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Analysis on the Impact of Typhoon HAITANG on Heilongjiang Province

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Abstract: In August 2017, Heilongjiang Province was affected by the weakening of the typhoon HAITANG, which turned into a low-pressure system northward, causing a heavy rainstorm. The data used in this paper was obtained from the 2.5°×2.5°NCEP reanalysis dataset, conventional observation data and FY-2C2D satellite images. Starting from the large-scale circulation situation, analyze the physical mechanism of the heavy rain in Heilongjiang Province and the characteristics of satellite images. The results show that typhoon HAITANG degenerates into a low pressure system that carries lots of warm and humid air northward, which is combined with the cold air in the north. Heilongjiang Province is affected by the interaction of warm and cold air. The large value area of water vapor convergence overlaps with the center of pressure and moves northeast with it. At the same time, the water vapor convergence gradient is relatively large, which is a good corresponding relationship with the appearance of heavy rainfall areas. The low-level convergent and high-level divergent circulation conditions are conducive to the maintenance of low-level ascending movement and provide favorable conditions for the occurrence of heavy rainstorms. Heavy rainstorms mainly occur in areas where the cloud system is thicker and densely structured, where the upward movement is relatively strong.

Key words: Typhoon HAITANG, water vapor convergence, satellite images

1. Introduction

Heilongjiang Province is located in the northernmost part of China and is affected by typhoons less frequently. Typhoons directly affect Heilongjiang Province rarely. Most of them are transformed into low air pressure after typhoons make landfall or the combination of low pressure and cold fronts affects Heilongjiang Province's heavy rains [1]. Most of the typhoons that can move northward and affect Heilongjiang Province occurred in July and August, and a very few typhoons also occurred in early September [2]. Since 2006, ten typhoons such as "Wipha" in 2007, "Muifa" in 2011, "Bolaven" and "Sanba" in 2012, "Chan-hom" and "Swan" in 2015, and "Lionrock" in 2016 all brought great wind and rain effects to the northeast region (incomplete statistics). The precipitation caused by the typhoon affecting Heilongjiang Province can be divided into two situations: 1) Precipitation produced by typhoons (including those that have become extratropical cyclones at the time of the impact), 2) Precipitation produced by the combined action of typhoons and westerly belt systems (some typhoons continue to move northward and directly affect them) [3]. The "Haitang" mentioned in this article is the second case. The northeast region has a higher latitude. When a typhoon passes through the Yellow Sea and the Bohai Sea, the sea temperature can no longer provide sufficient water vapor support. In addition, the severe wind shear brought by the westerly zone will quickly transform the system into an extratropical cyclone and disappear. Moreover, the generation and development of typhoons mainly depend on the guided airflow on the western edge of the subtropical high. The typhoon

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advances northward along the southerly air current on the west side of the subtropical high, and meets the cold air in the west wind belt, forming a semi-warm temperature and pressure field structure of "warm east and cold west", which can easily trigger heavy rains and strong winds [4]. "Begonia" is because the subtropical high is too eastward, causing the low-pressure system to move northward to reach the northeast region. Through detailed analysis of the circulation situation, water vapor conditions, physical quantity field and satellite cloud images of "Begonia", this paper explores the reasons for the heavy rainstorm caused by the typhoon, and accumulates experience for forecasting the stormy weather caused by the typhoon in the future.

2. Rainfall Distribution

Between August 1st and 2nd, 2017, affected by the long-distance transport of water vapor by Typhoon "1710-Haitang", heavy rain occurred in the southern part of Heilongjiang Province. Between 3rd and 4thn, affected by the combination of the weakened typhoon circulation northward and the mid-latitude system, the southern part appeared obviously stormy weather. Heavy rains occurred in southern Heihe, Daqing, Suihua, northern Harbin, and southern Yichun from August 1st to 4th. Cumulative precipitation: 15 stations exceeded 200 mm, mainly concentrated in southern Suihua and western Harbin, and the largest was in Yangcao Station of Anda County, Suihua City which is 292.7 mm; 108 stations are from 100 to 200 mm (Fig. 1). According to calculations, the area affected by the cumulative precipitation exceeding 25 mm in the early morning from 1st to 4th is about 337,000 square kilometers, the area exceeding 50 mm is about 196,000 square kilometers, and the area exceeding 100 mm is about 46,000 square kilometers. Heavy rains have caused urban waterlogging and farmland water accumulation, affecting flight operations and destroying houses.

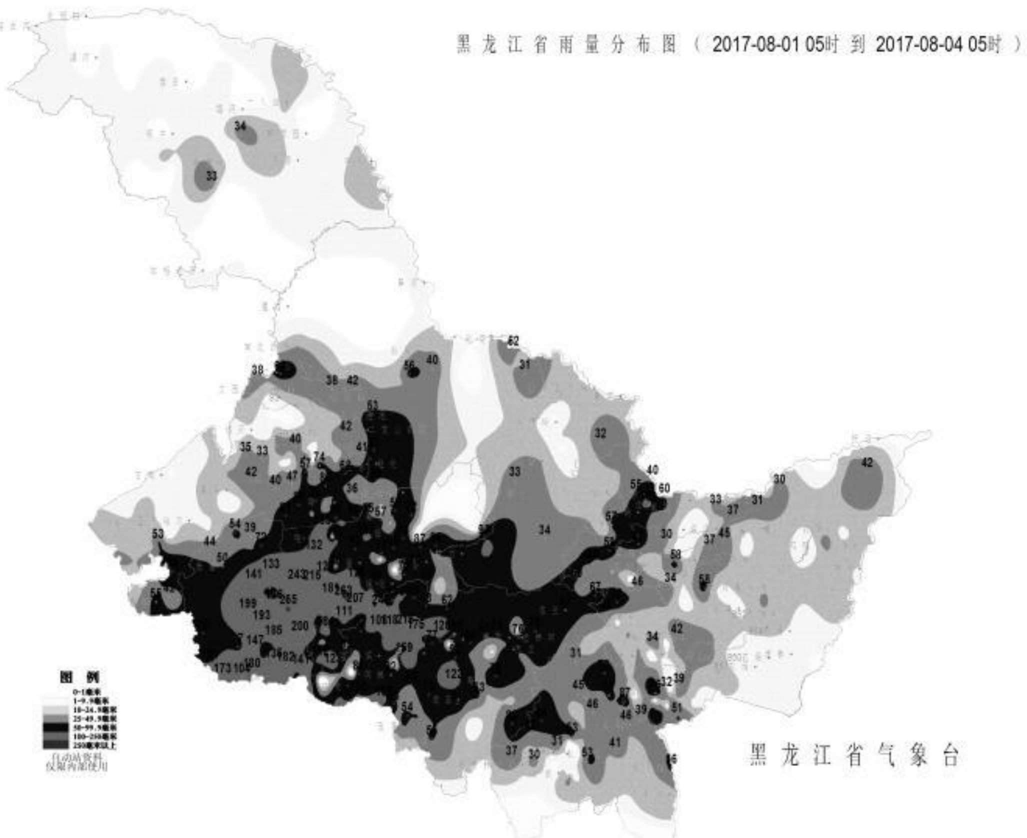

Fig. 1 Rainfall distribution map from 5 am August 1st to 5 am August 4th, 2017.

3. Large-Scale Circulation Background

Typhoon Haitang was generated on the sea south of the junction of Fujian and Guangdong on the evening of July 28th, moving slowly to the northeast and strengthening. It made landfall on the coast of Fuqing City, Fujian Province at around 2:50 am on July 31st. It was a tropical storm at the time of landfall. The maximum wind force near the center was level 8 (18 m/s). It merged with the remnant circulation after the weakening of Typhoon “Nassa” and moved northward. It stopped numbering at 08:00 on August 1st. After that, the weakened tropical low pressure system continued to move northward and combined with the west wind trough system in the north, bringing heavy rainfall to more than ten provinces in eastern China.

At 08:00 August 1st (picture omitted), the Asian mid-high latitude circulation situation showed two ridges and one trough, along the west of Lake Baikal to Xinjiang, there was a relatively deep high-altitude trough. Typhoon Haitang weakened into a tropical depression and a subtropical high ridgeline. Above 35°N, it is in a northeast-southwest direction, and rotates clockwise, guiding the airflow from southeast to south, which is conducive to the northward movement of the cyclone. The position of the subtropical high is more norther than usual, superimposed with the high pressure ridge of the westerly belt, and the southwesterly airflow transports abundant water vapor from the south over a long distance, bringing heavy rain in the southern part of Heilongjiang Province. Then the low pressure system quickly jumped northward, catering to Mongolia's high-altitude trough, and began to strengthen development at 02:00 on the 3rd and gradually moved northward. This article mainly focuses on the in-depth analysis of the impact of this system. The high-altitude trough developed and deepened during the eastward movement, forming a low vortex, and the subtropical high retreated eastward. At 8pm on the 3rd (picture omitted), the subtropical high retreated to the east of 130°, and the central pressure of the low pressure was at the junction of Inner Mongolia and Jilin. The outer wind was relatively strong. When the cyclone was rotating, the southerly east wind brought water vapor on the sea, which caused heavy rain. Generation and maintenance provide favorable conditions. By 8pm on the 4th, the system gradually weakened northward, and the impact on Heilongjiang Province tended to end.

4. Water Vapor Conditions

Water vapor flux divergence is a physical quantity closely related to vertical motion, and the convergence zone of water vapor flux and the rising zone of vertical motion are often the same. It can be seen from the analysis that there are two main sources of water vapor produced by this heavy rain. One is that the HAITANG brings a large amount of water vapor from the sea after landing, and the other is as the subtropical high retreats eastward, the southwest wind on the periphery of the subtropical high and the front of the degeneration typhoon The superposed southerly winds transported water vapor from the Sea of Japan to Heilongjiang Province. This is consistent with the water vapor source of Typhoon “Chan-hom” in 2015 [5]. The large-value area of water vapor convergence appears near the center of pressure and moves northeast with it, and the gradient is relatively large, and there is a fairly good correspondence with the appearance of the heavy rain area. A large water vapor convergence zone appeared in the southwestern part of Heilong Province at 850 hPa at 8 pm on the 3rd (Fig. 2), and the convergence intensity rapidly increased to -6.75×10^{-5}g s^{-1} cm^{-2} hPa^{-1}, along the cross-section of the convergence center (the figure omitted) shows that the large water vapor convergence area extends to 500 hPa. Such deep and high humidity conditions provide favorable conditions for the occurrence of heavy rains. After 8 am on the 4th, the overall water vapor convergence weakened and moved to the northeast, corresponding to the end of the rainstorm process in the southwest.

At the same time, it can be seen from the specific humidity field (Fig. 2) that the specific humidity conditions in the southwestern part of Heilongjiang Province have reached 12-14 g/kg. In general, a specific humidity greater than 8 g/kg is already conducive to the generation and maintenance of heavy rain. For the northeastern region in August, the 12 g/kg constant saturation specific humidity line can be used as a reference.

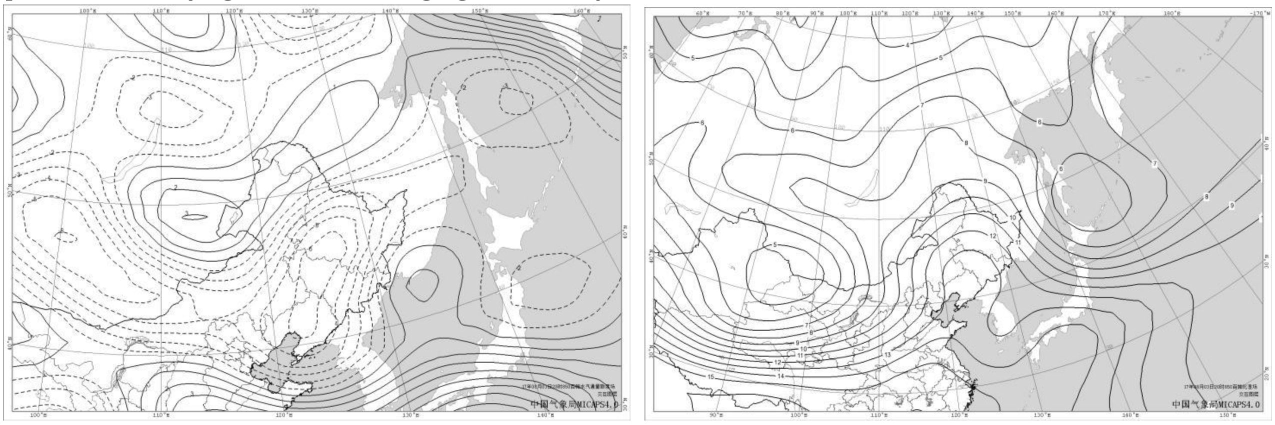

Fig. 2 Water vapor flux divergence (left) and specific humidity (right) at 8 pm on August 3rd, 2017.

5. Dynamic Condition

5.1 Vertical Velocity

There is a good corresponding relationship between the area of maximum vertical velocity and the center of heavy precipitation. The center of the maximum vertical velocity of 500 hPa at 8 am on the 4th was -0.2 Pa S^{-1} (picture omitted), and the center of the maximum vertical velocity of 500 hPa at 8 pm on the 3rd was -0.425Pa S^{-1} (Fig. 3), which was the same as the center of low pressure at 500 hPa. Coincident, the maximum vertical velocity area is near the 850hPa shear line, indicating that the upward movement is strongest here, the center of the maximum vertical velocity of 850 hPa is -0.225 Pa S^{-1} (the figure omitted), indicating that the upward movement is deep and strong. The mark of the five-pointed star is Anda, the center of the maximum precipitation. At 8 am on the 4th, the 500 hPa low-pressure center moved northeastward, the intensity weakened, and the vertical velocity weakened to -0.225 Pa S^{-1} (Fig. 3). Then as the system gradually moved out, Heilongjiang Province turned into a sinking movement, and precipitation tended to the end. The process of heavy rain corresponds to the process of rapid increase of the vertical velocity field.

5.2 Vorticity and Divergence

The rainstorm area is located in the positive vorticity zone, extending from the ground up to 300 hPa (picture omitted), and the central intensity reaches 23×10-5s^{-1}, forming a bottom-up positive vortex tube, which promotes the development of convection. From the change of the divergence field, the convergence zone in the southwest of Heilongjiang Province is also relatively deep, with a strong convergence center of 8×10-5s^{-1} at 700 hPa, and a divergence of 6×10-5s^{-1} near 300hPa. In the center, compared with the previous moment, it is found that due to the influence of cold air, the low-level convergence and the high-level divergence are significantly strengthened. This low-level convergence and high-level divergence circulation situation is conducive to the maintenance of the low-level ascending movement, thereby satisfying the dynamic configuration that is conducive to the development of convection in the rainstorm area under the mesoscale environment.

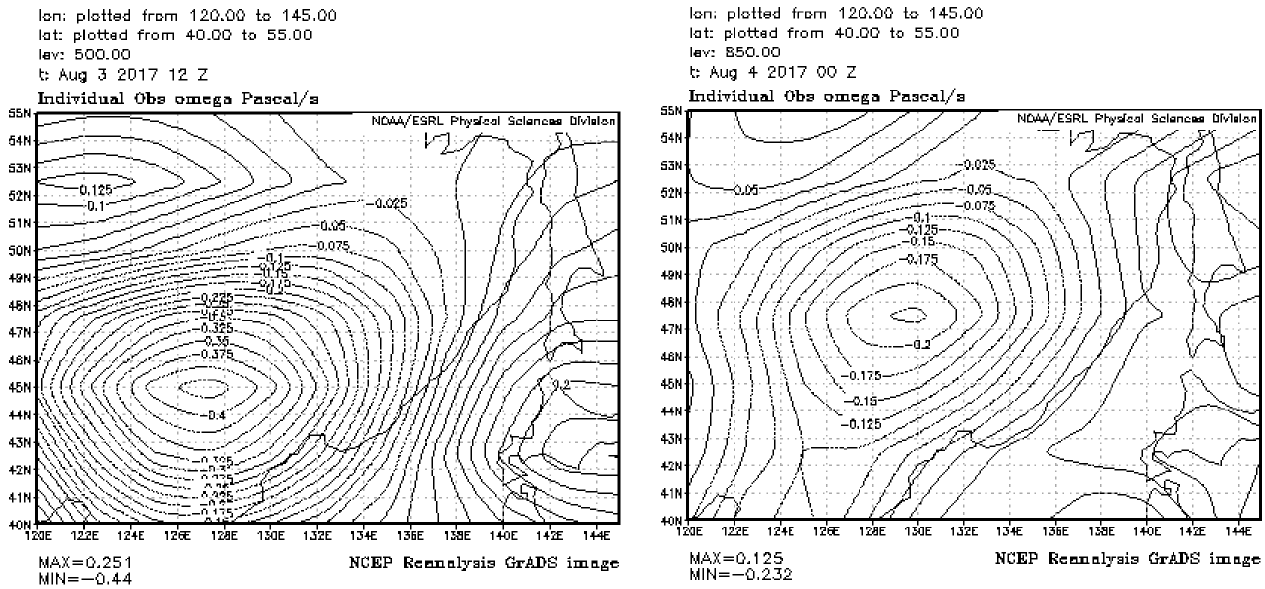

Fig. 3 500 hPa vertical velocity at 8 pm on August 3rd (left) and 8 am on August 4th (right), 2017.

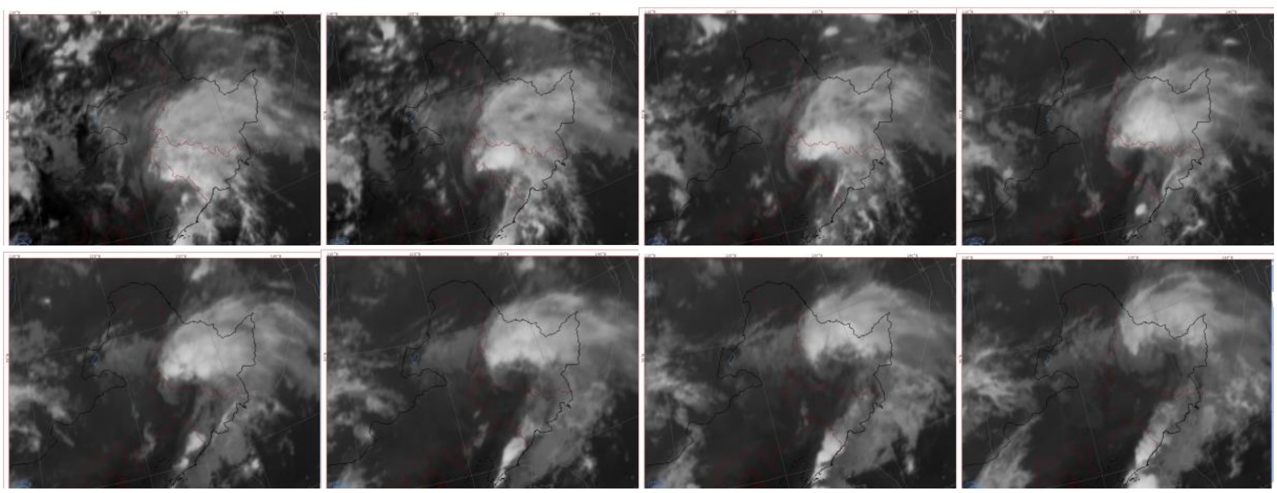

Fig. 4 Infrared satellite image from 4 pm on August 3rd to 6 am on August 4th, 2017 (Time interval 2h).

6. Satellite Images

The combination of the typhoon cloud system and the cold front cloud system caused the largest number of heavy rainstorms in Heilongjiang Province, accounting for 63% of the total heavy rainstorms affected by the typhoon in Heilongjiang Province. Before the typhoon moved closer to Heilongjiang Province, a complete cold front cloud system existed in the western part of Heilongjiang Province, and the cold front cloud belt moved from west to east, which happened to meet the outer cloud system of the landing typhoon. In this case, the typhoon cloud system that weakened after landing often strengthened again [6]. This process is formed by the interaction of cold and warm air. The ridgeline of the subtropical high turns into a northeast-southwest direction, and the strengthened northeast low vortex guides the cold air flow southward and merges with the warm and humid air flow north along the subtropical high.

During the northward movement of the low-pressure system, cold air invaded from the northwest, and a sinking air flow appeared in the south of the low-pressure center. Clouds developed rapidly, the cloud structure was tight, and a frontal cyclone structure appeared. The warm and humid air carried by the low-pressure system strongly converges with the cold air, and the vertical movement is the most obvious, producing strong precipitation. At 4 pm on the 3rd (Fig. 4), the cyclone cloud system showed an asymmetric structure, and the cloud system on the side near the cold air developed vigorously. At 8 pm, the area of strong convective activity at the head of the cloud system gradually entered Heilongjiang Province. The intensity of precipitation in the southeast area began to increase and remained for a long time. Corresponding to the relatively concentrated precipitation period on the ground, heavy rains occurred at individual sites in Suihua. After 2 am on the 4th, convective activity gradually weakened, and the cloud system as a whole moved to the northeast, and the cloud body was slightly looser than before.

7. Conclusion

This paper uses conventional observation data, FY-2C2D satellite cloud images and 2.5 °×2.5 ° NCEP reanalysis data, and the results show that:

(1) This process is due to the weakening of the typhoon degeneration and the combined influence of the northward movement of hot low pressure and the west wind trough system. The large-scale circulation background is “two ridges and one trough”.

(2) After the HAITANG landed, it brought a large amount of water vapor from the sea, and the subtropical high retreated eastward. The southwest wind on the periphery of the subtropical high overlapped with the southerly wind in front of the degeneration typhoon, transporting water vapor from the Sea of Japan to Heilongjiang Province. The large-value area of water vapor convergence appears near the center of pressure and moves northeast with it, and the gradient is relatively large, and there is a fairly good correspondence with the appearance of the heavy rain area. After 8 am on the 4th, the overall water vapor convergence weakened and moved to the northeast, corresponding to the end of the rainstorm process in the southwest.

(3) The mid-to-high latitudes are constantly replenished with cold air, converging with the warm advection northward, and strong ascending motion is generated at the intersection. At the same time, the low-level convergence and high-level divergence are conducive to the maintenance of low-level ascending motion. This vertical structure is the occurrence and Development provides powerful conditions.

(4) Heavy rain mainly occurs in areas where the cloud system is thicker and densely structured, where the upward movement is relatively strong.

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