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Analysis of Heavy Precipitation Process in Eastern China from July 26 to 29, 2022

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Abstract

Based on the data of the National Climate Center of China and the NCEP of the United States, a heavy precipitation process in eastern China during July 26-29, 2022 was analyzed. The results show that: The precipitation process was formed under the influence of the low level southwest jet stream at the edge of the subtropical high. The eastward development of the low vortex and trough and the continuous strengthening of the upper level jet stream, combined with the influence of topographic convergence, provided extremely favorable conditions for the occurrence of the rainstorm.

Keywords

Southwest Jet, Low Vortex, Low Trough, Topographic Convergence, Rainstorm

1. Introduction

In recent years, global climate change has led to an increase in the frequency of extreme weather events, with heavy precipitation events being particularly prominent. As a country with vast territories and diverse climates, China has frequently been hit by heavy precipitation disasters, especially in the eastern coastal regions and inland river basins. These heavy precipitation events not only cause severe flooding disasters but can also trigger secondary disasters such as landslides and debris flows, posing a significant threat to people's lives, property safety, and socio-economic development. From July 26 to 29, 2022, a precipitation process occurred in eastern China. This process is mainly moderate to heavy rain, some areas have heavy rain, local heavy rain. Since July 2022, there have been five heavy rainfall processes in eastern China, and the rainfall in North China, Huanghuai and central and southern parts of Northeast China is 50% to 2 times more than the same period of the year. The rainfall overlapped

with the rainy areas from the previous period, causing a high risk of disaster, and the public should have been alert to the secondary disasters that could have been caused by the rainfall.

Regarding the analysis and forecast of heavy rain, the following studies have been conducted in recent years: Using NCEP 0.25˚ × 0.25˚ reanalysis data, automatic station encryption observation data, satellite and radar data, the characteristics of a local heavy rain process in northern Anhui on June 27-28, 2018 were analyzed (Cai et al., 2021); Using national Automatic weather Station and ECMWF-interim reanalysis data, this paper discussed the causes of continuous heavy rain along the Yangtze River in Anhui Province from July 1-4, 2016 from the perspective of the high and low jet stream. It was found that the upper-level jet stream showed a significant northward jump and increased intensity from July 1-4, 2016. The intensity of the low-level southwest jet reached the maximum value in 2016 (Liu et al., 2018). Using conventional meteorological data, NCEP reanalysis data and other meteorological data, the weather process of a rainstorm in Linyi, Shandong Province from August 13 to 14, 2020 was analyzed (Zhang et al., 2021). The southern Indian city of Chennai received more than 1200 mm of rain between November 5 and December 10, 2015, with record rainfall exceeding the previous 24-hour rainfall record (290 mm) on December 1 and 2, resulting in severe urban flooding. According to the analysis, the precipitation process is caused by the superposition of three synopse-scale systems of ocean water vapor tracks (Panda and Rath, 2022). In the autumn of 2016, Typhoon "Chaba" landed on the Korean Peninsula, causing record rainfall in the southeastern region of South Korea, among which the urban area of Yursandu suffered the most severe flooding disaster, with 319 mm of heavy rainfall in just 3 hours, which may be related to the mountainous terrain of southeastern South Korea and the warm sea temperature anomaly in the East Sea. Using the Weather Research and Forecasting (WRF) model, the effects of topography and SST anomalies on heavy rainfall are discussed through high-resolution numerical experiments (Cho et al., 2022).

Especially in recent years, heavy precipitation events in eastern China have shown a trend of increasing frequency and intensity. These precipitation processes are often closely related to complex atmospheric circulation backgrounds, water vapor transport conditions, and topographic effects. Therefore, conducting in-depth research into the formation mechanisms of these heavy precipitation events and revealing the underlying physical laws are of great significance for improving disaster warning capabilities and reducing disaster losses. However, the data of the latest rainstorm season were used in the above study, so there is some lag. In this study, data from the latest rainstorm season are used to supplement the validation of the above studies.

2. Data and Methods

2.1. Research Data

With the continuous improvement of dynamic climate model forecasting system

in China, the integration and referencability of climate model output data are also improving. At present, dynamic climate prediction model has become an important tool in short-term climate prediction business. The Monthly dynamic Extended forecast product (DERF2.0) released by China National Climate Center has been widely used in climate prediction business because of its long time and fine grid points.

NCEP reanalysis data is a global meteorological data database developed by the U.S. Environmental Prediction Center after assimilating and processing meteorological observation data from ground, ships, radiosonde, sounding balloons, aircraft and satellites. Including 1000, 925, 850, 700, 600, 500 Hpa and other 17 pressure layers of atmospheric temperature, humidity and wind speed and other atmospheric environmental parameters, the grid number is 144 * 73 cells, the resolution is 2.5 * 2.5, the coverage is global.

2.2. Research Method

The methodology employed in this study revolves around a comprehensive analysis of weather systems and their spatial distributions, which are fundamental to weather forecasting. Given the intricate nature of weather dynamics, this research focuses on empirical forecasting techniques rather than delving into the fundamental equations of weather prediction.

Specifically, two primary methods were utilized to gain insights into the heavy precipitation event. The Similar Situation Method involves a comparative analysis between the weather situations prevailing a few days prior to the onset of the current heavy precipitation event and those observed during historical heavy precipitation events. By identifying similarities in the evolution of weather systems and patterns, this method allows for the prediction of future heavy precipitation processes based on the established patterns and trends observed in the past. The work of Dong et al. (2008) served as a valuable reference in implementing this method.

The Synoptic Model Method involves a systematic review and synthesis of multiple similar weather processes recorded in the historical record. The aim is to identify and summarize typical weather models that have led to heavy precipitation events in the past. By comparing the current weather situation with these established models, predictions can be made regarding the likely evolution of the weather and the potential for heavy precipitation. The framework provided by Pei et al. (2012) guided the application of this method in the present study.

To clarify the theoretical framework underlying these methods, it is important to note that they are rooted in the understanding that weather patterns and systems exhibit certain recurring features and behaviors. By leveraging this historical knowledge and applying it to current weather observations, these empirical forecasting techniques aim to improve the accuracy and timeliness of precipitation forecasts, ultimately contributing to better disaster preparedness and mitigation efforts.

3. Result Analysis

3.1. Circulation Background Analysis

In late July 2022, the high pressure in the northern part of the Caspian Sea was weak and the low trough in Lake Baikal was strong. The area from eastern Siberia to the Far East is controlled by high pressure. The strength of blocking high is strong, which makes the upper trough move slowly to the east in the central and western Siberia. The meridional degree of the circulation in the middle and high latitudes of China has increased, showing a tendency of high in the west and low in the east. The circulation situation is conducive to precipitation in the Yangtze River basin and northern China. The development of sub-high may cause local drought disaster. The subtropical high continues to extend from the west to the north, connecting with the Iranian Plateau to the African Subtropical High. To some extent, the subtropical high cut off the water vapor transport in the south, and the South continued to have high temperature and little rain.

3.2. Storm Weather Analysis

From 08:00 on July 26, 2022 to 08:00 on July 30, 2022, a large-scale rainstorm weather process occurred in some parts of Beijing, Hebei, Liaoning, Jilin, Shandong, Jiangsu and other provinces and cities due to the combined influence of the eastward shifting upper-level trough, low-level shear line and low-level jet stream. From the weather situation at 20:00 on the 27th (Figure 1 and Figure 2), it can be seen that the subtropical high position is north to west, and the northern boundary has moved to Jianghuai and Jiangnan, bringing sunny and hot weather to the region. At 500 hPa in the middle and high latitudes (Figure 1), an upper air trough moves eastward to Shanxi and Hubei. There is a southerly airflow in front of the upper air trough, which will bring a large amount of warm and humid air. In the first 850 hPa of the trough (Figure 3), a persistent shear

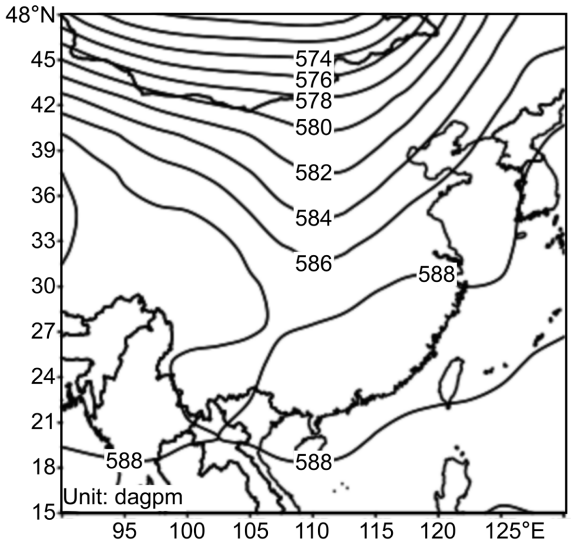

Figure 1. 500 hPa potential altitude at 20:00 on July 27, 2022.

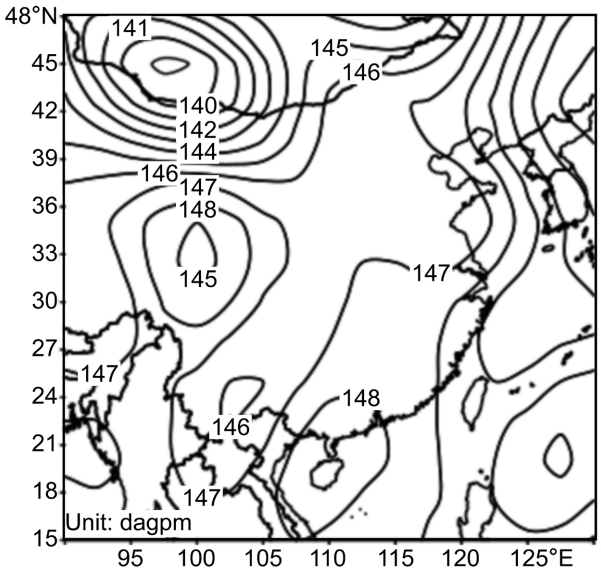

Figure 2. Potential altitude of 850 hPa at 20:00 on July 27, 2022.

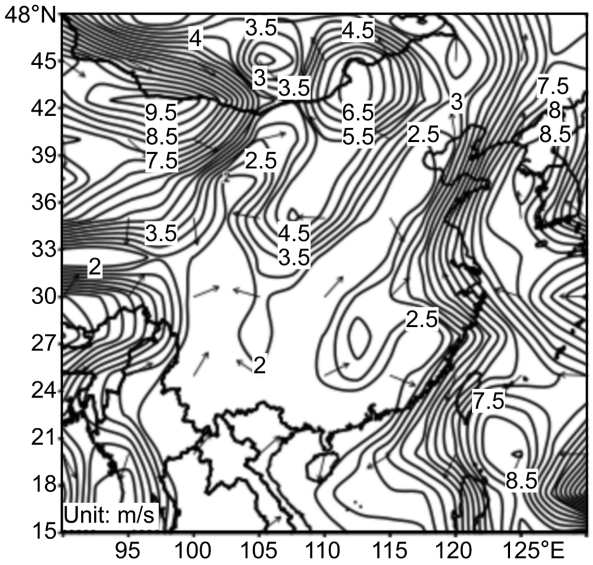

Figure 3. 850 hPa wind field at 20:00 on July 28, 2022.

line appeared, and in the second half of the night, a low vortex was generated and strengthened in the shear line, and there were sufficient water vapor conditions, thus forming a strong precipitation weather in the eastern part of China. The flow along the shear line is cyclonic circulation, which is conducive to upward movement and has great influence on the precipitation process. On July 28, the subtropical high over the Pacific Ocean was raised to the north, which blocked the eastward movement of the vortex to a certain extent, making the movement of the vortex system relatively slow. Coupled with the cooperation of water vapor, the rainfall lasted for a long time and the accumulated rainfall was large. According to the weather situation at 20:00 on the 28th (**Figure 4** and **Figure 5**), the low vortex shear line moved to Liaoning and Shandong, and the

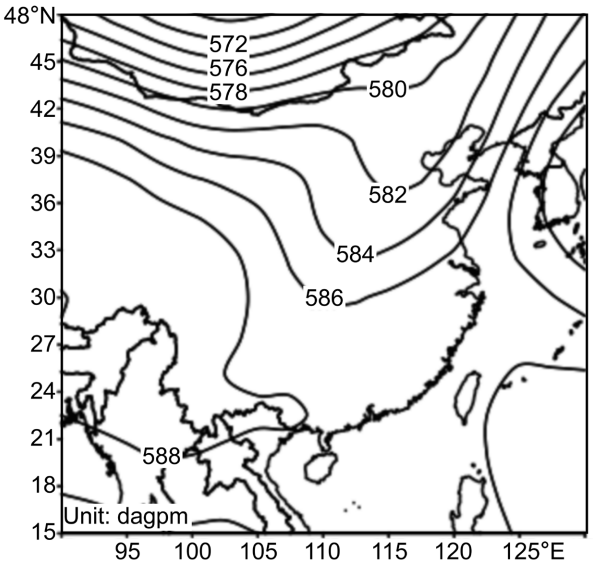

Figure 4. Potential altitude of 500 hPa at 20:00 on July 28, 2022.

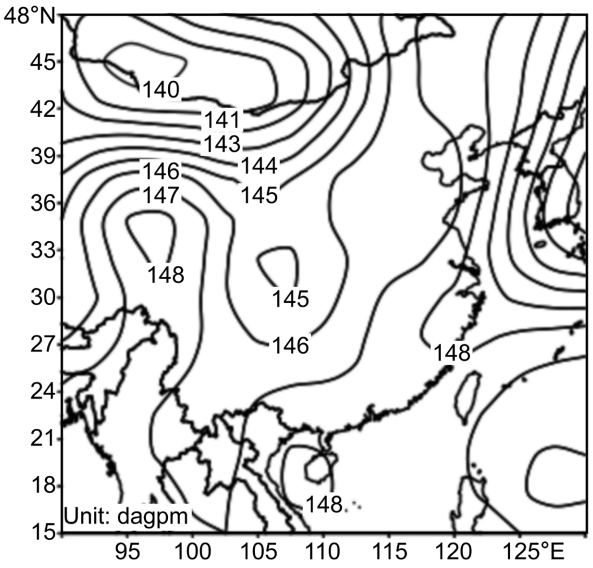

Figure 5. Potential altitude of 850 hPa at 20:00 on July 28, 2022.

low-level jet over Liaoning was obviously strengthened, and there was a strong convergence area on the eastern side of the jet stream.

3.3. Analysis of Water Vapor and Ascending Motion

The Bohai Bay provides abundant water vapor for the precipitation process. At 20:00 on July 27 (**Figure 6**), the precipitable water of the whole layer in Hebei, Henan and other places was above 40 mm. At 20:00 on July 28 (**Figure 7**), the precipitable water of the whole layer in western and northern Liaoning exceeded 50 mm. Under the influence of the southeast airflow, there is continuous water vapor transport in the low level, which has a large amount of water vapor and strong convective unstable energy, which provides favorable conditions for the

formation of heavy rain. Under the influence of the above dynamic system, abundant water vapor supply and certain unstable energy conditions, combined with the lifting effect of Taihang Mountain topography, heavy rain occurred in central and southern Hebei and northern Henan. The precipitation process has the characteristics of frontal precipitation, mainly stable precipitation, precipitation duration is relatively long, resulting in heavy rain and heavy rain weather in many areas.

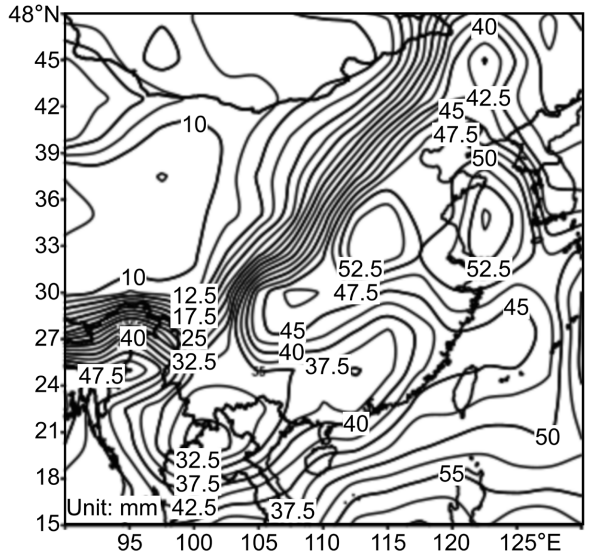

Figure 6. Precipitable water at 20:00 on July 27, 2022.

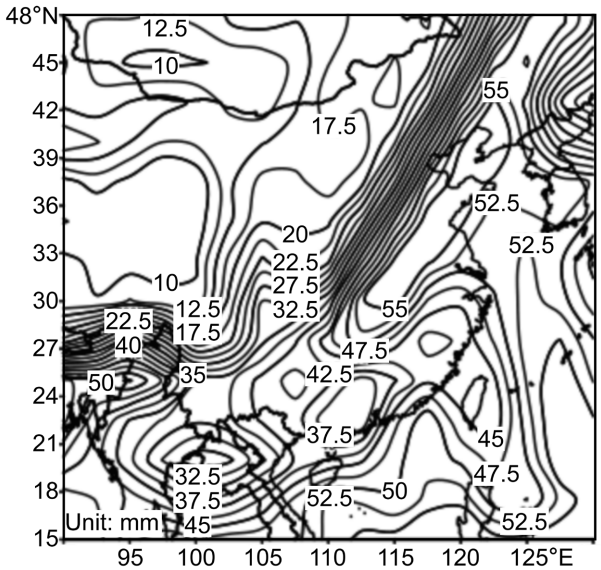

Figure 7. Precipitable water at 20:00 on July 28, 2022.

4. Conclusion

In conclusion, the analysis of the heavy precipitation process in eastern China from July 26 to 29, 2022, reveals that the rainstorm was predominantly driven by

the low-level southwest jet stream situated at the periphery of the subtropical high. The eastward progression of the low vortex and trough, coupled with the continuous intensification of the upper-level jet stream, created highly conducive conditions for the precipitation event. Furthermore, the influence of topographic convergence significantly contributed to the occurrence and intensity of the rainstorm. This study underscores the importance of considering multiple factors, including large-scale atmospheric circulation patterns, water vapor availability, and topographical effects, when analyzing and predicting heavy precipitation events. The findings provide valuable insights into the mechanisms underlying such extreme weather events and can inform future research and forecasting efforts aimed at improving disaster preparedness and response strategies.

Conflicts of Interest

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

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