Characteristics of ambient 1-min PM$_{2.5}$ variation in Beijing

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Abstract One-minute PM$_{2.5}$ concentration was obtained with LD-5C pocket microcomputer laser dust instrument from Dec. 15th, 2005 to Jan. 16th, 2006 and Mar. 17th to Apr. 28th, 2006 in Beijing. The concentration of SO$_2$, NO$_2$, O$_3$, CO, and PM$_{10}$ from Jan. 1st, 2001 to Dec. 31st, 2004 were obtained from the conversion of air pollution index. Results showed that all the pollutants showed cyclic characteristics. The longer yearly cycles was shown from SO$_2$, NO$_2$, O$_3$, CO, and PM$_{10}$, as the sampling time was 4-year long and daily collected. The shorter hourly and daily cycle was shown from 1-min PM$_{2.5}$, as the sampling time was about 1-month long and one collected at 1 min. The spectral density analysis confirmed this from the periodogram graphs. The longer yearly cycle (365, 180 days), the seasonal cycle (120, 60–90 days), and monthly cycle (21, 23, 27 days) of SO$_2$, NO$_2$, CO, O$_3$, and PM$_{10}$ were obviously shown. In addition, the shorter weekly cycle of 5–7 days is obviously shown, too. The shorter hourly cycle (8–12, 4–6, 3, 1–2 h, 20 min) of 1-min PM$_{2.5}$ was also indicated from spectral density analysis. Two major factors contribute the 1-min PM$_{2.5}$ cycles, i.e., the meteorological factors and source effects. Both the relative humidity and dew point showed consistent variation with PM$_{2.5}$, but the wind speed showed inverse variations with PM$_{2.5}$. Furthermore, the spectral density analysis of the meteorological factors (4–5, 2–2.5, 1–1.5 days, 12, 6–8, 3 h) may partially explain the cycles of PM$_{2.5}$. As for the sources effects, it can be shown from the strong dust storm of April 16–18th, 2006. PM$_{2.5}$ constantly increased tens and even hundreds of times high concentration within a few minutes due to the intensity of the dust sources.

Keywords One–minute PM$_{2.5}$ · Meteorological effects · Dust storm · Cycles

Introduction

Aerosol is now receiving worldwide attention, as it would have the potential impacts on the global
climate change and the effect on the health to human being all over the world. Aerosols also affect climate directly by scattering and absorbing radiation or indirectly by changing the depth and albedo of the clouds (Twomey 1974; Charlson et al. 1992). Atmospheric particulates, especially those fine particles, have been recognized to have serious health effects, and the level in ambient air are associated with increased cardiovascular and respiratory morbidity and mortality (Dockery et al. 1993). However, it is not yet known whether the health effects may be caused by the large number of particles (Penttinen et al. 2001) or perhaps due to some toxic components in the particulate matter. Thus, many studies of their physical and chemical characteristics are conducted to elucidate particle toxicity.

Aerosol particulate concentrations in urban areas are affected by several factors. Exhaust and suspension emission originating from local traffic are considered to be a major factor that contributes the short term and high concentration of the urban aerosol (Hussein et al. 2004). Besides vehicle-originated emissions, long-range transportation and coal burning especially in winter are also two most important contributors.

Studies on the characteristics of aerosol in Beijing have been conducted since 1980s of the twentieth century. Winchester and Bi (1984) have studied the fine and coarse particle compositions in Beijing in the late 1970s. Dust-soil, industry emission, coal burning, vehicle exhaust emission, and waste incineration were thought to be the major sources of particulate pollution at Beijing (Sun et al. 2004a). Chen et al. (1994) initiated the PM$_{2.5}$ (particles with diameters < 2.5) aerosol in Beijing, investigated the chemical compositions of PM$_{2.5}$, and observed that OC, EC, and sulfate, the three major components of PM$_{2.5}$, contributed 66% of the total fine particles, which had the yearly average of 89.7 $\mu$g/m$^3$ in Beijing. He et al. (2001) observed PM$_{2.5}$ concentrations of 37–357 $\mu$g/m$^3$ with significant seasonal variation and concluded that organic carbon was the most abundant species in PM$_{2.5}$ while sulfate, nitrate, and ammonium also were the major components. Yao et al. (2002) reported that sulfate, nitrate, and ammonium were the main ionic species in PM$_{2.5}$. Wang et al. (2005a) reported that temperature, relative humidity, rainwater frequency, and air mass origin might be the main factors regulating the PM$_{2.5}$ aerosol distribution by studying water soluble ions in different sites in Beijing.

However, most of these studies concentrated on the physicochemical species characterization of PM$_{2.5}$. Few studies have been conducted on the variation of aerosols during 1 day or shorter time. As a typical city of the mixing between coal burning and vehicle exhausts, Beijing is thought to be a good example of pollution. This study presents the characteristics of 1-min PM$_{2.5}$ for more than 1 month both in winter and in spring, with the special consideration of the influencing factors such as the sources effects and the meteorological information.

### Sampling and analysis

The 1-min PM$_{2.5}$ concentration was obtained with LD-5C pocket microcomputer laser dust instrument (Beijing BINTA Green Technology Co., Ltd), based on the principle of laser light scattering method. Two sampling seasons were collected, i.e., from Dec. 15th, 2005 to Jan. 16th, 2006 for winter and from Mar. 17th to Apr. 28th, 2006 for spring in Beijing. The sampling site is located on the roof (~40 m high) of the 12th floor in the Building of Science and Technology of Beijing Normal University, located between the second and third Ring Roads.

SO$_2$, NO$_2$, O$_3$, CO, and PM$_{10}$ data were obtained from air pollution index (API; API = 100 corresponds to Chinese air quality standard II) in the annual report of China EPA (http://www.bjepb.gov.cn). It was converted to be concentrations with the following formulas: $C = C_{\text{low}} + \left[(I - I_{\text{low}})/(I_{\text{high}} - I_{\text{low}})\right] \times (C_{\text{high}} - C_{\text{low}})$, where $C$ is the concentration and $I$ is the API value. $I_{\text{high}}$ and $I_{\text{low}}$, the two values most approaching value $I$ in the API grading limited value table, stand for the value higher and lower than $I$, respectively; $C_{\text{high}}$ and $C_{\text{low}}$ represent the concentrations corresponding to $I_{\text{high}}$ and $I_{\text{low}}$, respectively. The detailed procedures were given elsewhere (Tang et al. 2005).