Environmental Pollution 234 (2018) 29–38

Contents lists available at ScienceDirect

Environmental Pollution

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

Invited paper

Air pollution over the North China Plain and its implication of regional transport: A new sight from the observed evidences

Baozhu Ge [a], Zifa Wang [a, *], Weili Lin [b], Xiaobin Xu [c], Jie Li [a], Dongshen Ji [a], Zhiqiang Ma [d]

[a] State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China
[b] College of Life and Environmental Sciences, Minzu University of China, Beijing 100081, China
[c] Key Laboratory for Atmospheric Chemistry, Chinese Academy of Meteorological Sciences, Beijing, China
[d] Institute of Urban Meteorology, China Meteorological Administration, Beijing, China

ARTICLE INFO

Article history:
Received 23 March 2017
Received in revised form
19 October 2017
Accepted 22 October 2017

Keywords:
Regional transport
Local emission
Contribution
NCP
Field measurement

ABSTRACT

High concentrations of the fine particles ($PM_{2.5}$) are frequently observed during all seasons over the North China Plain (NCP) region in recent years. In NCP, the contributions of regional transports to certain area, e.g. Beijing city, are often discussed and estimated by models when considering an effective air pollution controlling strategy. In this study, we selected three sites from southwest to northeast in NCP, in which the concentrations of air pollutants displayed a multi-step decreasing trend in space. An approach based on the measurement results at these sites has been developed to calculate the relative contributions of the minimal local emission (MinLEC) and the maximum regional transport (MaxRTC) to the air pollutants (e.g., SO_2, NO_2, CO, $PM_{2.5}$) in Beijing. The minimal influence of local emission is estimated by the difference of the air pollutants' concentrations between urban and rural areas under the assumption of a similar influence of regional transport. Therefore, it's convenient to estimate the contributions of local emission from regional transport based on the selective measurement results instead of the complex numerical model simulation. For the whole year of 2013, the averaged contributions of MinLEC (MaxRTC) for NO_2, SO_2, $PM_{2.5}$ and CO are 61.7% (30.7%), 46.6% (48%), 52.1% (40.2%) and 35.8% (45.5%), respectively. The diurnal variation of MaxRTC for SO_2, $PM_{2.5}$ and CO shows an increased pattern during the afternoon and reached a peak (more than 50%) around 18:00, which indicates that the regional transport is the important role for the daytime air pollution in Beijing.

1. Introduction

Atmospheric haze pollution in China, caused by fine particle matters ($PM_{2.5}$), has attracted more and more attentions of the public. As a result, $PM_{2.5}$ limits are included in the new China National Ambient Air Quality Standards (CNAAQS) enacted in 2012, with daily and annual average values being limited to 75 μg/m^3 and 35 μg/m^3, respectively (MEP, 2012). In January 2013, the eastern China suffered severe heavy haze events, with the maximum daily concentration of $PM_{2.5}$ more than 500 μg/m^3, almost 7 times of the daily limit in the new CNAAQS. Many studies have focused on the physical and chemical formation mechanism of those extreme severe events by surface field measurements (Sun et al., 2014; Wang et al., 2014b), satellite observations (Tao et al., 2014) and the numerical model simulations (Wang et al., 2014a, 2014c; Zheng et al., 2015).

The North China Plain (NCP), as one of the most important part of eastern China and also as the second biggest Plain in China (taking up almost 1/5 of the total area of China), is a cluster of densely populated cities including several megacities (Beijing, Tianjin and Shijiazhuang) and is one of the most polluted regions in China (Shao et al., 2006). Several field campaigns, such as "*Influence of Pollution on Aerosols and Cloud Microphysics in North China" (IPAC-NC)* (Ma et al., 2012), "*The HaChi summer campaign*" (Ma et al., 2011; Ran et al., 2011) and "*CAREBeijing*" (Chou et al., 2011; Wang et al., 2011; Wu et al., 2011), have been implemented to investigate the formation, transport and deposition processes of aerosols, O_3 and other air pollutants in this area. These campaigns help to understand the causes of the air pollution over the NCP. For example, one important finding in IPAC-NC is the widespread occurrence of haze-

* Corresponding author.
E-mail address: zifawang@mail.iap.ac.cn (Z. Wang).

https://doi.org/10.1016/j.envpol.2017.10.084
0269-7491/

clouds, characterized by very high concentrations of gaseous pollutants and aerosol particles mixed within low-level stratiform clouds (Ma et al., 2010). Moreover, Wang et al., (2014c) reported that regional transports play an important role in regional haze episodes in the city cluster of NCP (e.g., Heibei, Beijing and Tianjing (HBT)) even in the stagnant weather system. Shi et al. (2005) reported that there existed a significant interacted area by the aerosols between Beijing and its surroundings using empirical orthogonal function (EOF) statistical method.

The NCP is bordered by mountains on the west and north sides (Zhang et al., 2014). Influenced by this special topography, the prevailing winds at many NCP sites are usually northeasterly and southwesterly. This is particularly true at the sites near the Mt. Taihang and Mt. Yan (Lin et al., 2008, 2009; Ge et al., 2012). Driven by the subtropical high, airflow over the NCP during summertime is dominated by southwesterly winds, favoring the transport of pollutants from the southwestern to northeastern sector (Ge et al., 2012; Lin et al., 2008; Shen et al., 2011). The situation can be reversed in winter. Wang et al. (2014a) simulated the sources of the $PM_{2.5}$ pollution in a severe haze episode occurred over the Southern Hebei during 2013 using CMAQ model. They found that Northern Hebei and Beijing-Tianjin city cluster were the two major regional contributors to the pollution in Southern Hebei, in comparison to the other directions in January 2013, although the local emissions contributed the most important part (65.1%–75.8% to Shijiazhuang). Chen et al. (2015) also reported the simulated surface $PM_{2.5}$ in NCP and believed that the pollution is mainly originated from local sources with Southern Hebei representing the largest contributions. However, the regional transport from Hebei Province can be the most important contributors to Beijing's PM (contribute 50–70%) during sustained wind flow from the south (Streets et al., 2007).

Although the numerical models help to better understand the influences of local and transport contributions over NCP, they are difficult to be validated directly due to the absence of measurement. It is warranted to explore alternative methods, such as observation-based analysis. In this paper, we attempt to establish an observation-based method for estimating local and transport contributions to pollution in areas downwind of highly polluted area. Measurements of $PM_{2.5}$ from Shijiazhuang (SJZ), Beijing (BJ) and Shangdianzi (SDZ) are used in our analysis, with SJZ representing the most polluted area.

2. Data and methods

2.1. Descriptions of the measurement sites

Fig. 1 shows the topography of surrounding regions of three measurement sites, e.g., BJ, SDZ and SJZ. SJZ is the capital city of Hebei province, located west of the NCP and is about 300 km away from Beijing. The measurement sites of SJZ and BJ all belong to the network of China National Environmental Monitoring Center

Fig. 1. The location of the measurement sites and the topography of the surrounding region (from NASA satellite map with community Landsat7 visible color; http://worldwind.arc.nasa.gov). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)