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Analysis of a Large Scale Cold Air Weather Process in China during January 2021

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Abstract

This study uses data provided by the National Meteorological Information Center of China, Japan Meteorological Agency (JMA) and National Oceanic Atmospheric Administration (NOAA) Physical Sciences Laboratory of the USA to analyze a cold air weather process at the beginning of January 2021. Synoptic analysis is mainly used to summarize synoptic laws or patterns based on observational data, and describe and infer weather processes. The main conclusions are as follows: The cold air travels south along the northwest path, affecting most of China. During the cold wave process, the first cold air is weak, which has a certain cooling effect on northern China. The second cold air was guided by the low vortex, the accumulation in the transverse groove of Mongolia was strengthened, and the cooling effect was significant. The southwest jet showed an increasing trend, and the water vapor transport conditions were good. However, due to the relatively gentle southern branch system, the warm and humid air flow was weak and the precipitation level was small. The purpose of this study is to better understand a large-scale cold air weather process in January 2021 in China.

Keywords

Cold Air, South Branch System, Low Vortex, Atmospheric Circulation

1. Introduction

From January 4th to 8th, 2021, a new round of strong cold air in China will appear again, and this wave of cold air will affect most parts of central and eastern China, with strong winds and cooling weather. The temperature in the areas north of the middle and lower reaches of the Yangtze River dropped by 4˚C to 6˚C, with a local drop of more than 8˚C. This cold air activity has reached the "strong cold air" standard and has not yet reached the level of a cold wave. During the development period of cold air, there is light to moderate snow or sleet in some parts of China's Jianghuai, Jianghan, Jiangnan and other areas.

In recent years, many scholars have done a lot of research on the complex cold wave weather process in China. Huang and Ren (2015) analyzed the relationship between cold air activity characteristics and temperature in China, and found the atmospheric circulation factors that have a significant impact on cold air activity, and can be used as tools for forecasting winter cold air activities. Chen and Ding (2006) pointed out that the cold air greatly enhanced the baroclinicity of the atmosphere in the process of moving southward, resulting in the release of Convective Available Potential Energy (CAPE). Under the condition of dynamic uplift provided by the secondary circulation, a wide range of convective activities are caused. Hari Prasad et al. (2010) used a high-resolution weather research and forecasting mesoscale model to simulate a severe cold wave. The good simulation results confirmed the feasibility of the forecasting model, and found that the high-pressure system and the cold air advection together affect the development of cold waves. Xu et al. (2018) indicated that the establishment of a disaster risk assessment system and the compilation of disaster risk thematic maps can effectively improve the ability to respond to cold wave disasters, ensure agricultural production, reduce the loss of people and provide a certain scientific basis. Li et al. (2006) found that the interdecadal variation of cold air outburst events in China in the past 30 years is closely related to the changes in the circulation system in the polar and near polar regions. And climate warming may also affect the occurrence of cold air events.

The above studies put forward a variety of effective theoretical studies on the cold wave weather process. We can adopt some of the methods of synoptic analysis used in the above research, so as to make some correlations between the previous research and the author's research, and provide a clear idea. However, the weather process changes in real-time, so it is very necessary to study and analyze the recent cold wave weather process. This research analyzes a strong cold weather process at the beginning of January 2021, discusses the physical mechanism behind the data, and obtains objective results that can provide a reference for future cold weather process analysis.

2. Data and Methods

2.1. Data

The study used the national climate impact assessment document and the precipitation data in early January 2021 provided by the National Meteorological Information Center of China (NCC), the 500 hPa high-altitude situation map of the Northeast Hemisphere in early January provided by the second-generation monthly Dynamic Extended Ensemble Forecast (DERF2.0) product, temperature field, 500 hPa geopotential height field, sea level pressure field, 700 hPa single-day geopotential height field and 700 hPa precipitable water map provided by the US NOAA Physical Science Laboratory (PSL) in early January, and sea level pressure field data provided by the Japan Meteorological Agency.

1) The precipitation data used in this study come from the Climate System Diagnostic and Prediction Room of NCC.

2) The national climate impact assessment document for January 2021 is provided by the NCC. The report includes weather changes and industry impacts within a month.

3) The 500 hPa geopotential height field used in this study in the first ten days of January comes from the DERF2.0. The DERF2.0 was established based on the atmospheric circulation model BCC_AGCM2.2 of the NCC, and its prediction skills for elements such as precipitation, temperature, and circulation are generally higher than those of the first-generation prediction system (Wu et al., 2013).

4) Temperature field, 500 hPa geopotential height field, sea level pressure field, as well as the 700 hPa geopotential height field and 700 hPa precipitable water on January 7th obtained on PSL. PSL provides the latest world temperature field, wind field, contour lines and other relevant weather data in order to track meteorological trends and carry out relevant meteorological research.

2.2. Methodology

This study uses synoptic analysis methods, such as structural changes in temperature and pressure fields, cold air movement paths, and low vortex movement (Zhu et al., 2007), to study the occurrence of this cold air weather process, and compares with the existing theoretical basis to demonstrate the feasibility of the results.

The weather method is a qualitative and empirical forecasting method. The development of weather processes is often continuous at a certain interval of time, so the past evolution trend of weather systems can be extended to a later period of time to predict the future change of weather patterns. The development of the shallow trough, the southward movement of the cold vortex and the accumulation of cold air are analyzed by using the 500 hPa geopotential height field map. Combined with the sea level pressure field, the movement of the surface cold high pressure center is analyzed. Through the 500 hPa high geopotential height field and the sea level pressure field, the path and intensity of the cold air intrusion into China were analyzed. The 700 hPa geopotential height field and the 700 hPa precipitable water map jointly analyze the gentle state of the south-south branch system. The rationality and innovation of this study are verified by comparing the conclusions drawn by predecessors based on different cold air intrusion situations.

3. Results and Analysis

3.1. Weather Brief

From the perspective of China as a whole, since January, most parts of China have experienced a large-scale and severe cooling process (**Figure 1**). According to the *National Climate Impact Assessment* in January 2021 released by National

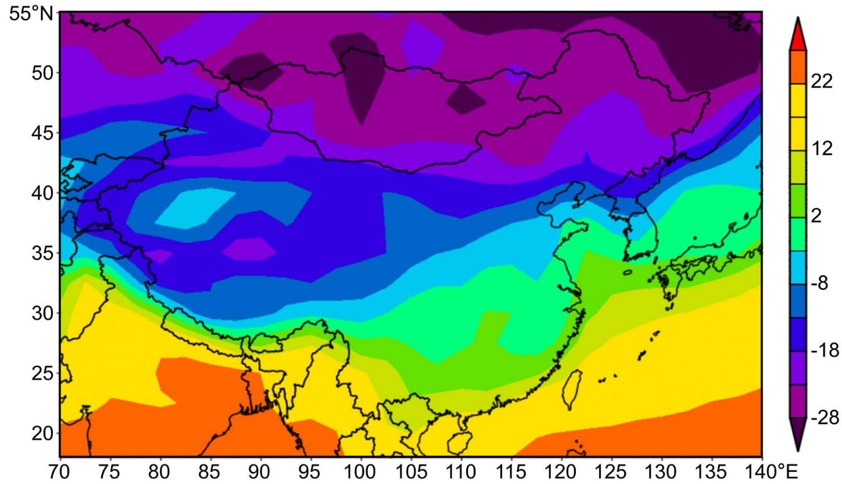

Figure 1. Distribution map of temperature in China's Mainland at the beginning of January 2021 (Unit: ˚C).

Climate Center of China, from January 4th to 7th, the central and eastern regions of China were successively affected by two strands of cold air. Among them, the cold air process on the 6th to 7th has the characteristics of a large cooling range, a wide range of influence, strong low temperature extremes, and a long duration of strong winds. There are gusts of magnitude 6th to 8th in central and eastern Inner Mongolia, southern Northeast China, most of North China, Huanghuai, Jianghuai and other places, and wind speeds of 9th to 10th in some areas. Dalian, Liaoning, Shandong Peninsula and other places have strokes to heavy snow, and local blizzards. The minimum temperature of more than 50 meteorological observation stations in Beijing, Hebei, Shandong, Shanxi and other provinces and cities broke through or reached the historical extreme value of this station. The lowest temperature in most parts of Beijing is −24˚C to −18˚C, and the lowest temperature at the southern suburbs observatory is −19.6˚C, the third lowest since 1951.

3.2. Atmospheric Circulation

At the beginning of January (**Figure 2**), the circulation in the middle and high latitudes of Eurasia was of two trough and one ridge type, and the central and eastern China was in the negative value area. There is a relatively strong high-pressure ridge near the Ural Mountains, which promotes the accumulation of cold air at the back of the Siberian transverse trough, and the Siberian high pressure is stronger than the same period of the year. The meridional degree of the circulation in the middle and high latitudes gradually increased, which provided conditions for the subsequent strong cold air accumulated in the high latitudes to move southward rapidly. During the cooling process, the Shandong Peninsula and the Liaodong Peninsula were accompanied by heavy snowfall. Because the southern branch trough system is relatively straight and the water vapor transport conditions are poor, there is no obvious precipitation process in the southern region in the first ten days (**Figure 3**).

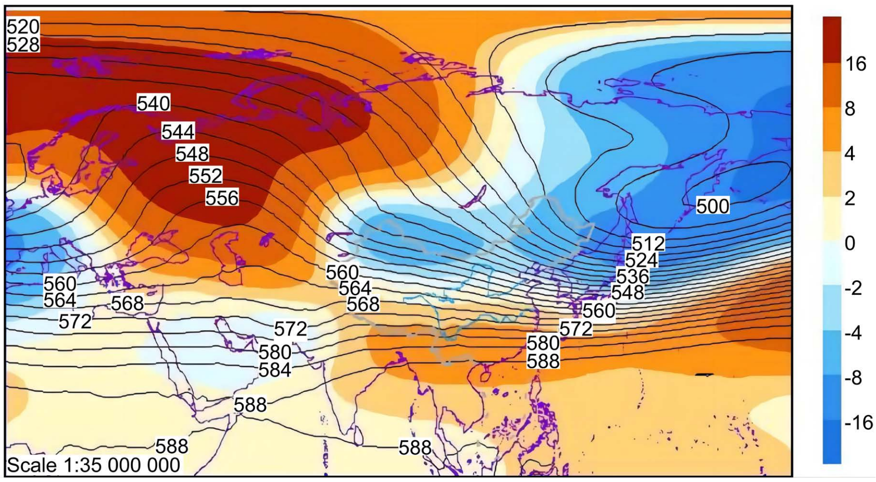

Figure 2. The 500 hPa geopotential height field mean (contour) and anomaly (shaded) in the northeastern hemisphere at the beginning of January 2021 (Unit: dagpm).

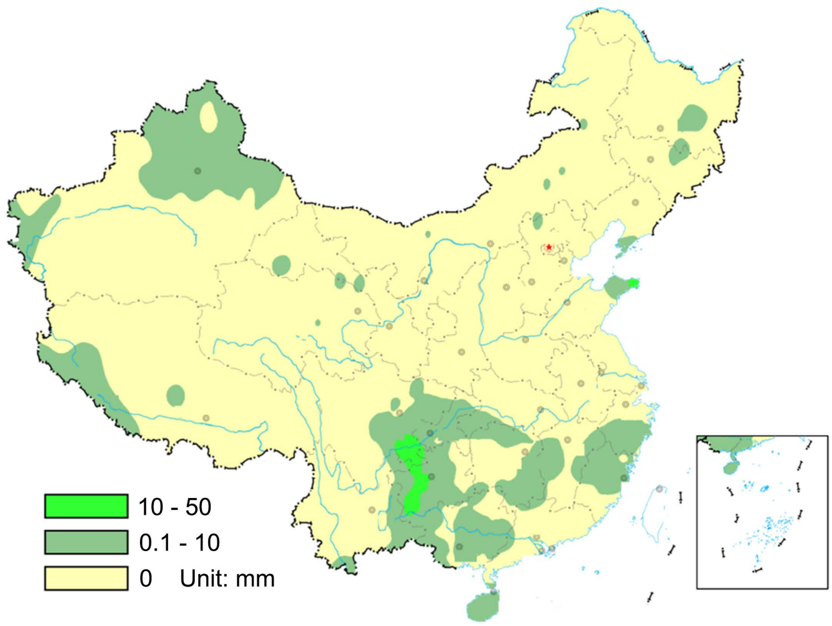

Figure 3. Distribution map of precipitation in China at the beginning of January 2021 (Data on Taiwan Province of China is currently lacking).

3.3. Cold Air Process Analysis

From January 4th to 7th, two strong cold airs in Siberia moved southward, causing most of China to experience a strong cold air process. In the central and eastern regions, there were obvious strong winds and cooling weather. Light rain or sleet occurred in parts of the Sichuan Basin and Guizhou, southern Hunan, central Jiangxi, western Zhejiang, and Fujian. Freezing rain occurred in central and southern Guizhou, southeastern Hunan, and western Fujian. This strong cold air process has the characteristics of a wide range of influence, significant low temperature extremes in Huanghuai, North China, and long duration of strong winds.

At 08:00 (Beijing time, the same below) on January 2, it can be seen from the analysis of the evolution of the 500 hPa geopotential height field (**Figure 4(a)**) and the surface pressure field (**Figure 4(b)**) that a shallow trough develops westward at a high altitude near the region from Balkhash Lake to the Altai Mountains. The surface cold high pressure occupies the east of West Siberia, and most of China is in the flat zonal circulation at the bottom of the low-value system.

At 08:00 on January 3 (**Figure 5**), the surface cold high pressure moved southward to the northern Xinjiang region of China, and the intensity of the high pressure center value can be greater than 1060 hPa. The cold air has also moved southward, and the front has reached the central and eastern part of Inner Mongolia, China. The small trough split from the trough moved eastward, bringing a weak cold air to northern China.

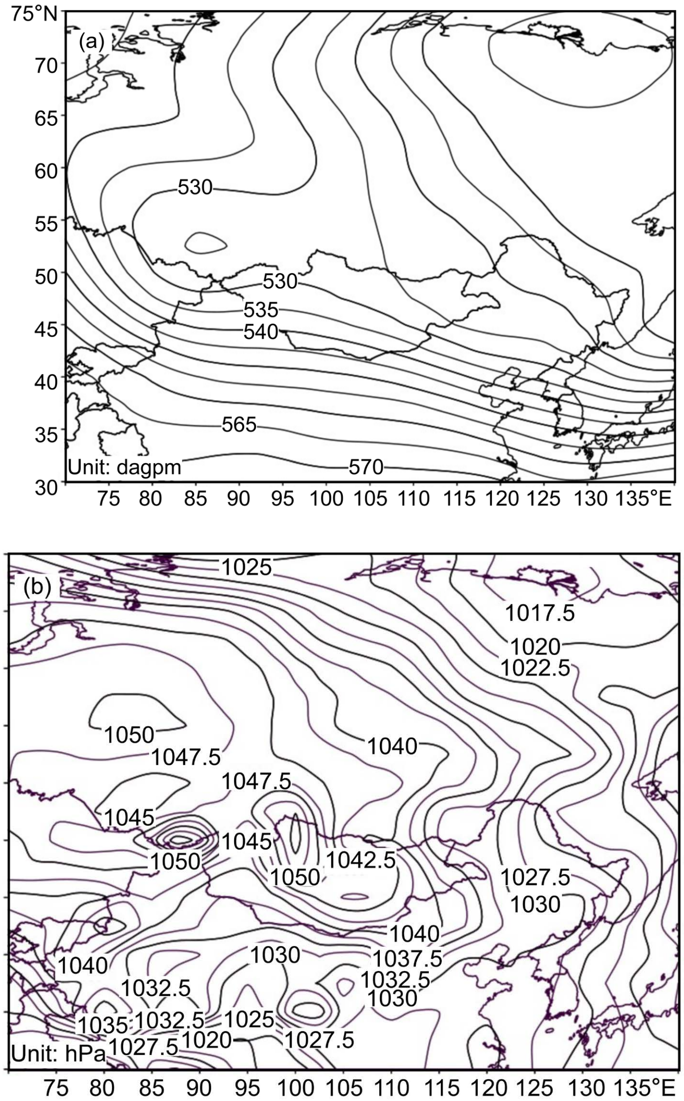

Figure 4. The 500 hPa geopotential height field (a) and sea level pressure (b) maps in East Asia at 08:00 on January 2, 2021.

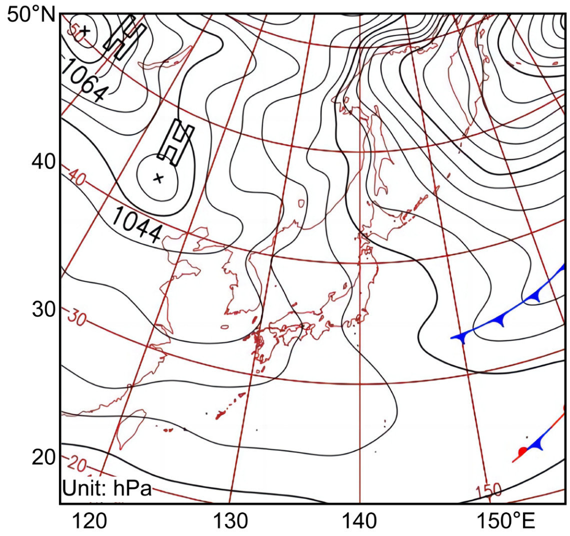

Figure 5. Sea level pressure map of East Asia at 08:00 on January 3, 2021.

Strong cold advection is the main cause of the drop in temperature (Zhang et al., 2017). According to the 500 hPa geopotential height field map (**Figure 6**) at 08:00 on January 5, the vortex in the middle and high latitudes began to move eastward and southward, and cold air entered China from Mongolia. The main body of cold air invaded most of the central and eastern China from north to south, and the lowest temperature in some northern areas refreshed the history. At 20:00 that day, the cold vortex continued to move southward to the area south of Lake Baikal. The cold air accumulated and strengthened in the central part of the Siberian (70˚E - 90˚E, 43˚N - 65˚N, cold wave key area) (Zhu et al., 2007) was guided by the northerly airflow behind the cold vortex and accumulated continuously in the transverse trough in the central and western parts of Mongolia. The large-scale cold wave weather process on the 6th and 7th paved the way.

At 08:00 on January 6, the weather can be analyzed according to the sea level pressure map (**Figure 7**). The central value of the surface cold high pressure in northwestern Mongolia reaches 1076 hPa. The cold center at the height of 850 hPa is as low as −36˚C, and the cold air is relatively strong. The striker has entered the Beijing area since the early morning of the 6th, and is showing a trend of pressing south. The pressure gradient is dense and the pressure changes greatly, causing strong winds in the central and eastern parts of Inner Mongolia, North China and Northeast China. The Shandong Peninsula and the Liaodong Peninsula are accompanied by cold current and heavy snowfall. At 20:00 that day, the Siberian cold high pressure moved eastward and southward (Yu et al., 2018), and the front of the cold front moved southward to the south of the Yangtze River. The near-surface wind direction in the eastern southwest, central and western Jiangnan, and southern China showed a northerly wind. At 08:00 on January 8, the main body of the cold high pressure moved eastward into the sea, and the cold air process ended.

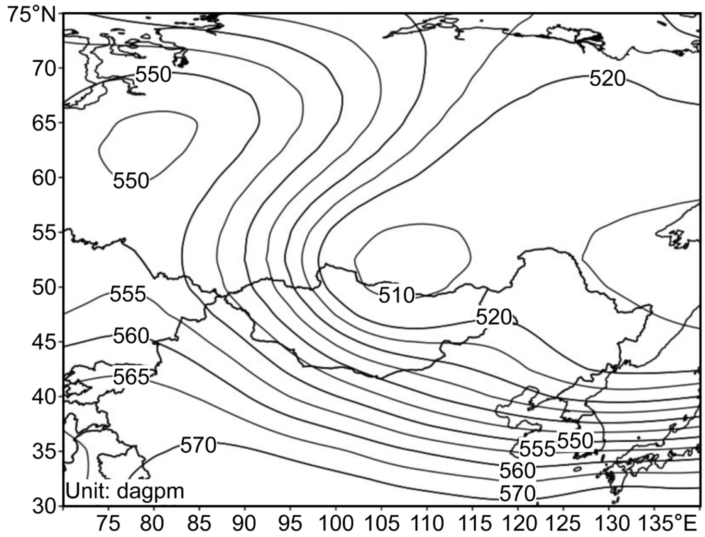

Figure 6. The 500 hPa geopotential height field map in East Asia at 08:00 on January 5, 2021.

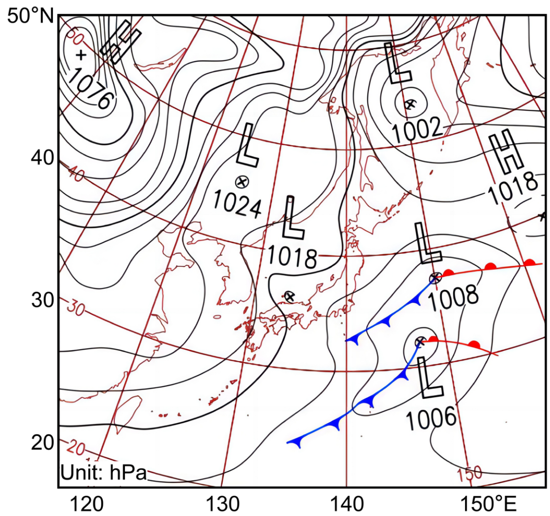

Figure 7. Sea level pressure map of East Asia at 08:00 on January 6, 2021.

3.4. Precipitation

From the geopotential height map of 700 hPa (**Figure 8**), it can be seen that the southwest jet shows an increasing trend. Water vapor is transported from the Bay of Bengal to China, and cold air and warm and humid air flow begin to meet. From the precipitable water map on the 7th (**Figure 9**), it can be analyzed that the water vapor transported from the Bay of Bengal makes the southern part of China have the conditions for precipitation. The actual situation is that scattered precipitation forms in parts of central and western Jiangnan, eastern Southwest China, and southern China. However, because the system of the southern branch trough is relatively gentle, the warm and humid airflow transported is weak, and the precipitation level formed is small, this phenomenon is also mentioned in Zhang and Xin (2016).

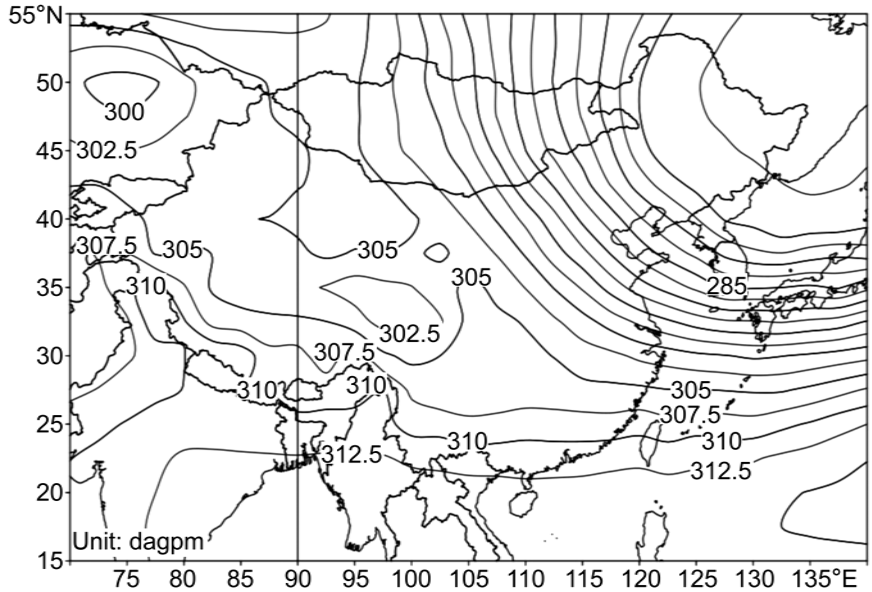

Figure 8. The 700 hPa geopotential height field in China's Mainland on January 7, 2021.

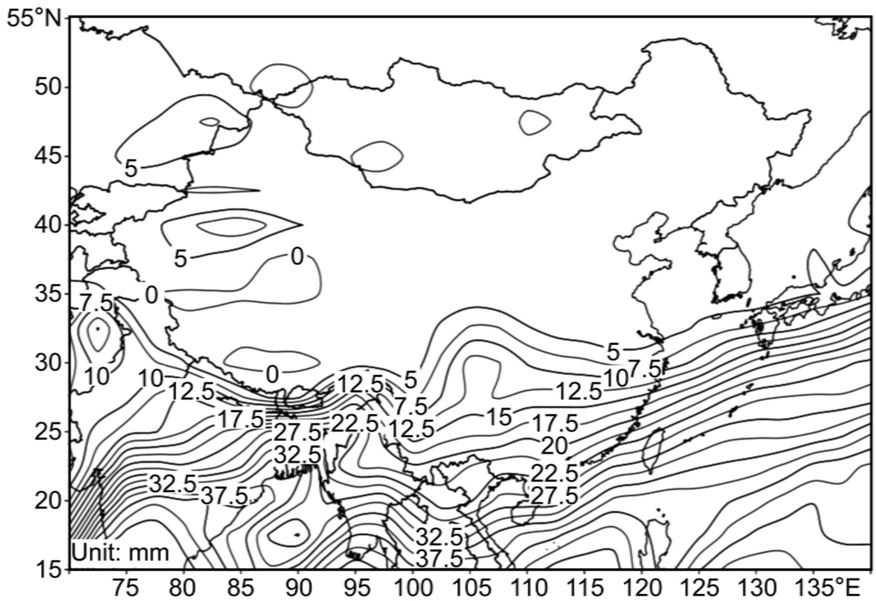

Figure 9. Precipitable water in China's Mainland on January 7, 2021.

4. Conclusion

Based on the above analysis, the following conclusions are drawn for this cold air process. The cold air starts from Novaya Zemlya, accumulates and strengthens as it passes through the key cold wave area, and then travels south along the northwest path, affecting most areas of China.

During the cold wave process, China was affected by two cold airs one after another. Guided by the eastward movement of the small trough, the first cold air caused a certain cooling effect on northern China. The second cold air was guided by the low vortex, the accumulation in the transverse groove of Mongolia was strengthened, and the cooling effect was significant.

During this weather process, the southwest jet showed an increasing trend, and the water vapor transport conditions were good. However, due to the relatively gentle southern branch system, the warm and humid air flow was weak and the precipitation level was small.

Because this research is mainly based on the weather analysis method, which is a qualitative and empirical forecasting method, there are some limitations and errors. At the same time, it is hoped that in the future research process, more high-precision and real-time observation data can be combined to make the weather analysis process more accurate and valuable.

Conflicts of Interest

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

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