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Analysis of Extreme Precipitation Weather Process in Henan during July 17-22, 2021

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Abstract

To learn more about the unusually heavy rainfall in central China, this research uses the monthly climatic data, weather map information and US NCEP re-analysis data to analyze the atmospheric circulation, precipitation and weather situation of this extreme precipitation weather process in Henan during July 17-22, 2021. The results show that the precipitation process is affected by the joint action of the subtropical high, the continental high, the low vortex, the low-level jet, the typhoon "In-fa" and other multi-scale systems in the middle and low latitudes. This precipitation process was also affected by the topographic uplift and blocking of Taihang Mountain and Funiu Mountain.

Keywords

Extreme Precipitation Weather, Henan Province, Subtropical High, Typhoon "In-Fa", Topographic Action

1. Introduction

Since July 17, 2021, a historically rare continuous rainstorm occurred in Henan Province. According to data released by the Zhengzhou Meteorological Bureau, from 20:00 on July 17 to 20:00 on July 20, the total accumulated rainfall in Zhengzhou was 617.1 mm, reaching the total rainfall level of the previous year. The hourly rainfall of 201.9 mm on July 20th created a new record of the hourly rainfall in mainland China. This ultra-routine heavy rainfall caused severe flood disasters in many regions of Henan, the subway was suspended, and the railway, highway, and civil aviation transportation were seriously affected. As of 12:00 on August 2nd, the rainstorm caused 14.5316 million people in 1663 towns and townships in 150 counties (cities, districts) in Henan Province. In the disaster, 302 people died and 50 people disappeared. There were also 933,800 people

transferred and 1.4708 million people resettled in emergency. There were 30,106 households (89,001 houses) collapsed in this rainstorm disaster. The area of crops affected was 8.72 million mu, and the area of crops destroyed was 3.8 million mu. The direct economic loss was 114.269 billion yuan.

Many scientists have done a lot of research of rainstorm. Zhang et al. (2014) found that the four most common radar echo evolution patterns of MCSs (mesoscale convective systems) leading to short-term intense precipitation are the zonal, meridional, turning (from zonal to meridional), and combined patterns. MCSs are linear in the zonal and meridional patterns and in 70% of the turning pattern, whereas the combined pattern is oval. MCSs move eastward or southward in the zonal pattern, eastward or westward in the meridional pattern, and toward all directions in the combined pattern. That is, MCSs can move northward only in the combined pattern. Yuan & Zhang (2020) pointed out that the precipitation is a convective short-time heavy precipitation process under the joint action of high and low layer system. This precipitation is a convective heavy precipitation process under the interaction of high and low layer systems. The middle and upper troposphere of the double stream is dispersed, and the lower layer has cyclonic convergence. The cold and warm air flows meet in the precipitation area, releasing the unstable energy in the middle and low layers of the troposphere, resulting in this heavy precipitation. The CAPE (Convective Available Potential Energy) index can reflect the accumulation of energy and has certain instruction significance for the occurrence of rainstorm. Guo et al. (2012) pointed out that the annual precipitation and precipitation days have decreased in 1961 to 2009, and annual amplitude is bigger. Precipitation and precipitation days show declining trends in springs and autumns, while increasing trends in summers and winters. Extreme precipitation events have increased during the study years. In the space, the trend of the rainfall and extreme precipitation events are upwards in the east and downwards in the west in the research area. Precipitation days mainly show a decreasing tendency in whole area. Chen et al. (2007) indicated that the strong vapour transportation band coming from Philippines and across South China Sea and arriving to the middle-east China is composed of two branches. The first one was from Pacific vapor transport center and it moved westward along the south region of equator. Zhang et al. (2017) analyzed the weather conditions and physical characteristics of Super Typhoon Rammasun (No. 1409), which caused special strong wind and severe rainstorm in Guangxi, and found that Typhoon Rammasun offshore sudden strengthening in one of the main reasons is that loop pressure ridge superimposed into the westward extension of subtropical high, to make rapid strengthening of the subtropical high. Rammasun from the Qiongzhou Strait into the northern Gulf, therefore the Strait of short passages and both sides belong to the low zone, friction consumption smaller, that is the main reason what is able to maintain the strength of the super typhoon, when Rammasun into the Beibu Gulf. Diagnostic analysis shows that Rammasun before entering the northern Gulf and into the Beibu Gulf later, vorticity weakened, divergence and vapor flux divergence

changed are smaller, meanwhile, vertical ascent speed and latent heat transport both increased, which is important reason of severe rainstorm caused by Rammasun.

The above research has some research on the formation mechanism and early warning mechanism of the heavy rainstorm. However, the time of the above research and the data used are relatively earlier. From a novelty point of view, in addition to using new data, the study also focused on this new and rare weather process. The above literature review focuses on the topic of precipitation. This paper will supplement the existing knowledge system to some extent. This research uses the data of Henan Province in 2021. The year of the data is new. Therefore, this research has good timeliness.

2. Data and Methods

2.1. Data

The research uses the monthly climatic data, weather map information during July 17-22, 2021, and US NCEP re-analysis data.

1) The 500 hPa geopotential height mean field in the middle and late July 2021 of the National Climate Center (http://cmdp.ncc-cma.net/cn/index.htm).

2) The NECP re-analysis data for this rainstorm process is provided by the NOAA Physical Sciences Laboratory (https://psl.noaa.gov/).

2.2. Methods

Weather analysis method and literature reading method was used in this study. This research uses precipitation data to analyze the distribution of rainfall, and uses humidity and wind speed data to analyze the water vapor and power conditions of this rainstorm (Zhu et al., 2007). According to the above analysis, this research combines the weather map to comprehensively analyze the weather process in July 2021 on Henan Province.

The references of this research come from CNKI, OALib (http://www.oalib.com). Through reading and studying a large number of literature, learn about the analysis of related weather processes, and establish a general analysis idea based on the actual situation of Henan Province.

3. Results and Analysis

3.1. Overview of Atmospheric Circulation and Precipitation

In mid July, 2021 (**Figure 1**), the form of high-latitude circulation over the high latitudes over the Eurasian continent was two high-pressure ridges and a low-pressure trough. Two high-pressure ridges were located in the western part of Eastern European Plain and over the sea of Ehiecker. This low-pressure trough was located near the Lake Balkham. The spine of the high-pressure ridge on the west side of the subtropical high retreated near 100˚E, and the control range expanded significantly to the north. At the same time, the continental high, located in Central Asia to North Africa, has also extended to the Qing-

hai-Tibet Plateau to the eastward, deepened to the inland regions of China, and confronted the subtropical high over the Northwest Pacific Ocean. Between the two high pressures was a wide low pressure zone. The stability of the two high pressures provided favorable conditions for the low vortex and low-altitude cutting systems in North China, Central China, Southwest, and Northwest of the low-pressure zone.

In late July, 2021 (Figure 2), the low-pressure trough located above the Lake Balkham weakened. A closed low vortex center appeared in the east of Lake Baikal, and its low-pressure trough extended south to central Inner Mongolia. Subtropical high retreated to the sea. The continental high in Central Asia also obviously retreated to the west of 65˚E. The central and eastern regions of China were in a wide low-pressure trough area.

Affected by the two landing typhoon "In-fa" and "Cempaka", Zhejiang, Shanghai, Jiangsu, Anhui, Shandong and other eastern coastal provinces and cities, and South China appeared in the process of heavy precipitation.

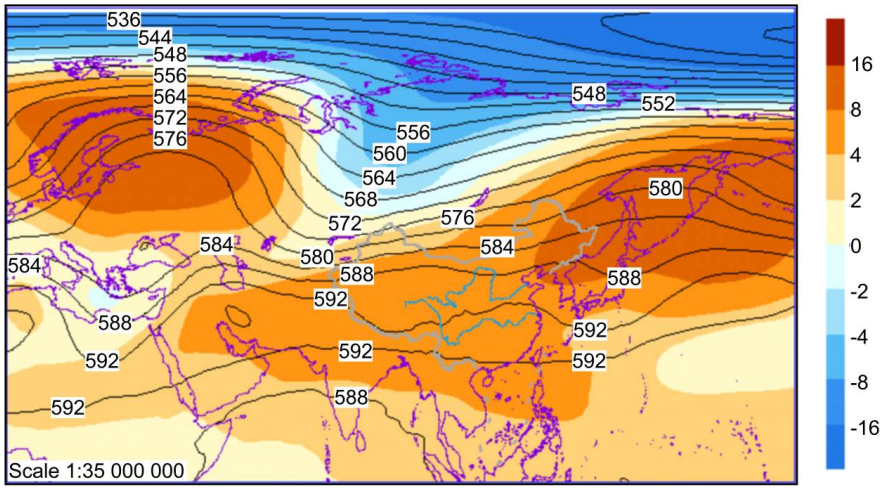


Figure 1. 500 hPa geopotential height mean field in mid July, 2021.

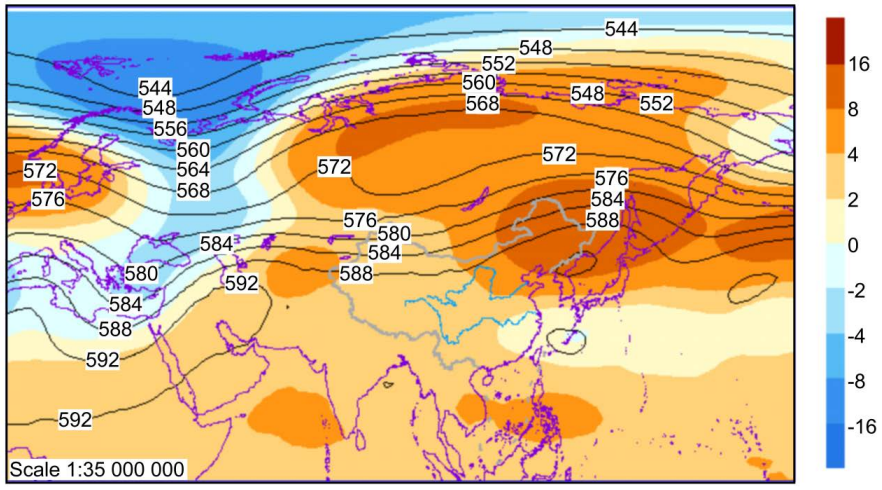
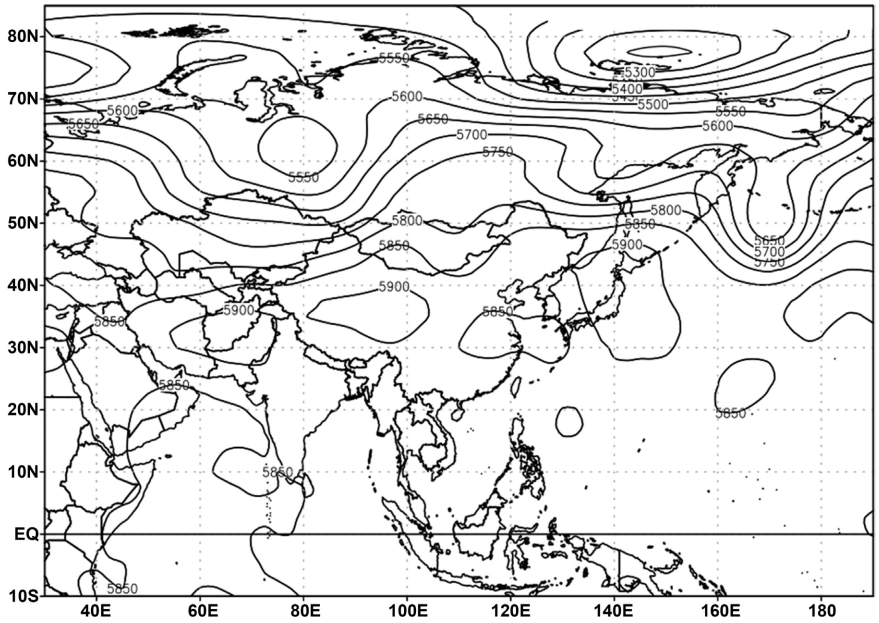


Figure 2. 500 hPa geopotential height mean field in late July, 2021.

3.2. Analysis of the Weather Situation of Precipitation Process

Under the common effect of multiple-scale systems such as subtropical high, low vortex, low level jet stream, a persistent extreme rainstorm occurred in Henan on July 17-22, 2021. In central and Northern Henan, southeastern Shanxi, central and southwestern Hebei, there were persistent extreme rainstorms rarely seen in history.

From July 17 to 18 (**Figure 3(a)** & **Figure 3(b)**), the ridge line of the western segment of the subtropical high was raised to about 40˚N, and the 5850 & 5900 gpm height line covered most areas of Heilongjiang, Jilin and Liaoning. The



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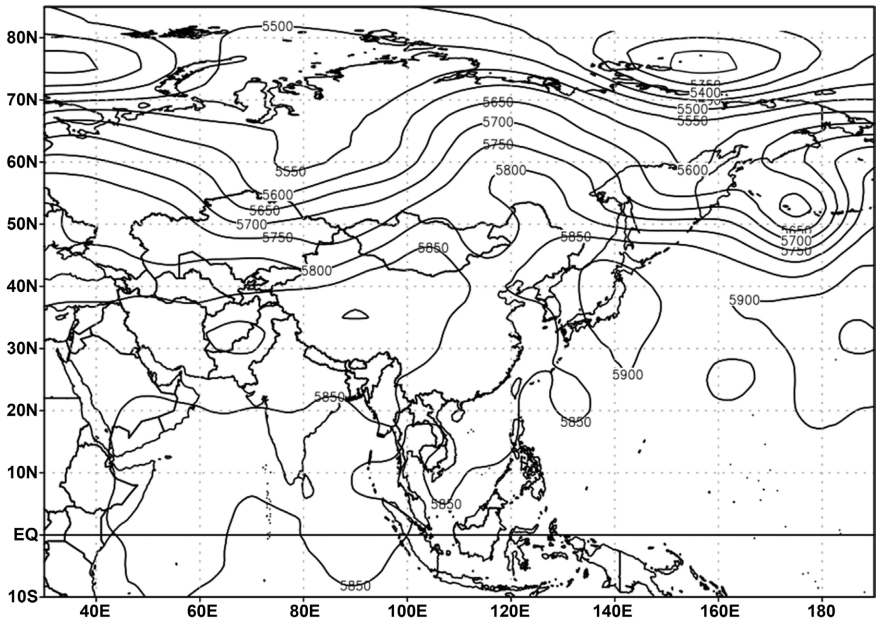

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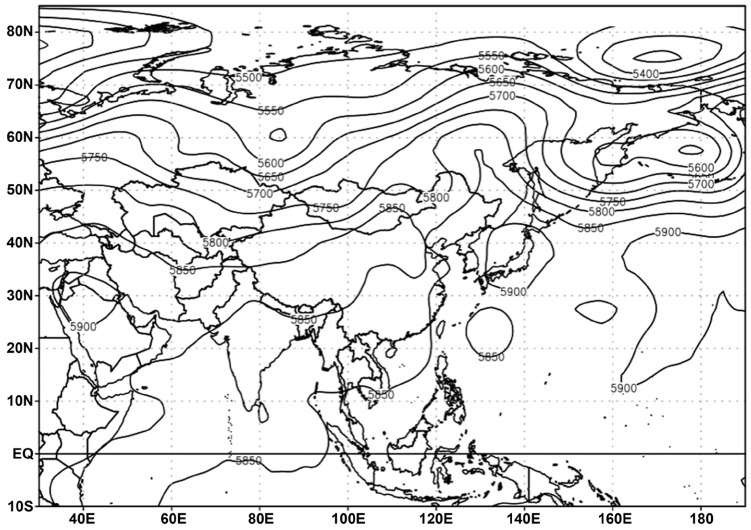
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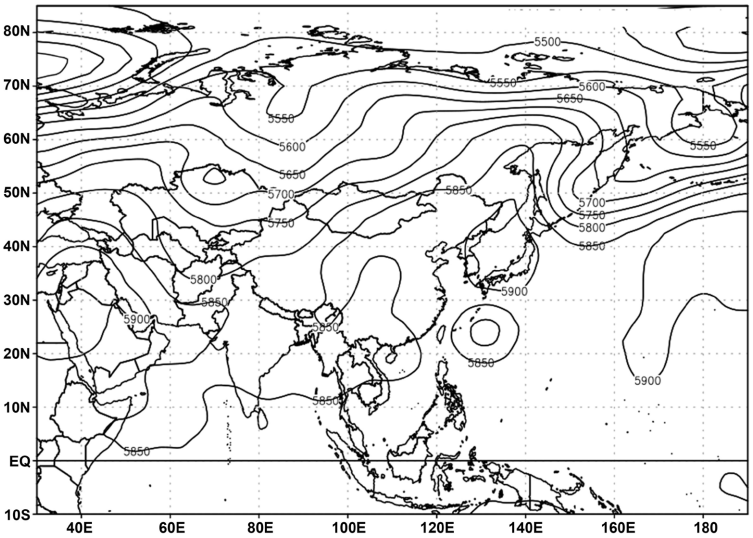
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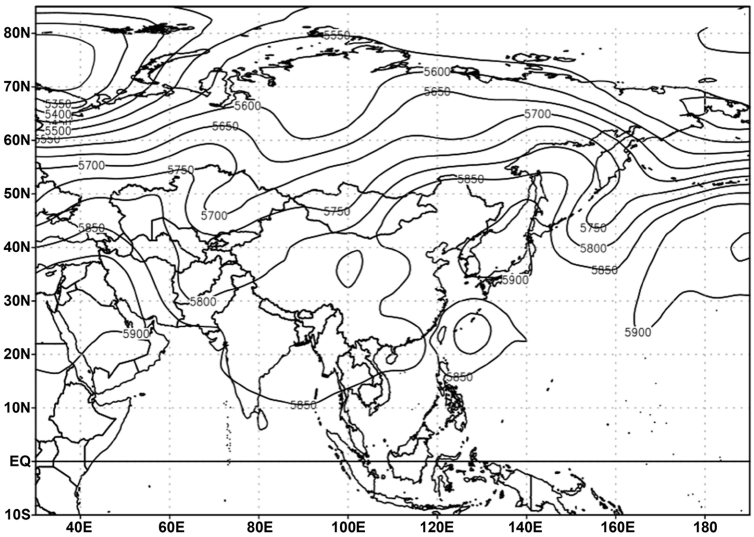
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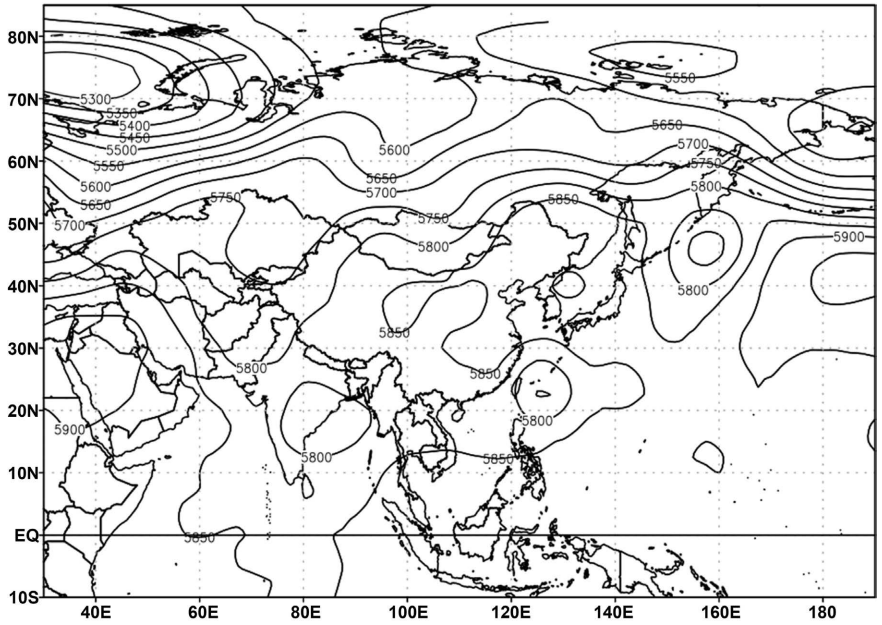

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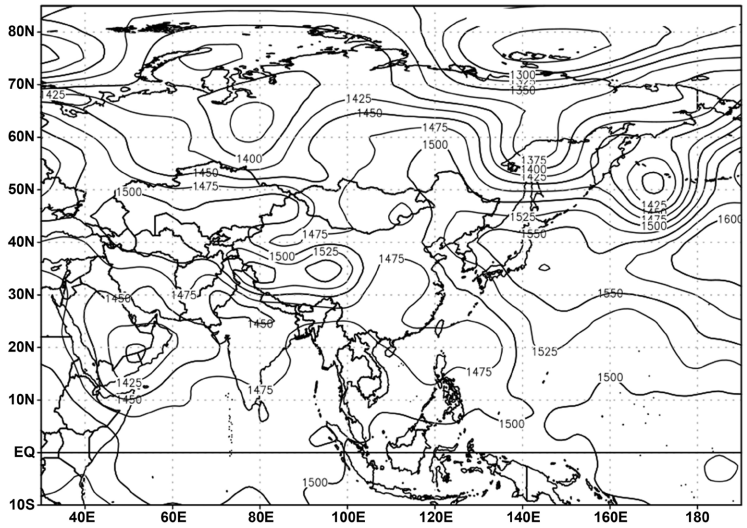
Figure 3. 500 hPa geopotential height in Asia at 08:00 on July 17 (a), July 18 (b), July 19 (c), July 20 (d), July 21 (e), and July 22 (f), 2021 (Beijing time, the same below).

continental high over the Qinghai Tibet Plateau is strong to the East and forms a circulation situation facing the subtropical high from east to West. There was a broad weak low pressure zone between the two high pressures. The 850 hPa vortex center is located at the junction of Anhui and Henan provinces (**Figure 4(a)** & **Figure 4(b)**). An inverted trough extended from the vortex center to the north of Henan and the south of Hebei. The precipitable water in Northern Henan and Southern Hebei was 50 - 60 mm (**Figure 5(a)** & **Figure 5(b)**). The combined action of the vortex trough, the periphery of the subtropical high and the southeast warm and humid air flow on the north side of the vortex, combined with the comprehensive influence of the Taihang mountain topography, makes the heavy rainfall appeared in the Northern Henan and Southern Hebei.

From July 19 to 21 (**Figures 3(c)-(e)**), with the weakening of the continental high and the westward extension of the subtropical high, the low vortex originally located over the eastern part of Henan moved slowly westward. The center first entered the northern part of Hubei, and then entered the western part of Henan. The strength weakened first and then strengthened. There was a reverse trough shear on the north side of the low vortex. The position of the subtropical high was stable in Japan Island northeast China, but the ridge of the high pressure over Northeast China was weakened, and the ridge of the subtropical high extending from the sea of Japan to East China was strengthened. At the same time, the strong tropical storm "In-fa" moved into the offshore, approaching the southeast coast of China in the northwest direction.

On July 19, the vortex center was located in the north of Hubei (**Figure 3** & **Figure 4(c)**). Under the joint influence of the peripheral air flow on the east side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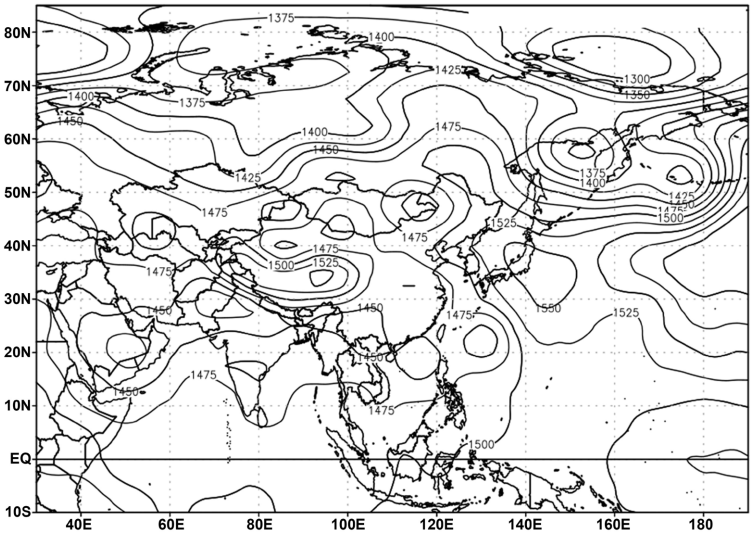
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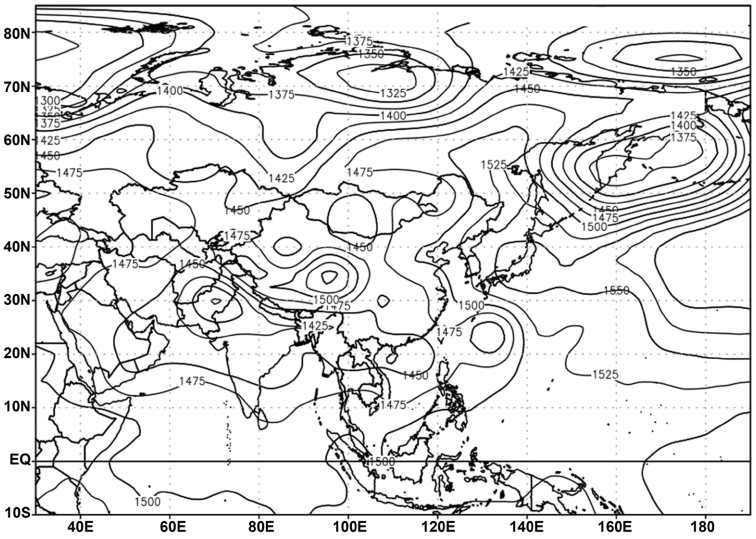
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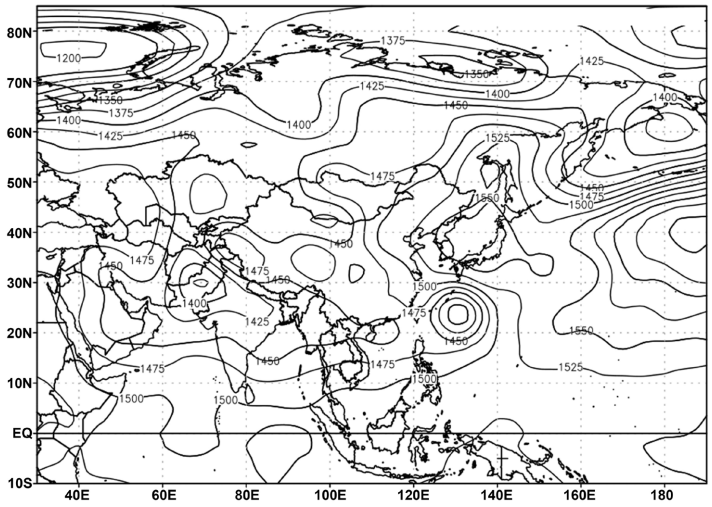

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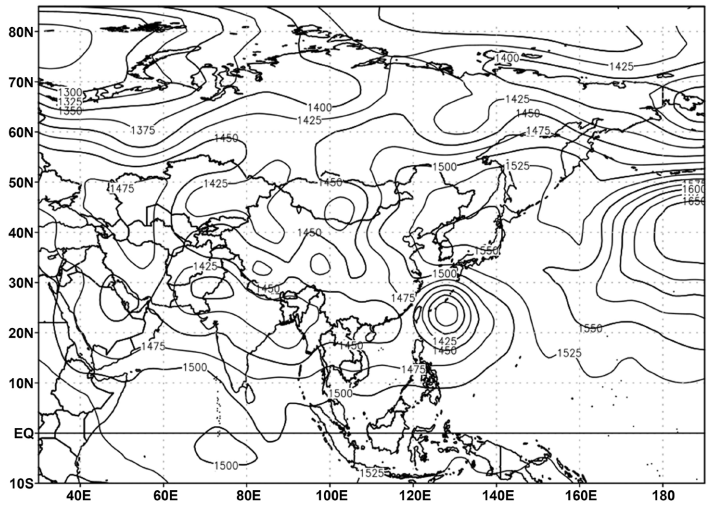

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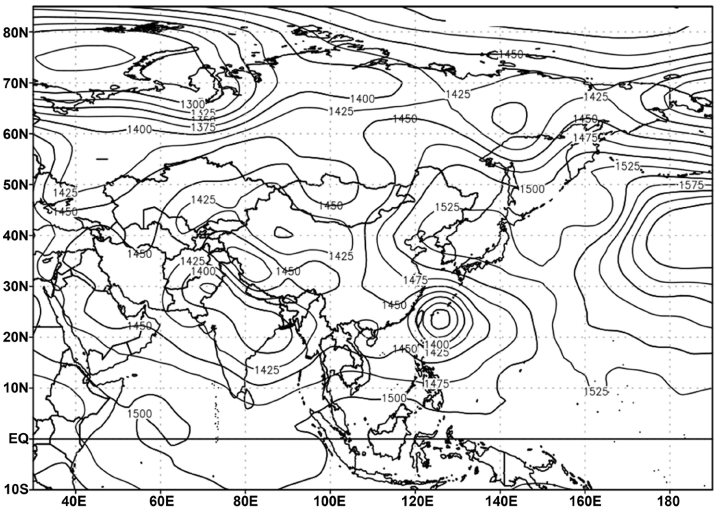

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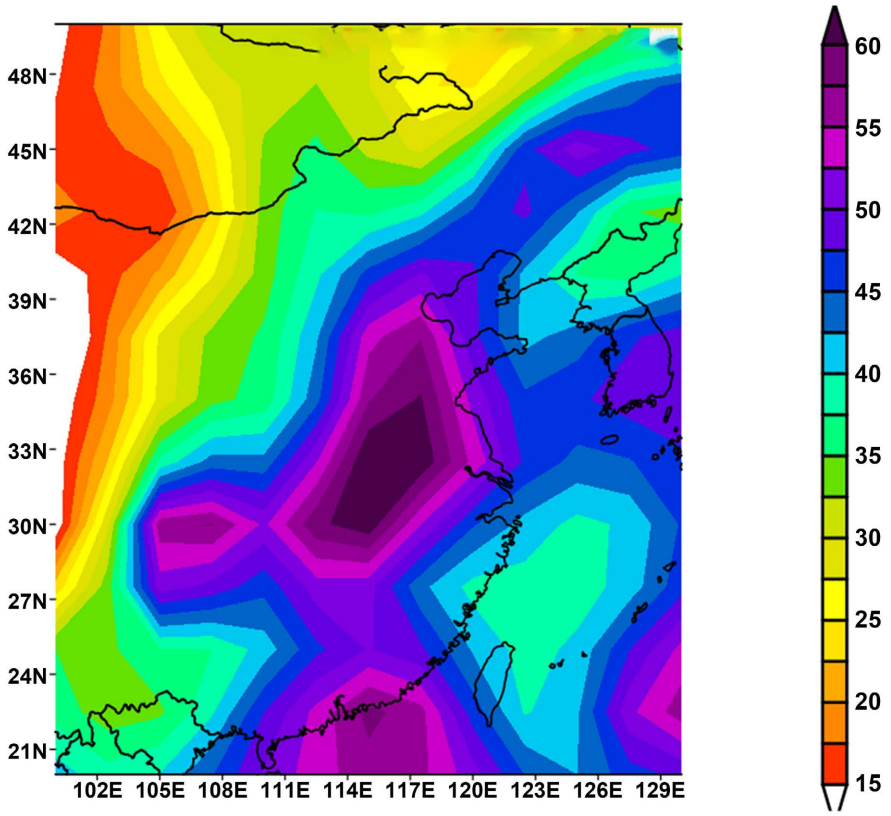
Figure 4. 850 hPa geopotential height in Asia on July 17 (a), July 18 (b), July 19 (c), July 20 (d), July 21 (e), and July 22 (f), 2021.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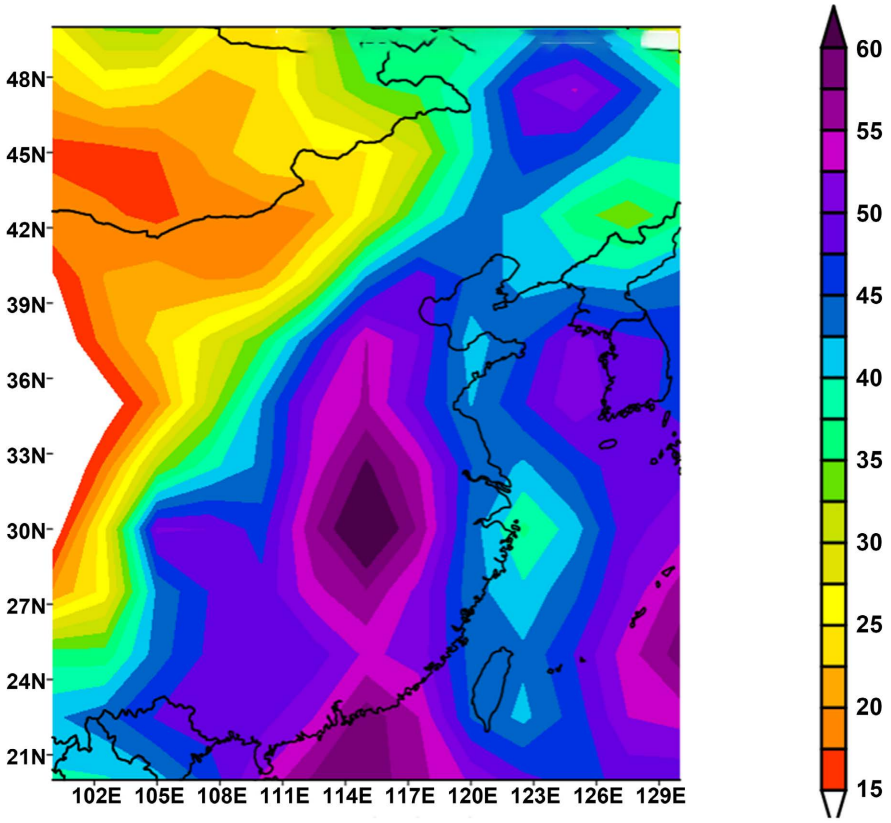
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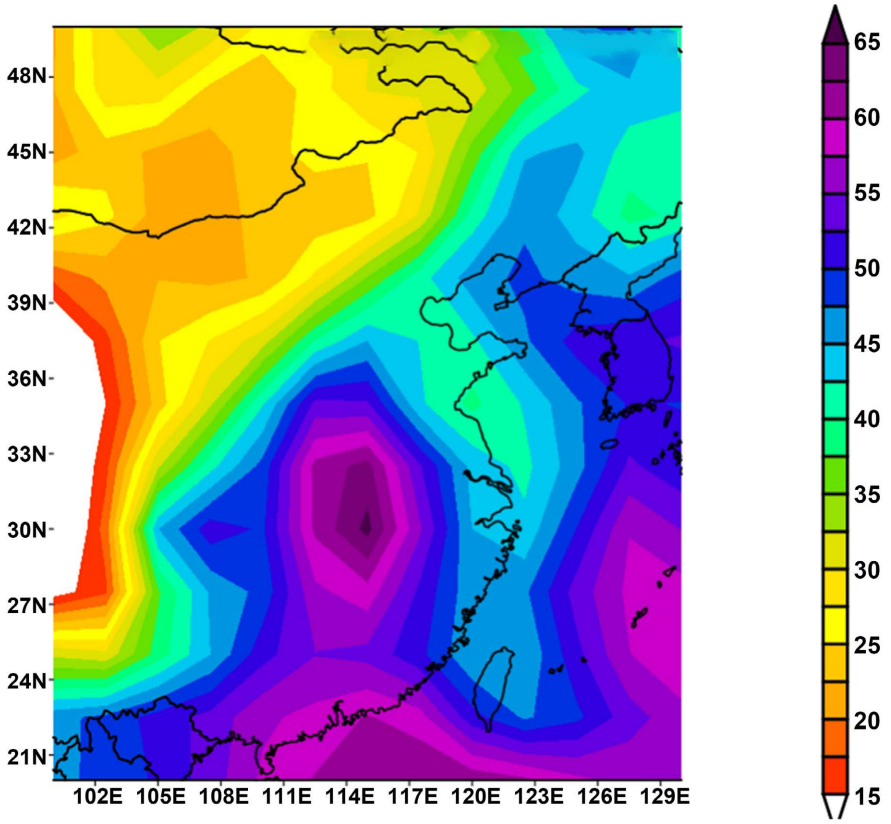
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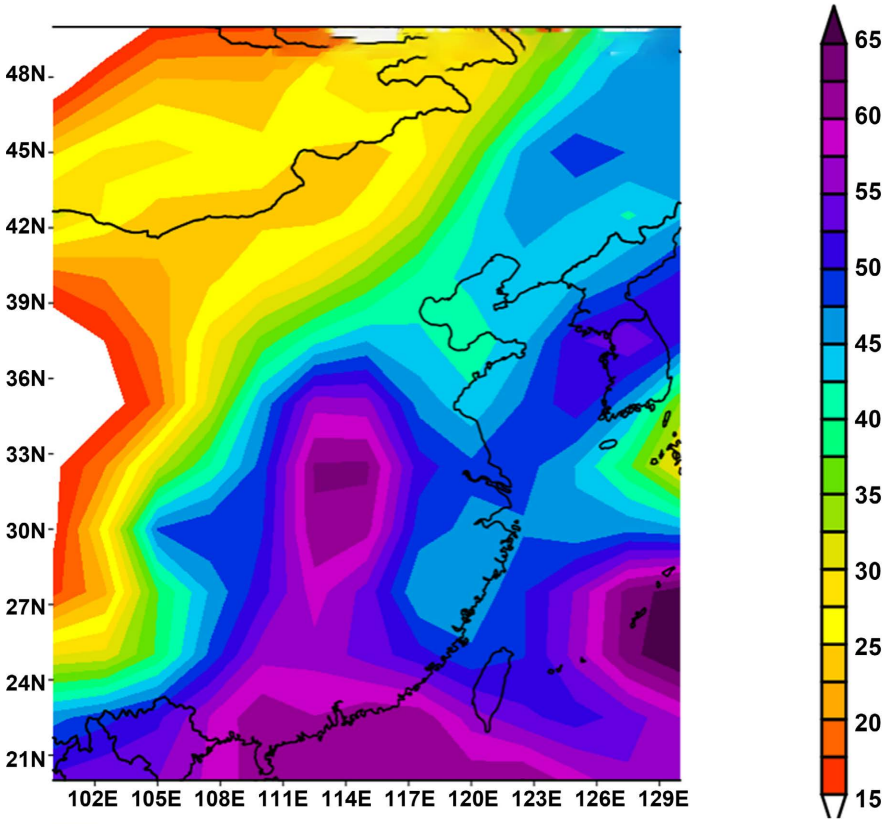
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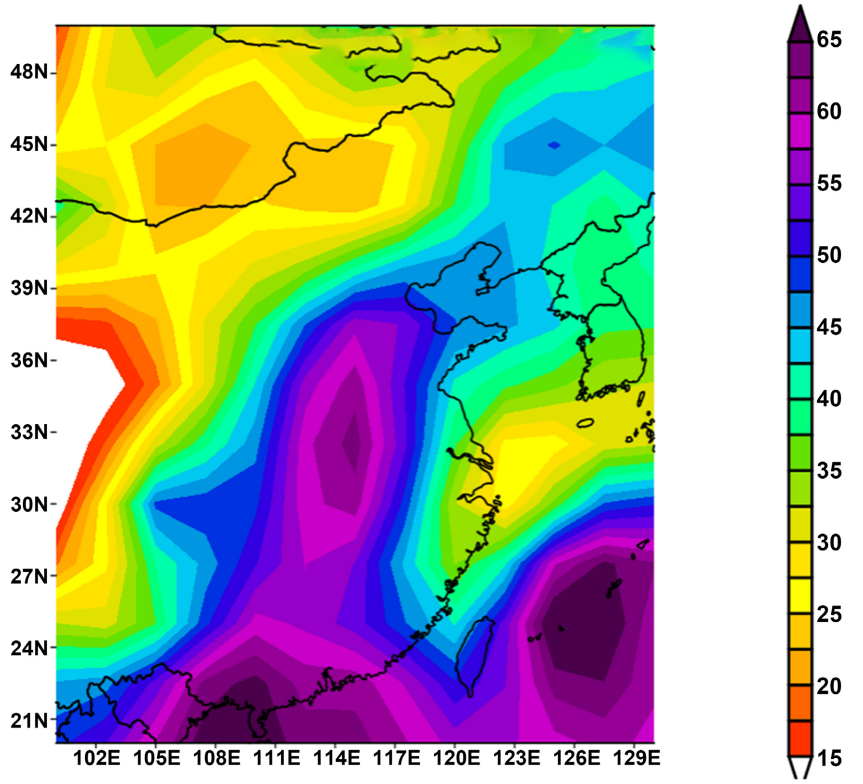

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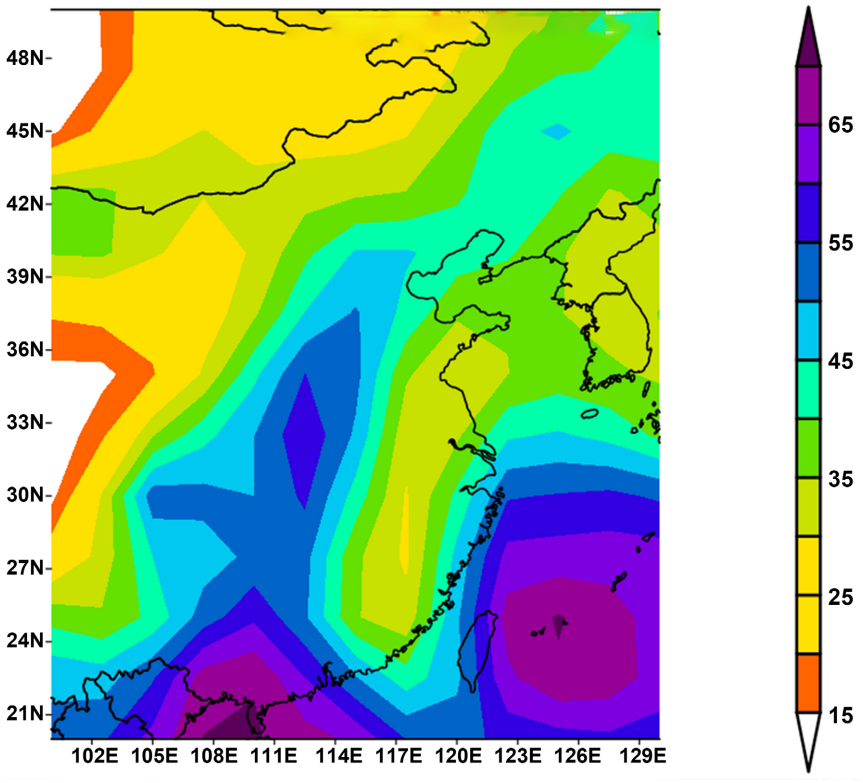

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Figure 5. Precipitable water on July 17 (a), July 18 (b), July 19 (c), July 20 (d), July 21 (e), and July 22 (f), 2021.

of the vortex, the northwest side of the "In-fa" and the western side of the subtropical high, the air over the Huanghuai Region was controlled by a large range of easterly and Southeast winds. Due to the blocking and uplifting of the terrain along the Taihang Mountains to Funiu Mountain in western Henan, a large amount of warm and humid air accumulated in Northern Henan. The convective system was formed in the southeast of Henan Province. Guided by the southeast wind, it moved slowly to the northwest and became organized.

On July 20 (**Figure 3** & **Figure 4(d)**), the location of the low vortex in western Henan was relatively stable, but its intensity increased significantly. The strong tropical storm "In-fa" strengthened to the typhoon level, increasing the pressure gradient between it and the subtropical high, and the southeast wind between them strengthened, forming a low-level jet. The northern part of Henan was just in the left front of the southeast low-level jet. Under the coordination of good dynamic conditions and water vapor conditions (**Figure 5(d)**), the heavy rain continued in Northern Henan.

On July 21 (**Figure 3** & **Figure 4(e)**), the low vortex in Henan slowly moved northward and weakened, the southeast low-level jet slightly lifted northward, and the low vortex trough also lifted northward. This made the influence range of the whole rainstorm belt gradually developed northward and expanded to the south of Hebei (**Figure 5(e)**).

On July 22 (**Figure 3** & **Figure 4(f)**), the subtropical high retreated to the East, and the vortex trough gradually weakened and disappeared. Heavy rainfall was sporadically distributed in Henan and Shanxi, so far this round of persistent extreme precipitation process tended to end (**Figure 5(f)**).

4. Conclusion

In general, this precipitation process was affected by the joint action of the subtropical high, continental high pressure, low vortex, low-level jet, typhoon In-fa and other multi-scale systems in the middle and low latitudes, and the influence of the terrain of Taihang Mountain and Funiu Mountain was superimposed to form an extremely heavy rainfall process.

Conflicts of Interest

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

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