plain. This region is the political center of China and the most important economic center in northern China. The rate of economic growth in this area is well above the national average, but the pattern of development, which has focused on heavy industry, has increasingly caused prominent environmental and resource problems (Feng et al., 2013; Han et al., 2009; Wang et al., 2014). On the other hand, the Yangtze River Delta region (YRD region), which lies on the eastern coast of China, includes Shanghai, Jiangsu province, and Zhejiang province. This region has the fastest growing regional economy, making the largest contribution to the Chinese economy, and has the highest urbanization rate and the largest foreign trade base in China (Sun and Wu, 2012; Wu et al., 2012).

In terms of emissions of GHGs and pollutants, these two urban clusters are the most important regions because of the positive association between anthropogenic emissions and recent rapid economic growth (Deng et al., 2014; Du and Fan, 2008; Long and Shao, 2015). In June 2006, the greenhouse gases and related tracers laboratory of the CMA began measuring GHGs from flask samples collected at Shangdianzi station (SDZ), which is located in the JJJ region, and Lin'an station (LAN), which is located in the YRD region. Both stations are regional stations of the World Metrological Organization (WMO)/Global Atmosphere Watch (GAW) (Zhou et al., 2008).

In this paper, the discrete air sample measurements of atmospheric CO_2, CH_4, and CO from stations SDZ and LAN are presented and characterized. The study periods are from January 2007 to December 2013 for CO_2 and CH_4 and from October 2008 to December 2013 for CO from both stations. The temporal variations and regional background characters are introduced and are compared with GHGs data results recorded at other observational stations. The regional/local impacts of high anthropogenic emissions in urban clusters on the observed GHGs mixing ratios have been mainly investigated by trajectory cluster analysis and correlation analysis of enhanced CO_2, CH_4 and CO values.