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Analysis of the Haze Weather Process in the East of China from January 21 to 28, 2021

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Abstract

Haze is a pollution weather phenomenon that has been widely concerned by people in recent years. It has a significant impact on people's production, life, and health. This study focuses on large-scale haze weather that happened in eastern China in late January 2021. The research uses multi-party data and synoptic analysis methods to analyze the occurrence, evolution, and end of the haze weather. The polar vortex, the change of the atmospheric circulation, the change of the cold air force, the temperature and humidity, and the rain and snow weather are the important reasons for this weathering process. It can be used for reference in future research on haze weather.

Keywords

Haze Forming, Atmospheric Diffusion Conditions, Eastern China

1. Introduction

From January 21 to 28, 2021, under the influence of continuous bad meteorological conditions, moderate to severe haze weather processes occurred in Beijing, Tianjin, Hebei, and its surrounding area, the north-central part of the Yangtze River Delta, the Fen Wei plain and Northeast China. This process has a wide influence and long duration, and the overall meteorological conditions are unfavorable. Since January 19, the atmospheric conditions in North China had gradually become static and stable, and the diffusion conditions have begun to deteriorate. The higher relative humidity and the regional inversion process in the south-central part of North China accelerated the transformation of gaseous pollutants to PM 2.5, while weakening the vertical diffusion and removal capacity of the atmosphere. Particularly from the 24th to the 25th, there was a large scale of small to moderate snow in the regions above, and the humidity before the snow increased significantly. Thick fog appeared in most cities of Hebei,

Henan, Shandong, Anhui, and Jiangsu, and the daily relative humidity was close to saturation, which was easy to aggravate the haze weather.

In recent years, the issue of haze pollution in northern and central-eastern regions of China has attracted widespread attention. Multiple studies have shown that the formation of haze is a complex process involving the interaction between anthropogenic emissions and atmospheric processes (An et al., 2019). At the same time, some research has predicted the future trends of PM 2.5 pollution in China. Li et al. (2018) suggested that the North China Plain has the potential to achieve a significant reduction in PM 2.5 pollution in the future. Liu et al. (2017) conducted a comparative analysis of meteorological conditions for different haze weather cases, revealing the important role of meteorological factors in haze formation. Wang et al. (2014) analyzed the causes of severe haze pollution in central and eastern China in January 2013, pointing out that multiple factors contributed to this serious pollution event. Zhang et al. (2019) assessed the driving factors behind the improvement of PM2.5 air quality in China from 2013 to 2017, providing a scientific basis for future pollution control. Zhao et al. (2013) analyzed a winter regional haze event and its formation mechanism in the North China Plain, offering important insights for understanding and mitigating haze formation. Chen et al. (2018) analyzed the relationship between particulate air pollution and daily mortality in 17 Chinese cities, highlighting the severe health impacts of particulate pollution. Ding et al. (2016) further discovered that black carbon plays a significant role in exacerbating haze pollution in major Chinese cities. The research by Guo et al. (2014) elucidated the formation mechanism of severe urban haze in China, emphasizing the combined effects of human activities and meteorological conditions. Ma et al. (2016) analyzed the spatiotemporal trends of PM 2.5 concentrations in China from 2004 to 2013 using satellite data. The study by Wu and Yang (2019) explored the impact of haze on consumers' desire for money from a unique perspective. Wu et al. (2010) reviewed the spatiotemporal changes of haze in China's mainland from 1951 to 2005, providing valuable data for understanding the long-term trends of haze. Sun et al. (2016) characterized the features of organic and inorganic aerosols in Beijing during summer through chemical composition monitoring, providing a deeper understanding of the chemical composition of haze. Meanwhile, Zhang (2019) briefly analyzed the causes and countermeasures of haze in the Beijing-Tianjin-Hebei region, offering useful references for haze governance in this area.

The haze and fog weather's changes and forms are very diverse. In order to further deepen the understanding of haze and its formation principle, I analyzed the recent relatively new data, used different analysis methods to analyze this haze weather, and reached my conclusions.

2. Data and Methods

2.1. Data

There are two sources of data samples used in this study. The first source is cli-

mate system monitoring, diagnosis, prediction, and evaluation data from the National Climate Center of China, especially the DERF2.0 model used in the website. The second is the reanalysis data provided by the National Center for environmental prediction (NCEP) of the United States. This website provides many data like hourly or daily average geopotential height field, relative humidity, and so on.

2.2. Methodology

This study adopts synoptic analysis methods and literature reading methods. The relevant principles of these methods are introduced as follows.

The synoptic method is a kind of scientific method that studies the formation process and evolution law of weather, and then comprehensively analyzes and forecasts weather changes. Here, it can be divided into synoptic map analysis and isobaric map analysis. The weather map and sea-level pressure field data in this study are from NCEP. The synoptic map can reflect the weather conditions in a certain area. Through the analysis of the weather map, we can know the development law of the weathering process. The isobaric map analysis is to analyze the humidity field, wind field, and temperature advection.

The literature reading method is mainly to find and read the literature related to this study, think about the research methods and analysis methods, grasp the key content, and apply it to the analysis of this study.

3. Result and Analysis

3.1. Atmospheric Circulation and Precipitation Overviews

In late January 2021 (Figure 1), with the eastward movement of the polar vortex, the middle and high latitudes in China were controlled by the zonal circulation, and the cold air force was weak on the whole. The temperature in most parts of the country was higher than that in the same period of the year. And the temperature in the northeast, the central, and southern parts of the country was

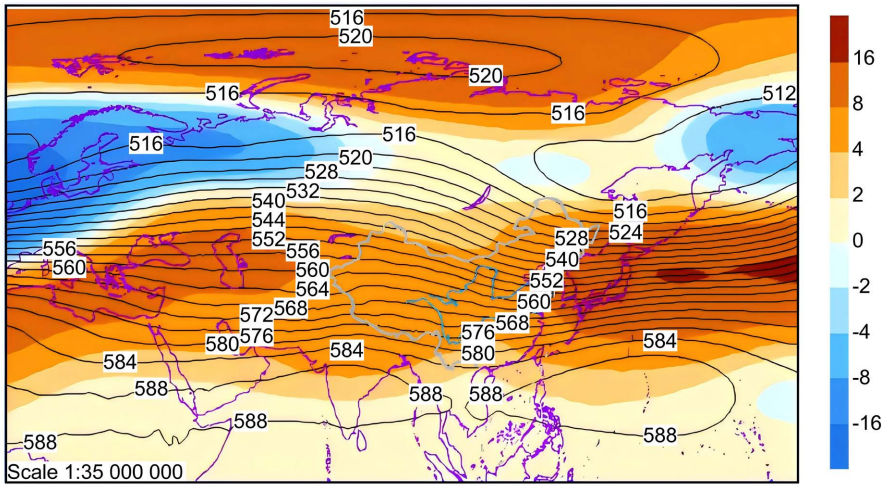

Figure 1. The 500 hPa average geopotential height field in late January 2021.

abnormally high. The high temperature led to continuous unfavorable atmospheric diffusion conditions. Based on the atmospheric circulation above, a continuous large-scale fog haze weather occurred in the central and eastern areas of China on the 20th and 28th.

The south branch trough gradually developed and deepened compared with the previous period. So, the rain and snow weather process was in the trend of increasing, and the range was also expanding. But the precipitation intensity was weak (Figure 2).

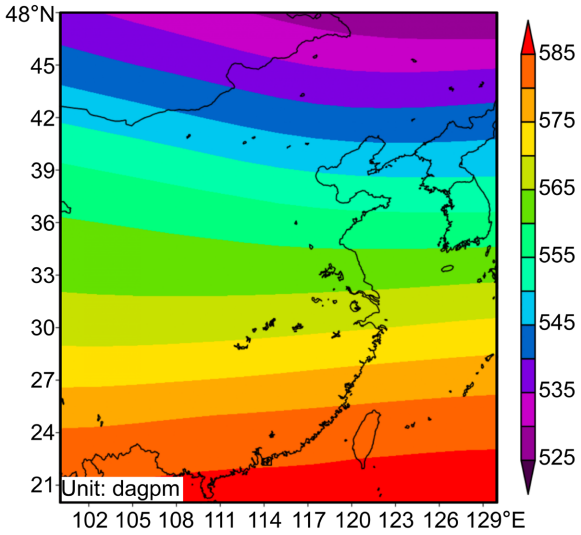

Figure 2. Daily 500 hPa geopotential height field from January 21 to 28, 2021.

3.2. Weather Situation Analysis of Haze Process

In the period of January 21st to 28th, a large-scale continuous fog haze weather occurred in Beijing Tianjin Hebei and its surrounding areas, the north-central part of the Yangtze River Delta, the Fen Wei plain, and northeast China. In this process, most parts of Henan, western Shandong, and other parts of the country were heavily polluted. In addition, from night to morning, because of the high humidity which was close to saturation (Figure 3), many relative areas were often accompanied by heavy or dense fog.

From January 21 to 28, according to the large-scale circulation background field, the central and eastern part of China was located in the zonal circulation control area of the westerly zone, with no obvious trough ridge activity (Figure 1). In the meantime, the strength of the cold air was weak. Most of the central and eastern part of China was controlled by the pressure-equalizing field in front of the cold high pressure, with sparse isobars, small pressure gradient (Figure 1), and poor atmospheric diffusion ability. Under this static and stable situation, it was conducive to the occurrence and maintenance of fog haze weather.

From January 24 to 25, there was small to moderate snow in the area, the humidity before the snow increased, and the moisture absorption of atmospheric particles increased, which aggravated the pollution (Figure 3). Due to the influ-

ence of easterly or Southeast winds in the central and southern parts of North China, Huang Huai, and other places (Figure 4), pollutants continued to accumulate in the central and southern parts of Beijing, Tianjin, Hebei, Shandong, and Henan, resulting in light to moderate haze. Among them, some areas along the mountains in the West of Hebei, Southeast of Henan, and Guanzhong of Shaanxi appeared in heavy haze.

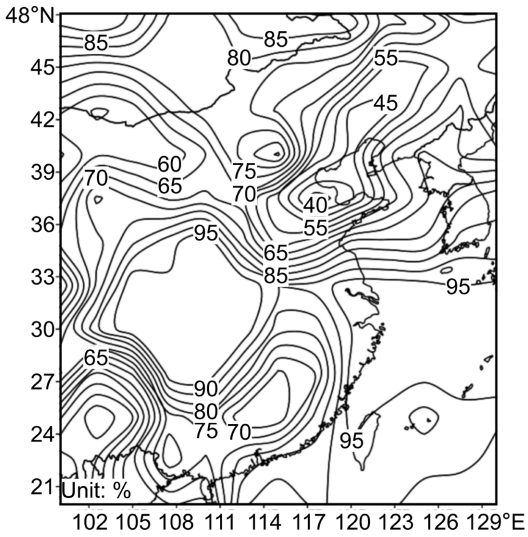

Figure 3. At 20:00 on January 24, 2021, 925 hPa relative humidity (Beijing Time, the same below).

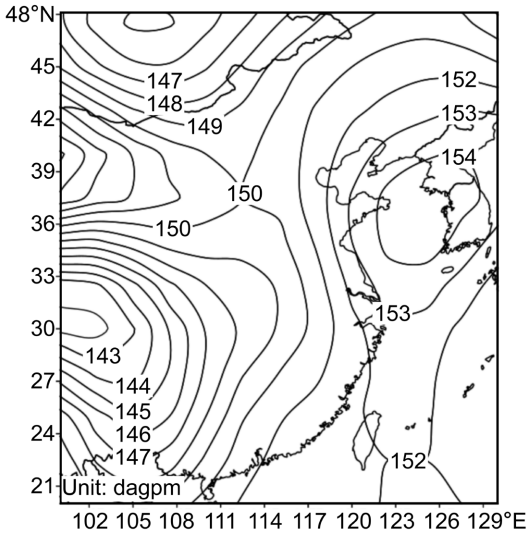

Figure 4. The 850 hPa geopotential height at 20:00 on January 24, 2021.

On January 26, affected by the weak cold air (Figure 5), the haze weather in the northern part of the region weakened, but the haze in the southern part of North China, Huang Huai, Fen Wei plain, and other places continued to maintain. On January 27, affected by the southerly wind (Figure 6), the atmospheric diffusion conditions deteriorated again, and affected by the backflow of pollu-

tants, light to moderate haze appeared in central and southern North China, Huang Huai, and other places. And severe haze occurred in some areas.

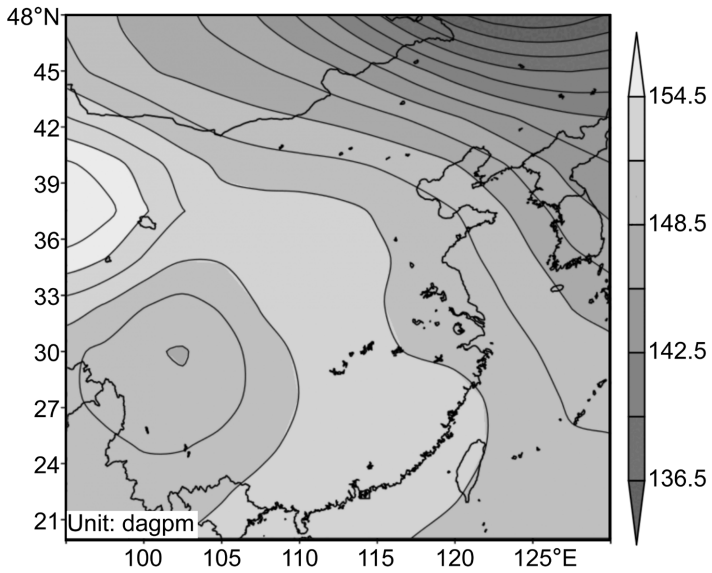

Figure 5. The 850 hPa geopotential height on January 26, 2021.

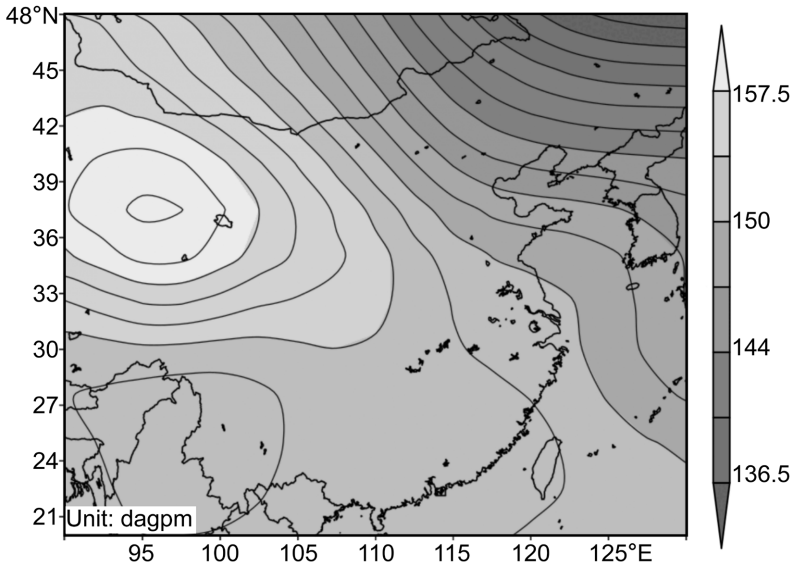

Figure 6. The 850 mb geopotential height on January 27, 2021.

On the night of January 28, affected by the cold air in the northwest (**Figure 7**), the northerly wind on the ground gradually increased, the atmospheric diffusion conditions were significantly improved, the PM2.5 concentration rapidly decreased, and the visibility gradually improved. The fog haze weather process ended.

Prior to that, from January 21 to 28, the high relative humidity in the south-central part of North China (**Figure 8**) and the existence of regional inversion accelerated the transformation of aerosol particles and weakened the vertical diffusion and removal ability of the atmosphere.

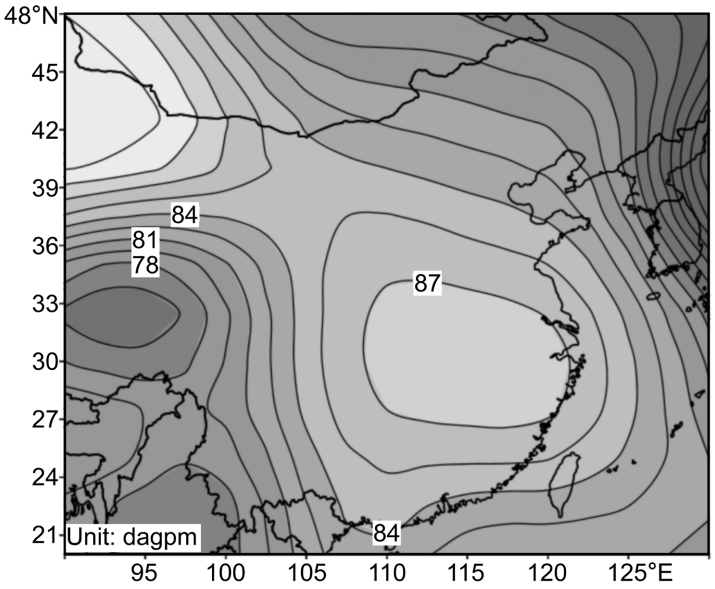

Figure 7. The 925hPa geopotential height at 20:00 on January 28, 2021.

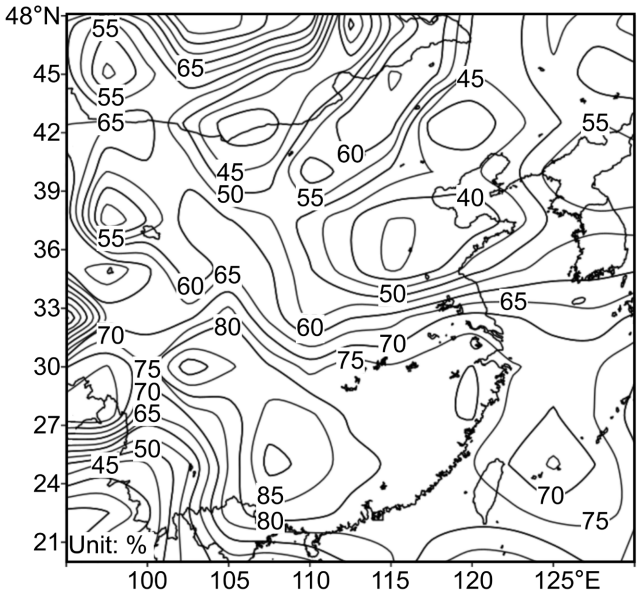

Figure 8. The 850 hPa relative humidity from January 21 to 28, 2021.

4. Conclusion

The haze weather process analyzed in this study, which occurred from January 21 to 28, 2021, in eastern China, was a complex phenomenon resulting from the interplay of multiple weather systems. The event primarily affected Beijing, Tianjin, Hebei, and their surrounding areas, the north-central part of the Yangtze River Delta, the Fen Wei plain, and Northeast China. The haze process was characterized by its wide spatial coverage, severe pollution levels, extended duration, and unfavorable meteorological conditions.

The static and stable atmospheric conditions, coupled with high relative hu-

midity, played pivotal roles in the formation and maintenance of the haze weather. The southerly winds contributed to the accumulation of pollutants in central and southern regions, while the presence of regional inversion layers further weakened the vertical diffusion and removal capacity of the atmosphere. These factors, in combination with anthropogenic emissions, facilitated the transformation of gaseous pollutants into PM 2.5 particles, exacerbating air pollution.

A notable aspect of this haze event was the large-scale occurrence of small to moderate snowfall from January 24 to 25. The increase in humidity prior to the snowfall enhanced the moisture absorption by atmospheric particles, resulting in aggravated pollution levels and the formation of thick fog in many cities across the eastern region. This phenomenon further complicated the haze situation, reducing visibility and posing additional challenges to air quality management.

The event finally dissipated on January 28, when cold air from the northwest arrived, leading to an increase in northerly winds at the surface. This improved atmospheric diffusion conditions significantly, resulting in a rapid decrease in PM 2.5 concentrations and a gradual improvement in visibility.

In conclusion, this study highlights the intricate interplay between atmospheric circulation patterns and meteorological factors in shaping haze weather processes in eastern China. The findings underscore the importance of comprehensive monitoring and forecasting to effectively address haze pollution and protect public health. Future research should continue to explore the underlying mechanisms and drivers of haze formation, as well as develop more targeted and effective pollution control measures.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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