Science of the Total Environment 575 (2017) 309–320

Contents lists available at ScienceDirect

Science of the Total Environment

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

Observation of aerosol number size distribution and new particle formation at a mountainous site in Southeast China

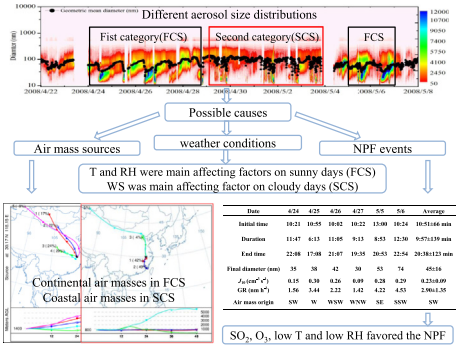
Xiaoru Zhang [a,b], Yan Yin [a,b,*], Zhenyi Lin [b], Yongxiang Han [a,b], Jian Hao [b], Liang Yuan [b], Kui Chen [b], Jinghua Chen [b], Shaofei Kong [a,b], Yunpeng Shan [c], Hui Xiao [b], Wen Tan [b]

[a] Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing 210044, China
[b] Key Laboratory for Aerosol-Cloud-Precipitation of China Meteorological Administration, Nanjing University of Information Science & Technology, Nanjing 210044, China
[c] Atmospheric Science Division, Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512, USA

HIGHLIGHTS

- The characteristics of two different categories of aerosol spectra were revealed.
- Air mass sources, weather conditions and NPF events were responsible to the differences of aerosol spectra.
- Favorable meteorological conditions and potential precursor gases for NPF events were analyzed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 July 2016
Received in revised form 6 September 2016
Accepted 27 September 2016
Available online xxxx

Editor: Dr. D. Barcelo

Keywords:
Aerosols
Size distribution
High mountain
Southeast China
New particle formation

ABSTRACT

To quantify the physical/chemical properties, and the formation and growth processes of aerosol particles on mountainous regions in Southeast China, an intensive field campaign was conducted from April to July 2008 on the top of Mt. Huang (1840 m above mean sea level). The average particle number concentration was 2.35×10^3 cm^{-3}, and the ultrafine particles (<0.1 μm) represented 70.5% of the total particle number concentration. Excluding the accumulation mode particles, the average daytime particle number concentrations were prominently higher than those measured at nighttime, suggesting there was a diurnal pattern of changes between planetary boundary layer and free troposphere air. The aerosol spectra were classified into two categories: the first category (FCS) exhibited a clear diurnal cycle, with relatively higher number concentration (3.19×10^3 cm^{-3}), smaller sizes and air masses from the inland; the second category (SCS) presented less obvious diurnal cycle, with lower number concentration (1.88×10^3 cm^{-3}), larger sizes and air masses from coastal regions. Air mass sources, weather conditions, and new particle formation (NPF) events were responsible for the differences of these two particle spectra. Six NPF events were identified, which usually began at 10:00–11:00 LT, with the estimated formation rate J_{10} in the range of 0.09–0.30 cm^{-3} s^{-1} and the growth rate at 1.42–4.53 nm h^{-1}. Wind speed, sulfur dioxide and ozone concentrations were higher on NPF days than those on non-NPF days, whereas temperature, relative humidity, concentrations of nitrogen oxide and carbonic oxide were lower on NPF days. Sulfur dioxide and ozone might be main potentially precursor gases for those NPF events. The NPF events at Mt. Huang corresponded closely to a southwest winds. These results are useful for improving our understanding of the main factors controlling the variation of aerosol size distribution and NPF events in this region.

* Corresponding author at: Key Laboratory for Aerosol-Cloud-Precipitation of China Meteorological Administration, Nanjing University of Information Science & Technology, 219 Ningliu Road, Nanjing 210044, China.
E-mail address: yinyan@nuist.edu.cn (Y. Yin).

http://dx.doi.org/10.1016/j.scitotenv.2016.09.212
0048-9697/

1. Introduction

Atmospheric aerosol particles can affect the Earth's energy budget through directly scattering and absorbing solar radiation (Charlson et al., 1992; Heal et al., 2012), and indirectly impacting the cloud albedo and precipitation by serving as cloud condensation nuclei (CCN) or ice nuclei (IN) (Twomey, 1974; Albrecht, 1989; Lebo and Feingold, 2014). However, the uncertainties of these effects are still considerable (Solomon et al., 2007), which require temporally and spatially representative datasets about chemical/physical properties of aerosol particles. One of the key physical parameters is the number size distribution in the submicron range (Kumar et al., 2014). In fact, submicron particles make a significant contribution to particle number concentration (Morawska et al., 1998), and studies also show evidences of their adverse effects on human health (Charlson et al., 1992; Rodriguez et al., 2005). Therefore, the knowledge of particle size distribution especially for submicron particles is crucial in avoiding human exposure, estimating climate effects, and designing controlling strategies (Charlson et al., 1992; Kumar et al., 2014).

New particle formation (NPF), associated with a rapid burst of nucleation mode particles, results in increasing the total number concentration of submicron particles (Twomey, 1976). Observations revealed that the NPF events and subsequent growth are universal in the atmosphere. The formation rates of 3 nm particles often range from 0.01 to 10 cm^{-3} s^{-1} in the boundary layer and higher (up to 100 cm^{-3} s^{-1}) in urban areas. However, the formation rates as high as 10^4–10^5 cm^{-3} s^{-1} in coastal areas and industrial plumes were also reported (Kulmala et al., 2004). Typical particle growth rates vary from 1 to 20 nm h^{-1} in mid-latitudes depending on the temperature and the availability of condensable vapors, such as sulfuric acid and possibly other organic compounds with low saturation vapor pressure formed via photochemical reactions (Kulmala et al., 2004; Zhang et al., 2004). Moreover, larger pre-existing particle concentrations suppress the formation of new particles by consuming condensable vapors concentrations and accelerating the coagulation scavenging of newly nucleated particles (Kerminen and Kulmala, 2002; Kulmala et al., 2004).

Field measurements of particle size distribution in the submicron range size and NPF processes have been conducted in the free troposphere, Arctic, boreal forest, marine, urban and rural environments (Zaizen et al., 1996; Reus et al., 2000; Komppula et al., 2003; Stanier et al., 2004; Dal Maso et al., 2005; Rodriguez et al., 2005; Lee et al., 2008). Observations of particle size distribution and NPF events were also carried out in several megacities and relatively polluted regions in recent years in China, such as Beijing (Yue et al., 2009), Pearl River Delta (PRD) (Liu et al., 2008; Chen et al., 2016), and Yangtze River Delta (YRD) (Gao et al., 2009; Wang et al., 2014; Qi et al., 2015). Those studies show that the number concentrations of accumulation mode particles are relatively high in urban areas, and the NPF events are much more frequently occurred in more remote locations (Kulmala et al., 2004; Wu et al., 2008).

The atmosphere in mountainous areas is usually controlled by lower temperature, higher relative humidity, and more intense solar radiation conditions (Seinfeld et al., 2004; Li et al., 2011). Tropospheric aerosols over mountains are often impacted by long-range transport (Li et al., 2011; Wang et al., 2012). The size distribution and their formation and growth of submicron particles have been characterized at some high altitude stations (Venzac et al., 1995; Nyeki et al., 1998; Weingartner et al., 1999; Nishita et al., 2008; Rodriguez et al., 2009; Kanehiro et al., 2011; Guo et al., 2012), and in China, a few studies were conducted at Mt. Waliguan (3816 m), remote western China (Kivekäs et al., 2009), Mt. Tai (1534 m), east China (Zhang et al., 2014), and Mt. Hua (2060 m), central China (Wang et al., 2012). In southeast China, only two studies were performed on Mt. Huang to characterize the aerosol number size distribution and NPF events, but both were conducted at the foot of Mt. Huang in the autumn (Wang et al., 2014; Hao et al., 2015). Wang et al. (2014) laid emphasis on the effects of air masses on aerosol spectral distribution and the characteristics of NPF. The various characteristics and influential factors on aerosol size distribution, the favorable conditions and potential gaseous compounds participating in NPF and growth have remained still unclear at the top of Mt. Huang. Therefore, it is essential to enrich the database of particle size distribution and NPF observations at this high altitude site.

An intensive field campaign to measure the concentration, size distribution, chemical composition of aerosol particles (10–10,000 nm) and related quantities (including trace gases and meteorological parameters) was conducted at the top of Mt. Huang (1840 m above mean sea level) in southeast China (Fig. 1) from April to July in 2008. The aims of this paper are two folds: Firstly, to characterize the particle number concentration, size distribution and new particle formation events;

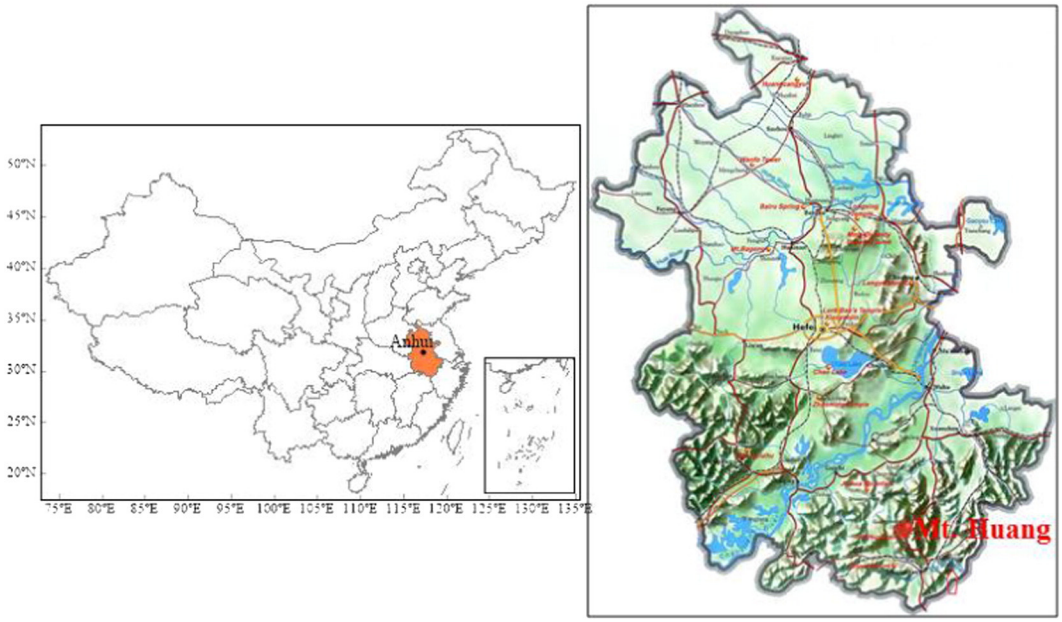


Fig. 1. The location of Mt. Huang.