Meteorological and Environmental Research 2025, 16(6): 45 -48, 52

Analysis of Meteorological Conditions in Ulanqab City and Application of Intelligent Grid Forecast in Meteorological Service Guarantee for Major Events

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Abstract Weather, climatic conditions and assessment of meteorological disaster risks are all important factors that restrict and affect the smooth holding of major events. It is crucial to accurately and promptly grasp the weather forecast at key nodes such as the start, critical period and end of major events to deal with the adverse effects caused by sudden weather. The intelligent grid forecast system has been gradually applied in meteorological service guarantee work, and effectively improved the accuracy and refinement level of weather forecast. It is needed to provide full-process and refined meteorological service guarantee, promote the standardization and normalization of meteorological services for major events, and enhance the level and efficiency of meteorological services.

Key words Meteorological services; Major events; Climatic conditions

DOI 10.19547/j.issn2152 -3940.2025.06.011

In recent years, with the continuous development of Ulanqab's economy and society, more and more major events have been held in Ulanqab City. These events are not only rich in content and diverse in form, but also are improved in scale. Major events have received extensive attention from all levels of Party and government departments as well as all sectors of society. It is particularly important to comprehensively design and plan the meteorological service work for major events. In recent years, the meteorological departments of Ulanqab City have successively provided successful support services for large-scale events and activities such as the Ulanqab International Marathon and the 7th 10 000-person Hiking Event in 2017, the 8th Food Culture Festival of China, Russia and Mongolia and the 3rd Food Culture Festival of Ulanqab, China in 2019, the National Potato Staple Food Industry Alliance Annual Conference in 2020, and the creation of civilized cities, and the content covers a wide range of fields including politics, sports, culture, ecology and tourism. It is necessary to analyze and summarize the practices and experiences of meteorological support services for major events, improve the accuracy of weather forecast during major events, and provide better meteorological support services for major events in the future.

1 Analysis of climate background and assessment of meteorological disaster risks

The analysis of climate background and the assessment of meteorological disaster risks mean analyzing the most important factors that may affect the smooth progress of an event, as well as possible high-impact weather based on the characteristics of the event, and then proposing the key meteorological issues that should be focused on when conducting this event, the possible impacts on the event, and preventive measures from a climatic perspective. During the analysis of climate background and the assessment of meteorological disaster risks, historical data in the past 30 years are generally used as statistical samples, but the characteristics of climate change in the past 10 years should also be paid attention to.

The analysis of climate background mainly includes climate characteristics, changes in meteorological elements, and high-impact weather. For instance, the climatic characteristics of the host city generally includes geographical environment, climate zones, climate types, the features of major meteorological elements, *etc.*

The main climate features affecting activities should be paid more attention to, such as temperature, precipitation, thunderstorms and other elements. For the assessment of the impact of high-impact weather, the possibility of its occurrence during the event and its impact on the event should be discussed based on the daily variation characteristics of weather elements. Analyzing climate characteristic and assessing the impact of high-impact weather at key nodes of major events is an important link to ensure the success of meteorological support and also the basis for formulating emergency plans for major events.

2 Analysis of meteorological conditions in Ulanqab City in the past decade

The changing characteristics of meteorological elements in the past 10 years should be paid attention to, and the historical averages, extremes and daily variation characteristics of meteorological

Received: October 15, 2025   Accepted: November 18, 2025
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elements closely related to activities such as temperature, precipitation, wind and relative humidity are analyzed. In this paper, the guarantee period of the Beijing Winter Olympics and Paralympics in 2022 is taken as an example, and meteorological elements such as temperature, precipitation, wind speed and relative humidity in Ulanqab City from January to March from 2012 to 2021 were analyzed.

2.1 Temperature Over the past decade, the average temperature in Ulanqab City from January to March ranged from −9.8 ℃ (in 2012) to −5.1 ℃ (in 2021), and the average maximum temperature varied from −2.4 ℃ (in 2012 and 2016) to 2.3 ℃ (in 2021), while the average minimum temperature was from −15.5 ℃ (in 2012) to −11.1 ℃ (in 2021), showing an obvious upward trend (Fig. 1).

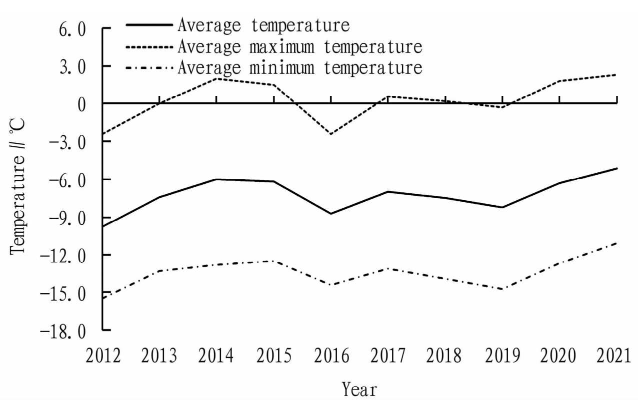

Fig. 1 Changes in temperature in Ulanqab City from January to March in the past ten years

2.2 Precipitation In the past ten years, the precipitation in Ulanqab City from January to March ranged from 5.1 mm (in 2015) to 21.0 mm (in 2017), averaging 11.3 mm. It showed an upward trend. Among them, except for 2017, 2019, 2020 and 2021, the precipitation in the other years was lower than the average (11.3 mm) (Fig. 2).

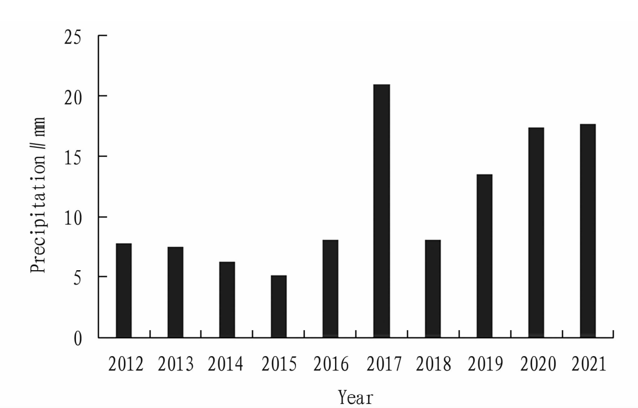

Fig. 2 Variations in precipitation in Ulanqab City from January to March in the past decade

2.3 Wind speed Over the past decade, the 2-min average wind speed in Ulanqab City from January to March was stable, ranging from 2.5 m/s (in 2012, 2013, and 2014) to 3.4 m/s (in 2021), with little fluctuation overall (Fig. 3). From the daily average wind speed in Ulanqab City from January to March over the past decade, it is seen that wind directions were relatively concentrated, and the prevailing wind directions were west−south−west (WSW), west (W), and west−north−west (WNW), with the wind frequency of 17.4%, 15.2%, and 13.0%, respectively (Fig. 4). In terms of hourly wind speed in Ulanqab City from January to March over the past decade, 2-min average wind speed was between 1.4 m/s (at 05:00) and 4.0 m/s (at 15:00), showing a single-peak variation pattern. The wind speed during the day was greater than that at night. It significantly increased at 09:00, and significantly decreased at 17:00. The peak appeared between 13:00 and 16:00 (Fig. 5).

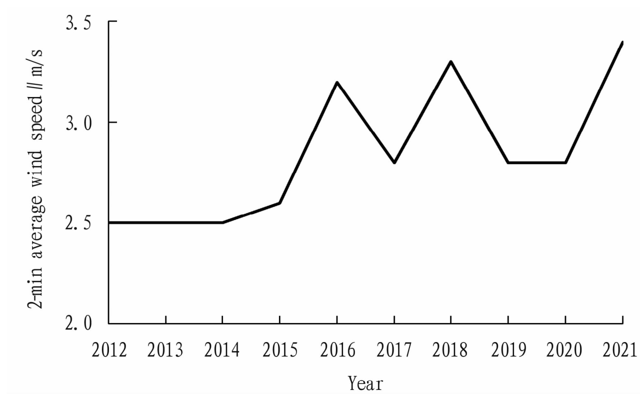

Fig. 3 Changes in 2-min average wind speed in Ulanqab City from January to March in the past ten years

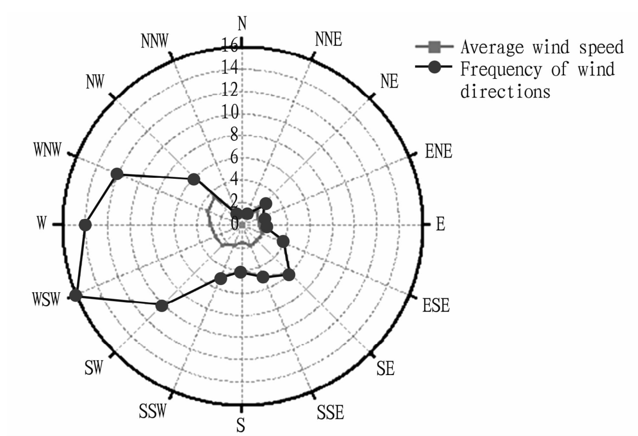

Fig. 4 Wind rose diagram of Ulanqab City from January to March in the past decade

2.4 Relative humidity Over the past decade, the average relative humidity in Ulanqab City from January to March was basically stable, varying from 42% (in 2014) to 53% (in 2020), with a small variation (Fig. 6).

From the hourly relative humidity in Ulanqab City from January to March in the past ten years, the maximum relative humidity was up to 51%, occurring at 10:00, while the minimum humidity was 25%, appearing from 17:00 to 19:00. The relative humidity during the day was lower than that at night (Fig. 7).

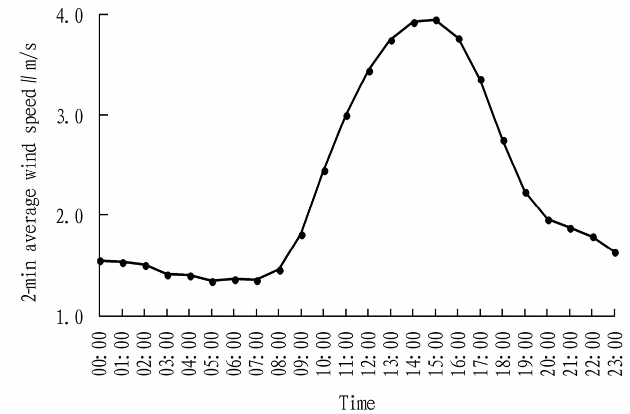

Fig. 5 Variations in hourly 2-minute average wind speed in Ulanqab City from January to March over the past ten years

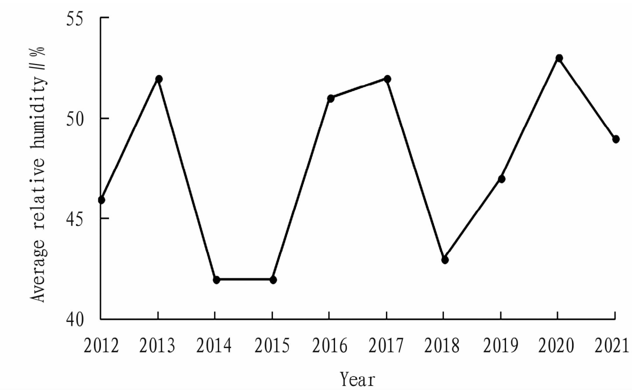

Fig. 6 Changes in average relative humidity in Ulanqab City from January to March over the past decade

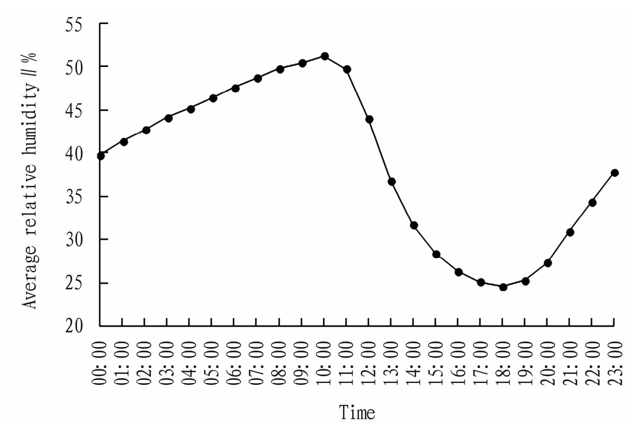

Fig. 7 Variations in hourly relative humidity in Ulanqab City from January to March over the past ten years

3 Analysis of high-impact weather and meteorological risks

With global warming, extreme weather and climate events occur frequently. It is of vital importance to closely monitor the occurrence of high-impact weather during the Winter Olympics and Paralympics. For example, a decrease in wind speed and an increase in humidity in the early morning every day may lead to a deterioration in the meteorological diffusion conditions for air pollution. A snowfall process can effectively inhibit the accumulation of pollutants and improve air quality. Low visibility weather caused by sandstorms and sandstorms has an adverse impact on the competition areas. It is needed to do a good job in the forecasting and warning of extreme weather (such as strong cold waves, extreme strong winds, sandstorms, heavy snow, as well as low temperatures and excessive warm snowmelt) that may have adverse effects on the Winter Olympics and Paralympics. Besides, various departments should strengthen cooperation. During favorable precipitation processes, meteorological departments should promptly carry out artificial snow enhancement operations, and promptly produce and release relevant meteorological risk warning information. Next, the high-impact weather during the guarantee period of Liangcheng competition area for the Beijing Winter Olympics and Paralympics in 2022 will be analyzed.

3.1 Low temperature Since the meteorological observation was conducted in Liangcheng stadium, the extreme minimum temperature in November was −25.4 ℃, occurring on November 26, 1981. The maximum number of days with the lowest temperature of below −20 ℃ reached 5 d, appearing in 1981. The extreme minimum temperature in December was −34.0 ℃, which can be found on December 27, 2002. The maximum number of days with the lowest temperature of below −20 ℃ appeared in 1981, up to 21 d. It is seen that the risk of low temperatures cannot be ignored.

3.2 Snow melting due to excessive warmth In Liangcheng stadium, the extreme maximum temperature in November occurred on November 15, 1990, reaching 18.9 ℃. The maximum number of days with the daily maximum temperature of above 5 ℃ was 23 d, appearing in 1990. The extreme maximum temperature in December occurred on December 4, 2010, up to 11.6 ℃. The maximum number of days with the daily maximum temperature of above 5 ℃ was 7 d, appearing in 1996. There was a risk of snow melting due to excessive warmth, and it would bring huge difficulties to the operation and maintenance of the stadium.

3.3 Strong winds The largest number of days with strong winds in Liangcheng stadium in November was 3 d, occurring both in 1966 and 2017. The maximum of extreme wind speed appeared on November 10, 2010, up to 23.2 m/s. In December, the number of days with strong winds was the largest in 1965 and 1972, reaching 5 d. The maximum of extreme wind speed was up to 22.1 m/s, appearing on December 29, 2010. It shows that there was a risk of strong winds.

3.4 Precipitation In November, Liangcheng stadium was mainly characterized by rain or sleet, and the maximum daily precipitation reached 25.5 mm, occurring on November 6, 2015. The largest number of precipitation days appeared in 1967, up to 12 d. The largest number of consecutive precipitation days was 6 d, occurring in 1967. The maximum continuous precipitation occurred in 2015, reaching 39.8 mm. In December, it was mainly snowy, and the maximum daily snowfall was up to 8.3 mm, appearing on

December 16, 2019. The number of snowfall days in 2012 was the largest, up to 11 d. The largest number of consecutive snowfall days was 4 d, occurring in 2002. The maximum continuous snowfall was 10.2 mm, appearing in 2002. Snowfall had put pressure on the operation, maintenance and traffic of the stadium.

3.5 Blowing sand and sandstorms In the past 30 years, there was almost no blowing sand or sandstorm weather in Liangcheng stadium in November and December, so the probability of sand and dust weather was relatively small.

3.6 Snow accumulation Since the meteorological observation was conducted in Liangcheng stadium, the average number of snow cover days in November was 4.2 d. The maximum number of snow cover days was 21 d, occurring in 2012. The maximum snow depth reached 18 cm, appearing in 2015. The average number of snow cover days in December was 8.6 d. The maximum number of snow cover days appeared in 1967, 1981, 1986 and 2015, up to 31 d. The maximum snow depth occurred in 1968, reaching 16 cm. Snow accumulation has certain impacts on road traffic and the operation and maintenance of the stadium.

3.7 Low visibility Since the meteorological observation was conducted in Liangcheng stadium, the maximum probability of visibility being less than 1 000 m in November was 16.7%, occurring in 2019. The minimum visibility was 50 m, appearing on November 1, 1959. In December, the maximum probability of visibility being less than 1000 m occurred in 2016, up to 32.3%. The minimum visibility occurred on December 23, 2015, only 50 m. There was a risk of low visibility, and low visibility had a certain impact on the normal progress of the competition.

4 Application of intelligent grid forecasting in meteorological service guarantee

With the continuous development and improvement of China's weather system, seamless and all-coverage intelligent grid forecasting has become an important business system and technical support for modern weather services. In the meteorological service guarantee for major events, intelligent grid forecasting has well met the meteorological service guarantee requirements for major events, and has played an important supporting role in improving the level of meteorological services for refined decision-making.

The forecast validity period of intelligent grid forecast is 7 – 10 d, and forecast elements include temperature, humidity, precipitation, wind direction and speed, cloud cover, weather phenomena and other meteorological elements. It realizes hourly rolling release, integrates various numerical forecast products to conduct comprehensive analysis, continuously generates decision-making service products and makes rolling corrections, and makes real-time adjustments to the occurrence time, magnitude and landing area of weather processes, predict the meteorological conditions for major events, respond promptly to the adverse effects caused by sudden weather, and effectively enhance the accuracy and refinement level of weather forecast.

5 Measures for the improvement of meteorological service guarantee work

5.1 Optimizing service processes and improving the content of meteorological services In recent years, the China Meteorological Administration has adjusted the layout of business services of municipal and county bureaus, optimized the process of meteorological service guarantee work according to the different demand characteristics of major events, given full play to the role of intelligent grid forecast in grassroots decision-making meteorological services, improved the content of different decision-making service products, optimized the standardization of product templates, and played the technical support role of municipal and provincial departments, and enhanced the meteorological service capabilities of county-level meteorological departments.

5.2 Conducting thorough reviews and summaries, and enhancing the assessment of the impact of disaster risks For major disastrous, critical and turning-point weather processes, timely review and summary should be conducted. After major events, technical reports should be made, and existing problems and deficiencies should be analyzed and improved. By leveraging intelligent grid forecasting products, it is needed to enhance the forecasting and early warning capabilities for local severe convective weather, establish a refined forecasting indicator system, strengthen the assessment of disaster risks based on impact such as small and medium-sized rivers, mountain floods and geological disasters, provide accurate, timely and authoritative decision-making suggestions to decision-making departments, and improve the scientific nature of decision-making meteorological services.

5.3 Improving service mechanisms and optimizing the plan of meteorological service guarantee According to the diverse demands for meteorological service guarantee at different nodes of major events and the varying impacts of various meteorological conditions on the activities, more refined meteorological services are provided. Based on the actual situation, it is necessary to optimize the implementation plan for meteorological service support work for major event decision-making, strengthen the coordination among the government and other departments, further improve the multi-departmental emergency response plan, and enhance the quality of meteorological service support.

6 Summary

With the continuous growth of the social economy, the government and other departments have higher requirements for meteorological services for major events. In recent years, extreme weather has occurred frequently. Therefore, Continuously improving the capacity of meteorological forecasting services and providing good meteorological service guarantees for major events are conducive to promoting the adaptation of meteorological services to social and economic development and enhancing the social status and influence of public meteorological services provided by meteorological departments. Meteorological support for major events is

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accuracy of early warnings. By constructing an integrated network of "ground – air – space" and applying technologies such as intelligent grids and short-term nowcasting, the ability to capture and predict disaster weather can be significantly enhanced, which is the material basis for achieving precise risk identification.

(2) Institutionalized and proceduralized basin joint prevention mechanisms are the organizational guarantee for achieving efficient cross-departmental collaboration. A closed-loop business process centered on information sharing, joint consultations, and warning linkage is established, and is supplemented by institutional arrangements such as joint drills, thereby effectively breaking down administrative barriers and converting warnings into collaborative prevention and control actions.

(3) The deep integration of technology and mechanism is the fundamental path for systematically enhancing the prevention capability of grassroots meteorological disasters. Only when advanced technologies provide precise guidance for the collaborative mechanism and the collaborative mechanism provides efficiency amplification for technology application can a truly efficient and resilient risk prevention and control system be constructed.

4.3 Future outlook In the future, three main directions should be continuously deepened and enhanced. At the technical level, it is needed to further optimize the "ground – air – space" monitoring network, add equipment such as unmanned aerial vehicle patrol and soil moisture monitoring, and ingeniously apply artificial intelligence forecasting models to improve the ability to accurately predict extreme weather. At the mechanism level, it is necessary to expand the scope of the basin joint prevention, establish cross-regional joint prevention communities with surrounding cities, improve a multi-department data sharing platform, and achieve intelligent decision-making for joint prevention. At the service level, it is needed to strengthen the popularization of warning information interpretation, carry out targeted science popularization publicity of disaster prevention, enhance the public's self-rescue and mutual rescue capability, and build a comprehensive meteorological disaster prevention system of "technical support – mechanism guarantee – public participation".

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an important part of public meteorological services. It is necessary to scientifically analyze and judge the climate background of the event location and the impact of high-impact weather on major events, and provide all-round, full-process and refined meteorological services for major events, targeted, timely and scientific meteorological services, and favorable support for the decision-making and arrangement of major events.

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Acknowledgement

Meteorological and Environmental Research [ISSN: 2152 – 3940] is a comprehensive meteorological and environmental scientific journal, and contains strong technicality and high orientation in China, being published bimonthly in Rhode Island, USA. It has been included by UPD, Chemical Abstracts, CABI, Cambridge Scientific Abstracts, EBSCO, AGRIS, EA, Chinese Science and Technology Periodical Database, Library of Congress (United States), and CNKI.

Fortunately, for the contributions of all authors and readers to *Meteorological and Environmental Research*, it has been published successfully for fifteen years. And we, all members of the editor office of *Meteorological and Environmental Research*, appreciate all help and assistance from you in the publication of our journal.