Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2022, 10, 184-193
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Analysis of Rainfall Weather Process in Most of China from 3-6 October, 2021

Yifei Liu

College of Aeronautical Meteorology, Civil Aviation Flight University of China, Guanghan, China
Email: 1973274922@qq.com

How to cite this paper: Liu, Y. F. (2022). Analysis of Rainfall Weather Process in Most of China from 3-6 October, 2021. *Journal of Geoscience and Environment Protection, 10,* 184-193.
https://doi.org/10.4236/gep.2022.1011012

Received: September 5, 2022
Accepted: November 25, 2022
Published: November 28, 2022

Abstract

Heavy rain is a common abnormal weather in China, which is prone to major natural disasters such as floods. By using China National Climate Center's DERF2.0 (the second-generation product of monthly dynamic extended ensemble prediction) models and NCEP (National Centers for Environmental Prediction) data, and using synoptic and dynamic methods and other research methods, the rainfall weather process in most of China from October 3-6, 2021 is analyzed. The results show that: 1) this process had a long duration, large cumulative rainfall and strong extreme. 2) The warm and wet flow and the cold air intersected in the central and western regions of China and Northeast China, which resulted in a regional rainstorm process within ten days. 3) There was a low-level jet moving from Guizhou and Hunan to the south of Northeast China, bringing a lot of water vapor. To sum up, the rainfall process of this round has a certain relationship with the adjustment of atmospheric circulation.

Keywords

Rainfall Weather Process, Subtropical High, Warm and Wet Flow, Cold Vortex, Low-Level Shear Line

1. Introduction

From 3 to 6 October, 2021, a regional rainstorm occurred in Sichuan Basin, the eastern part of Northwest China to the southern part of Northeast China, North China and the northern part of Huanghuai Area. This process had a long duration, large cumulative rainfall and strong extreme. During this period, the accumulated precipitation in northern Sichuan Basin, eastern Gansu Province, central and southwestern Shaanxi Province, central Shanxi Province, central Hebei Province, central Tianjin Province, northern Henan Province, northern

Shandong Province, central and eastern Liaoning Province and southeastern Jilin Province was 100 - 250 mm. The accumulated precipitation in Guangyuan City and Bazhong City of Sichuan Province, Hanzhong City of Shaanxi Province, Dandong City and Benxi City of Liaoning Province was 300 - 400 mm, and that in Nanjiang County, Bazhong City, Sichuan Province was 487 mm. The daily precipitation of 155 national weather stations of China exceeded the local October extremum.

Previous researchers conducted the analysis as follow. Liu et al. (2013) pointed out that the excessive precipitation in Northeast China, North China and the south of the Yangtze River in the fall of 2012 was mainly related to the anomalous southeasterly wind water vapor transport in the middle and high latitudes of the Northwest Pacific, the southwesterly warm and wet water vapor transport on the west side of the subtropical high in the Western Pacific and the SST (Sea Surface Temperature) anomaly. Duan et al. (2012) analyzed that the heavy rain weather in Beijing was largely affected by the long-range influence of typhoon Rosa (0716) along the southeast coast by the way of the numerical simulation and sensitivity test using WRF (Weather Research and Forecasting Model). Wang et al. (2012) found that the upper and lower humidity advection differential during the short-term heavy rainfall caused by the supercell in the north-central Jiangsu Province on 4 November 2011 was the main reason for the instability of the previous situation. The strong back inflow at the lower level of the supercell storm continuously input warm and humid air flow, and at the front side was the strong updraft, while strong back outflow at high altitude. Under the action of this flow field, the development of supercell storm was strengthened and maintained. The movement and enhancement of mesoscale ground convergence line played a role in triggering, maintaining and strengthening the supercell storm. Ju et al. (2011) utilized the aircraft detection data of a rainfall stratiform cloud system in Shijiazhuang City from October 4 to 5, 2008, combining with real-time weather, satellite, radar and other data to analyze the weather background conditions of the rainfall process, the liquid water content in the early precipitation period, the vertical distribution and variation characteristics of the average diameter and particle spectrum of the cloud particles, and the vertical microphysical structure of the cloud system. Huebner et al. (2022) found warning signals of increased risk of extreme temperatures and heatwaves resulting from changes in albedo and latent heat flow. He reviewed the afforestation measures underlying three simulation studies, together with a restoration model in which compartments were formed by greenbelts to enable succession of savanna vegetation, protected from hot wind and drought.

These studies found that the Western Pacific subtropical high, which is the main rainstorm, is closely related to typhoons and other weather systems, and the main causes of short-term heavy rainfall include unstable systems. Microscopically, the content of liquefied water, the mean diameter of cloud particles, the vertical distribution and variation characteristics of particle spectrum, and the vertical microphysical structure of cloud system are closely related to precipitation. Based on the very advanced data and materials, the synoptic analysis and statistical analysis of the observation data of Sichuan Basin, the eastern part of Northwest China to the southern part of Northeast China, North China and the northern part of Huanghuai Area from October 3 to 6, 2021 are carried out. Finally, rigorous and objective conclusions are obtained. It provides reference for future research on extreme weather processes.

2. Data and Methods

2.1. Data

In this study, the rainfall weather process is analyzed in detail by using the ten-day and monthly climate data from the National Climate Center of China and the reanalysis data from NCEP (National Centers for Environmental Prediction) of the United States.

1) The National Climate Center of China is a national scientific research center for climate business. The precipitation distribution map of China in the study is from the basic elements of China climate monitoring data of the National Climate Center of China. The map of 500 hPa geopotential height field is from the second-generation product of monthly dynamic extended ensemble prediction (DERF2.0) data.

2) The NCEP/NCAR reanalysis dataset is jointly produced by NCEP and NCAR (National Center for Atmospheric Research) of the United States. They use the most advanced global data assimilation system and perfect database to control and assimilate the observation data from various sources (ground, ship, radiosonde, wind balloon, aircraft, satellite, etc.), and obtain a complete set of reanalysis dataset. The data of the maps of 850 hPa geopotential height field and specific humidity in China are from NCEP, which have a temporal frequency of every 6 hours and a spatial resolution of $2.5^\circ \times 2.5^\circ$.

2.2. Methodology

The research mainly uses synoptic methods to analyze this weather process. The synoptic method is a kind of scientific method to study the formation and evolution of weather, and then to comprehensively analyze and forecast weather changes (Japheth et al., 2021; Ndiaye et al., 2021; Wang et al., 2019). Using atmospheric sounding data or processed data, various atmospheric physical quantities, including geopotential height, relative humidity, etc., are calculated. And the atmospheric circulation and weather system are qualitatively analyzed by atmospheric dynamic equation and physical equation, including the equation of atmospheric motion, the equation of continuity, the equation of heat flow, plus the equation of state and the water vapor equation.

3. Results and Analysis

From the perspective of the whole of China, a wide range of rainfall process occurred in most of China in early-October 2021. Major affected areas included

Sichuan Basin, the eastern part of Northwest China to the southern part of Northeast China, North China and the northern part of Huanghuai Area. The accumulated precipitation in many places reached 100 - 200 mm. The largest monthly cumulative precipitation area of 300 - 500 mm was located in Hainan Island in the south of China. This process had a long duration, large cumulative precipitation and strong extreme.

3.1. Atmospheric Circulation and Precipitation Distribution

Figure 1 comes from the second-generation product of the extended set of monthly power forecasts of China National Climate Center (DERF2.0). It indicates that the circulation in Europe was in the form of blocking high. The large trough before the high pressure was located in West Siberia, where cold air was continuously transported from high latitudes. Cold air entered Xinjiang, China's northwest border, affecting China from west to east. The belt of mid-high latitude westerlies in East Asia was relatively flat. However, the south area of Huaihe River in China was controlled by the subtropical high, so that the warm and wet air flows were transported northward along the northwest side of the subtropical high. The warm and wet flow and the cold air intersected in the central and western regions of China and Northeast China, which resulted in a regional rainstorm process within ten days.

In addition, it can be seen from Figure 2 that influenced by the easterly airflow on the southwest side of subtropical high and typhoon Lionrock, another precipitation process in China was formed in this ten-day period.

3.2. Synoptic and Dynamic Analysis

On October 3-6, 2021, the regional rainfall process was mainly caused by the intersection of cold and warm air in the north of the Yangtze River. The rainstorm

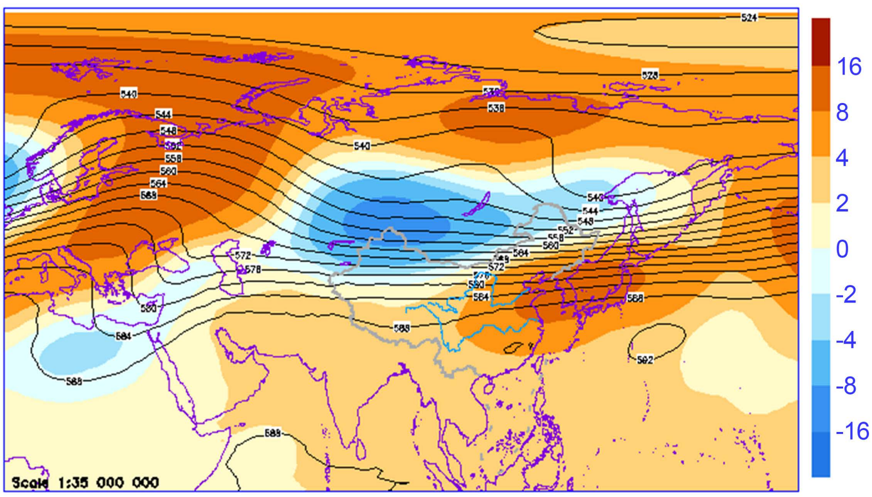


Figure 1. The 500 hPa geopotential height field in Euro-Asia in early-October 2021 (The contour line is the geopotential height, the unit is dagpm, and the shaped area is the anomaly).

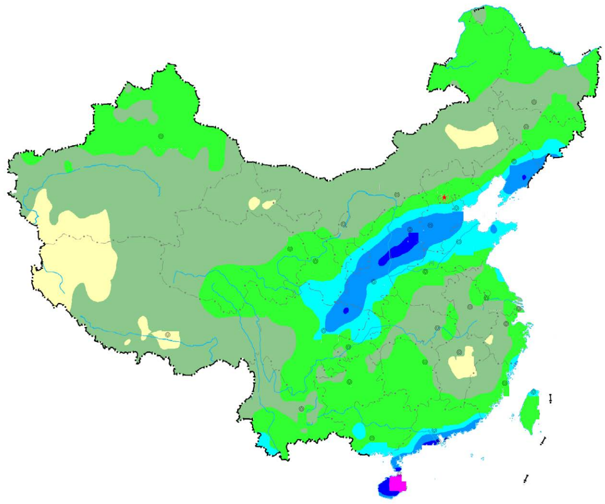


Figure 2. Precipitation distribution of China in early-October 2021 (The shaded area is the precipitation in millimeters).

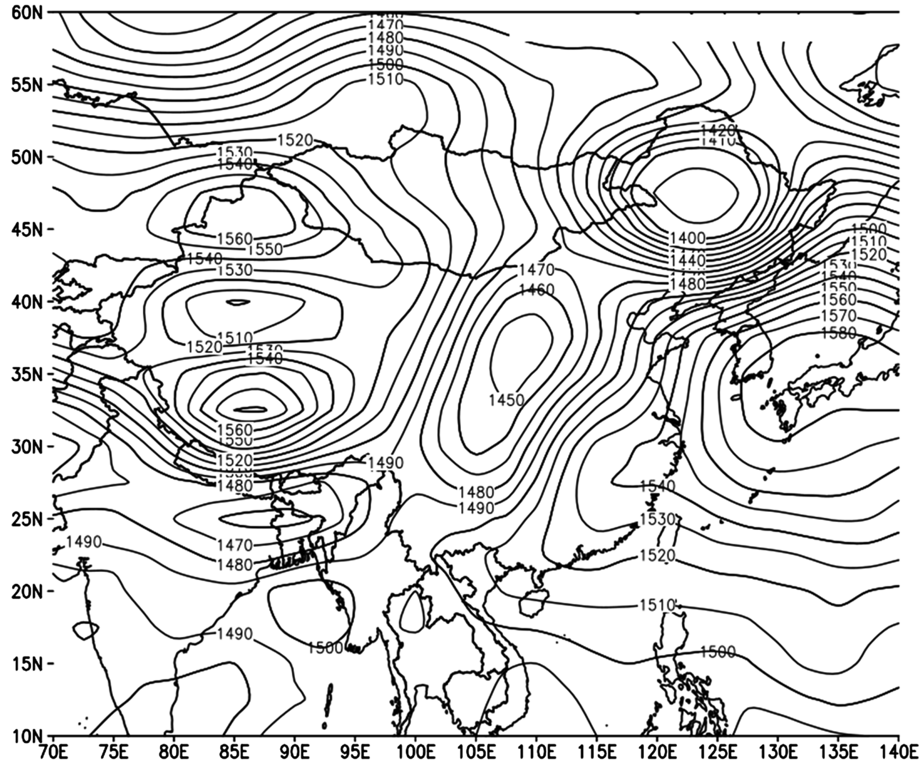
area occurred in the Sichuan Basin, the eastern part of Northwest China to the southern part of Northeast China, North China and the northern part of Huanghuai area. This process had a long duration, large cumulative precipitation and strong extreme.

As shown in Figure 3(a), there was a cold vortex moving in the northeast region at 08:00 (Beijing time, the same below) on October 3rd, 2021. And behind the cold vortex, there was a large range of cold advection from Siberia through Mongolia to the regions lying from Inner Mongolia of China to Xinjiang of China. In the south of the Yellow River, there was a strong low-level jet moving from Guizhou and Hunan to the south of Northeast China, bringing a lot of water vapor. The cold and warm air intersected in the central and western regions of China and the Northeast China, forming a low-level shear line with northeast-southwest trend.

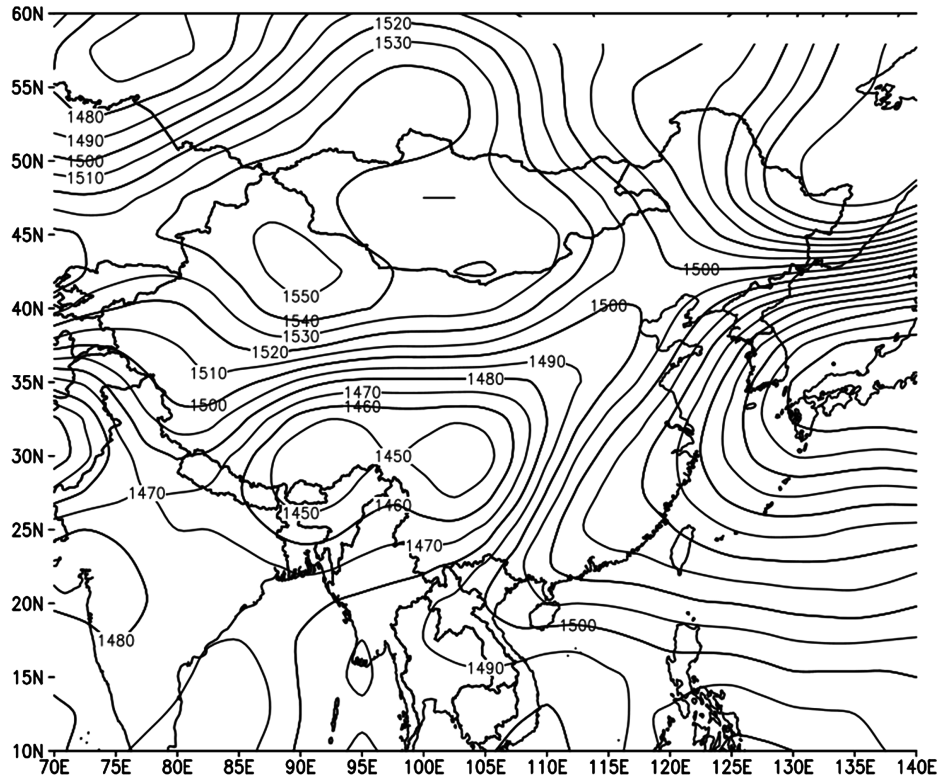
At 20:00 on October 3rd (Figure 3(b)), there was a vortex development on the shear line from the eastern Sichuan Basin to the southeast of Shaanxi, which brought heavy rainfall to the central and western regions of China and Northeast China.

From Figure 4, at 08:00 on October 4th, the northeast cold vortex moved eastward rapidly under the action of westerly belt, and the heavy rainfall in the south of northeast China and the north of Huanghuai area ended. However, the shear line formed by the cold advection area behind the cold vortex and the warm and humid low-level jet on the south side of the cold vortex still maintained for a long time and had a slight north-south swing. The main rain area moved to the south of North China, the eastern part of Northwest China and the Sichuan Basin.

At 08:00 on October 5th, with the weakening of cold and warm advection, the low-level shear line also gradually weakened, and the heavy rainfall process ended (Figure 5).



(a)



(b)

Figure 3. The 850 hPa geopotential height field in China at 08:00 (a), Beijing time, the same below and 20:00 (b) on October 3rd, 2021.

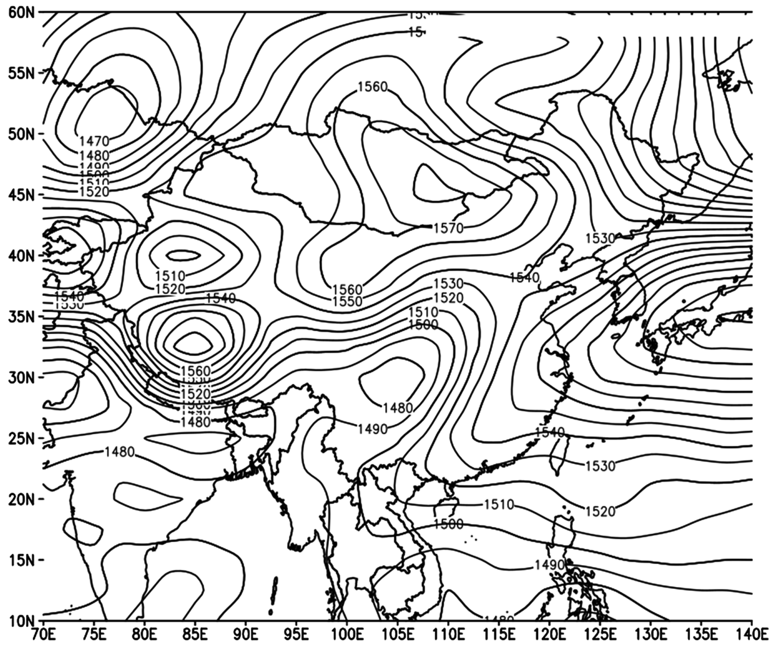


Figure 4. The 850 hPa geopotential height field in China at 08:00 on October 4th, 2021.

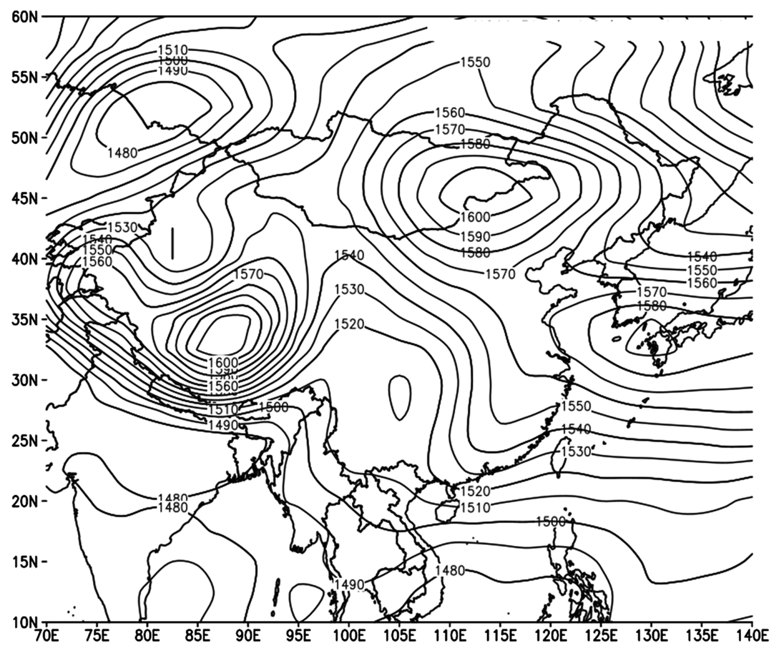


Figure 5. The 850 hPa geopotential height field in China at 08:00 on October 5th, 2021.

3.3. Analysis of Water Vapor Condition

Figures 6-8 are the 850 hPa specific humidity maps in China at 08:00 on October 3-5, 2021. Specific humidity refers to the ratio of water vapor mass to total air mass (water vapor mass plus dry air quality) in a group of wet air. It is the index to record the atmospheric water vapor condition. The pictures show that the source of water vapor during the precipitation was the North Indian Ocean and the Western Pacific.

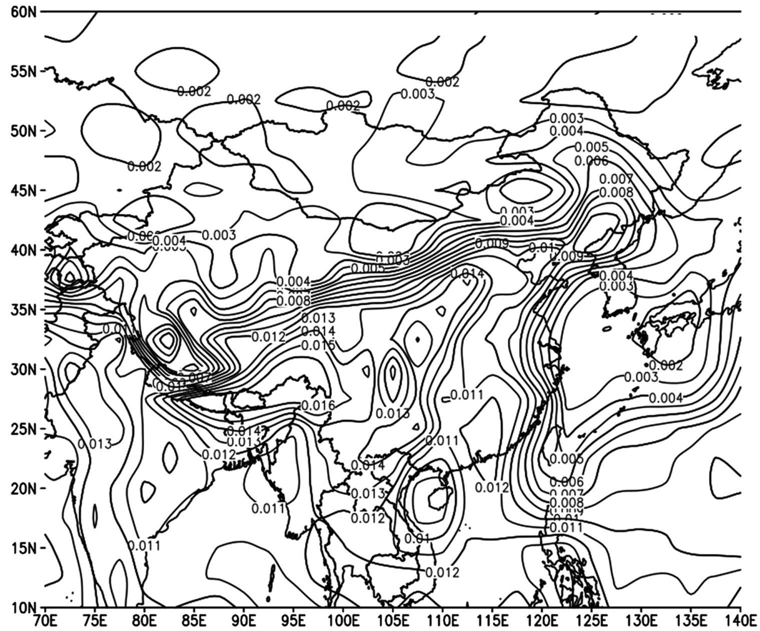


Figure 6. The 850 hPa specific humidity in China at 08:00 on October 3rd, 2021.

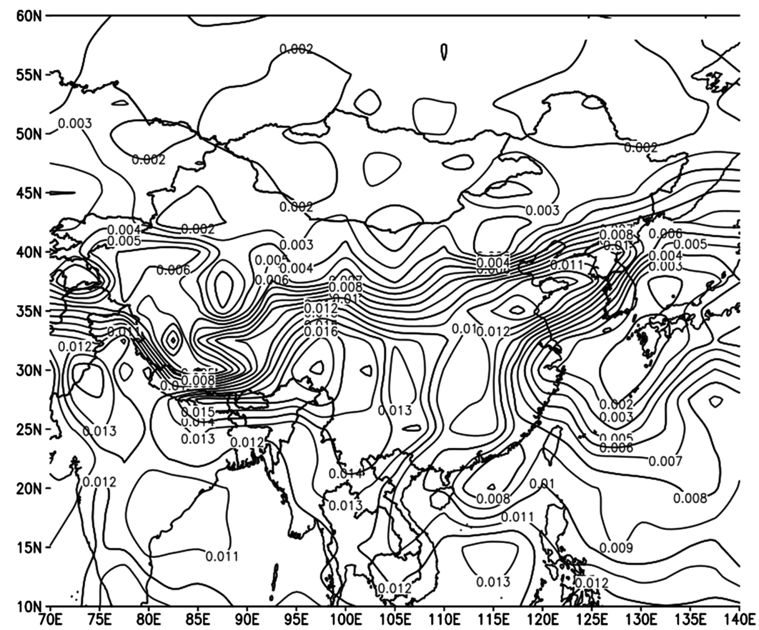


Figure 7. The 850 hPa specific humidity in China at 08:00 on October 4th, 2021.

It can be seen from **Figure 6** that water vapor from the Indian Ocean was transported through India from the southwest border to China on October 3rd, 2021. The maximum specific humidity in the figure was 0.016 kg/kg. By October 4th, 2021, a wet tongue was formed over Tibet and Sichuan, and water vapor was continuously transported eastward and northward (**Figure 7**). Sufficient water vapor supply made the precipitation process have a long duration and influence most areas of China. On October 5th, the water vapor basically dissipated and the precipitation process ended (**Figure 8**).

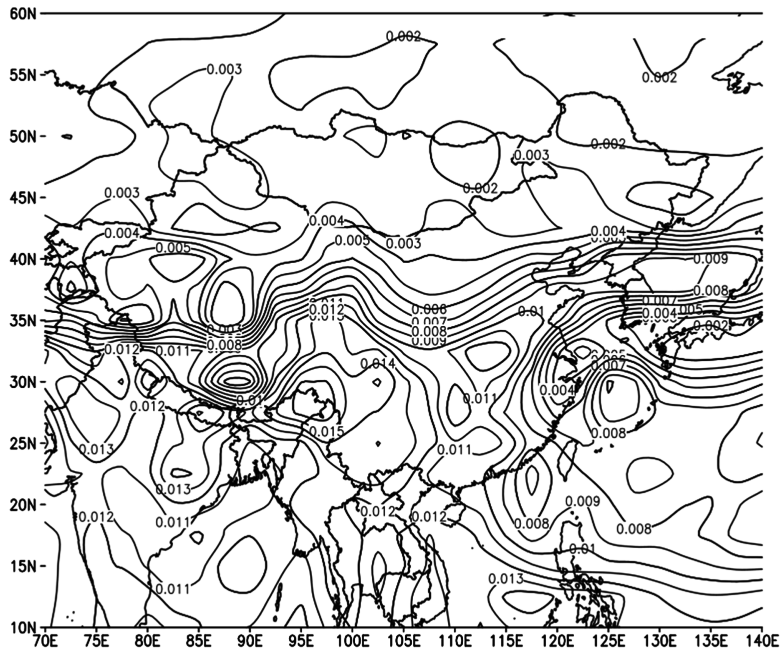


Figure 8. The 850 hPa specific humidity in China at 08:00 on October 5th, 2021.

4. Conclusion

The rainfall process affected most areas of China, and had a long duration, large cumulative precipitation and strong extreme. The main cause of the heavy rain was the intersection of the cold air from high latitudes and the warm and humid air from the subtropical high in the north of the Yangtze River. And during this period, there was a low-level jet moving from Guizhou and Hunan to the south of Northeast China, bringing a lot of water vapor. To sum up, the rainfall process of this round has a certain relationship with the adjustment of atmospheric circulation.

Conflicts of Interest

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

References

Duan, L., Zhang, J., Wang, J. J. et al. (2012). Effect of Typhoon Rosa (0716) on Fall Rainfall in 071005 Beijing. *Journal of Tropical Meteorology, 28,* 664-674.

Huebner, L., Al-Quraishi, A. M. F., Branch, O., Gaznayee, H. A. A. et al. (2022). Sahel Afforestation and Simulated Risks of Heatwaves and Flooding Versus Ecological Revegetation That Combines Planting and Succession. *Journal of Geoscience and Environment Protection, 10,* 94-108. https://doi.org/10.4236/gep.2022.102007

Japheth, L., Tan, G., Chang'a, L., Kijazi, A., Mafuru, K., & Yonah, I. (2021). Assessing the Variability of Heavy Rainfall during October to December Rainfall Season in Tanzania. *Atmospheric and Climate Sciences, 11,* 267-283. https://doi.org/10.4236/acs.2021.112016

Ju, L. L., Niu, S. J., Duan, Y. et al. (2011). An Observation on Vertical Microphysical

Structure of Cold Front Cloud System in Autumn in Shijiazhuang. *Plateau Meteorology, 30,* 1324-1336.

Liu, Y. J., Wang, Y. J., Si, D. et al. (2013). Analysis of Climatic Anomalies and Causes in the Fall of 2012 in China. *Meteor. Mon., 39,* 526-530.

Ndiaye, B., Moussa, M., Wade, M., Sy, A., Diop, A., Diop, A., Diop, B., & Diakhaby, A. (2021). Spatial and Temporal Distribution of Rainfall Breaks in Senegal. *American Journal of Climate Change, 10,* 533-560. https://doi.org/10.4236/ajcc.2021.104027

Wang, L., He, K., Zhu, W., & Subrahmanyam, M. (2019). Rainfall Variations over Zhoushan during Last Four Decades. *Open Access Library Journal, 6,* e5819. https://doi.org/10.4236/oalib.1105819

Wang, X. H., Cao, S. Y., Wang, J. X. et al. (2012). Analysis of a Heavy Precipitation Supercell Storm in Fall. *Journal of the Meteorological Sciences, 32,* 685-693.