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Analysis of a Haze Weather Process in Eastern China from November 11th to 17th, 2020

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Abstract

This study mainly introduces a large-scale heavy haze weather process in northern China from November 11 to 17, 2020, and analyzes the weather process. Methods such as comparative analysis and data analysis were used in this study. The main reasons for the formation of smog are as follows. First, the relative humidity is high and the water vapor content is relatively high. Second, the atmosphere is in a static and stable state, and suspended particulate matter in the atmosphere is not easy to diffuse and dilute, so it will gradually accumulate in urban areas and suburban areas. Third, there is a temperature inversion in the vertical direction, and the suspended particles in the air are difficult to drift to high altitudes and are blocked at low altitudes and near the ground. Fourth, there must be cooling conditions. Meteorological factors are the external causes for the formation of smog. And inversion intensity has a negative correlation with visibility, which has some indicating importance in fog and haze predictions. Large-scale haze weather mainly occurs in the large-scale atmospheric circulation with weak cold air and good water vapor conditions, and wind near the ground is small. Due to the high humidity in haze weather, fog droplets provide adsorption and reaction sites, accelerating the conversion of gaseous pollutants to liquid particles. At the same time, particles are also easy to act as condensation nucleus to accelerate the generation of haze. When the two interact, the pollutants are not easy to diffuse outward, resulting in agglomeration effect, and the pollution is getting heavier.

Keywords

Haze, Fog and Smog, North China, Meteorological Conditions, Air Pollution

1. Introduction

There was a round of severe haze weather from November 11 to 17, 2020 in North China, and many cities including the central and southern parts of Beijing, Tianjin and Hebei reached heavy pollution levels. Starting from November 11, 2020, mild haze weather hit some cities in North China. And severe haze weather hit several major cities in North China on the 12th. The AQI (Air Quality Index) of Beijing and Shijiazhuang both exceeded 200 and the haze level on the 12th can be said to be extremely serious. The worst-hit areas of haze moved to the southern plains of Shanxi and Shaanxi from November 13th to 17th, and Anyang, a city of Henan Province, suffered severe pollution with AQI exceeding 200 for three consecutive days from November 15th. This haze weather lasted for a long time, and covered a wide area. The pollution caused by the haze was serious. From the afternoon of the 17th, due to the combined influence of precipitation and cold air, the haze of the above areas gradually weakened and dissipated from west to east.

Haze is a kind of disastrous weather that often occurs in winter. Many scientists have done a quantity of research of haze. Chen & Xue (2019) found that smog pollution in China has significant spatial spillover effects and spatial characteristics of high-high (low-low) aggregation. And through the method of spatial Durbin model, it is found that the smog pollution in China is time-dependent due to the significant influence of its term. In view of the spatial spillover effect and time lag effect of smog pollution in China, it is necessary to strengthen regional joint prevention and control. And it is also supposed to optimize industrial structure, achieve clean and efficient use of resources, rationalize urbanization, and encourage public transportation and new energy vehicles. Sun & Huang (2014) thought the air pollution index continues rising and the data of the environmental protection department show that from the northeast to northwest, from north China to central and Huanghuai, Jiangnan region, there was a wide range of heavy and serious pollution, leading to a fall in quality of people's life gradually. Hazy weather has become a serious and urgent problem causing impact on human's survival. Guo et al. (2015) studied a relatively rare severe haze weather in North China from December 1 to 7, 2011. And they thought that low-visibility haze weather generally occurs in the stable atmospheric boundary layer. Zhang et al. (2014) thought that atmospheric aerosols accumulate in the boundary layer when smog occurs, resulting in increased air pollution and reduced air quality. The changing trend of smog recently is closely related to human activities and climate change. Urban expansion and the associated enhancement of the heat island effect can cause the frequency of smog to decrease in urban areas and increase in suburban areas. Hua et al. (2015) pointed out that typical fog-haze processes are selected to analyze vertical structure of boundary layer and inversion layer characteristics, which are also compared with those of clear days. Dynamical and thermal differences in boundary layer are summarized according to different intensities in fog-haze processes. Analysis result shows that inversion intensity has a negative correlation with visibility, which has some indicating importance in fog and haze predictions.

The above research has achieved corresponding results, but the weather phenomenon is constantly updated. The above research was carried out relatively early, and it is difficult to study the latest haze weather process in 2020. With the deepening of climate change and the further implementation of the air quality control project, there is a question mark whether the causes of the haze weather process in the new period are similar to those before it.Therefore, this study is carried out on the haze weather process in November 2020, which has a certain novelty.

2. Data and Methods

2.1. Data

The data used in this study are from the climate hazards system of the National Climate Center of China, Nation Oceanic and Atmospheric Administration (NOAA) Physical Sciences Laboratory (PSL), National Centers for Environmental Prediction (NCEP) of the United Statesand the Japan Meteorological Agency.

1) The climate hazards system of the National Climate Center of China (http://cmdp.ncc-cma.net/) provides the data on the air quality index of some cities in North China in November 2020, the anomaly graph of 500 hPa geopotential height, ASPI (Air Self-Purification Index) and the meridional wind graph the minimum temperature change of 1000 hPa in November 2020.

2) The weather maps and relative humidity map used in this study are from the data released by the Japan Meteorological Agency (https://www.jma.go.jp/), NCEP and NOAA/PSL (https://psl.noaa.gov/).

2.2. Methods

The main methods used in this paper are data comparison and analysis. First of all, through the reference of previous studies, we have a preliminary understanding of the principle and process of haze weather. Based on the analysis method of previous research results, this study makes a new analysis of the haze weather process, and puts forward its own views. At the same time, this study uses the comparative analysis method to compare the various stages of this haze, and analyze the similarities and differences in different periods. The data analysis is mainly based on the research of multiple smog, and analyzes the causes and hazards of smog. Summarize the main characteristics of the weather changes at that time, so as to provide basis for accurate prediction.

Therefore, synoptic analysis (Luiz et al., 2015) can also be used in this study. Synoptic analysis is a kind of scientific method to study the weather formation process and evolution law, and then comprehensively analyze and forecast the weather change. It is an integral part of the meteorological method. Air masses and fronts, cyclones and trough ridges are the concepts and theories that are the basis of synoptic analysis methods.

3. Results and Analysis

3.1. Overview of Atmospheric Circulation and Precipitation

In mid-November 2020, the circulation in the middle and high latitudes of Eurasia was adjusted to the situation of "two trough and two ridges" (Figure 1), and the zonal circulation was dominant. The East Asian trough is located to the east of China, and its intensity is weak, so it is not conducive to the cold air from the north affecting China. From the figure, it can be seen that there are large-scale positive levels of the anomaly of 500 hPa geopotential height in northern, northeastern China and its surrounding areas. It can be found that this abnormal situation has a great relationship with this haze weather process after analysis. From November 11 to 17, most parts of China were controlled by a ridge of high pressure, and the temperature was significantly higher than that in the same period of the year. The stable weather conditions in the central and southern parts of North China, the western part of Huang-Huai Area and the Fen-Wei Plain have led to the occurrence of fog-haze weather. In mid-late November, as the northern high-altitude trough moved eastward, the meridional direction of the circulation increased. China suffered a large-scale strong cold air process, with obvious cooling in many places. Subsequently, a large range of heavy rain and snow occurred in many parts of China.

According to the different causes and pollution characteristics of heavy pollution weather, it can be divided into two types: stationary type and dust type. Stable heavy pollution weather refers to the occurrence of continuous meteorological conditions that are not conducive to the diffusion of air pollutants, leading to the accumulation of pollutants in a large range, and eventually the inhalable particles (PM10) reach the level of heavy pollution. The stationary heavy pollution weather mainly appeared in October to December.

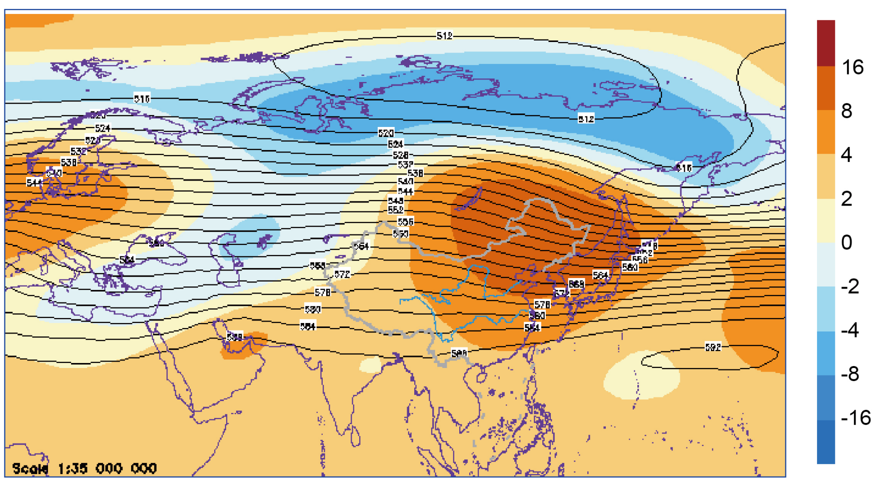

Figure 1. The 500 hPa geopotential height mean (contour) and anomaly (shaded) field in Asia in mid-November 2020.

3.2. Analysis of the Weather Process

From November 11th to 17th, 2020, the cold air force affecting my country was weak, which was not conducive to the spread of atmospheric pollutants. When there is a vertical temperature inversion, airborne particles are blocked at low altitudes and near the ground. This is conducive to the accumulation of pollutants and the formation of haze. A fog occurred in central and southern North China, western Huang-Huai Area, Fen-Wei Plain, and central and southern Northeast China. haze weather process. In addition, from the 16th to the 17th, the ground humidity in the central and southern parts of North China, Huang-Huai Area, and eastern Jiang-Huai Area was high to saturation, resulting in heavy fog in some areas, and local strong fog with visibility less than 200 meters. This fog-haze weather process lasted for a long time, with haze in the early stage and mixed fog-haze weather in some areas in the later stage.

The haze process in North China was controlled by the surface weak air pressure system for a long time, and the wind speed near the surface was small. And due to the transport of water vapor and pollutants from southerly and easterly winds and precipitation, the relative humidity increases significantly, sometimes approaching saturation. There is a boundary layer temperature inversion in the entire haze process, which is not conducive to the vertical diffusion of pollutants. The pollutants weakened and dissipated at noon on the 18th, and the fog-haze process ended.

The main difference between fog and haze is not only the degree of visual range, but also the moisture content. The moisture content of the fog is saturated or nearly saturated, reaching more than 90%. The moisture content of haze is less than 80%, and the moisture content between 80% and 90% is a mixture of fog and haze, but its main component is still haze (Sun & Huang, 2014).

Judging from the 500 hPa average geopotential height field from November 11th to 17th, the zonal circulation was dominant in the middle and high latitudes of Eurasia, and most of northern China was controlled by a weak high-pressure ridge, and there was no obvious cold air activity. The mean sea level pressure field shows that North China, Huang-Huai Area and other places were controlled by the weak pressure field behind the high pressure. The prevailing downdraft in the upper air, the low horizontal wind speed on the ground, and the poor horizontal and vertical diffusion conditions of pollutants lead to the formation of haze weather.

At 08:00 on November 12th, it can be seen from the sea level pressure field (**Figure 2**) that the North China and Huang-Huai Area were located in the low pressure convergence area between the Mongolian cold high and the Yellow Sea high. The near-surface wind field shows that the Beijing-Tianjin-Hebei region and its surrounding areas were located in the convergence area of the weak northeasterly wind in front of the Mongolian high on the west side and the weak southwesterly wind behind the Yellow Sea high on the east side. This is very beneficial for the concentration of pollutants into the convergence zone. Therefore, the worst pollution occurred on the 12th in southern Beijing, Tianjin, and

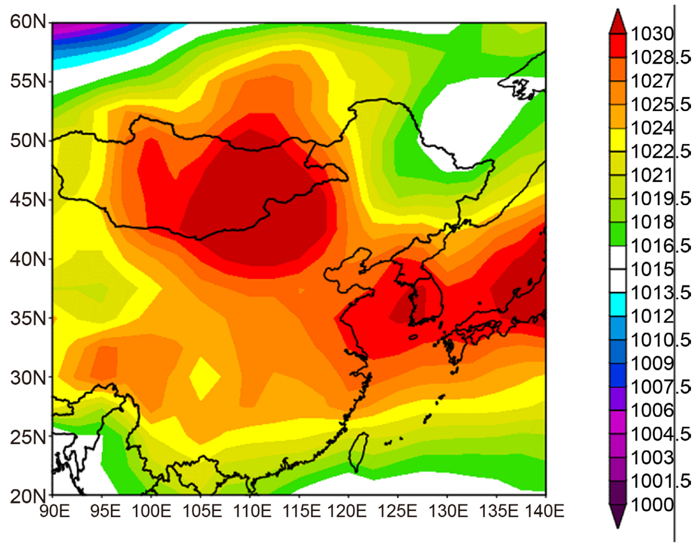

Figure 2. The Sea level pressure field at 8:00 on November 12, 2020 (Beijing time, the same below).

central Hebei, and the haze had been repeated for the next few days.

At 08:00 on November 13th, Beijing was located at the bottom of the short-wave trough at 500 hPa (**Figure 3**). Affected by the weak cold air along the northeast route, the haze weather in the central and northern parts of Beijing-Tianjin-Hebei gradually dissipated, while the air pollution was transmitting southward. And the haze weather in southern Hebei, Henan, and central and western Shandong remained or aggravated. At the same time, at 08:00 on the 13th, the ground (**Figure 4**) in these areas was controlled by high pressure, so it was difficult for air to circulate, which was also conducive to the maintenance of haze.

Typical fog-haze processes are selected to analyze vertical structure of boundary layer and inversion layer characteristics, which are also compared with those of clear days. Dynamical and thermal differences in boundary layer are summarized according to different intensities in fog-haze processes. Analysis result shows that inversion intensity has a negative correlation with visibility, which has some indicating importance in fog and haze predictions (Hua et al., 2015).

At 08:00 on November 14 (**Figure 5**), the convergence zone of surface wind field was pushed southward to the south of Hebei, the east of Henan, and the west of Shandong, which was also conducive to the accumulation of surrounding pollutants in the convergence zone. Correspondingly, the air pollution in the above-mentioned areas reached a severe level at this time. Under the control of high pressure system, atmospheric circulation is weak. Air pollution has stalled in the North China Plain, causing widespread smog. The continuous north-south swing of the ground convergence line under weak cold air makes it difficult to remove pollution in the Beijing-Tianjin-Hebei region, consequently the haze occurred repeatedly.

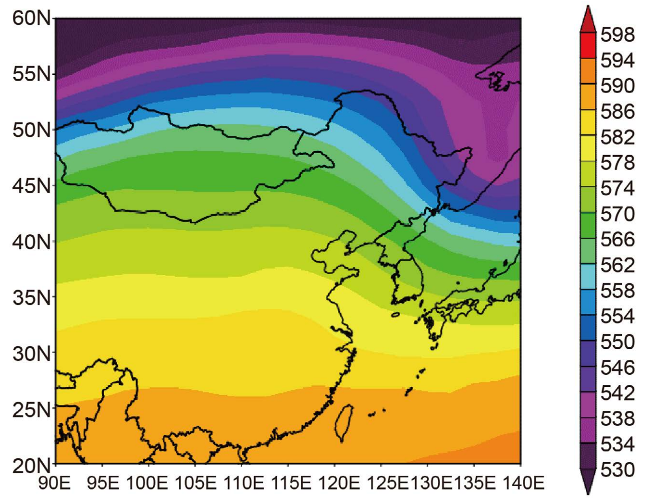

Figure 3. The 500 hPa geopotential height field at 8:00 on November 13, 2020.

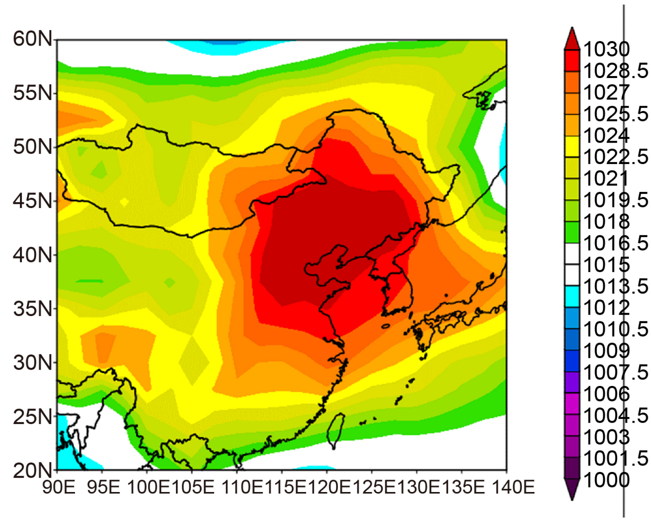

Figure 4. Sea level pressure field at 8:00 on November 13, 2020.

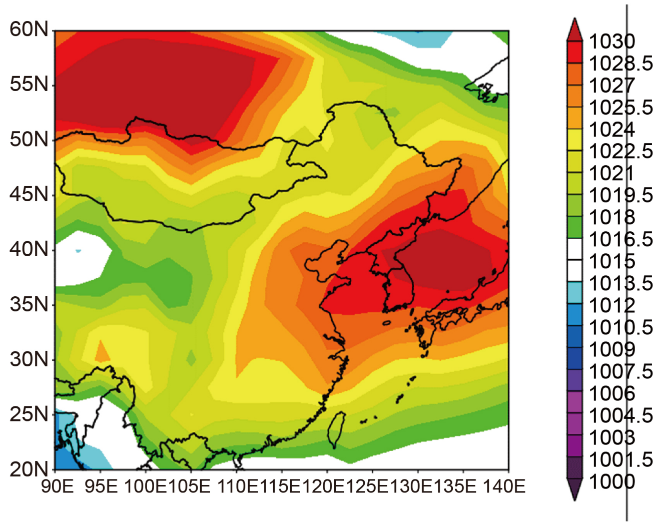

Figure 5. Sea level pressure field at 8:00 on November 14, 2020.

It can be seen that the heavily polluted area is basically the same as the ground convergence zone, so the study of the position change of the convergence zone has a great role in predicting the heavily polluted weather.

Relative humidity, expressed as RH, and it refers to the ratio of the actual water vapor pressure in the air to the saturated water vapor pressure at the current temperature, which reflects the degree of the air from the saturated air. It represents the ratio of the absolute humidity in the air to the saturated absolute humidity at the same temperature and pressure, and the number is a percentage.

From November 15th to 17th, under the easterly and southerly winds in the lower layers of North China and Huang-Huai Area, the ground relative humidity (**Figure 6**) increased significantly, and water vapor accumulated in the convergence area. Fog and poor visibility still remained in some areas. The high relative humidity and the content water vapor are closely related, and both play an important role in the formation of haze weather.

It can be seen that under the combined influence of precipitation and cold air, the haze that lasted for many days dissipated slowly. And the air pollution diffusion and wet removal conditions in North China, Huang-Huai and other places

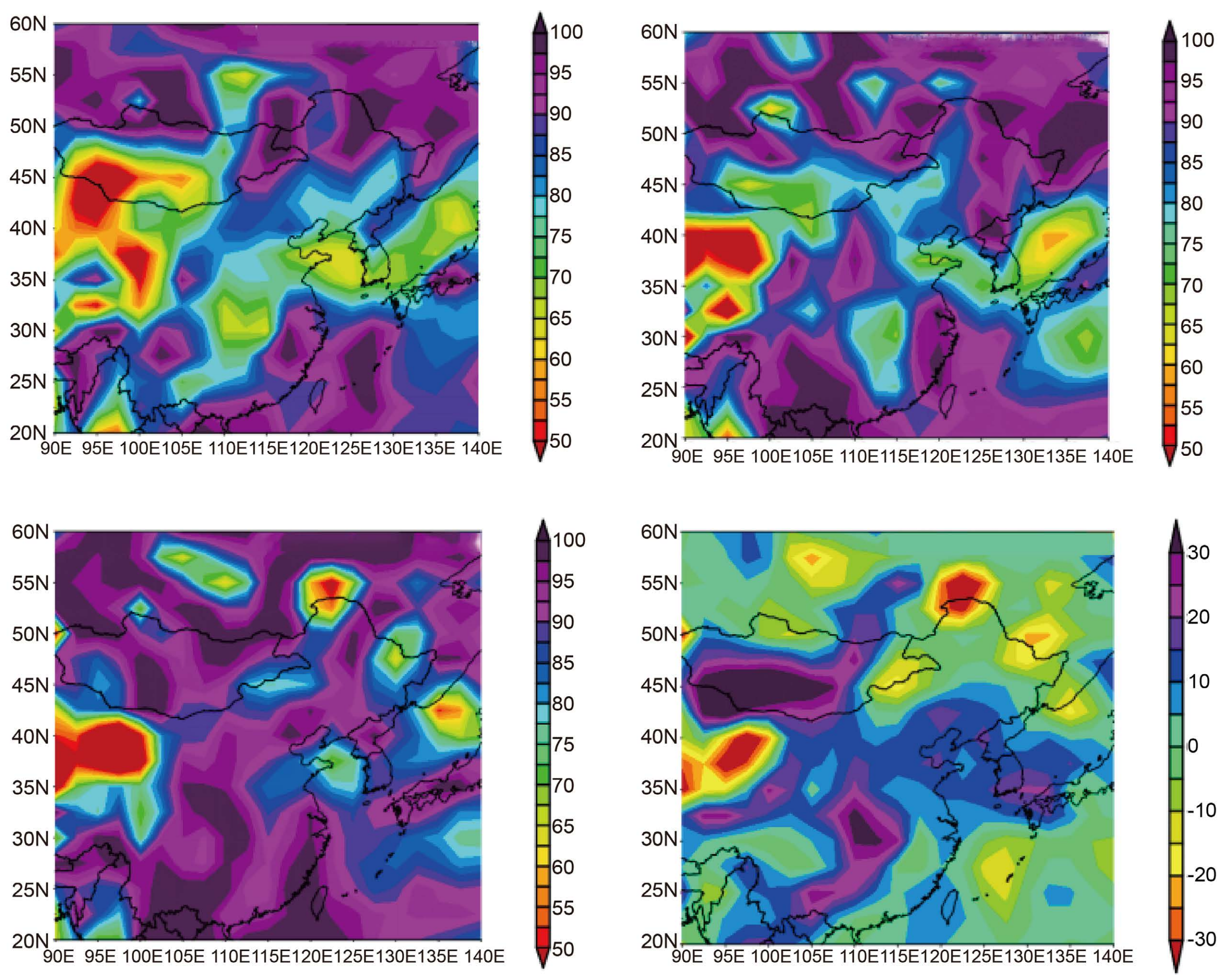

Figure 6. Relative Humidity map November 15-17, 2020 and humidity difference map.

improved markedly, and the large-scale haze process gradually came to an end (Figure 7).

The atmospheric environment can dilute and remove atmospheric pollutants, but it is affected by various meteorological elements such as temperature stratification, wind direction, wind speed, and humidity.

Atmospheric self-purification ability index (Figure 8) comprehensively reflects the ability of the atmosphere to remove pollutants, including two aspects: one is the ventilation dilution effect of atmospheric movement on pollutants. The other is the wet removal of pollutants by precipitation.

Atmospheric self-purification ability index (Wang et al., 2020) is the movement of the atmosphere itself have a clear effect on atmospheric pollutant, atmospheric's own movement to the spread of pollutants in the atmosphere, the

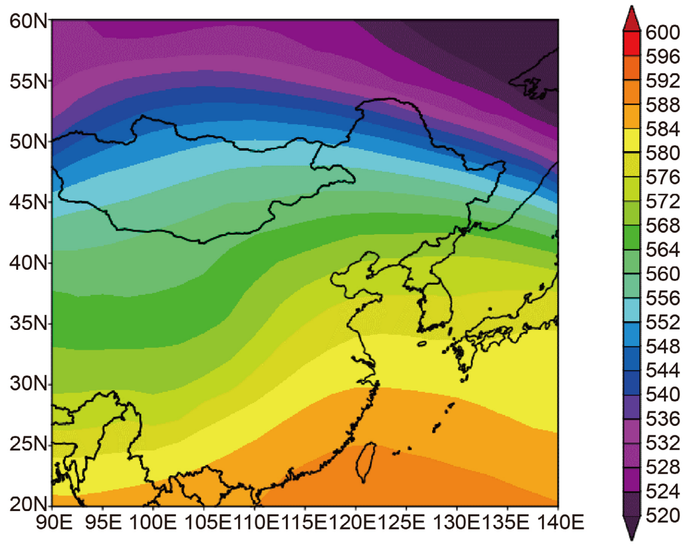

Figure 7. The 500 hPa geopotential height field at 8:00 on November 20, 2020.

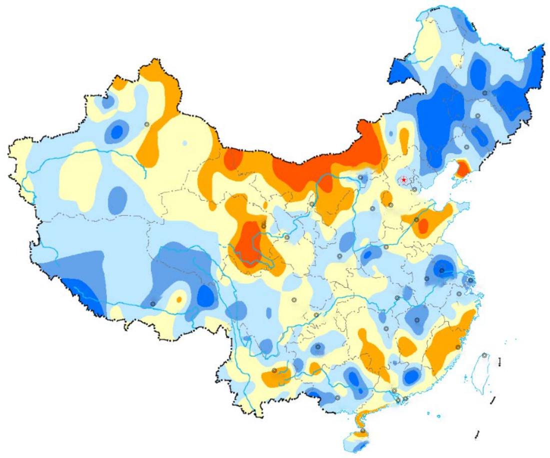

Figure 8. The anomaly of atmospheric self-purification ability index in China in November, 2020.

dilution and wet removal ability is defined as the atmospheric self-purification ability, wide range of serious pollution incident is associated with the discharge of atmospheric pollutants, are also associated with specific weather conditions, The corresponding atmospheric self-cleaning capacity can be predicted by future meteorological conditions, which will provide a basis for local governments to grasp the timing of air pollution prevention and control, and improve the efficiency of local governments in air pollution prevention and control.

It can be seen from the figure that there is a negative anomaly level in a large area of North China. So Atmospheric Self-Purification Ability can be very indicative of the air pollution weather comprehensively.

In addition, the location of the ground convergence area is highly coincident with the heavily polluted area, which proves that the study of the location change of the convergence area has a good indication and reference significance for the forecast of heavy haze weather.

4. Conclusion and Discussion

The main reasons for the formation of smog are as follows. First, the relative humidity is high and the water vapor content is relatively high. Second, the atmosphere is in a static and stable state, and suspended particulate matter in the atmosphere is not easy to diffuse and dilute, so it will gradually accumulate in urban areas and suburban areas. Third, there is a temperature inversion in the vertical direction, and the suspended particles in the air are difficult to drift to high altitudes and are blocked at low altitudes and near the ground. Fourth, there must be cooling conditions.

Meteorological factors are the external causes for the formation of smog. And the relative humidity of the air near the ground is high, and there is a lot of dust on the ground. Then there is no significant cold air movement and less wind. The stable atmosphere and stagnation of air cause tiny particles in the air to aggregate and float in the air. The sky is clear and less cloudy, which is conducive to radiation cooling at night, which makes the air with high humidity near the ground saturate and condense to form fog. And inversion intensity has a negative correlation with visibility, which has some indicating importance in fog and haze predictions. Large-scale haze weather mainly occurs in the large-scale atmospheric circulation with weak cold air and good water vapor conditions, and wind near the ground is small. Due to the high humidity in haze weather, fog droplets provide adsorption and reaction sites, accelerating the conversion of gaseous pollutants to liquid particles (Guo et al., 2015). At the same time, particles are also easy to act as condensation nucleus to accelerate the generation of haze. When the two interact, the pollutants are not easy to diffuse outward, resulting in agglomeration effect, and the pollution is getting heavier.

Conflicts of Interest

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

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