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ANALYSIS OF SPRING TEMPERATURE ANOMALY AND ITS CAUSES IN 2020

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Abstract: The maximum temperature in Hebei Province was unusually high for a week on March 17-23, 2020. We select the maximum temperature data of 6 representative stations in Hebei Province and NCEP / NCAR reanalysis data to analyze the cause of formation. The results show that: the polar vortex is stronger and more easterly than usual and there is no ridge to guide the cold air southward near the Ural Mountains. The East Asian trough is relatively weak in strength and east in location, resulting in a weak influence of cold air on Hebei Province. Hebei Province is located in the center of the maximum positive anomaly of the temperature field at 850hPa. The positive anomaly of 850hPa zonal wind, the strong foehn effect and the weak meridional wind make the influence of cold air weaker than usual. The sea-level mean wind patterns are different from the average years, indicating that they are less affected by the moist and cold air from the Bohai Sea, which is conducive to rising temperatures.

Keywords: Spring 2020, Maximum temperature anomaly, Cause, Hebei Province

I. INTRODUCTION

In March at the turn of winter and spring, the influence of the cold and warm air mass in our country was reversed compared with that in winter. The Cold Air Mass power gradually weakened but still has some influence and the warm air mass power gradually strengthened, which caused spring temperatures to oscillate. In the spring of this year, there were unusually high temperatures in many parts of China. In the

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middle of March, the centers of maximum temperature anomaly ≥6 °C were found in Hebei, Shanxi, Shandong, Henan, Shaanxi, Anhui, Hubei and Hunan of China[1]. Under the background of global warming, the high-temperature weather process and its influence on local weather and climate, as well as the serious consequences to the whole society have attracted wide attention[2-5]. According to the research of scholars at home and abroad on the characteristics of extremely high temperatures, it is found that the change from synoptic-scale to planetary-scale atmospheric circulation is the main cause of the extreme temperature events[6-7]. In recent years, under the background of global warming, record-breaking high-temperature events occurred frequently in summer all over China. The extremely high-temperature weather in summer has attracted people's attention. There are many pieces of research on the cause of high temperature in summer in China, but few on the weather process and atmospheric circulation characteristics of persistent high temperature in spring.

On March 17-23, 2020, the unusually high temperature in Hebei Province lasted for a week, which was rare in the same period of history. Based on the NCEP / NCAR reanalysis data and the meteorological station data, we analyze the temperature anomaly and the general circulation characteristics, which provides a valuable reference for prediction of spring temperature anomaly.

II. DATA SOURCES AND RESEARCH METHODS

Hebei Province is located in the eastern part of East Asia, with the east-west trending Yanshan Mountains in the north, with an average elevation of 800-1,000 m. To the west is the Taihang Mountains running north-south, with an average elevation of 1000-1500 m. To the east is the Bohai Sea. The terrain is high in the northwest and low in the southeast. The elevation of the southeast plain is mostly below 50 m. Affected by the Yan Mountains, the cold air from the North sinks to warm up at the southern foot of the Yan Mountains. Due to the influence of the Taihang Mountains, the foehn effect caused by the westward airflow at the eastern foot of the Taihang Mountains is very obvious[8]. The return flow in spring is often influenced by cold and humid air from the Bohai Sea, which makes the winter and spring temperature in Hebei Province fluctuate greatly. The topography remarkably influences the temperature of Hebei Province.

Following the principle of the long data age, excellent exploration environment and even spatial distribution[9], we select 6 stations in Hebei Province, i.e. Zhangjiakou, Qinglong, Langfang, Huanghua, Shijiazhuang and Handan for the study, including the northern mountains, the western hills, the eastern coast and the southern

plain, which can reflect the weather and climate characteristics of Hebei Province. Using the temperature data of these stations since their establishment, the climatic average values are based on the corresponding temperature data of 30 years from 1990 to 2019, and some of the statistical data are taken from the intensive integrated meteorological operational platform of Hebei Province, *http://10.48.38.209/hb/mainframe/init.do#*. By comparing the temperature data of March 17-23, 2020 with the climatic data of the same period, we analyze the cause of the high temperature with the methods of meteorology, climatology and statistics. The NCEP / NCAR reanalysis data are used for atmospheric circulation analysis. The horizontal resolution is 0.25°×0.25°. The vertical direction is 17 layers and the time scale is 1990-2020. The variables include potential height field, wind field and temperature field.

III. CHARACTERISTICS OF ABNORMALLY HIGH TEMPERATURE

Figure 1 illustrates the spatial distribution of the mean maximum temperature at each station on March 17-23, 2020 compared with the same period in history (1990-2019). It can be seen that the range of the mean maximum temperature is 6.9-9.1 °C. The northernmost, Zhangjiakou, recorded 17.6 °C with a mean of 10.6 °c and the

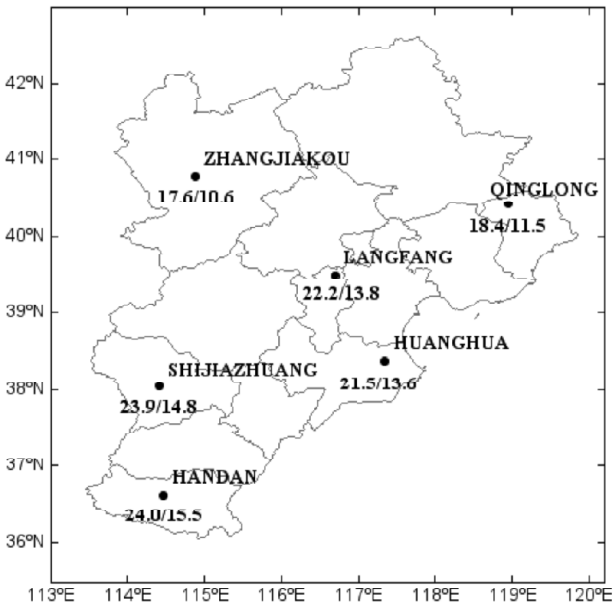

Figure 1: The distribution of mean maximum temperature in Hebei Province on March 17- 23, 2020 and the comparison of the same period (1990- 2019) (mean maximum temperature/mean maximum temperature for the same period in history, unit)

southernmost, Handan, recorded 24.0 °C with a mean of 15.5°C over the same period. Table I shows the extreme maximum temperature at each representative station in Hebei Province from March 17 to 23, 2020, historical extreme value and extremal ordering of the same period since the station was built: Qinglong, Langfang, Huanghua and Shijiazhuang ranked 2nd, Handan 3rd and Zhangjiakou 5th. Although each representative station has not reached the extreme value since the establishment of the station, the ranking is very high. Figure 2 shows the sequence of the maximum temperature at each station in mid-late March 2020 (10-31). According to the graph, the maximum temperatures on the 18th and 20th appeared two peaks, and the maximum temperatures on 17-23 were significantly higher than other periods.

From the above analysis, it can be seen that the maximum temperature anomaly on the high side is extreme in scope, intensity and extent.

Table I
Extreme maximum temperatures at various stations in Hebei Province on March 17-23, 2020 and historical extremum and extremum ordering of the same period since the station was built

Name of Station	*Maximum Temperture on March 17-23, 2020 (°C)*	*Historical Extreme Value for the Same Period (March 17-23) Since the Station was Built (°C)*	*Extremum Sort*
Zhangjiakou	20.4	25.5	5
Qinglong	22.5	26.8	2
Langfang	27.1	30.4	2
Huanghua	27.3	30.7	2
Shijiazhang	29.6	30.7	2
Handan	29.8	31.7	3

IV. CAUSES OF THE ABNORMALLY HIGH TEMPERATURE

4.1. Circulation Pattern Characteristics

From March 17 to 23, 2020, the 500hPa Eurasian mid-high latitude is a trough-crest type. The center of the polar vortex is at 85°N and 120°E (Figure 3a), and the center value is lower than 474 gpm. Compared with the same period in previous years (Figure 3b), the polar vortex is easterly and stronger. The high-pressure ridge area is located at 50°E—100°E, south of 50°N, and westward and wider than usual. There is a slight cyclonic bend near the Ural Mountains (60°E) and to the north of 50°N. An abnormal weak ridge leads the cold air south to affect Hebei Province.

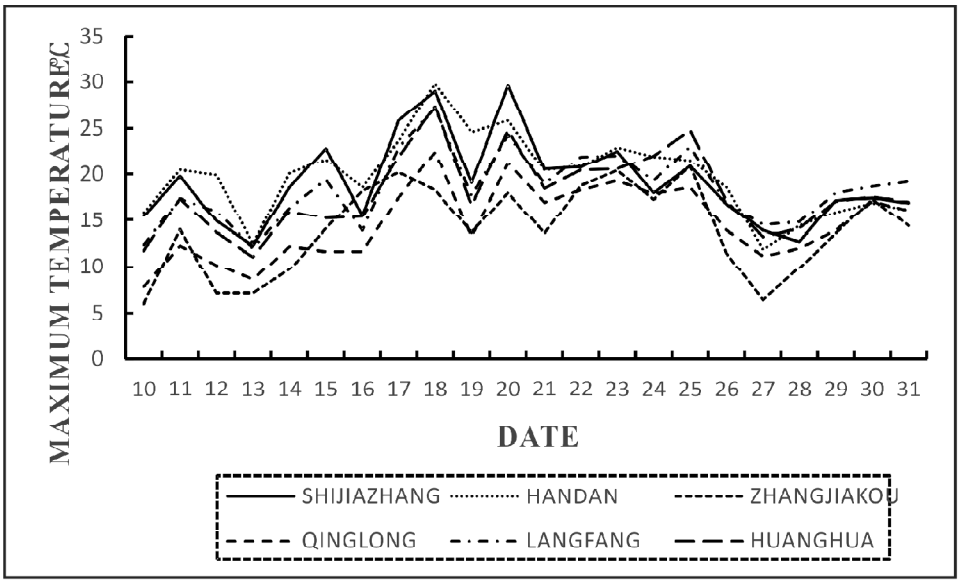

Figure 2: Daily variation of maximum temperature in Hebei Province during 20200310-31

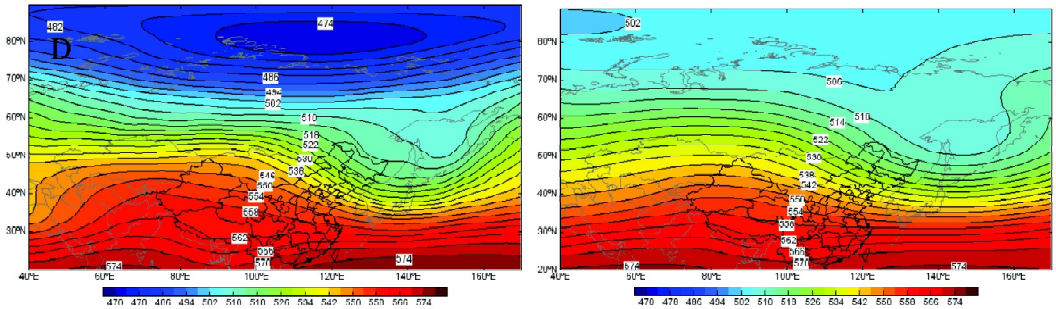

Figure 3: 500 hPa average height field from 17 to 23 March 2020 (a) and climate field (1990-2019) (b)

4.2. Characteristics of the East Asian Trough

In winter and spring, the East Asian trough is a strong and stable planetary-scale circulation system located in the upper troposphere. The intensity, position and range of the East Asian trough are closely related to whether the cold air from the polar region goes southward to affect Hebei Province. 17-23 March 2020, the 200hPa East Asian trough was located near (135°E-145°E, 45°N-60°N) (Fig. 4a). Analyzing the contemporaneous anomaly map (Fig. 4b), there is a positive anomaly of more than 15gpm near the East Asian trough, which indicates that the East Asian trough is

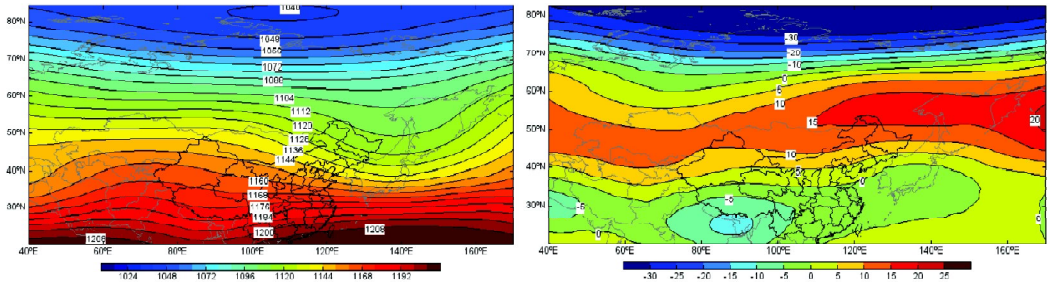

Figure 4: 200 hPa average height field (a) and anomaly (relative to 1990 to 2019) (b) from March 17 to 23, 2020

obviously weaker and its position is more easterly than that of the same period in previous years. Therefore, the influence of the polar cold air is weak in Hebei Province.

4.3. Characteristics of Temperature Field and Wind Field at 850hPa

According to temperature field at 850hPa on March 17-23, 2020 (Fig. 5a), we find that Hebei Province is controlled by the temperature crest; in central-south plain the 850 hPa temperature is no less than 8 °C; in the central region the 850 hPa temperature is between 5-8 °C and in the northern mountain area the 850hPa temperature is between 2-5 °C. Based on the analysis of the temperature anomaly over the same period (Fig. 5b), in Hebei Province the 850 hPa temperature is a positive anomaly, located in the center of the maximum value of positive anomaly and unusually higher than those in previous years; in the southern plain the 850 hPa temperature anomaly is no less than 7.2 °C; in central China the 850 hPa temperature anomaly ranges

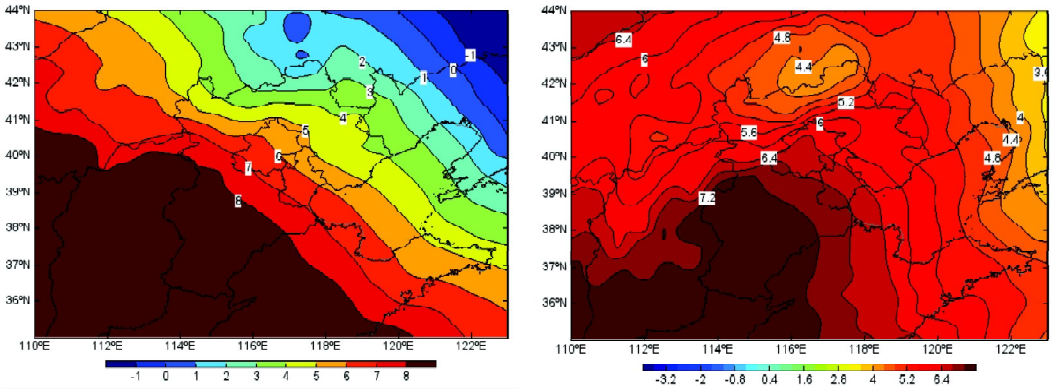

Figure 5: 850 hPa average temperature field from March 17 to 23, 2020 (a) and anomaly (b) (relative to 1990 to 2019)

from 6 to 7.2 °C; in the northern mountain area the 850 hPa temperature anomaly is basically between 4.4 °C and 6 °C.

The west of Hebei Province is the Taihang Mountains. As the westerly winds cross the Taihang Mountains vein, the Foehn effect is very significant. On March 17-23, 2020, the 850hPa zonal wind anomaly field (Fig. 6a) was a positive anomaly in Hebei Province, indicating that the westerly winds are stronger and more frequent than usual and the Foehn effect becomes stronger accordingly. According to the 850hPa meridional wind anomaly field on March 17-23, 2020 (Fig. 6b), Hebei Province's anomaly values are between -1-1 °C and most of them are weak negative anomaly; the component of north wind is weak, indicating that the influence of cold air is weaker than normal.

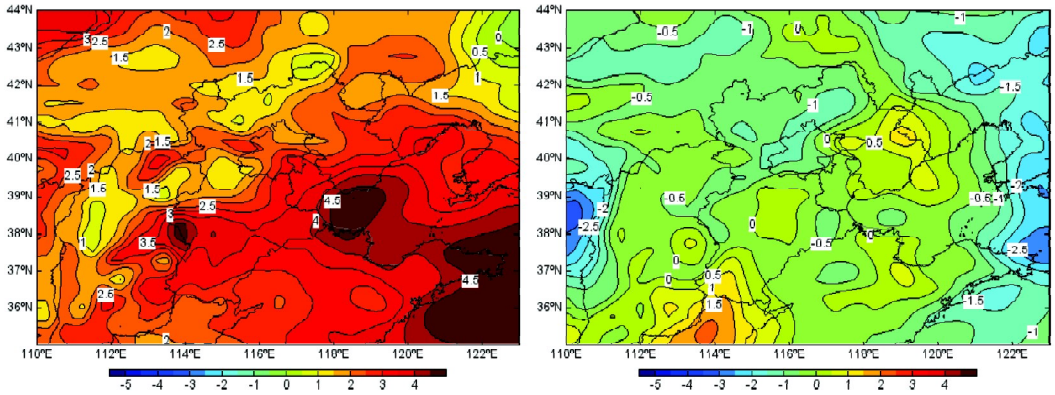

Figure 6: 850hPa zonal wind distance field (a) and meridional wind distance field (relative to 1990 to 2019) (b) from 17 to 23 March 2020

4.4. Topographic Impact

As mentioned above, the terrain has a significant impact on the temperature in Hebei Province. In spring, the cold air goes south on a northeast or eastward path and affects Hebei Province, which is called return weather. In this case, the cold and humid air from the Bohai Sea is a major factor in the drop in temperatures in Hebei Province.

According to the mean sea level wind field (Fig. 7a) on March 17-23,1990-2019, there is a convergence line of north-south wind near the northern part of Hebei Province (114°E-116°E, 39°N-41°N), which is caused by the Yan Mountains: the cold air in spring is weaker than that in winter and the component of the south wind is stronger, which forms the convergence line of the south-north wind; there is a

convergence line of east-west wind at the junction of southern Hebei and Shanxi Province (114°E, 37°N-38°N), which is caused by the confluence of the cold and moist air from the Bohai Sea and the westward airflow in front of the Taihang Mountains.

From the mean sea-level wind field on March 17-23, 2020 (Fig. 7b), the convergence line in northern Hebei is similar to that of normal years and the convergence line in the south is the convergence of westerly and southerly winds, indicating the cold and moist air from the sea less than usual.

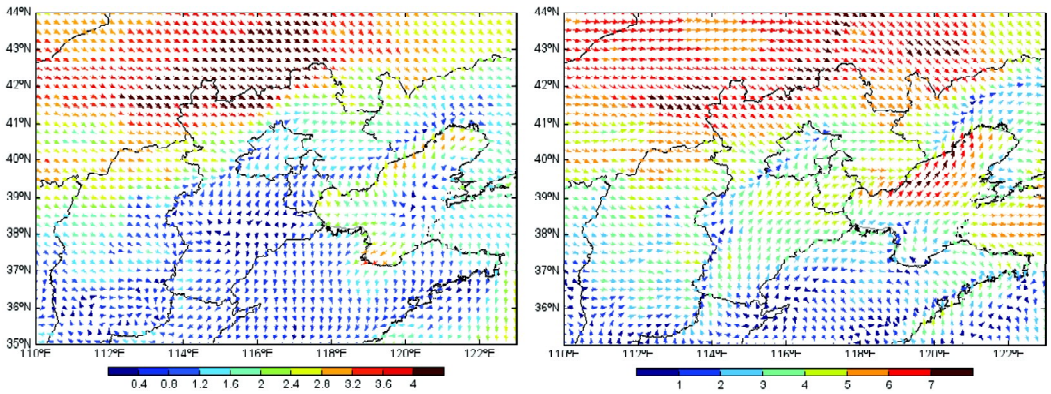

Figure 7: Mean sea level winds from 17 to 23 March 1990-2019 (a) and mean sea level winds from 17 to 23 March 2020 (b)

V. CONCLUSIONS

In the early spring of 2020, abnormally high temperatures occurred in many parts of China. We choose Hebei Province as an example to illustrate the fact that the daily maximum temperatures are abnormally high, and briefly analyze its causes from the aspects of atmospheric circulation, influence systems and topography. Conclusions are listed as below:

- In the spring of 2020 in Hebei Province, there was a week-long and large-scale high daily maximum temperature phenomenon, which is rare in the same period in history.
- The 500hPa circulation pattern is a trough-ridge pattern in the middle and high latitudes of Eurasia; the polar vortex is stronger and more easterly than usual; the main body of the high-pressure ridge area in the mainland is wider and more south than usual; there is a slight cyclonic curvature around the

Ural Mountains. These phenomenons are not conducive to guiding the cold air southward. Moreover, the East Asian trough is obviously weaker than usual, and its location is more east than that of the same period in normal years, which is also not conducive to guiding the cold polar air southward to affect Hebei Province.

- On the 850hPa temperature field, Hebei Province is higher than normal and located in the center of temperature positive anomaly. In Hebei Province, the 850 hPa zonal wind is a positive anomaly; the foehn effect is stronger than usual; the meridional wind is generally a weak negative anomaly; the influence of cold air is weaker than that of normal years.
- The mean sea-level wind field is different from that of normal years and rarely influenced by the moist and cold air from the Bohai Sea, which is conducive to the temperature rising.

The abnormal reflection of meteorological elements inevitably affects the weather and climate. In addition to making accurate predictions for it, we should also pay close attention to its impact on the global climate and human society.

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