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Analysis of Snowstorm Process in Northeast China during 5-9 November, 2021

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Abstract

In November 2021, Northeast China had more precipitation than in the same period. Among them, Heilongjiang and Jilin provinces in the Northeast China were the highest precipitation in the same period. I study a snowfall weather process from November 5 to 9, which mainly includes dynamic situation, synoptic background and situation. The results show that: In the middle and high latitudes of Eurasia, circulation is adjusted from zonal to meridional with large fluctuations. The northerly wind behind the trough continuously transports the polar cold air to the south. The northwest airflow behind the trough led the cold air to erupt to the southeast. In the process of moving southward, the cold air meets the warm and humid air in front of the trough, causing snowfall in the northeast. The southerly airflow and southeasterly airflow on the east side of the vortex continued to transport warm and humid airflow from the Yellow Sea and the Sea of Japan, which enhanced the snowfall.

Keywords

Snowstorm, Ridge, Trough, Cold Front, Northeast China

1. Introduction

Affected by the cold wave, most parts of China suffered strong gale, cooling, rain and snow in November 2021. Snowstorm caused certain disaster losses in Northeast China and part of Inner Mongolia. From November 5, 2021, Northeast China was hit by continuous snowfall. The worst snowstorm in a century occurred in central and western Liaoning and eastern Inner Mongolia. The intensity, scope and duration of the snowstorm were the largest recorded in a century. On the morning of November 9, Shenyang Meteorological Observatory announced that the snowstorm in Shenyang from November 7 to 9 was the strongest snowstorm since the establishment of Shenyang Observatory in 1905.

Snowstorm is not an uncommon weather phenomenon in the Northeast China. Many scientists have done a lot of research on snowstorm. There are some relevant abstracts about them. Dong et al. (2010) found that the occurrence of snowstorm in Northeast China has obvious spatial and temporal distribution characteristics. In the past 50 years, the annual snowfall in Northeast China has shown a certain trend of increase, among which, in spring, the snowfall in North and South China has an obvious upward trend, while in autumn, the snowfall in most parts of Northeast China has a significant downward trend. Gao et al. (2007) believed that the low-pressure weather system that caused the snow in Heilongjiang came from the northwest, west and south. The weather system is mainly affected by low trough, followed by low vortex, but most of them are low vortex during snowstorm. Warm front and occluded front are the most common frontal systems causing heavy snow. Zhang et al. (2018) showed that the transversal trough from the rear of the upper cold vortex southward caused the dry cold air southward and the southwest jet in front of the cold vortex northward jumping; moreover, the convergence that strengthened sharply provided the favorable circulation conditions for the snowstorm. The southwest jet as the moisture transport belt provided adequate water vapor for the snowstorm. The center of the vertical ascending motion was corresponding to the location of the center of the convergence and strengthened gradually, which offered the dynamic conditions for the snowstorm and promoted the development of ascending motion. Silvestre et al. (2014) analyzed a prevalence of 36% for PTSD 2 years after the disasters, with a high prevalence also of depression (31.7%) and anxiety (21.1%). Some of the risk factors identified are being female, a history of psychiatric treatment, and the amount of personal and material losses. The instauration of crisis management and follow-up protocols after traumatic events was deemed to be needed. Wu et al. (2011) pointed out that significantly impacted the onset of posttraumatic stress reactions in students living in Hunan, China following a snowstorm disaster were the school-to-home distance, negative coping, neuroticism, and teacher.

Although scientists have done a lot of research on snowstorm and achieved so much excellent results (Ma et al., 2022; Tetsuya et al., 2017; Zhang et al., 2023; Zheng et al., 2022; Zhou et al., 2020). Meteorology is not constant. Sometimes, old studies cannot show the recent situation. As a result, I will use the latest data to analyze a recent snowstorm in the Northeast China. The purpose of this study is to better understand the process analysis of heavy snowfall in Northeast China during November 5-9, 2021.

2. Data and Methods

2.1. Data

1) There are three major sources of data in this study and they are the National Meteorological Information Center of the China, the National Climate Center of China and the National Centers for Environmental Prediction of the United States.

2) Temperature, one-hour precipitation, surface pressure and relative humidity in Northeast China on November, 2021 released by the National Meteorological Information Center and the National Climate Center of China (http://cmdp.ncc-cma.net/).

The National Centers for Environmental Prediction (https://psl.noaa.gov/) provide the relevant weather maps in this study.

2.2. Methodology

Synoptic method, dynamic method, and general scientific research methods are used in this research. Synoptic method uses the relevant weather map to analyse. Dynamic method is the analysis of atmospheric characteristics using relevant data and equation calculations.

Synoptic methods are mainly used to generalize synoptic laws or patterns based on observational data, and to describe and infer weather processes.

The method of dynamic meteorology refers to the application of physical laws and mathematical methods to study the dynamic process of atmospheric motion, thermal process, and the relationship between them, and theoretically explore the atmospheric circulation, the evolution of weather systems and other atmospheric motion processes.

General scientific research methods contain literature research and contrastive analysis. The former means finding information from Open Access Library (https://www.oalib.com/) and analyze the useful literatures. The latter refers to compare and analyze the snowfall in different time periods and looks for differences.

3. Results and Analysis

3.1. General Situation of Circulation and Precipitation

In early November 2021 (**Figure 1**), the general circulation in the middle and high latitudes of Eurasia showed a zonal multi-fluctuation type. In middle of early November, the Caspian Sea high pressure ridge developed strongly to the northeast. An east-west horizontal trough was formed from the west of Lake Baikal to Lake Balkhash. The strong northerly wind behind the trough transports the polar cold air to the south continuously. Later, the horizontal trough slowly moved eastward. Since the temperature trough lags behind the height trough, it is favorable for the development of the trough to deepen to the south. Subsequently, the horizontal trough turns vertical, and the meridional direction of the circulation increases. The northwest airflow behind the trough guides the cold air to erupt southeast. It affects most of China from northwest to southeast, causing a nationwide cold wave process. During the southward movement of the cold air, it merged with the warm and humid air flow in front of the trough, bringing a wide range of rain and snow weather to central and eastern China (**Figure 2**). Heavy snowfalls generally fell in northern North China, eastern Inner Mongolia, and western Jilin. It is even more serious in some specific areas of them.

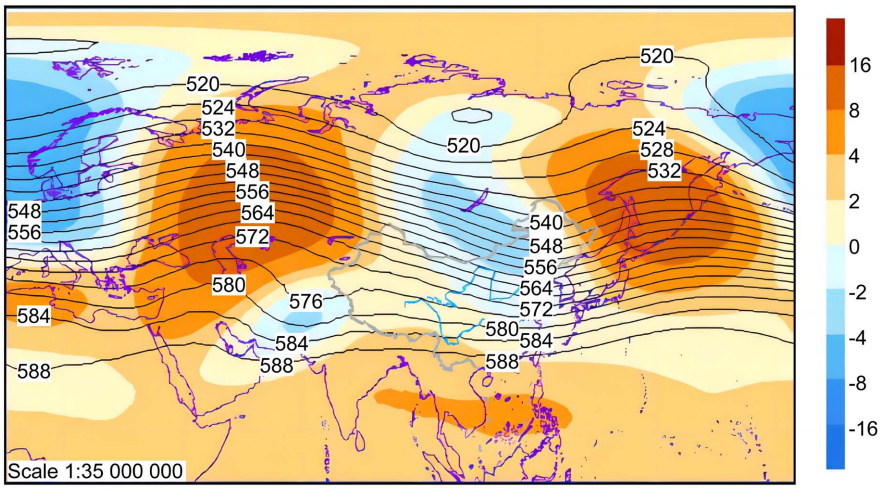


Figure 1. The 500 hPa geopotential height mean (contour) and anomaly (shaded) in early November 2021 (Unit: dagpm).

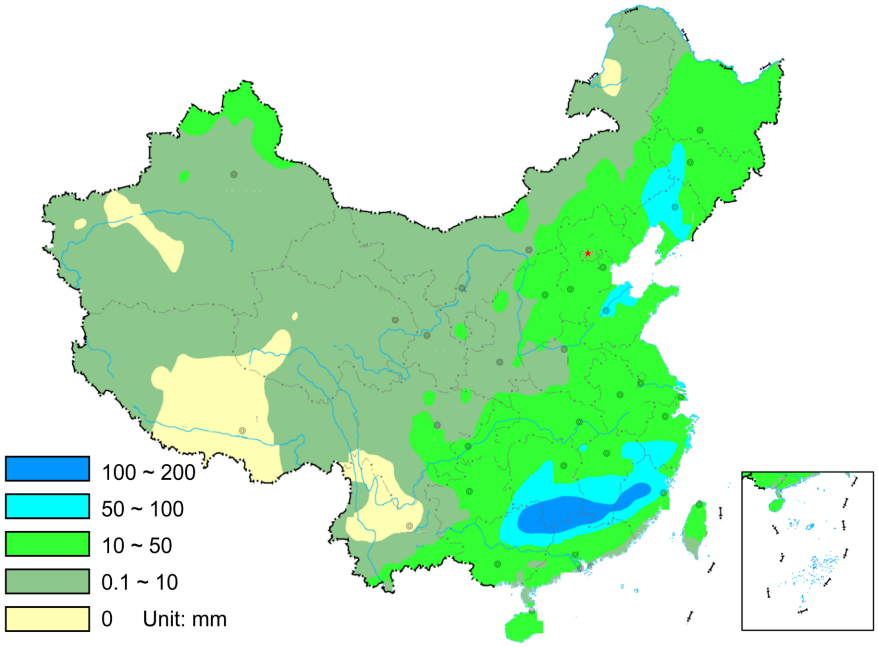


Figure 2. The precipitation accumulation distribution of China in early November 2021.

3.2. Analysis of Snowfall Weather

During the impact of the cold wave process from November 5 to 9, 2021, large-scale rain and snow will occur in eastern China, and the precipitation is generally above 10 mm. Snowfall mainly occurred in North China, Northeast China, Huanghuai and other places. Among them, northern North China, eastern Inner Mongolia, western Jilin and other places generally experienced blizzards or heavy snowstorms, and local heavy snowstorms occurred. Eastern Inner Mongolia, western Jilin, and western Liaoning had snow depths exceeding 40 cm. Freezing rain also occurred in Heilongjiang, Jilin, Liaoning and other places. This process is caused by the frontal precipitation generated by the upper trough leading the northward

cold air mass to move eastward and the convergence of the warm and humid air mass in front of the surface cyclone.

At 08:00 on November 6, the 500 hPa upper trough (**Figure 3(a)**) was located in the western part of Gansu, and the ground (**Figure 3(b)**) cold front was located in the western part of Northeast China, the northern part of North China and the eastern part of Northwest China. After the cold front, pure snow appeared in Northwest China, Inner Mongolia, and western Northeast China. Central Inner Mongolia appear moderate snow to heavy snow, local appear snowstorm.

At 20:00 on November 6 (**Figure 3(c)** and **Figure 3(d)**), as the horizontal trough turned vertical, the cold air erupted southward.

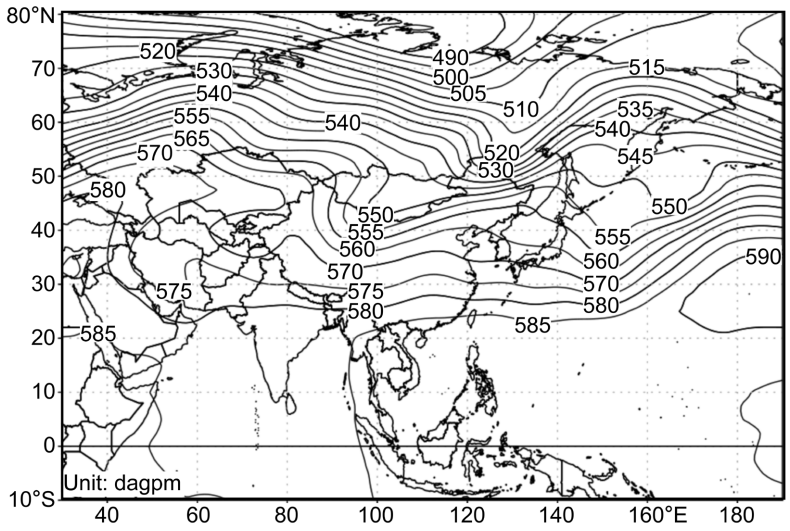
At 08:00 on November 7, the 500 hPa upper trough (**Figure 3(e)**) moved eastward to the Hetao area. The western of the surface cold (**Figure 3(f)**) front moved faster and advanced to Hunan and Guizhou. The eastern segment of the cold front moved slower and was located in eastern Shandong, which was conducive to the strengthening of cold air supplementation. From the perspective of dynamic conditions, the strong convergence and rising motions before the 500 hPa upper trough (**Figure 4(a)**) and near the 700 hPa (**Figure 4(b)**) and 850 hPa vortices (**Figure 4(c)**) are all conducive to the generation of snowy weather, with moderate to heavy snowfall in North China, Huanghuai, eastern Inner Mongolia, and western Liaoning. Blizzards or heavy snowstorms occurred in some areas, and extremely heavy snowstorms occurred locally.

At 20:00 on November 7, a low-level jet was established at 700 hPa (**Figure 5(a)**) from Shandong to Liaoning. The jet is strong and continuously transported water vapor from the Yellow Sea and Bohai Sea to the northeast. The strong convergence and rise near the upper cold vortex (**Figure 5(b)**) is beneficial to the ground (**Figure 5(c)**) decompression. The decompression excites the surface cyclone in the Yellow Sea and then moves to the northeast along the southwesterly airflow in front of the trough. Some areas appear snowstorm, local appear extreme snowstorm.

At 08:00 on November 8, the 700 hPa and 850 hPa low vortexes (**Figure 6(a)**) continued to transport warm and moist air (**Figure 6(b)**) from the Yellow Sea and the Sea of Japan to the southeast and southeast, respectively, which intensified the precipitation and caused northeastern Inner Mongolia, Heilongjiang, Jilin, Liaoning and other places. There will be moderate to heavy snow in some areas, and extremely heavy snowstorms occurred locally.

At 08:00 on November 9, the center of the surface cyclone moved eastward into the Sea of Japan, and the eastern part of Heilongjiang was located on the north side of the surface cyclone. The southeasterly wind continued to transport water vapor, causing continued snowfall in the area.

At 08:00 on November 10, as the upper trough moved eastward into the sea, the East Asian trough was established, and most of China was controlled by the northwest airflow (**Figure 7(a)**) behind the trough, and the snowfall process gradually ended.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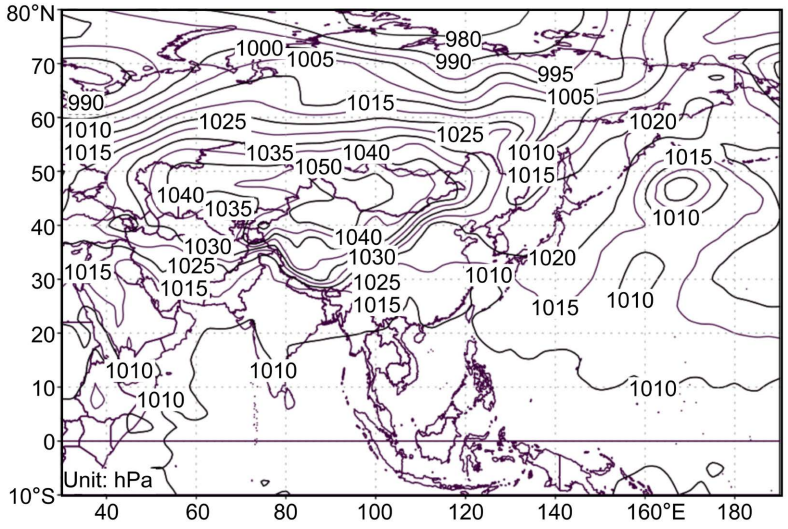
(a)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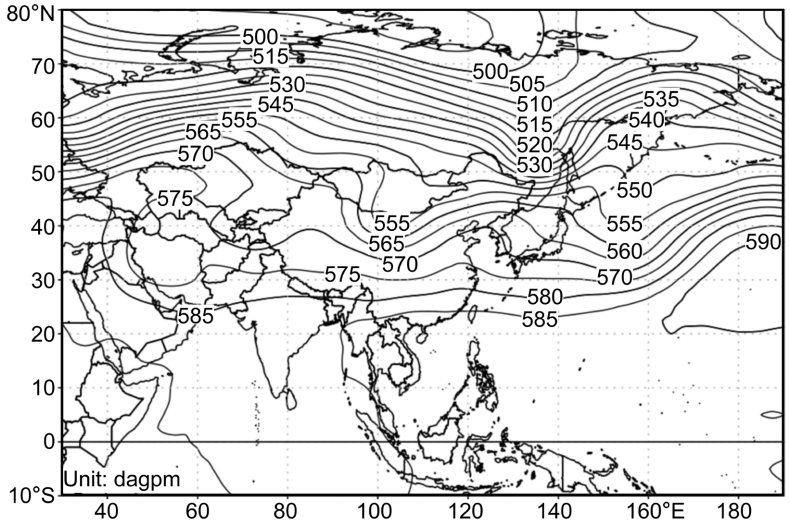
(b)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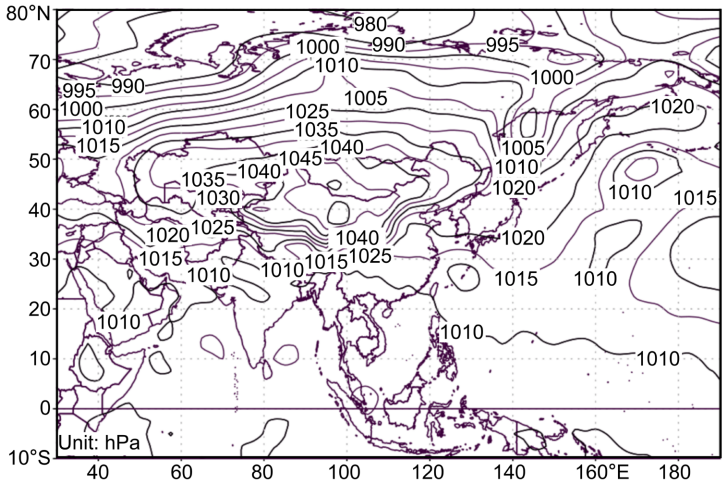
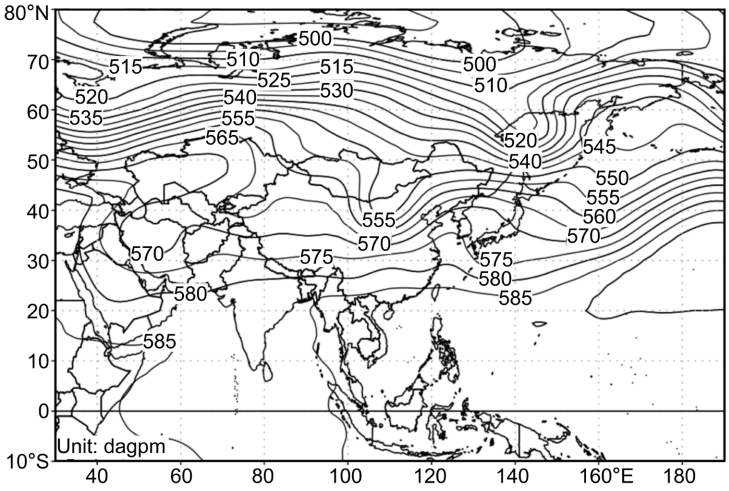
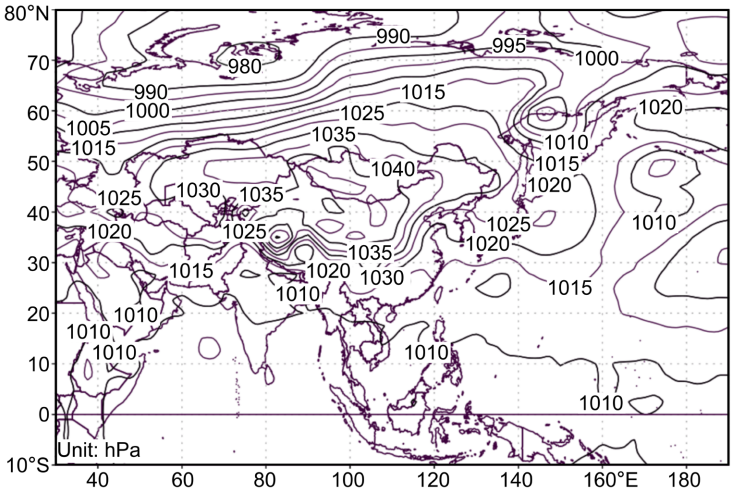
(c)



(d)

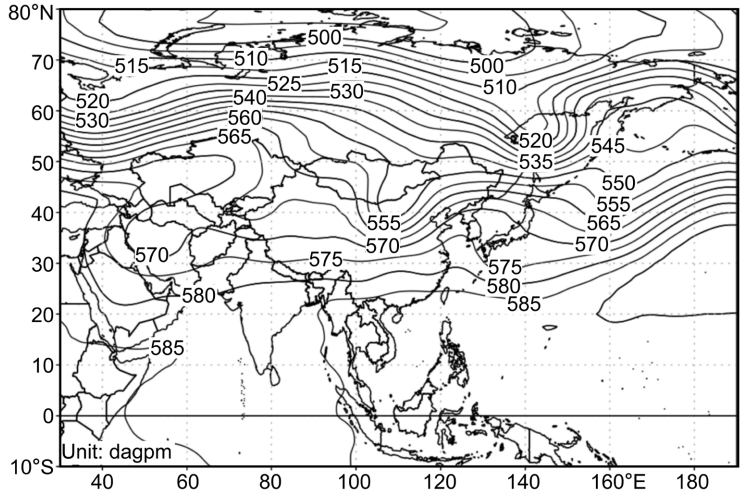


(e)

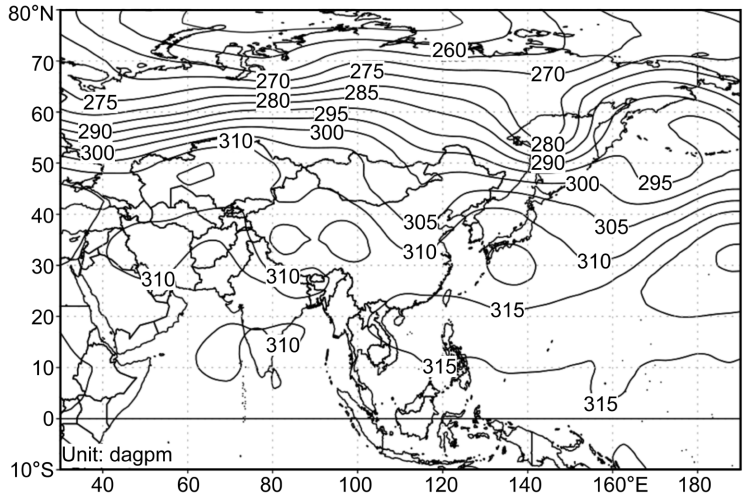


(f)

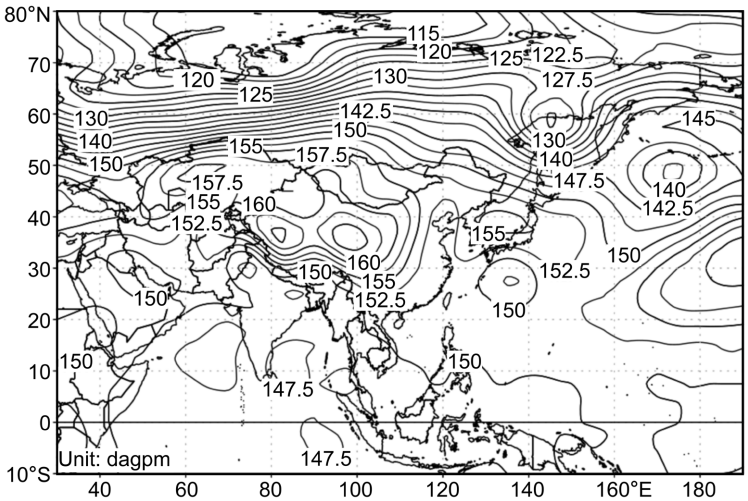
Figure 3. The 500 hPa geopotential height fields ((a), (c), (e)) and sea level pressure fields ((b), (d), (f)) at 8:00 ((a), (b), (e), (f); Beijing time, the same below) and 20:00 ((c), (d)) on November 6 ((a), (b), (c), (d)) and 7 ((e), (f)), 2021.



(a)

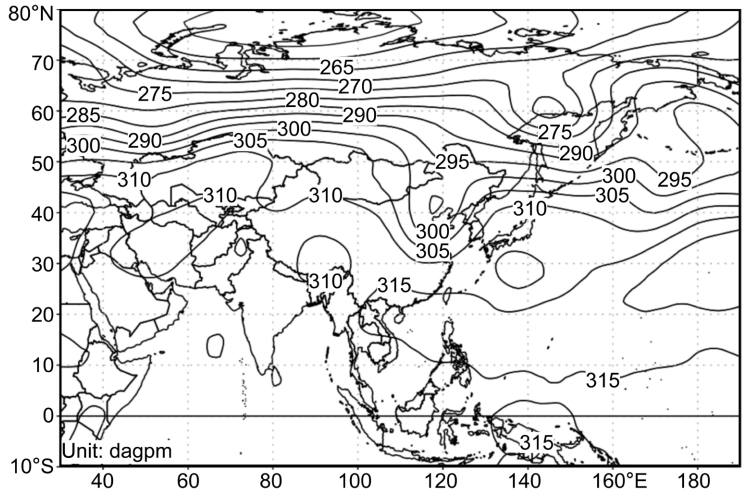


(b)

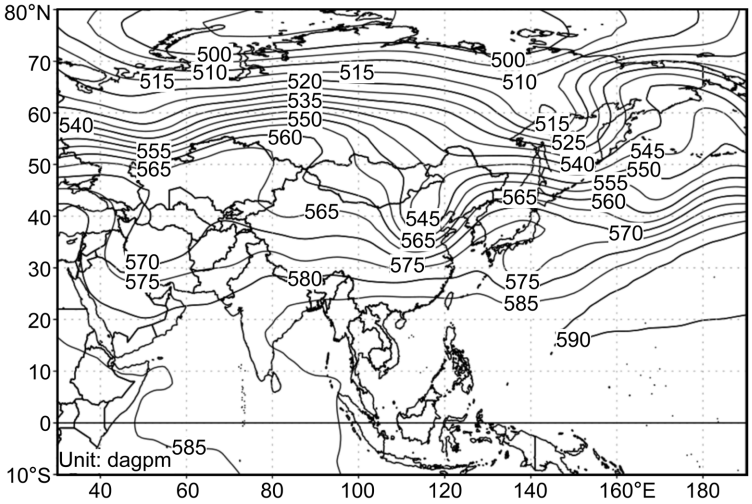


(c)

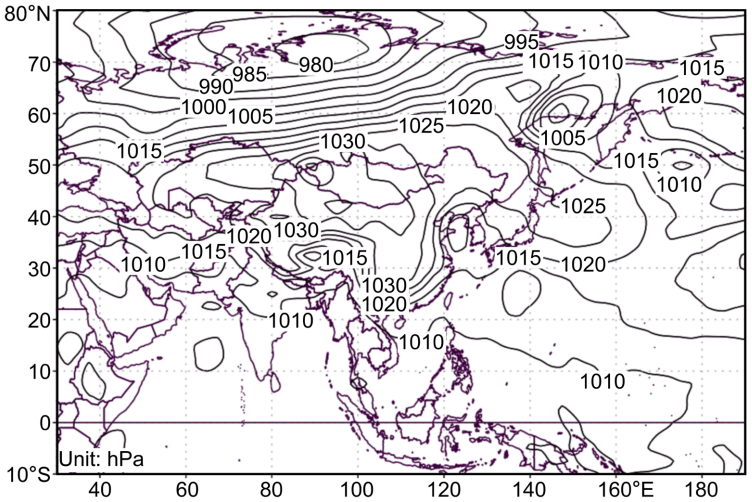
Figure 4. The 500 (a), 700 (b) and 850 (c) hPa geopotential height fields at 8:00 on November 7, 2021.



(a)

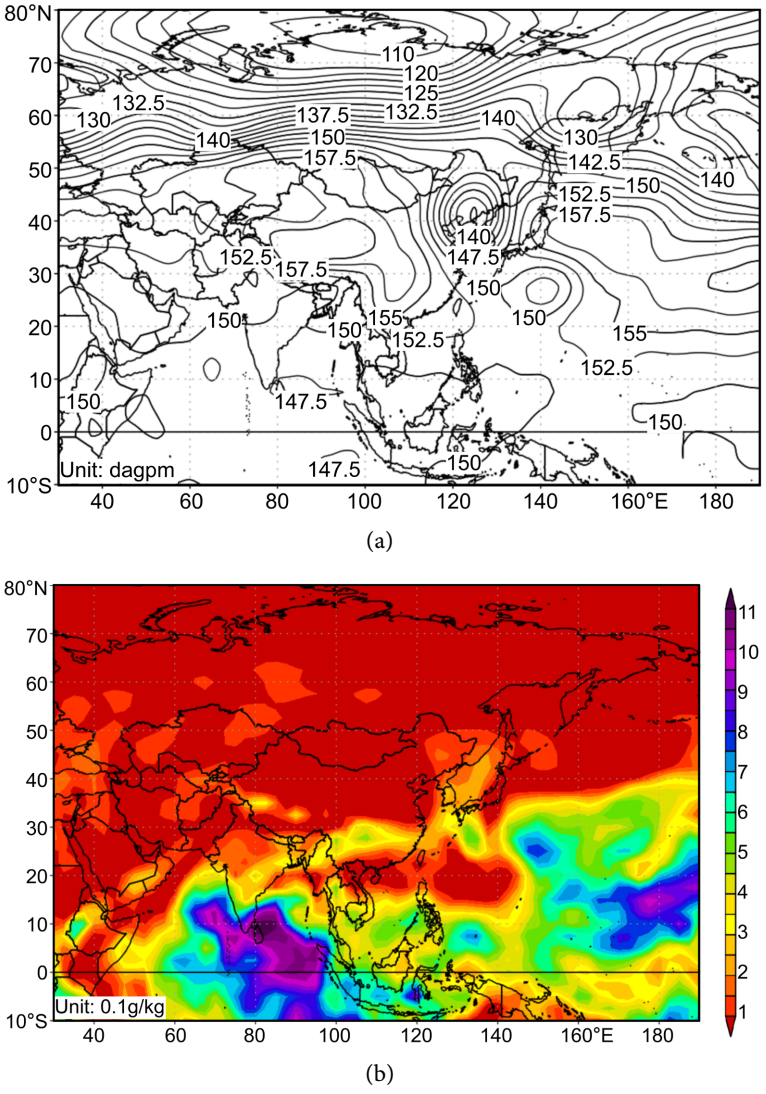


(b)



(c)

Figure 5. The 700 (a) and 500 (b) hPa geopotential height fields and sea level pressure field (c) at 20:00 on November 7, 2021.



(a)

(b)

Figure 6. The 850 hPa geopotential height (a) and specific humidity (b) fields at 8:00 on November 8, 2021.

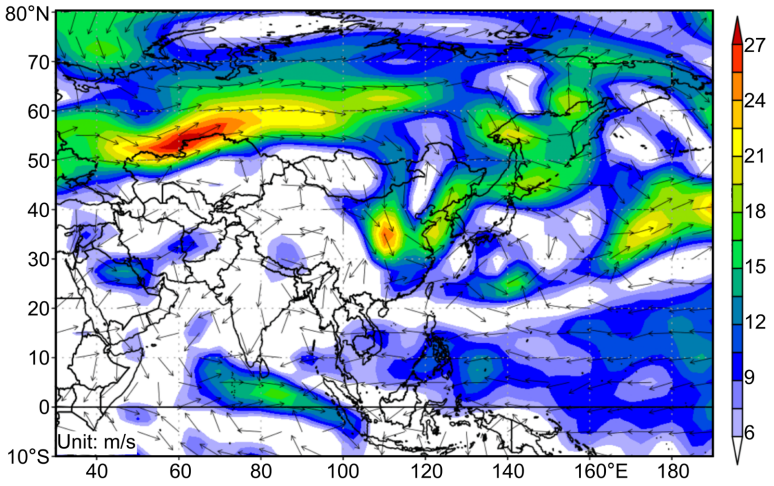


Figure 7. The 700 hPa vector wind field at 20:00 on November 7, 2021.

4. Conclusion

In the middle and high latitudes of Eurasia, circulation is adjusted from zonal to meridional with large fluctuations. An east-west horizontal trough is formed from the west side of Lake Baikal to Lake Balkhash, and the northerly wind behind the trough continuously transports the polar cold air to the south. Then, the horizontal trough slowly moved eastward and turned vertical, the circulation direction increased, and the northwest airflow behind the trough led the cold air to erupt to the southeast. In the process of moving southward, the cold air meets the warm and humid air in front of the trough, causing snowfall in the northeast.

The southerly airflow and southeasterly airflow on the east side of the vortex continued to transport warm and humid airflow from the Yellow Sea and the Sea of Japan, respectively, which enhanced the snowfall.

As the upper trough moved eastward into the sea, the East Asian trough was established, and most of China was controlled by the northwest airflow behind the trough, and the snowfall process gradually ended.

Conflicts of Interest

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

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