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Analysis of Heavy Precipitation Process in North China from August 23 to 24, 2020

Yunfei Qi

School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing, China
Email: 1102352593@qq.com

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Abstract

In order to better understand the formation mechanism of rainstorm in China and promote disaster prevention and reduction, based on the meteorological data of National Meteorological Information Center and Japan Meteorological Agency, this paper draws the isobaric surface map of 850 hPa and 500 hPa, relative humidity and precipitation distribution map. In this study, synoptic methods were used to analyze the heavy precipitation process in North China from August 23th to 24th, 2020. The results show that 1) The formation of short-term heavy precipitation requires sufficient water vapor and very strong upward movement; 2) the heavy precipitation in August 23th to 24th 2020 in North China was influenced by the upper-level trough line, cold vortex and cold front, which made the warm and cold air strongly converge over North China, resulting in strong convective weather; 3) the heavy rainfall over North China was also influenced by Typhoon Bawei, which caused maximum precipitation and air humidity.

Keywords

North China, Short Time Heavy Precipitation, Typhoon, Convective Weather

1. Introduction

The rainy season in North China is concentrated in July and August each year, when the Western Pacific subtropical high reaches the northernmost position of the whole year. Under the influence of this, the north enters the main rainy season. At the same time, the typhoons activities in the South China Sea with the western Pacific enter the active period, and the coastal areas are affected by typhoon precipitation and storm surge. According to meteorological data, from 08:00 on August 23 to 08:00 on August 24, 2020, the heavy rain (25 - 50 mm) appeared in some parts of North China, including heavy rains (50 - 90 mm) in central North China, torrential rain in Beijing from the evening of 23 to the night, and the rainstorm in Tongzhou, Daxing and Pinggu. According to the Beijing Meteorological Bureau, 200 observation stations (36.0% of the total) in the city had more than 50 millimeters of rain from 2 P.M. on 23 to 6 A.M. on next morning, and 12 observation stations (2.2% of the total) had more than 100 millimeters.

In recent years, there has been an increasing trend of local extreme rainstorm weather (relative to extreme rainstorm weather, which refers to historical weather and climate events with low probability). It has many characteristics, such as serious, sudden and so on. Research on the formation mechanism of regional heavy rain is helpful to carry out waterlogging early warning and prevention, and reduce the loss of public property. In the past, scientists have studied heavy rainfall events during the rainy season in North China. The research of Liang et al. (2007) showed that the water vapor of heavy precipitation in North China came from the water vapor transport of the western Pacific Ocean and the high latitude westerly belt, and the water vapor transport from the Bay of Bengal also had a certain strengthening effect on the rainstorm. Yang et al. (2010) analyzed the heavy precipitation weather in the southern part of North China from May 9 to 10, 2009, and showed that the heavy precipitation was generated in the process of the intersection of cold air and warm and humid air in the southwest. Fu et al. (2017) studied the characteristics and synoptic causes of extreme heavy precipitation in North China during "16·7". It is pointed out that the heavy precipitation occurred under the circulation background of the eastward strengthening of the South Asian high, the westward extending of the subtropical high and the development of the westerly vortex system in the middle and high latitude. The Huang-Huai cyclone, the abnormal development of the southwest and southeast low-level jet and the abnormal abundance of water vapor provided favorable dynamic uplift and water vapor conditions for the heavy precipitation. Chen et al. (2017), conducted a convective scale ensemble simulation experiment of different precipitation microphysical processes on the extreme rainstorm process in North China on July 19, 2016. Sun & Guan (2021) studied the Rossby wave activity and energy change of "16·7", and showed that during extreme precipitation, wave disturbance energy mainly propagated in the lower troposphere and zonally in the upper troposphere, and the wave disturbance energy in the lower troposphere had a more obvious influence on North China. In addition, warm and humid air is transported northward in the lower layer, dry and cold air is transported southward in the upper layer, which supports the conversion of positive pressure and baroclinic pressure. The change of eddy momentum flux enhances the eddy dynamic energy in the air stream, thus affecting the occurrence and development of extreme precipitation events. Previous studies have some relevance to this study, and the current study can serve the purpose of complementing the existing literature.

This study starts with the heavy precipitation event in North China from August 23 to 24, 2020. Three types of weather maps are used to analyze the change of meteorological elements. 1) The data of 850 hPa and 500 hPa isobaric surface map, 2) relative humidity at time 08 and 20 with the 850 hPa geopotential height field, 3) PWV (precipitable water vapor) in the atmosphere. The control variable method will also be used to analyze the change of isobaric line. This study summarizes the role of typhoons in the heavy precipitation event in North China, the formation mechanism and meteorological conditions of heavy precipitation.

2. Data and Methods

2.1. Data

Sources of meteorological data:

1) Meteorological data of China National Meteorological Information Center (http://www.nmic.cn/), including meteorological observation data of North China station, such as pressure, temperature, humidity, precipitation, etc.

2) NCEP (National Centers for Environmental Prediction) (https://ncep.amnh.org/) reanalysis data and NOAA (National Oceanic and Atmospheric Administration) (https://www.ncei.noaa.gov) of meteorological data.

Data selection time: 08:00 and 20:00 on August 23 and 24, 2020, and 08:00 on August 25, 2020 (Beijing time, the same below).

2.2. Methodology

The synoptic method is used in this study, which combines the equations of atmospheric dynamics, continuity, gas state and heat flow. Combined with the control variable method, the changes of air mass, front, cyclone, trough and ridge were comprehensively analyzed, reveal the meteorological elements, conditions and formation mechanism of the heavy rainfall in North China at the same time.

Using the synoptic method, it is analyzed that the cold vortex moving toward the northeast brings southerly warm and humid air and the low-level jet meet to generate strong convective air, which causes the divergence of the upper atmosphere, convergence of the lower atmosphere, and continuous upward movement of the atmosphere, providing good dynamic conditions for short-term heavy precipitation. The relationship between relative humidity and precipitation is also studied (Zhu et al., 2007; Pang et al., 2019).

3. Results and Analysis

3.1. Overview of Atmospheric Circulation and Precipitation

According to the average situation in late August 2020 in **Figure 1**, the atmospheric circulation in the middle and high latitudes of Eurasia presents the situation of "two ridges and one trough". The high pressure ridge area is near Lake Baikal and the Eastern European plain area north of Caspian Sea and Black Sea. Trough the north of Lake Balkhash area, there is a closed low pressure center over the Kazakh Hills and the central pressure below 556 hPa. Near 40˚N, there is a closed center of high pressure over North China and the central pressure is

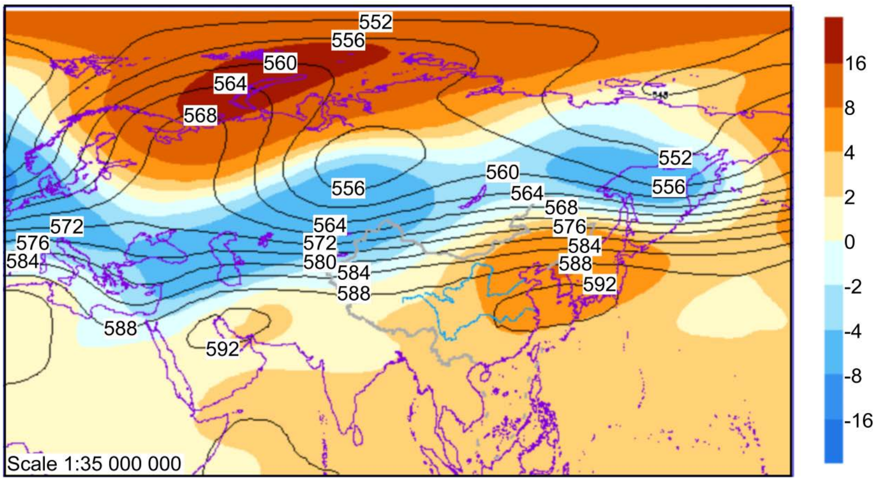

Figure 1. The 500 hPa geopotential height field and anomaly in late August 2020 (Isolines in late August represent isobars on 500 hPa, and shadows represent isobaric surface anomalies).

above 592 hPa. Northeast China and eastern North China are located in front of the upper-level trough. With the movement of the trough line, cold air from northwest China is transported to North China, and weak cold air activities are frequent. In the latter of the month, the North-West Pacific subtropical high was stronger, which is the western ridge was stronger from north to south, especially from northeast China to Japan. Compared with the historical average height field of 500 hPa, there was a larger positive anomaly. The subtropical high deviated to the north and weakened to the east, leading to the northward path of Typhoon Bawei, which affected North China and northeast China within 10 days.

In the early part of late August, heavy precipitation occurred in Sichuan Bsin, the eastern part of Northwest China, Northeast China and North China under the influence of the upper trough, vortex and cold front. In the middle and late period, affected by Typhoon Bawei, the central and northern Jiangsu, the western Shandong Peninsula, the central and eastern Liaoning, most of Jilin, the eastern and southern Heilongjiang and other places arose short-time strong rainfall.

3.2. Analysis on Weather Process

During August 23-24, influenced by the upper-level trough on the isobaric surface of 500 hPa, low-level shear and low-level jet, heavy rain occurred in central Hebei, eastern Beijing, northern Tianjin, central eastern Liaoning and central Jilin. Among them, the average rainfall in Beijing from 14 PM on August 23 to 6 PM on August 24 was reaching 50 mm.

As show in **Figure 2**, on August 23, on the isobaric surface of 500 hPa, there was a weak upper trough from central Inner Mongolia to the vicinity of Hetao Plain. North China is located in front of the upper-level trough, on 850 hPa isobaric surface corresponding to **Figure 3**, there is a quasi-north-south shear line

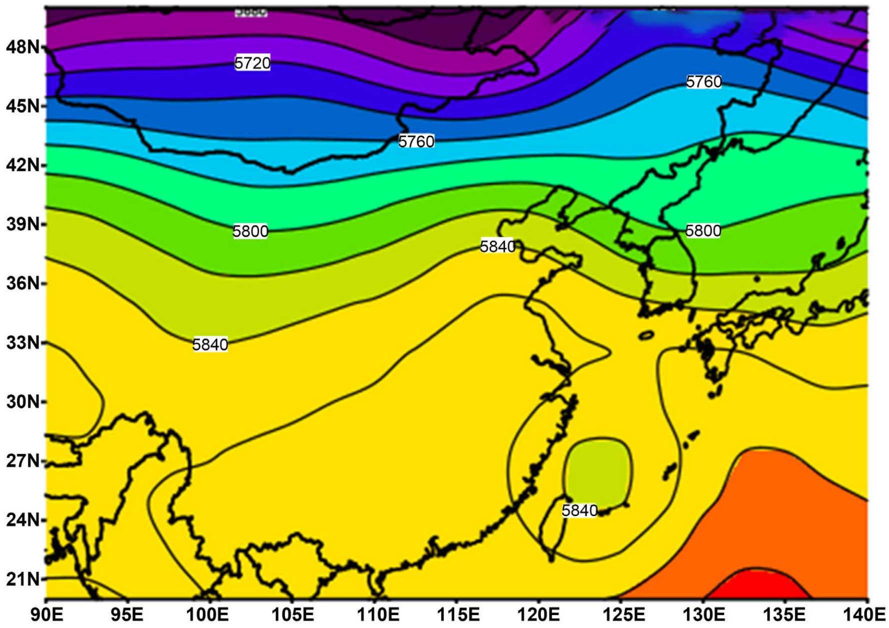

Figure 2. The 500 hPa geopotential height field at 08:00 on August 23, 2020.

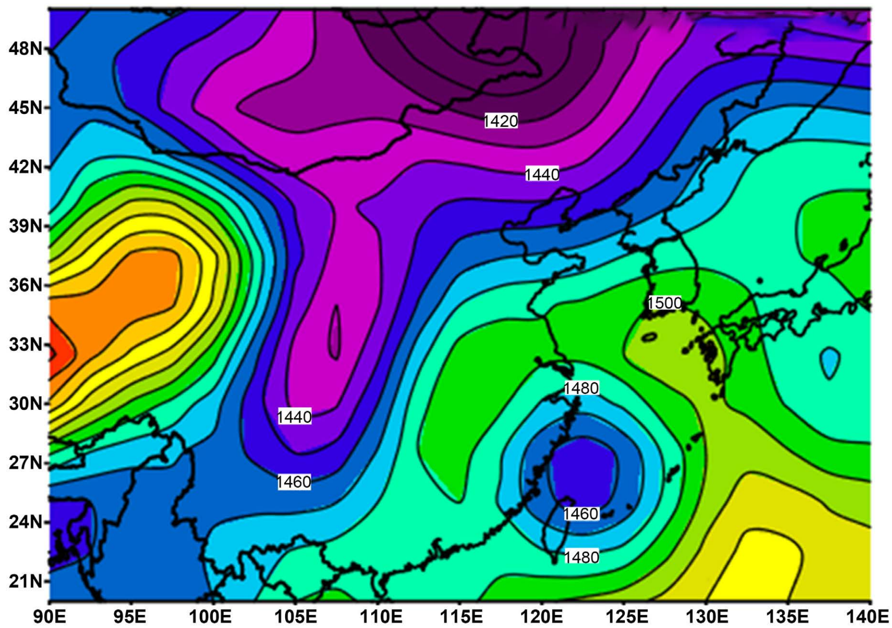

Figure 3. The 850 hPa geopotential height field at 08:00 on August 23, 2020.

in eastern Inner Mongolia and northern Hebei. The configuration of high and low air circulation conditions provides favorable dynamic conditions for precipitation, and the precipitation process in North China starts.

On August 24, the upper-level trough deepened eastward. As seen in Figure 4, the 850 hPa isobaric surface developed a low vortex system in the northeast of Inner Mongolia, and the shear line on its south side also moved eastward. There is significant wind shear on the east and west sides of the shear line, resulting in a strong intersection of warm and cold air near the shear line. The heavy precipitation was mainly concentrated in front of the trough and near the shear line on the isobaric surface of 500 hPa and near the shear line on the isobaric surface of 850 hPa, and it can be seen from **Figure 5** and **Figure 6** that the atmospheric precipitable water of the whole layer in this area reached 65 mm, and the relative humidity approached 100%, far exceeding the atmospheric conditions required for precipitation. Under the influence of the above system, heavy precipitation occurred in the eastern and northeastern parts of North China from west to east.

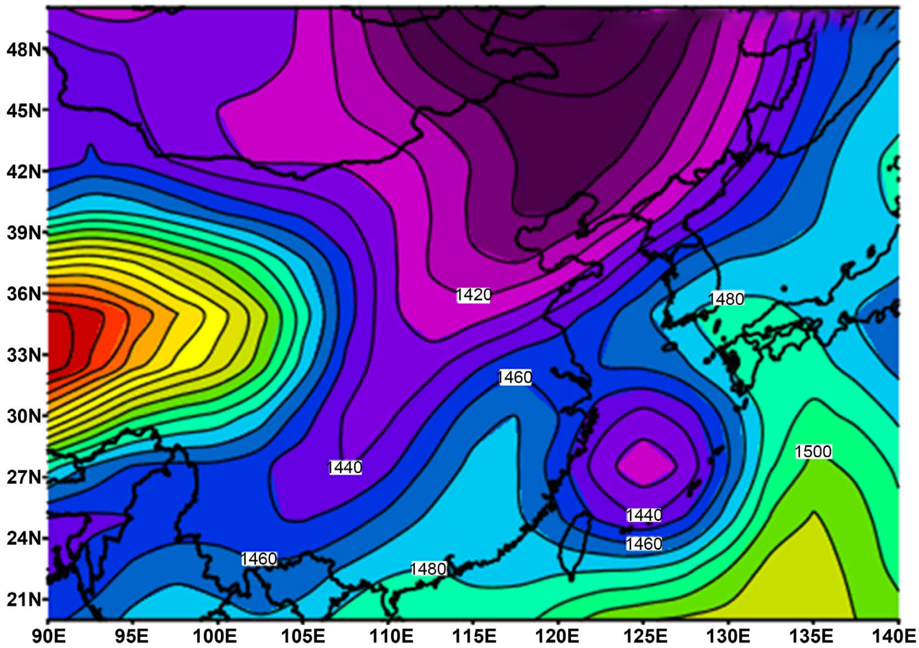

Figure 4. The 850 hPa geopotential height field at 08:00 on August 24, 2020.

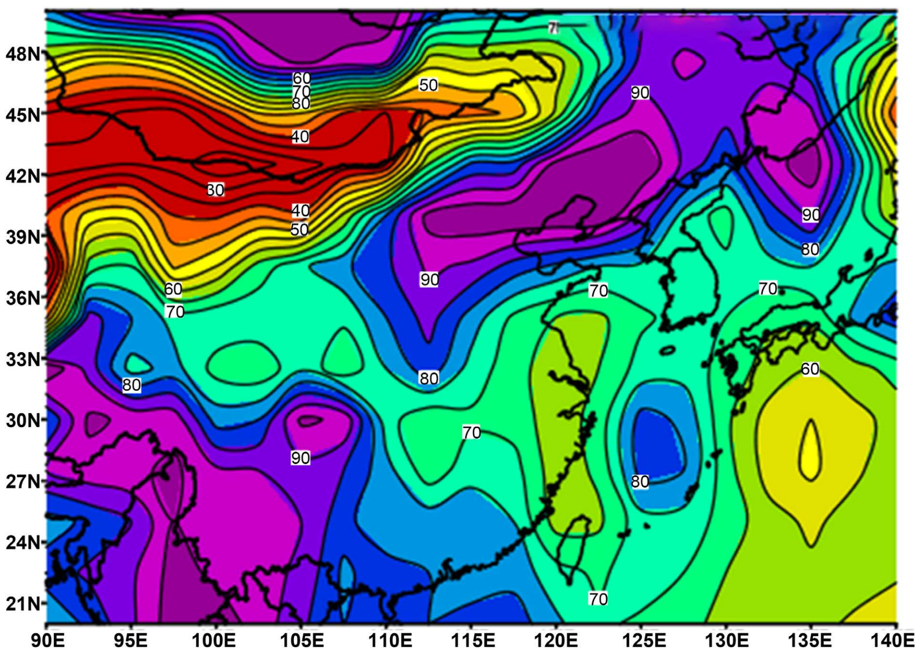

Figure 5. The 850 hPa relative humidity at 08:00 on August 24, 2020.

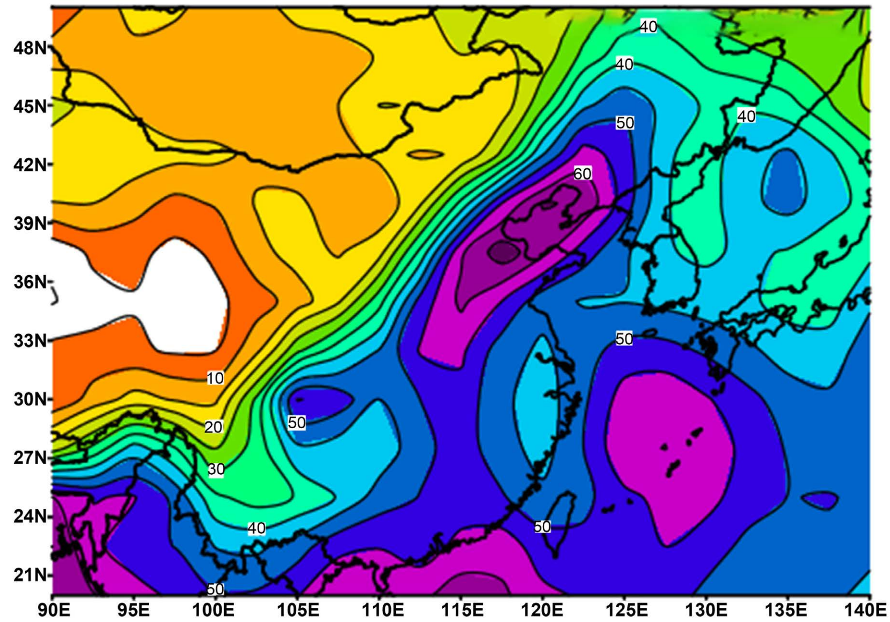

Figure 6. The 850 hPa atmospheric precipitable water at 08:00 on August 24, 2020.

On August 25, the upper-level trough on the 500 hPa isobaric surface weakened eastward, the heavy precipitation process over North China and Northeast China tended to end.

3.3. The Particularity of Water Vapor Conditions

The particularity of this process is mainly reflected in the water vapor transport source of heavy precipitation. In addition to a water vapor transport channel from the Bay of Bengal, Typhoon Bawei located in the northern part of the East China Sea also continuously transported water vapor from itself and around the East China Sea to North China and Northeast China. Due to the existence of suitable weather system configuration conditions, sufficient water vapor and energy supply, and the intersection of warm and cold air during the process, the average cumulative precipitation in North China and Northeast China from August 23th to 24th was relatively large.

4. Conclusion

Short-term heavy rainfall mainly occurs in summer (June to August) in China. The formation of short-time heavy precipitation requires sufficient water vapor and very strong upward movement. The favorable water vapor conditions in summer provide a good water vapor basis for the frequent occurrence of short-time heavy precipitation. Therefore, short-time heavy rainfall is more active in North China, which is susceptible to summer monsoon. At the same time, the temperature rose in summer, and multiple mesoscale convective systems were formed. The heavy rainfall in North China in August 23th to 24th 2020 was affected by the upper-level trough line, cold vortex and cold front, resulting in strong convective weather, which was also the main reason for the increase of the short-term heavy rainfall. In addition, the heavy rainfall was also affected by Typhoon Bawei. High temperature and humidity air from the ocean continued to rise and condense, moving to North China, and precipitability and air humidity over the sky continued to climb. Combined with the above meteorological conditions, the precipitation in North China increased by nearly 100 percent over the same period.

Conflicts of Interest

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

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