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"APEC Blue" association with emission control and meteorological conditions detected by multi-scale statistics

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ABSTRACT

The term "APEC Blue" has been created to describe the clear sky days since the Asia-Pacific Economic Cooperation (APEC) summit held in Beijing during November 5–11, 2014. The duration of the APEC Blue is detected from November 1 to November 14 (hereafter Blue Window) by moving *t* test in statistics. Observations show that APEC Blue corresponds to low air pollution with respect to $PM_{2.5}$, PM_{10}, SO_2, and NO_2 under strict emission-control measures (ECMs) implemented in Beijing and surrounding areas. Quantitative assessment shows that ECM is more effective on reducing aerosols than the chemical constituents. Statistical investigation has revealed that the window also resulted from intensified wind variability, as well as weakened static stability of atmosphere (SSA). The wind and ECMs played key roles in reducing air pollution during November 1–7 and 11–13, and strict ECMs and weak SSA become dominant during November 7–10 under weak wind environment. Moving correlation manifests that the emission reduction for aerosols can increase the apparent wind cleanup effect, leading to significant negative correlations of them, and the period-wise changes in emission rate can be well identified by multi-scale correlations basing on wavelet decomposition. In short, this case study manifests statistically how human interference modified air quality in the mega city through controlling local and surrounding emissions in association with meteorological condition.

1. Introduction

The term APEC Blue has been used by news and other media in China since the Asia-Pacific Economic Cooperation (APEC) conference held in Beijing during November 5–11, 2014 (Liu, Y., et al., 2015; Gong, 2015). The term describes the phenomenon of air pollution with clear skies, which is unusual for this heavily polluted city in the season. The creation of this term reflects a strong expectation of local residents for clear sky because heavy haze episodes have prevailed in past decades, especially in winter-half year (Zheng et al., 2005; Liu, Y., et al., 2015; Liu, Z., et al., 2015; Swinbanks, 1998; Li et al., 2015; Huang et al., 2011). Air pollution has increasingly worsened in Beijing as a result of rapid economic development and urbanization in the city (Ma et al., 2012; Xiao et al., 1983; Sun, 2008). Dark haze events have appeared more and more frequently in this region (Marshall, 2013; Sun et al., 2006; Wang et al., 2015), leading to various negative impacts on the health and daily activities of local residents (Men et al., 2015; Zhang et al., 2007). Determining methods for mitigating air pollution have become a priority for local authorities, the Chinese government (Qiu, 2012; Wang and Hao, 2012; Fang et al., 2009; Zhuang et al., 2014), and the scientific community, as well. Some investigations using back trajectory technique have shown that the air pollutants in Beijing originate from local emissions or are transported from neighboring or even remote areas (Zhang et al., 2013; Huang et al., 2008a, 2008b); local emission sources include coal burning, vehicles, cooking fuels, power plants, industrial facilities, construction sites, biomass burning, and dust (Wang et al., 2008; Guo et al., 2011; Zhang et al., 2014). Improving air quality has become a systematic engineering issue that depends on the broad cooperation of various sectors for controlling emissions. One of such projects has been supported by the Chinese government (Brandmeyer et al., 2009; Guo et al., 2014), and a series of policies or measures were launched in the past decade for mitigating air pollution in the country (Parrish and Zhu, 2009; Wang et al., 2014; Zhang et al., 2012). For example, a Five-Year Clean Air Action Plan (2013–2017) was unveiled by Beijing's authorities in 2013 to curb local air pollution (Beijing Municipal Government, 2013). In addition, a number of measures for temporarily decreasing emissions have been implemented for special international political events or sport events held in China, such as the 2008 Olympic Games or 2014 APEC summit (Xu et al., 2005; Cai and Xie, 2011; Streets et al., 2007). Thus far, the strictest emission-control measures (ECMs) against air pollution in Beijing and its surrounding areas were implemented prior to, and during the APEC summit (Beijing Municipal Government, 2014). For example, a measure only allowed drivers to operate vehicles only on specific days according to whether their license

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plate numbers were odd or even. Other measures included shutting down coal burning plants, halting work at construction sites, keeping roads clear, and launching an APEC holiday for local residents, which led a part of them leaving Beijing for traveling outside. These compulsory measures were highly effective on improving local air quality and ultimately leading to consecutively clear sky days during the APEC summit (Tang et al., 2015; Huang et al., 2015; Wang et al., 2016). A number of new studies show substantial changes in aerosol composition, size distribution, oxidation properties, and precursors of secondary aerosol prior to, during and after the APEC summit (Han et al., 2015; Chen et al., 2015; Sun et al., 2016). However, the duration of the APEC Blue around the conference (hereafter Blue Window) with low air pollution is longer than the APEC week (3–11 November, due to multi-factors that exerted on the air quality during the window, such as wind variability or atmospheric instability except for the emission reduction. Hence, the Blue Window should be tested and assessed statistically basing on local pollutant observations. Besides, it is difficult to know real emission rates in a city. So, developing an alternative technique has become necessary in identifying potential emission changes owing to the coherency between the pollutant concentration and wind variability.

The remainder of this paper contains six sections. Section 2 introduces data and methods. Section 3 presents two official assessments on the air pollution around the 2014 APEC summit in Beijing and surroundings. Observation analysis using the *t* test is conducted in Section 4 for determining the significances of period-wise pollutant changes. Section 5 shows detailed comparisons day by day among PM_{10}, static stability of atmosphere (SSA) and wind speed. Coherency between daily oscillations of the wind and PM_{10} or their wavelet components is estimated for identifying potential period-wise changes in pollutant emission rate (developed in Section 6) and Section 7 is the conclusion with a short discussion.

2. Data and methods

The investigation incorporates three datasets: wind observations at 11 m above the surface, air pollutant concentrations of $PM_{2.5}$, PM_{10}, SO_2, and NO_2, assessment results involving SO_2, NOx, PM_{10}, $PM_{2.5}$, and VOCs and the corresponding emission reduction rates in Beijing for November 3–12. The wind records were obtained from China Meteorological Administration (CMA), and the pollutant concentrations were taken from Beijing Municipal Environmental Monitoring Center (BMEMC; http://zx.bjmemc.com.cn/). The assessment results were gotten from BMEMC and Beijing Municipal Environmental Protection Bureau (BMEPB). The concentrations of $PM_{2.5}$, PM_{10}, SO_2, and NO_2 were observed hourly at 11 stations in Beijing Metro area (Fig. 1).

The 11 stations are named as Wanshouxigong, Dongsi, Temple of Heaven, Nongzhanguan (agriculture exhibition building), Guanyuan, Olympic Center, Gucheng, Ding Ling (Tomb of Ding), Shunyixincheng (new town of Shunyi county), Huairou town (2014 APEC site), and Changping town. The last five stations are situated in the northern suburb of Beijing, and the others are located in the urban area near downtown of the capital city. The daily pollutant concentrations used are the averages of the transient pollutant concentrations recorded hourly at the stations from 00:00 to 23:00 in Beijing time, and the ensemble of the daily pollutant sequence is represented by the average of the pollutants observed over the 11 stations.

Fig. 1. Map of Beijing metro area. Red dots show the locations of the 11 stations for air pollutant observations.