Atmospheric Environment 89 (2014) 807–815

Contents lists available at ScienceDirect

Atmospheric Environment

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

A multisource observation study of the severe prolonged regional haze episode over eastern China in January 2013

Hong Wang [a,b,*], Sai-Chun Tan [c,**], Yu Wang [a], Chao Jiang [d,a], Guang-yu Shi [c], Meng-Xiang Zhang [d,a], Hui-Zheng Che [a]

[a] Institute of Atmospheric Composition (IAC)/Key Laboratory of Atmospheric Chemistry of China Meteorological Administration (CMA), Chinese Academy of Meteorological Sciences (CAMS), Beijing 100081, China
[b] Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing 210044, China
[c] State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS), Beijing 100029, China
[d] College of Atmospheric Physics, Nanjing University of Information Science & Technology, Nanjing 210044, China

HIGHLIGHTS

- The haze episode impacted the area from east China to the sea west of 140°E.
- Study shows a strong linkage among the cities in Jing-Jin-Ji and their around area.
- 100–800 m is the peak height where the pollutants concentrate during this haze.

ARTICLE INFO

Article history:
Received 12 November 2013
Received in revised form
27 February 2014
Accepted 3 March 2014
Available online 3 March 2014

Keywords:
East China
Haze episode
Visibility
AOD
PM_{10}
Extinction coefficient

ABSTRACT

By employing visibility observation, PM_{10}, SO_2 and NO_2 concentration, MODIS AOD at 550 nm, CARSNET AOD at 440 nm, CALIPSO extinction coefficient at 532 nm, we studied the air pollution condition of a severe haze episode occurred on 6–16 January 2013 over eastern China. The study found that this severe pollution episode of large area haze was accompanied with low visibility, high PM_{10} and AOD in eastern China. The most polluted regions is the Jing-Jin-Ji and its near southern neighboring region including central and south Hebei, west Shandong and north Henan province in the whole China Mainland. The haze pollutants were spread to the offshore area of 125°E to the east of China, and even affected to the west of 140°E. The PM_{10} variation trend shows a strong linkage among the big cities in Jing-Jin-Ji and their near surrounding cities, indicating the possible inter-transport and influence among them. The suburb area of megacity suffered the similar serious pollution with urban region during this kind of severe haze episode. Most aerosol pollutants concentrated in boundary layer below 1500 m vertical height, in particular, the vertical heights of 100–800 m above the ground are peaks of the aerosol pollutants.

1. Introduction

Many megacities and their immediate vicinities suffer from air pollution problem world-wide (Kanakidou et al., 2011). This has been receiving more and more attention because of the close relationships between air pollution and atmosphere environment, human health and ecosystems (Mayer, 1999; Lee et al., 2000; WHO, 2006; Sun Yu et al., 2012; Duan et al., 2012). Air pollutants can also be transported across continents and ocean, such as the plumes of atmospheric brown clouds suspending in the atmosphere, participating in the process of regional and global climate change (Ramanathan and Feng, 2009). Drastically economic growth accompanied by rapid industrializing and urbanizing is the main reason for the serious air pollution in Chinese megacities. In the industrialized and developed countries, air pollution generally

* Corresponding author. Institute of Atmospheric Composition/Key Laboratory of Atmospheric Chemistry of China Meteorological Administration (CMA), Chinese Academy of Meteorological Sciences (CAMS), Beijing 100081, China.
** Corresponding author.
E-mail addresses: wangh@cams.cma.gov.cn (H. Wang), sctan@mail.iap.ac.cn (S.-C. Tan).

http://dx.doi.org/10.1016/j.atmosenv.2014.03.004
1352-2310/

undergoes great reductions during their economic growing periods, passing through a maximum and then reducing (Gonçalves et al., 2008). However, some damages on the environment, ecosystems and human health due to the air pollution may not be reversed during this process.

Chinese has suffered from the severe air pollution recently (Sun et al., 2006; Ma et al., 2010; Fu et al., 2008; Liu et al., 2010a, 2010b) when they enjoy the benefits from the rapid GDP increasing and economic growth which inevitably results in more energy consumption, expanding of size of megacities and dense urban area population. It is important and essential to study China current air pollution condition in detail, which is helpful to China air pollution control policy (Xu et al., 2013) and will benefit avoiding irreversible damages from air pollution (Wang et al., 2010).

Haze pollution events have been occurred frequently in a large-scale in China, resulting in increasingly serious influences. It has the characteristics of large polluted area, long duration and high concentration level, especially in the densely populated, highly industrialized and economically developing eastern China (Ma et al., 2010; Wang et al., 2012). The regional severe air pollution in the central and eastern China is divided into dust type and non-dust type generally. The dust type air pollution mainly occurs in spring, and there have been more studies on its influences (Zhang et al., 1996; Zhuang et al., 2001; Debell et al., 2004; Gong and Zhang, 2008). Most of non-dust type severely polluted processes correspond to haze and 80% occur in fall and winter with long duration, and bring even more serious damages to environment and human health (Wu et al., 2005, 2010). In the winter of 2012–2013, severe haze episode occurred in east China more frequently. In January 2013, $PM_{2.5}$ concentrations at most observational sites reached the peak in recent years. The haze episode from 6 to 16 January 2013 was the severest pollution episode in mainland China in recent years in terms of the influenced region, duration and pollution intensity. Multisource-observation data are employed to study the characteristics of this severe haze/episode in his paper.

2. Data and study methodology

This paper employs the ground visibility and the operational weather observation data from China Meteorological Administration (CMA). The data range covers the mainland China, totally including 600 ground observation stations.

Daily mean concentration of SO_2, NO_2 and PM_{10} are from the surface observation of China National Environmental Monitoring Center (CNEMC, http://www.mep.gov.cn). It includes a total of 46 cities in the mainland China. The data are obtained by the mean value of different observation stations distributed in variousdown-town, suburb, and suburban areas of the city, for example, the pollutants concentration in Beijing is obtained by the mean value of 8 observation sites. In addition, the daily pollutants concentrations in other 45 cities are also calculated by the similar method. Therefore, the value of the pollutant concentration used in each city is able to represent the mean pollution condition of the whole city.

AOD products from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite have been widely used in the evaluating and investigating aerosol burden (Chu et al., 2002; Ichoku et al., 2002; Kahn et al., 2007; Zhang and Reid, 2010). The Deep Blue daily AOD data over land at 550 nm of MODIS/Aqua Collection 5.1 MYD08_D3 product with spatial resolution of $1^\circ \times 1^\circ$ are used in this paper. The advantage of Deep Blue algorithm (Hsu et al., 2006) is that it can fill in data gaps left by the Dark Target-Land aerosol retrieval, which does not operate over bright surfaces, such as bright urban areas and deserts.

For contrast to the pollution condition between urban and rural area of the megacities during air pollution, China Aerosol Remote Sensing NETwork (CARSNET) AOD data at Beijing and Shangdianzi sites are also used in this paper (Che et al., 2008). CARSNET is an operational network for the study of aerosol optical properties established in 2002. The instrument deployed by CARSNET Beijing and Shangdianzi sites are automatic Cimel sun and sky scanning radiometer (Cimel Electronique Cimel-318), the same instrument used by AERONET, with which 440, 675, 870, and 1020 nm bands AODs are retrieved [Holben et al., 1998].

The vertical height of the pollutants is crucial to the transportation distance and regional linkage effect, or even it will be of great influence on aerosol radiation effect and regional atmospheric circulation. Lidar measurement is an important way giving vertical profile information of aerosols currently. Aerosol vertically-resolved extinction and depolarization ratio are available from Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) (Winker et al., 2007; Huang et al., 2007). The data products include both 532 and 1064 nm aerosol extinction coefficient and particulate depolarization ratio at 532 nm (Winker et al., 2009). The horizontal resolution was 5 km and the vertical resolution was 60 m below and 180 m above 20 km, respectively. CALIPSO 532 nm extinction coefficient (Winker et al., 2009) is used to study the vertical distribution characteristics of particles during air pollution episode.

3. Result discussions

3.1. Visibility and weather observation

Haze and fog are defined as two different weather phenomena respectively in this observation system. According to the observation standard released by CMA, haze is defined as a pollution phenomenon characterized by deteriorated horizontal visibility of less than 10 km that is caused by fine particles suspended in the atmosphere, while fog is a weather phenomenon characterized by deteriorated visibility of less than 1 km resulting from water vapor condensation. By this definition, haze and fog are both possible pollution weather because of the low visibility.

According to the operational observation network conducted by CMA, most areas of the eastern China occurred long-lasting haze episode with low visibility on 6–16 January 2013 and the duration time of haze were even 5–7 days in certain area. The haze on 12 January has the largest pollution area and highest pollutants intensity. Fig. 1 indicates the weather phenomena observation on 12

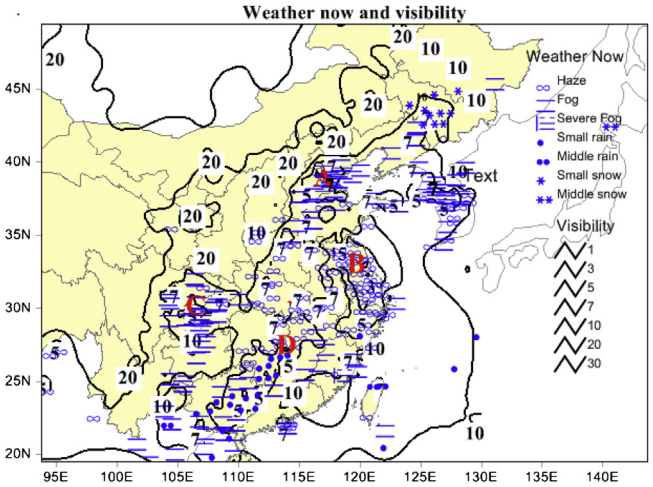

Fig. 1. Daily averaged visibility of 12 January and weather phenomena observation on 06 UTC 12 January over east China.