Atmospheric Environment 186 (2018) 32–44

Contents lists available at ScienceDirect

Atmospheric Environment

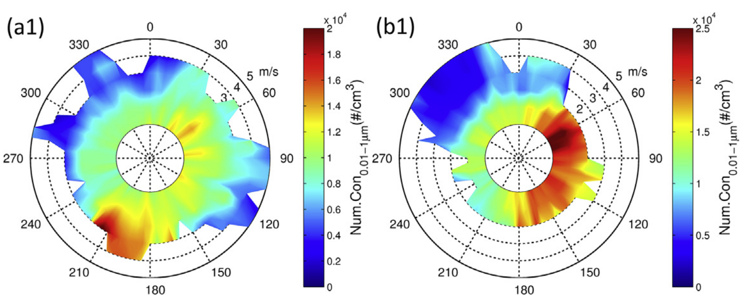
journal homepage: www.elsevier.com/locate/atmosenv

Number size distribution of atmospheric particles in a suburban Beijing in the summer and winter of 2015

Peng Du[a,b], Huaqiao Gui[a,c], Jiaoshi Zhang[a,*], Jianguo Liu[a,c,**], Tongzhu Yu[a], Jie Wang[a], Yin Cheng[a], Zongbo Shi[d]

[a] Key Laboratory of Environmental Optics and Technology, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] Center for Excellence in Regional Atmospheric Environment, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China
[d] School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Particle number size distribution
Beijing
Aerosol
Trajectory cluster analysis
New particle formation

ABSTRACT

Particle number size distribution in a suburban Beijing was measured during the HOPE-J3A (Haze Observation Project Especially for Jing–Jin–Ji Area) field campaigns in 2015 from 18 June to 23 July (summer) and 2 to 25 December (winter). Average particle concentrations during the summer and winter campaigns were $9.6 \pm 4.8 \times 10^3 cm^{-3}$ and $13.9 \pm 8.3 \times 10^3 cm^{-3}$, respectively. Particle numbers were dominated by Aitken mode particles in both seasons. During the winter campaign, pollution events occurred every four to five days, each lasting for two to three days. In contrast, pollution events lasted for one to two days every six to seven days during the summer campaign. Aitken mode particles were 50% higher in the winter but new particle formation (NPF) events occurred more frequently in the summer. NPF events usually starts at around 10:00 LT (local time) in the summer but 12:00 LT in the winter. Aitken and accumulation mode particles accounted for 43.5% and 38.2% of all particles. The proportion of Aitken mode to total particles remained almost the same during summer, while it increased as haze intensified in winter. Particle number concentration was closely correlated with traffic and residents living activities and wind speed, with higher concentrations during rush hours, heating period and in the southerly wind. These results, when combined with trajectory cluster analysis, suggest that Aitken and accumulation mode particles were mainly from regional transport during the summer campaign, but from vehicle and coal-combustion emissions during the winter campaign.

* Corresponding author. Key Laboratory of Environmental Optics and Technology, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China.
** Corresponding author. Key Laboratory of Environmental Optics and Technology, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China.
E-mail addresses: jszhang@aiofm.ac.cn (J. Zhang), jgliu@aiofm.ac.cn (J. Liu).

https://doi.org/10.1016/j.atmosenv.2018.05.023
Received 23 December 2017; Received in revised form 15 April 2018; Accepted 12 May 2018
Available online 15 May 2018
1352-2310/

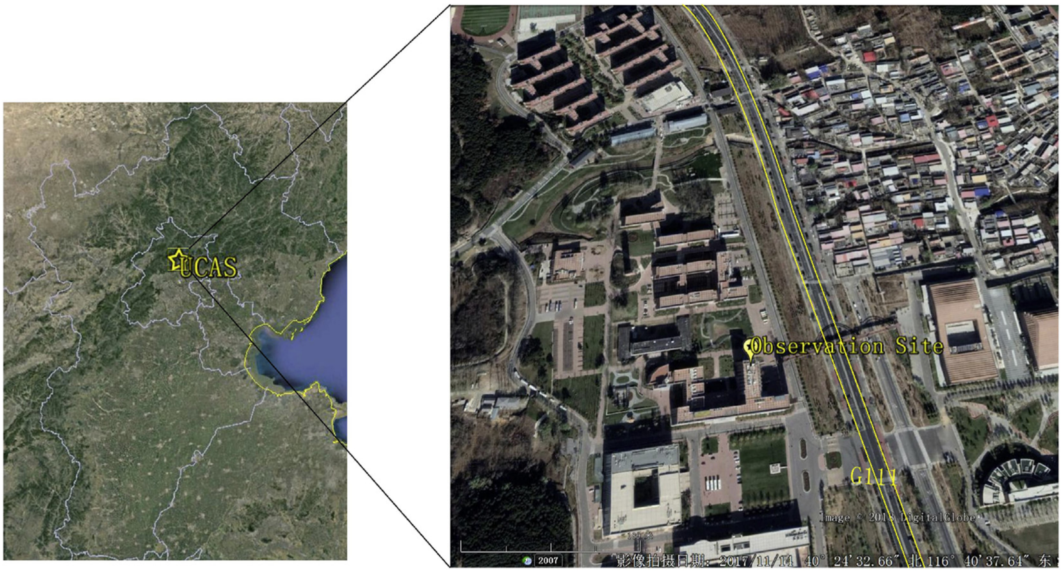


Fig. 1. The map of the North China Plain. The observation site (UCAS) is marked with yellow balloon sign. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

1. Introduction

Aerosol particles play an important role in the atmosphere because of their significant effects on air quality, visibility (Watson, 2002), direct and indirect climate forcing (Anderson et al., 2003; Andreae and Rosenfeld, 2008; Bahadur et al., 2012; Mahowald, 2011; Ramanathan et al., 2001), the environment (Cao et al., 2013; Huang et al., 2014) and human health (Nel, 2005; Tang et al., 2017; Zheng et al., 2014). Accordingly, these particles have received a great deal of attention from the government and the general public. The rapid economic and industrial development and urbanization that have occurred in China have brought about serious environmental problems in Chinese megacities, especially in the Beijing–Tianjin–Hebei region, the Yangtze River delta, and the Pearl River delta (Chan and Yao, 2008; Gao et al., 2009; Han et al., 2015; Parrish and Zhu, 2009; Zhuang et al., 2014). As the capital of China and a rapidly developing city, Beijing has been experiencing severe haze pollution for years. Despite many measures taken by the government to address this issue (Sun et al., 2016; Tang et al., 2015; Wang et al., 2010; Xu et al., 2016a), air pollution is not improving as rapidly as it could. The $PM_{2.5}$ in Beijing is still abnormally elevated, and often greatly exceeds the level of 75 μgm^{-3} considered by the China National Ambient Air Quality Standard (NAAQS) to be harmful to health (Ji et al., 2014; Xu et al., 2016b; Zhang et al., 2013).

Measurements of particle number size distributions have been conducted worldwide (Gao et al., 2009, 2012; Hussein et al., 2004; Quan et al., 2014; Stanier et al., 2004; Wehner and Wiedensohler, 2003; Zhang et al., 2016). When compared with rural areas and background areas, the concentrations of atmospheric particles in urban areas is higher (Wehner and Wiedensohler, 2003; Hussein et al., 2004). Moreover, the concentration of atmospheric particles in winter in urban areas was higher than that in summer, and the diurnal variation of atmospheric particles was significantly influenced by traffic emissions. To study the formation and evolution of atmospheric particles in Beijing, many scholars have conducted observations and experiments investigating the number concentration distribution of atmospheric aerosols. However, most of these have only focused on a pollution process or unique period (An et al., 2007; Liu et al., 2017; Sun et al., 2014; Tang et al., 2015; Wang et al., 2010, 2014c; Xin et al., 2010; Zhang et al., 2017). The seasonal variation of particle number size distribution can reflect the periodic pollution process to a certain extent, such as the higher frequency of haze in winter than that in summer. The distribution of particles under different pollution conditions may demonstrate implicit links to the pollution source (Wang et al., 2014b). The new particle formation (NPF) is one of the important sources of atmospheric particles and cloud condensation nuclei. The NPF events also exhibits a regular seasonal variation (Wu et al., 2007). Studying the characteristics and mechanisms of NPF will help to further understand the climatic, environmental and health effects of atmospheric particulates. In addition, meteorological parameters such as wind direction temperature and wind speed play an important role in influencing the particle number size distribution, accounting for about 37% of all factors. Because of the typical warm temperate semi-humid continental monsoon climate, hot and rainy summer, and cold and dry winter, it had a significant impact on the distribution of particles in Beijing (Liang et al., 2017; Schäfer et al., 2013; Sun et al., 2015). Moreover, regional transport plays an important role in changing the particle number concentrations (Chen et al., 2017; Zhu et al., 2016). The meteorological parameters could alter the size distribution of atmospheric particles, which may signify the potential sources of the particles–local emissions and regional transport.

Here, we report continuous measurements of the particle size distribution of aerosols at a suburban site (Huairou) during winter and summer in 2015. The influence of meteorological parameters, especially wind speed and direction, on the particle number size distributions of atmospheric aerosols was analyzed. The mixed single-particle Lagrangian integral transport and diffusion model (HYSPLIT) developed by the Ocean Resources and Atmospheric Administration (NOAA) Air Resources Laboratory (ARL) was used to simulate the trajectories of air masses reaching the observation points during summer and winter. The correlation between different mode particles and local emissions as well as regional transport were then investigated.

2. Methodology

The observations took place at the Yanqi Lake campus of the University of Chinese Academy of Sciences (UCAS), which is located in the Huairou District, northeastern Beijing (40°24′24.45″N, 116°40′32.95″E), as shown in Fig. 1. The summer campaign was from 18 June to 23 July and winter from 2 to 25 December 2015. Due to the SMPS was broke down from 15 to 21 December 2015, the data for this period was missing. The Yanqi Lake Campus of the UCAS is about 50 km away from the central Beijing. The campus is located at the junction of