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Case Study on a Snowfall Event in Beijing from March 17 to 18, 2022

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Abstract

On March 17, 2022, a city-wide snowfall occurred in Beijing, China, with significant snowfall in Northwest China and other places. By using the surface meteorological observation data and NCEP/NCAR reanalysis data, we carried out a case study of a snowfall event in Beijing from March 17 to 18, 2022. Results show that this process had the characteristics of a wide range of influence and a large range of cooling. The temperature in the north of the middle and lower reaches of the Yangtze River changed from an obvious high to low in the previous period, and the rain and snow in northern China were obvious. The snowfall in Beijing is the result of the combined influence of warm and humid air and cold air. The warm and humid air flow from the Indo-China Peninsula all the way to the north brought abundant water vapor and unstable energy. The southward cold air and warm and humid air met and collided in the central and eastern part of China, and brought about precipitation under the combined action of atmospheric instability energy and other factors. The temperature in Beijing dropped significantly, but it still has not reached the standard of "cold spring" in the meteorological sense.

Keywords

Snowfall Event, Beijing, Cold Spring, Synoptic Method, Weather Evolution

1. Introduction

On March 17, 2022, a city-wide snowfall occurred in Beijing, China, with significant snowfall in Northwest China and other places. On March 18, the snowfall in the Beijing-Tianjin-Hebei area started around 10 am (Beijing time, the same below) and spread from west to east. As of 16:00, the snowfall in Beijing was 5.1 mm, which has reached the level of heavy snow (4.2 mm) in the urban area of Beijing. The maximum precipitation in Yanqing was 10.6 mm, reaching the

magnitude of blizzard. The temperature also fell further, with a maximum temperature of only 2.5˚C as of 15:00, the coldest day in mid-March since March 13, 1980.

Snowfall is a common weather phenomenon in winter. Based on ERA5 reanalysis data, the characteristics of weather situation, water vapor condition, dynamic uplift condition, energy condition, ice accumulation environment and flight effect of aircraft in the heavy snowfall process in northeast China from November 5 to 12, 2021 are analyzed (Zhang et al., 2022). However, Beijing is located in North China, and historically, snowfall in March is rare. Zhang et al. (2013) simulated, diagnosed and analyzed the heavy snowfall in North China on March 14, 2010, and the results showed that the snowfall in North China was mainly affected by the westerly trough, low vortex and shear line in the middle and lower layers, and the Mongolian cyclone moved eastward. Liu et al. (2021) used automatic weather station, dual polarization radar, microwave radiometer and NCEP reanalysis data, combined with the simulation results of the mesoscale WRF model, and analyzed the snowfall in Jiangsu along the Yangtze River and southern Jiangsu on March 28, 2020. Hu (2016) used conventional meteorological observation data and NCEP reanalysis data to test and analyze a large-scale snowstorm process in Henan Province from February 4 to 7, 2014. The secondary circulation and frontogenesis forcing are generated, and the results showed that the "pumping" mechanism is beneficial to the formation of secondary circulation and strengthens the dynamic effect of heavy snowfall. Du et al. (2019) used multi-source observation data to analyze the extreme nature and formation mechanism of the rare snowstorm in Beijing from April 4 to 5, 2018, and the results show that this process is the first pure snow day in Beijing in April, and the snowfall and the snow depth exceeded the historical record for the same period, and the daily snowfall ranked in the top 5% of the entire cold season, which is an extreme weather process.

The relatedness of these previous studies with our study includes analysis using conventional meteorological observations and NCEP reanalysis data. They usually analyze weather patterns, water vapor conditions, dynamic uplift conditions, and illustrate the effects of high-altitude troughs, vortices, and shear lines. However the weather phenomenon is constantly updated. The above research was carried out relatively early, and it is impossible to study the latest Beijing spring snowfall weather process in 2022. Therefore, our study is carried out on the Beijing spring snowfall weather process in March 2022.

2. Data and Methods

2.1. Data

The ground surface meteorological observation data used in this study were obtained from the National Climate Center of China and the Beijing Municipal Meteorological Bureau. Reanalysis data was from the National Center for Environmental Prediction (NCEP) in the United States. The 10-day upper tropospheric

situation field data used in this study is derived from the second-generation product of the extended set of monthly dynamic forecasts (DERF2.0) of the China National Climate Center (Zhang et al., 2019; Wu et al., 2013; Qi, 2021).

2.2. Methods

The synoptic method is a kind of scientific method to study the formation process and evolution of the weather, and then comprehensively analyze and forecast the weather changes. It is an integral part of the meteorological method. Air masses and fronts, cyclones and ridges are the concepts and theories that are the basis of synoptic methods. Weather evolution occurs and develops under a certain weather situation. Correctly judging the changes of the future weather situation, it is possible to make a correct forecast for the weather changes or a weather process in a certain area in the future. This is the basic idea and process of the weather map forecasting method (Ahmadi et al., 2017; Wang et al., 2017).

3. Results and Analysis

3.1. Weather Brief

From the perspective of the whole of China, a wide range of precipitation occurred in central and eastern China in mid-March (**Figure 1**). Since the night of March 15, there has been a clear process of precipitation and cooling in central and eastern China, with snowfall in Beijing-Tianjin-Hebei and Inner Mongolia, and strong precipitation and large-scale strong convective weather in the southern region. The China Central Meteorological Observatory issued a blue rainstorm

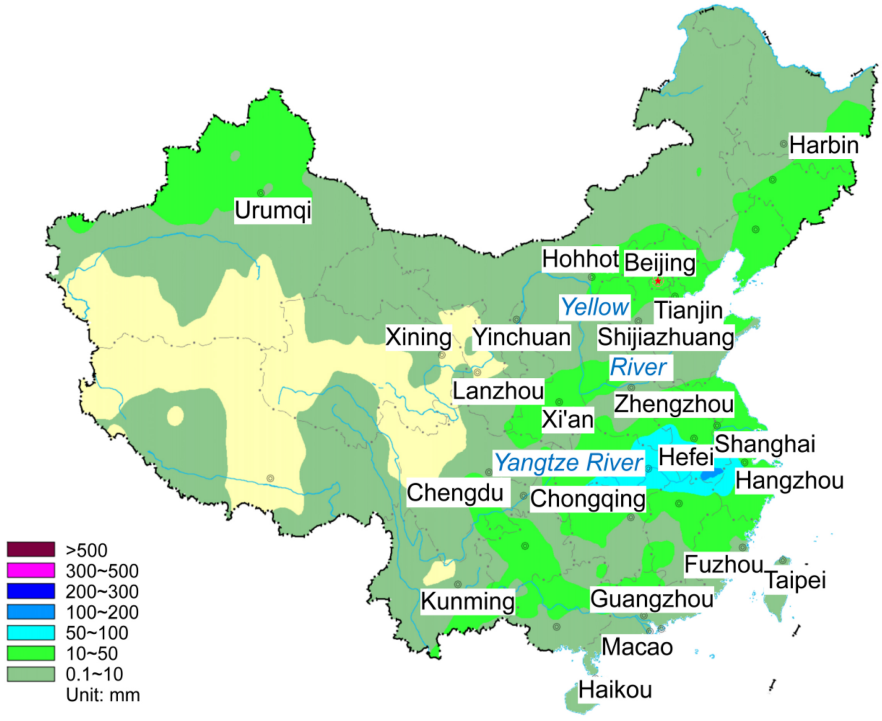

Figure 1. Distributionof precipitation across China mainland in mid-March 2022.

warning and a blue snowstorm warning at 18:00 on the 16th. On March 17, the temperature in most parts of central and eastern China dropped by 4˚C to 10˚C, and there were short-term heavy precipitation, thunderstorms, strong winds or hail in some areas. This time, the intensity of cold and warm air is very strong. The convergence of cold and warm air in the south has led to strong convective weather such as hail and strong winds in many places. The strong cold air has caused the maximum temperature in most parts of the north to drop to single digits. Actively responding to ensure that the production and life of the masses are not affected, Beijing, Tianjin, Henan and other places have extended the heating time. Under the combined influence of short-wave trough and low-level shear line, northern China experienced heavy snowfall. There were light to moderate snow or sleet in central and western Inner Mongolia, Beijing-Tianjin-Hebei, Shanxi, Liaoning and other places. Central Inner Mongolia and northern Hebei, There was heavy snow in parts of northern and western Beijing, northern Shanxi and other places, with local blizzards (10 - 15 mm), and there was continuous rain and snow in northern Xinjiang.

On March 17, a city-wide snowfall occurred in Beijing, with obvious snowfall in Northwest China and other places. As of 5:00 on March 18, the average precipitation in Beijing was 4.2 mm, and the largest precipitation occurred in Gujiang, Changping District, reaching 13.1 mm (Figure 2). On March 18, the snowfall in the Beijing-Tianjin-Hebei area started from around 10:00 a.m. and spread from west to east. By 18:00, it had entered the core period of snowfall. As of 16:00 on March 18, the snowfall in Beijing was 5.1 mm, which has reached the level of heavy snow. The snowfall in the urban area of Beijing was 4.2 mm. The

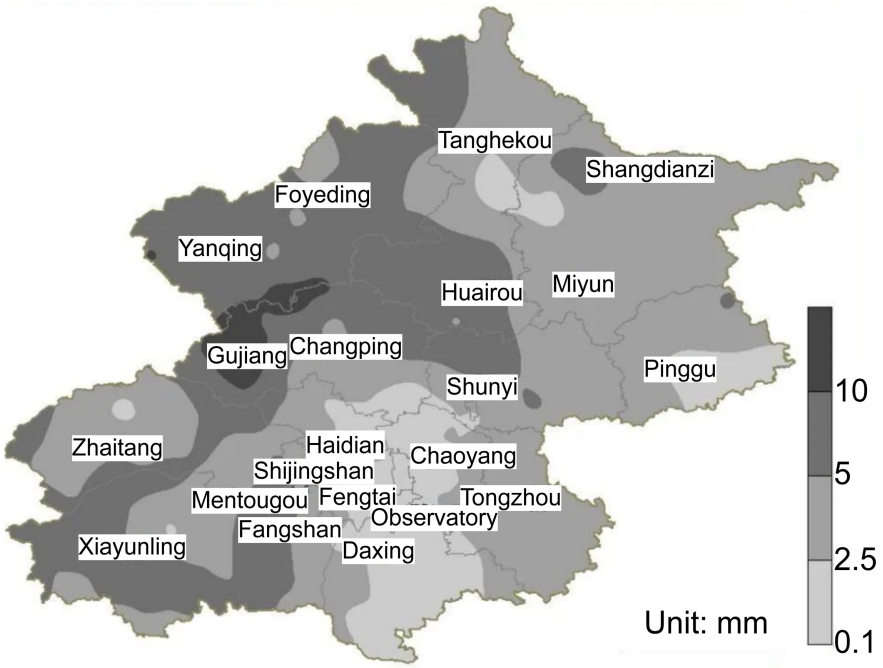

Figure 2. Cumulative precipitation map of Beijing (The shaded area is the precipitation in millimeters).

maximum precipitation in Longqing Gorge, Yanqing District, was 10.6 mm, reaching the magnitude of blizzard. Affected by the snowfall, the ground humidity has increased, and the visibility has deteriorated. The Beijing Meteorological Observatory also issued a yellow warning signal for heavy fog at 16:30 on March 18. Affected by the snowfall, most parts of Beijing were foggy, and the visibility was less than 1000 meters. Visibility in some area was less than 500 meters.

3.2. Atmospheric Circulation

It's already March, is it normal to have such heavy snow? It is not uncommon for Beijing to experience snowfall in March. It has happened in many years in history. The latest snowfall is in April, so snowfall in March is a very normal weather. Since March is just in the transition period between winter and spring, it is prone to violent fluctuations in temperature. Once the water vapor conditions are better, precipitation is likely to appear in the form of snow.

In mid-March, China was still under the control of the ridge of high pressure east of Lake Baikal (Figure 3). From March 16th to 20th, the high-pressure ridge in the east of Lake Baikal in the middle and high latitudes moved eastward, a short-wave trough was formed and developed in southern China, the East Asian trough deepened, and the meridional degree of circulation increased significantly. The power of cold air in China has strengthened, and the temperature in North China and Northeast China has changed from high to low. Among them, from March 16 to 17, affected by the high-altitude eastward-moving short-wave trough, combined with the obvious southwest warm and humid jet at the lower level, a large-scale precipitation process occurred in the central and eastern China.

From the evolution trend of the 500 hPa geopotential height field and the sea level pressure field, the cold air process from March 16 to 18 shows that the source is the ocean to the east of Novaya Zemlya, and the path is the northwest

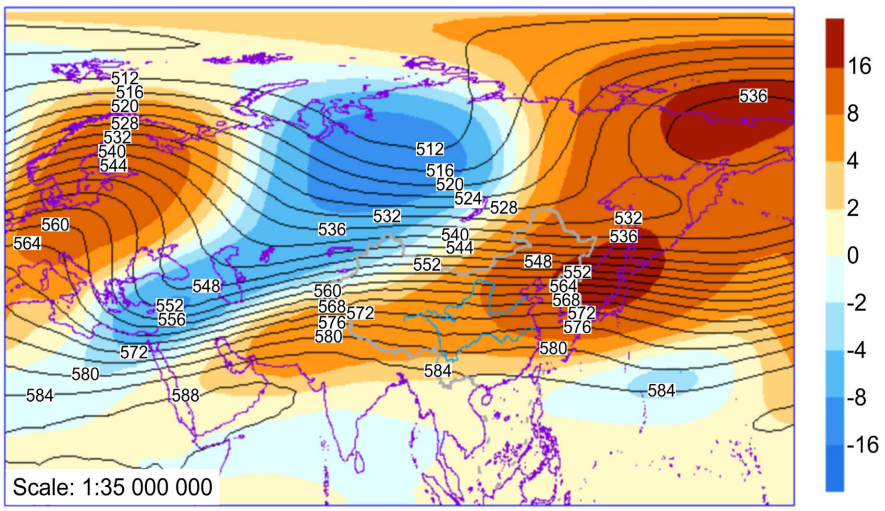

Figure 3. 500 hPa average field in Northeast Asia in mid-March, 2022 (the contour line is the geopotential height, the unit is dagpm, and the shaded area is the anomaly).

path. The cold air travels from the key area through Mongolia to the vicinity of North China, then moves east and south, affecting most of China. At 08:00 on March 16, the 500 hPa high-altitude trough moved eastward to northeastern China, and merged with the short-wave trough in this area to deepen. The surface cold high pressure moved eastward to Lake Baikal to the central part of Inner Mongolia, China, and the central pressure was greater than 1042 hPa (Figure 4). The Mongolian cyclone was strong, and the central pressure was lower than 1012 hPa. At the same time, the cold front extending from the Mongolian cyclone had already pressed into the northern part of China. There is a weak southerly water vapor transport in front of the trough, where the cold and warm currents meet.

The snowy weather in Beijing is the result of the combined influence of warm and humid air flow and strong convection of cold air. It is due to the warm and humid air flow from the Indo-China Peninsula all the way to the north, sending abundant water vapor and unstable energy. Cold air and warm and humid air flow meet and collide in the central and eastern part of China, and with the cooperation of water vapor, high-altitude trough, ground Jianghuai cyclone and other systems, and under the combined action of atmospheric unstable energy and other factors, heavy precipitation weather is also accompanied by strong snow.

3.3. "Cold Spring" Weather Judgment

Affected by cold air and snowfall, the highest temperature at the observatory during the day was 3.5˚C on the 17th, and the lowest temperature at night was −1.1˚C; on March 18, the highest temperature in Beijing continued to drop. As of 15:00 on March 18, the highest temperature in Beijing was only 2.5˚C, the

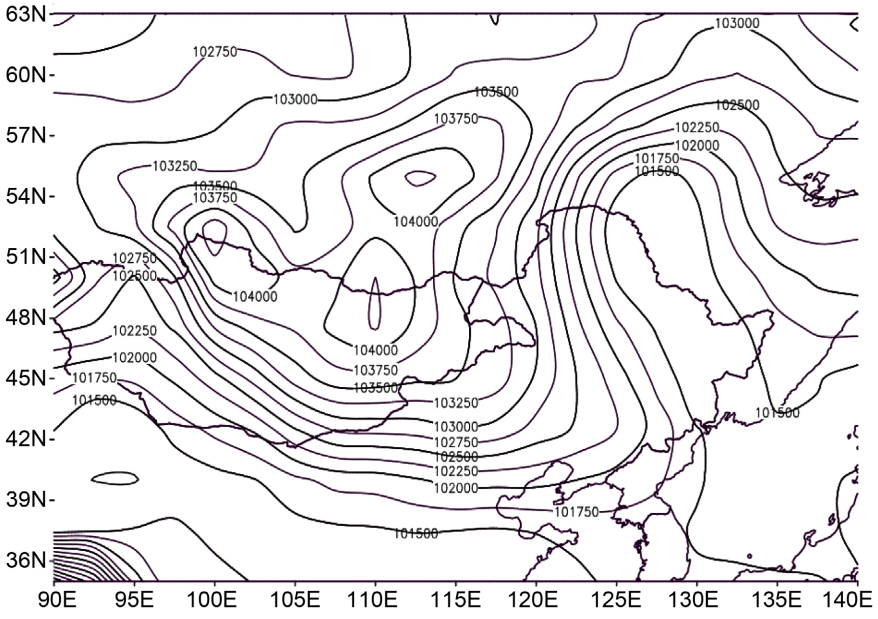

Figure 4. The sea level pressurefield at 08:00 on March 16.

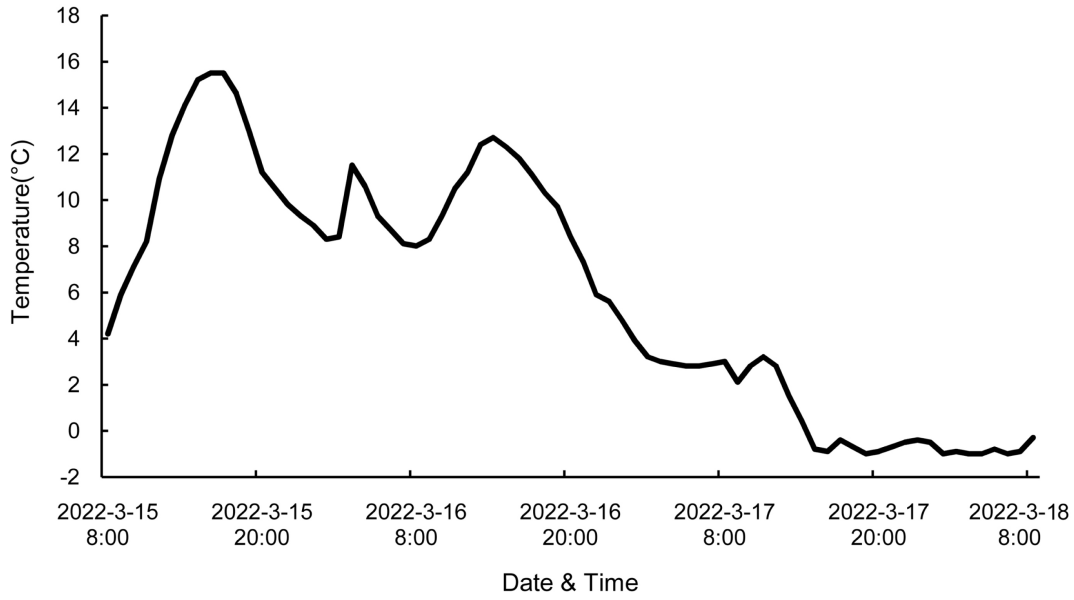

Figure 5. Beijing hourly temperature chart (The date boundary is 8:00, Beijing time).

coldest day in mid-March in the past 40 years. It was the second lowest in the same period in the past 40 years (the daily maximum and minimum temperature in mid-March in the past 40 years was 2.2˚C on March 12, 1980), and it was also the coldest day in mid-March since March 13, 1980. Although the temperature drop in Beijing this time is very large, it still does not meet the standard of "cold spring" in the meteorological sense. The cold spring countries have strict standards. The temperature must be lowered by more than 8˚C in 24 hours, or by more than 10˚C in 48 hours, and this temperature refers to the daily average temperature or the daily minimum temperature. Judging from the actual situation in Beijing, the lowest temperature on the 15th was 7.9˚C, and the lowest temperature on the 16th was 2.7˚C (**Figure 5**).

4. Conclusion

This process had the characteristics of a wide range of influence and a large range of cooling. The temperature in the north of the middle and lower reaches of the Yangtze River changed from an obvious high to low in the previous period, and the rain and snow in northern China were obvious. The snowfall in Beijing is the result of the combined influence of warm and humid air and cold air. The warm and humid air flow from the Indo-China Peninsula all the way to the north brought abundant water vapor and unstable energy. The southward cold air and warm and humid air met and collided in the central and eastern part of China, and brought about precipitation under the combined action of atmospheric instability energy and other factors. The temperature in Beijing dropped significantly, but it still has not reached the standard of "cold spring" in the meteorological sense. This study has achieved some useful results, however, in future research work, we can use more numerical models and radar and satellite

data for further research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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