Atmospheric Environment 192 (2018) 94–103

Contents lists available at ScienceDirect

Atmospheric Environment

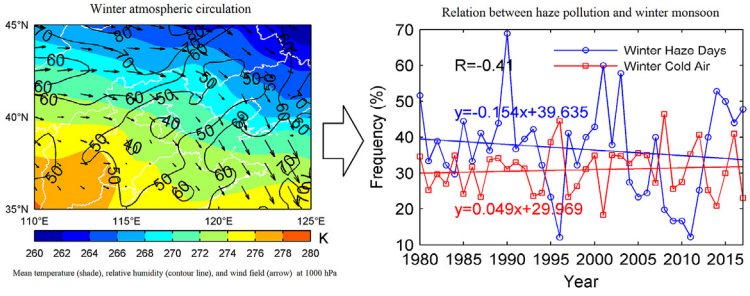
journal homepage: www.elsevier.com/locate/atmosenv

Analyses of winter circulation types and their impacts on haze pollution in Beijing

Jianjun He[a,*], Sunling Gong[a], Chunhong Zhou[a], Shuhua Lu[a], Lin Wu[b,**], Ying Chen[c], Ye Yu[d], Suping Zhao[d], Lijuan Yu[e], Chengmei Yin[e]

[a] State Key Laboratory of Severe Weather & Key Laboratory of Atmospheric Chemistry of CMA, Chinese Academy of Meteorological Sciences, Beijing, 100081, China
[b] The College of Environmental Science & Engineering, Nankai University, Tianjin, 300071, China
[c] Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK
[d] Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, 730000, China
[e] Jinan Meteorological Bureau, Jinan, 250002, China

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Circulation types
Local meteorology
Haze pollution
$PM_{2.5}$

ABSTRACT

To better understand the interannual variation of winter haze pollution, this paper investigates winter circulation types and their impacts on local meteorological conditions and haze pollution during 38 winters from 1980 to 2017 in Beijing. Circulation types were classified by T-mode principal component analysis combined with the K-means cluster method using European Centre for Medium-range Weather Forecasts ERA-interim sea level pressure data. The results can significantly distinguish the cold air process, a degeneration of cold air, and stagnant weather. The cold air process over Beijing was accompanied by a low temperature, high relative humidity, large pressure gradient and near-surface wind speed, and deep mixing layer. The cold air process facilitated pollutant dispersion and transport to the outside (such as East China, Bohai Sea, and Yellow Sea) and formed low $PM_{2.5}$ concentrations and low frequencies of haze days. In contrast, the local meteorology and haze pollution were almost the inverse for stagnant weather. The local meteorological conditions and haze pollution for the degeneration of cold air are between the previous circulation types. Considering $PM_{2.5}$ observation during 2010–2017, the occurrence frequency of cold air was low in the recent winters of 2013, 2014 and 2017, and resulted in severe $PM_{2.5}$ pollution. High frequency of stagnant weather (48.4%) was one of the reasons that haze pollution reached 37% during 38 winters from 1980 to 2017 over Beijing. The time series of haze frequency was negatively correlated with that of cold air frequency. Winter haze pollution was affected by climate change over Beijing. During 38 winters from 1980 to 2017, a decreased trend of haze days was found, which was partly

* Corresponding author.
** Corresponding author.
E-mail addresses: hejianjun@cam.gov.cn (J. He), envwu@vip.qq.com (L. Wu).

https://doi.org/10.1016/j.atmosenv.2018.08.060
Received 17 January 2018; Received in revised form 11 April 2018; Accepted 28 August 2018
Available online 30 August 2018
1352-2310/

related to an increased trend of cold air frequency. However, the trends of haze days and cold air in Beijing were not significant based on regression analysis.

1. Introduction

Haze is defined as large amounts of fine dry particles floating in the atmosphere that result in low visibility (less than 10 km) and turbid air. It is a weather phenomenon and a natural weather disaster (Zhang et al., 2013). With rapid economic development, haze pollution has occurred frequently and has attracted attention from government, the public, and researchers. Severe haze, which is mainly caused by serious aerosol pollution, is not a completely natural phenomenon in China (Zhang et al., 2013). And it also affects weather, such as cloud and precipitation (Guo et al., 2016; Li et al., 2017). The formation of haze decreases atmospheric visibility, affects the production and lives of people, and has an adverse impact on human health (An et al., 2015). Unfortunately, at least 30% of the area and nearby 800 million people in China are affected by different degrees of haze (Che et al., 2009). There were relatively few annual haze days in the 1960s, but they increased sharply in the 1970s, remained stable to 1995, and then increased from 1995 to 2012 in North China (Chen and Wang, 2015). Understanding the formation mechanisms of haze is very important for haze prevention.

Pollutant emission and meteorological conditions are two key factors for haze pollution, and high pollutant emission is the primary cause. According to the China Statistical Yearbook, the emission of sulfur dioxide, nitrogen oxide and dust reached 1.86×10^7, 1.85×10^7, and 1.54×10^7 tons, respectively, in 2015 (http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm). Emission statistic has some uncertainties, and the uncertainty of emission is a main reason for the bias of air quality simulation (Chen et al., 2016). Meteorological conditions are another important factor for haze pollution. Meteorological parameters, such as temperature, relative humidity, wind speed, and boundary layer height, were significantly correlated with pollutant concentrations in most Chinese cities and explained more than 70% of the variance of daily average pollutant concentrations (He et al., 2017a). In January 2013, a persistent severe haze event occurred over eastern China. Unusual meteorological conditions were responsible for this persistent severe haze event (Zhang et al., 2014). The long term trend of haze

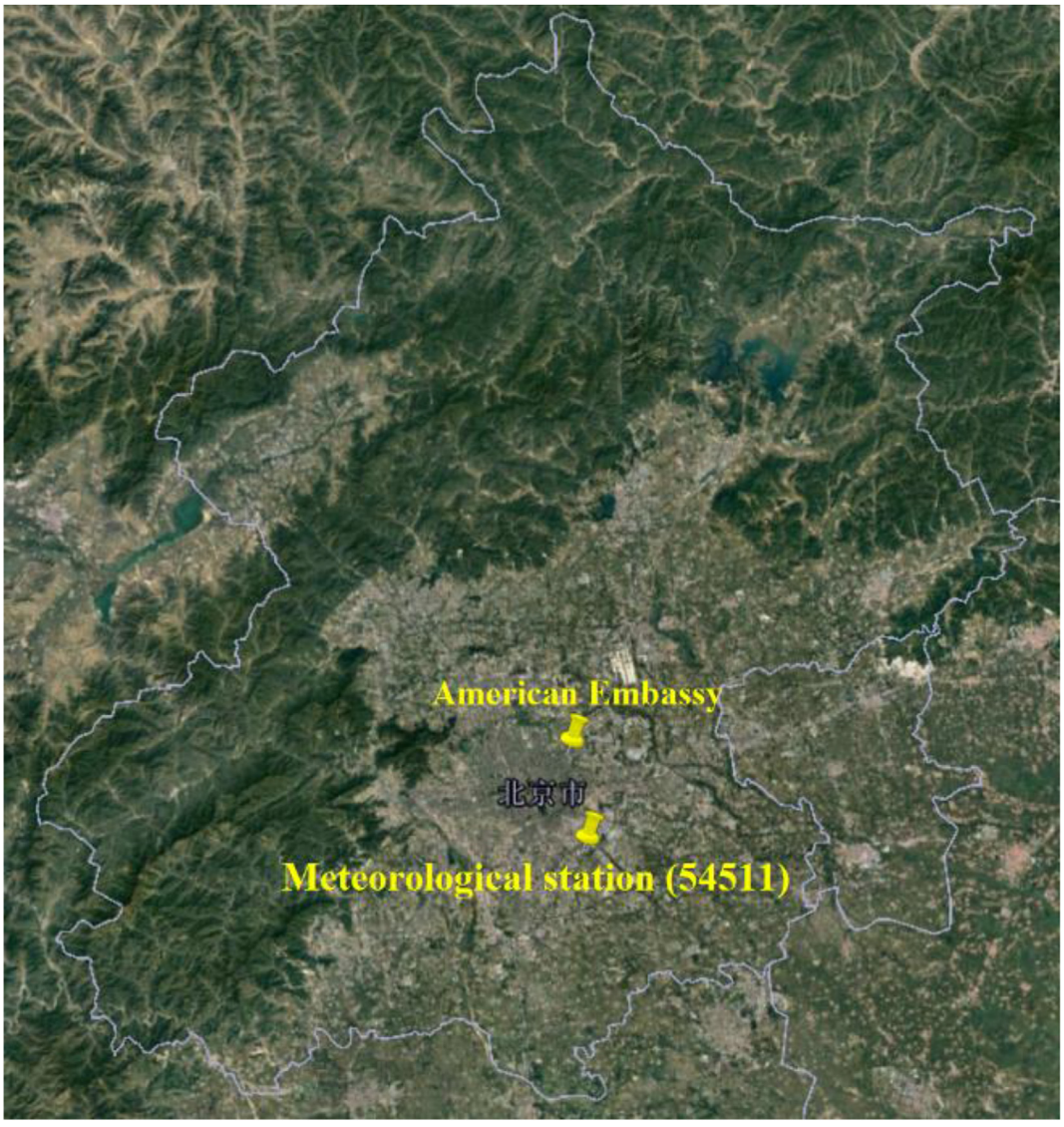


Fig. 1. The location of air quality monitoring stations (American Embassy) and meteorological station.