

Analysis of a Large-Scale Heavy Precipitation Weather Process in Northern China from September 17 to 20, 2021

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Abstract

In the autumn of 2021, China's precipitation appears the distribution characteristics of "more in the South and less in the north". Compared with the same period in history, the precipitation is more. The analysis is based on a large-scale heavy precipitation weather process in the middle and late September. The atmospheric circulation situation and weather situation of this precipitation process are mainly discussed. The results show that the low-pressure trough between the Balkesh Lake and Baikal Lake area made the cold air move eastward, and the warm and humid air flow extending westward was conducive to the enhancement of precipitation. The anticyclone circulation in the Sea of Japan transported the cold and humid air to the northeast of China. The southeast air flow around the subtropical high in the Western Pacific, the southwest air flow in the bay of the Bengal Bay and the South China Sea met in the southwest to produce precipitation and continued to move northward. They merged with the cold and humid air flow in the Northeast in the north of the Yangtze River, resulting in large-scale precipitation in northern China.

Keywords

North China, Precipitation, Vortex, Shear Line, Relative Humidity

1. Introduction

During September, 2021, there were five regional rainstorm processes in China, of which the process of September 17th to 20th had the largest impact range. On September 17-20, a regional rainstorm occurred in the eastern part of the Northwest China, North China, Huanghuai and the south of Northeast China.

The precipitation in southern Hebei, southeastern Shanxi, northern Henan, northwestern Shandong and northern Liaoning coastal areas was 100 - 250 mm. The rainstorm process affected an area of 611,000 square kilometers in China. From the night of September 17th to 20th, the rainfall in China showed a trend of increasing and strengthening gradually. More than 10 provinces (autonomous regions and municipalities) in northern China experienced heavy rainfall from west to east. This rainfall process was dominated by stable rainfall, which affected a wide range area, and the rainfall period coincided with the Mid-Autumn Festival holiday, which had a great impact on people's travel.

Strong convection is the direct cause of severe precipitation weather processes, such as heavy rainstorms, thunderstorms and other disastrous weather processes. Therefore, strong convective weather processes have always been a key content in the field of meteorological research (Song et al., 2020). Many scholars have done a lot of research on the process of heavy precipitation in northern China. Zhai & Pan (2003) found that the number of extreme precipitation events in most of northwest China and the western part of northeast China had increased significantly, and the number of days of extreme precipitation events from eastern northeast China to northern China had decreased obviously in the past several years. Wu (1988) pointed out that heavy precipitation in the north is often accompanied by intense thunderstorm activity, a short duration, and a small precipitation coverage area. Xu et al. (2014) indicated that low-level vertical wind shear and ultra-low-altitude rapids may play an important role in convective triggering and maintenance. Secondary weather and lift conditions of the following scales can lead to heavy precipitation. According to Liang et al. (2007), water vapor transport from the western Pacific Ocean and the high latitude westerly wind belt plays an important role in the rainstorm in North China, and water vapor transport from the Bay of Bengal also has a certain strengthening effect on heavy rain. The research of Xie et al. (2012) showed that heavy rains are preconditioned the transport of large amounts of water vapor, which in turn contributes to the anomalous subtropical high pressures of the western Pacific Ocean. Anomalous western Pacific subtropical high is primarily driven by anomalous transient eddy feedback from forcing nearby East Asian jets, and the development of the Northeastern China Cold Vortex circulation occurs simultaneously with regional rainstorm events.

In view of the direct causes and key contents of the heavy precipitation process, the authors above have done relevant research. The study area covers north China, northwest China and northeast China. The synoptic dynamics systems involved include low-level vertical wind shear, ultra-low level jet and northeast cold vortex circulation, etc. The role of water vapor transport is also studied. Therefore, this study has made a detailed analysis of the large-scale precipitation weather process in northern China in September 2021, therefore, it has a good reference significance for the future large-scale precipitation forecast. In addition, this research has a good timeliness, which can provide meaningful

latest data for future research.

2. Data and Methods

2.1. Data

The data selected in this article is based on precipitation data from the National Climate Center of China and weather charts from the Japan Meteorological Agency from September 17 to 20, 2021. It is hourly rainfall observation data and the NCEP data with spatial resolution of $1^\circ \times 1^\circ$, which is relatively accurate and therefore meets the requirements of the study.

2.2. Methods

In this study, synoptic and diagnostic analysis methods (Ahmadi et al., 2017; Luiz Silva et al., 2015; Agbazo et al., 2021) are used to analyze the weather situation, such as pressure field analysis method, water vapor flux analysis method and so on. According to the distribution characteristics of meteorological element fields on the weather map, analyze and summarize the weather situation and the reasons for this large-scale weather process.

3. Results and Analysis

3.1. General Situation of Atmospheric Circulation and Precipitation

As China is located in the southeast of Eurasia, the monsoon characteristics are significant. In September, the summer monsoon retreated and the Western Pacific subtropical high retreated eastward and southward. During this period, there was a large-scale autumn rain in our country.

In the middle of September 2021 (Figure 1), long wave adjustment occurred in the middle and high latitudes of Eurasia. The trough to the west of Novaya Zemlya Island moved eastward, and the middle and high latitudes changed into

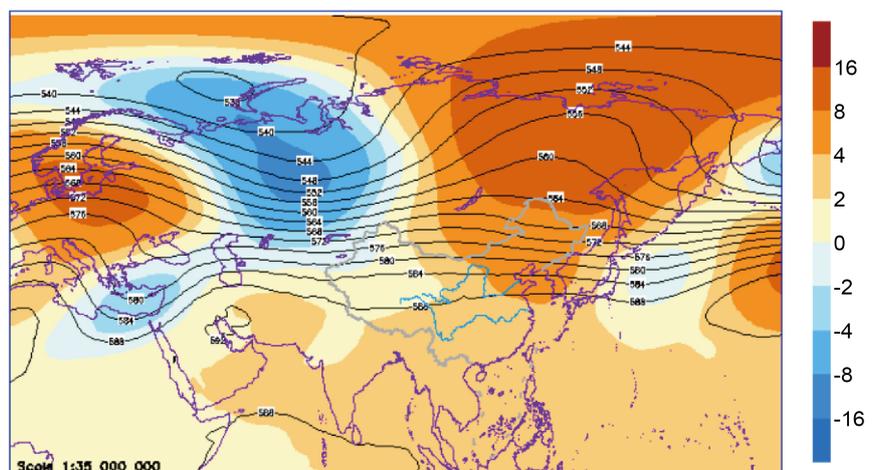


Figure 1. Sea level field in Eurasian in Mid-September, 2021 (The contour line is the geopotential height, the unit is dagpm, and the shaded area is the anomaly).

the situation of “two ridges and one trough”, with small fluctuations continuously spreading eastward. There was a large low trough area from Balkesh Lake to Baikal Lake, and the high pressure ridge controlled the air over East Asia, which was conducive to the southward diffusion of cold air. At the same time, the ridge line of the subtropical high was northward, which was conducive to the northward transport of water vapor.

From September 11 to 16, 2021, under the joint influence of typhoon Candu and southwest vortex, heavy rain occurred in Sichuan Basin, Northern Guizhou, eastern Zhejiang and most of Shanghai. From September 17 to 20, 2021, affected by low vortex and shear line, northern China experienced a continuous large-scale heavy precipitation weather process (**Figure 2**).

3.2. Weather Situation

It can be seen from the 500 hPa (**Figure 3**) and 850 hPa (**Figure 4**) weather maps at 8 o'clock on September 19, the north of Northeast China was controlled by a high pressure weather system with closed contours, the northwest of Inner Mongolia was controlled by a small low pressure weather system with closed contours, and the northwest was affected by the eastward expansion of the cold low pressure on the Qinghai Tibet Plateau. The low pressure with closed contours from the Jianghuai area extended northward, bringing a large range of cold air to North China, which was conducive to the formation of precipitation. The Southwest China, North China and Northeast China were located in front of the high altitude trough. A southwest-northeast shear line was formed between the eastern Qinghai Tibet Plateau and the Sichuan Basin.

It can be seen from the 850 hPa geopotential height map on September 20 (**Figure 5**) that the cold vortex developed and strengthened in the eastern coastal area of China. The high pressure weather system with closed contours in the

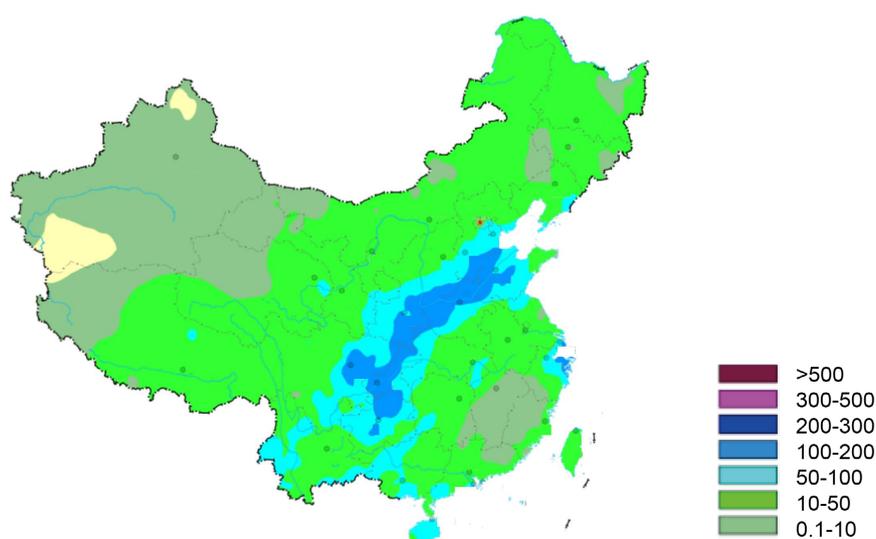


Figure 2. The precipitation of China mainland in late-September, 2021 (the shaded area is the precipitation in the unit of mm).

north of Northeast China moved eastward, controlling a large area of Northeast China and Sea of Japan. The western and northwest regions of China continued to be controlled by closed high pressure. This made the circulation situation of “high pressure on both sides and low pressure in the middle” formed in northern China. At this time, the shear line in the east of the Qinghai Tibet Plateau became southeast northwest.

It can be seen from the sea-level pressure field from 19 to 20 (**Figure 6** and **Figure 7**) that the low vortex in the Yangtze Huaihe River Basin moved northward and strengthened its development in the eastern coastal areas of China. The closed high located in the northwest of Northeast China moves eastward to the east of Northeast China, and the large-scale closed high in Southwest China affected Western China. The closed vortex strengthened in Mongolia.

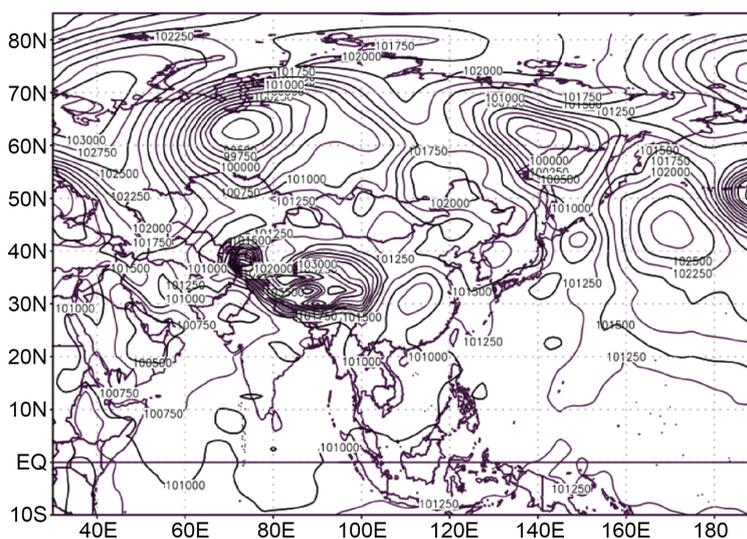


Figure 6. The sea level pressure map in Asia at 08:00 on September 19, 2021.

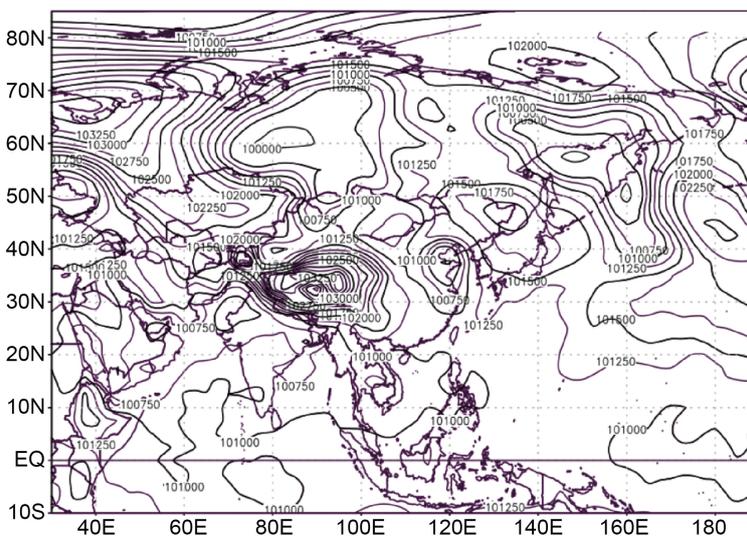


Figure 7. The sea level pressure map in Asia at 08:00 on September 20, 2021.

Figure 8 and **Figure 9** are the 850 hPa relative humidity maps on September 19 and 20, respectively. It can be seen that the relative humidity in central and southern China was relatively high and the water vapor conditions were abundant on September 19. On the 20th, the relative humidity in Central China was relatively low, and the relative humidity in eastern, southeastern and southern areas was relatively high. Compared with the 19th, the maximum relative humidity decreased. However, it still had precipitation condition.

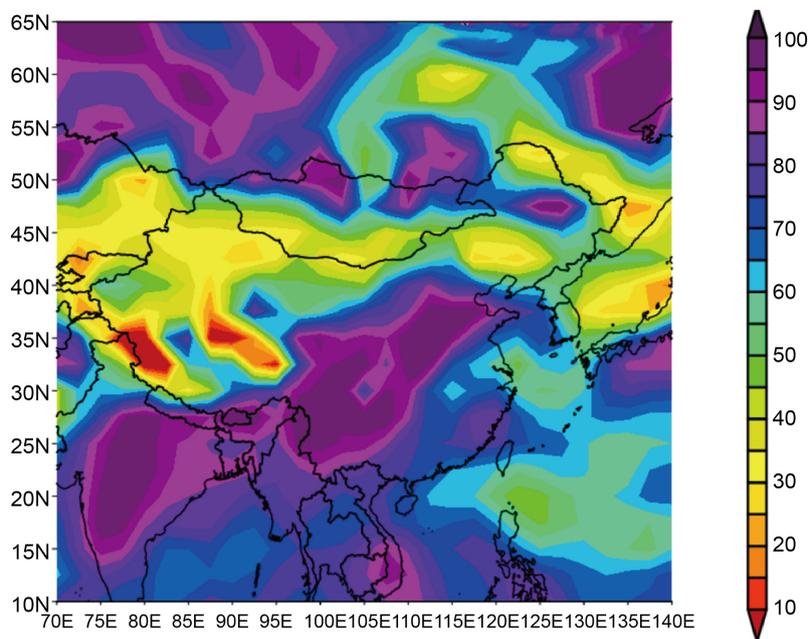


Figure 8. The 850 hpa relative humidity in Asia at 08:00 on September 19, 2021.

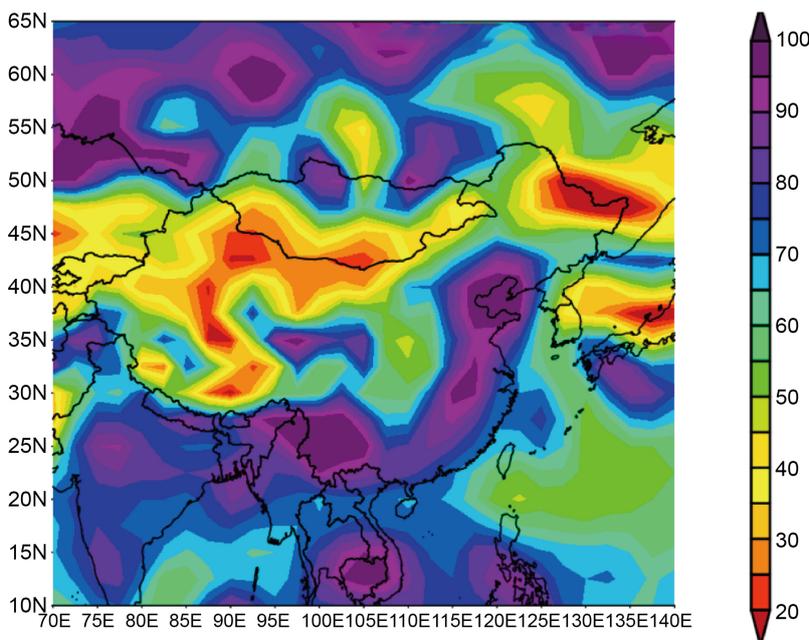


Figure 9. The 850 hpa relative humidity in Asia at 08:00 on September 20, 2021.

In general, Southwest, North and Northeast China were located in front of the high altitude trough. Since the 19th, under the action of positive vorticity advection, the development of low-level vortice in North China had strengthened, forming cyclonic convergence, promoting the occurrence of atmospheric convection, leading to a further increase in precipitation. The subtropical high stretched westward and was stably maintained in South China. It continuously transported the water vapor from the Northwest Pacific and South China Sea to the southwest, North China and northeast, providing sufficient water vapor supply for the occurrence of heavy rainfall. Above 600 hPa, anticyclonic divergence was maintained in the upper layer, strong cyclonic convergence was maintained in the lower layer, and mass divergence in the upper layer flowed out (Zhu et al., 2007), causing the ground pressure to drop, thus enhancing the convergence of low air swirling circulation and promoting the increase of rainstorm.

4. Conclusion

The circulation field in the north of China presented a radial distribution. There were low vortices in the northern China, and troughs and shear lines appeared in the upper air. At the same time, the low-pressure trough between the Balkesh Lake and Baikal Lake area made the cold air move eastward, and the warm and humid air flow extending westward was conducive to the enhancement of precipitation. The anticyclone circulation in the Sea of Japan transported the cold and humid air to the northeast of China. The southeast air flow around the subtropical high in the Western Pacific, the southwest air flow in the bay of the Bengal Bay and the South China Sea met in the southwest to produce precipitation and continued to move northward. Finally, it merged with the cold and humid air flow in the Northeast in the north of the Yangtze River, resulting in large-scale precipitation in northern China.

Conflicts of Interest

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

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