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Comparative Analysis and Research on the Wind since Relocation of Meteorological Stations: A Case Study of Urad Rear Banner

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Abstract Based on the observation data since the establishment of meteorological stations in Urad Rear Banner from 1974 to 2023, using meteorological data evaluation techniques, a comparative analysis was conducted on the observation data of the two station sites during the same period. The results showed that ① the mean for daily 2-min average wind speed at the meteorological stations in Urad Rear Banner from 1974 to 2023 was 4.4 m/s, which was 2.7 m/s lower than the average value after the relocation of the station, showing obvious periodic interannual variation characteristics. After the relocation of the station, the annual average wind speed was 2.2 m/s from 2007 to 2023, with a difference of 3 m/s in average wind speed between the two periods. ② After the relocation of the station, the days of strong wind decreased, and the days of strong wind in the new station site reduced by 57.28% compared to the old station. The largest reduction was in winter, with a decrease of 55.25% compared to the original site. ③ After the relocation, the dominant wind direction at Urad Rear Banner Meteorological Station was ENE. ④ According to the statistics of the average strong wind days at two meteorological stations, it was found that strong wind at Chaogewenduer Town Meteorological Station was mainly concentrated from April to June and October to next January, while strong wind at Urad Rear Banner Meteorological Station was mainly concentrated from March to June. The average strong wind days in winter decreased significantly, while the decrease in spring was relatively little. In addition, changes in wind speed and direction had a significant impact on local agricultural production, particularly on the risk of wind erosion and irrigation efficiency during crop growth seasons.

Key words Wind; Relocation of station; Comparative analysis; Agricultural impact
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Urad Rear Banner belongs to Bayannur City in western Inner Mongolia, with a geographical location of 107°05′ E and 41°06′ N. It is a border banner of ethnic minorities mainly composed of Mongolian Nationality. It borders the South Gobi Province of Mongolia to the north, with a border length of 195 km. It borders Alxa League to the west, Urad Middle Banner in Bayannur City to the east, and Hanggin Rear Banner and Dengkou County in Bayannur City to the south. The total area of the entire banner is 25 000 km^2, with a population of 67 300. The terrain of the banner is high in the south and low in the north, with an average elevation of 1 056.6 m and the highest point reaching 2 365 m. The terrain and landforms are relatively complex, with the Yinshan Mountains spanning the southern part of the banner, forming a watershed between the Hetao Plain and the northern plateau. It is a desert and semi desert grassland in the north of the Yinshan Mountains. Urad Rear Banner has a vast territory and excellent grass quality, making it an ideal grazing place since ancient times[1].

This area belongs to the temperate continental arid climate zone, with a dry climate and frequent sandstorms. National meteorological station in Urad Rear Banner was established in 1974. Due to the relocation project implemented by the banner government, the national meteorological station underwent site relocation in 2006. The new site was moved from the back of the mountain to the front of the mountain, with a relocation distance of 40 km and a decrease in altitude of more than 600 m. Moreover, the old site is still preserved as a regional meteorological station (national assessment station) for real-time observation of the six elements in the autonomous region. After the relocation, the surrounding environment of the national meteorological station has undergone changes, with significant differences in the observed values of meteorological elements when compared with the data from the old site, resulting in discontinuity, a significant increase in temperature[2], and a decrease in wind speed.

In this paper, the continuous observation data of the national meteorological stations in Urad Rear Banner from 1974 to 2023 was compared and analyzed, as well as the daily average wind speed data of the new and old stations over the past 10 years after the station site change. It revealed the differences in wind speed between the two stations at different time periods, providing reference for the monitoring and analysis of meteorological data and the development of meteorological services in the area. In addition, it also explored the impact of changes in wind speed and direction on local agricultural production, particularly on the wind erosion risk and irrigation efficiency during crop growth seasons.

1 Materials and methods

The data of 2-min average wind speed and extreme wind speed and direction obtained from the Urad Rear Banner National Meteorological Station (referred to as the "current station") from January 2007 to December 2023, as well as the Chaogewenduer Town Regional Meteorological Station (referred to as the "old sta-

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tion") from January 1974 to December 2006 was selected. Using descriptive and climate statistical methods, the annual, seasonal, monthly, and daily variation characteristics of wind before and after station relocation were analyzed[3]. According to the *Ground Meteorological Observation Standards*, a wind with an instantaneous wind speed of 17.0 m/s or more is called a strong wind[4]. If there is a strong wind on a certain day, it is generally referred to as a strong wind day. The average wind speed refers to the 2-min average wind speed[4]. According to the climate characteristics of Urad Rear Banner, the four seasons are divided into: spring from March to May, summer from June to August, autumn from September to October, and winter from November to next February.

The daily, monthly, and annual variation characteristics of wind speed were statistically analyzed, and the differences in observation data such as average wind speed, extreme wind speed, strong wind days, and wind direction frequency of extreme wind speed between two station sites from 1974 to 2023 were compared and analyzed. The correlation coefficient and arithmetic difference between the observation data of two sites during the same period were calculated. The difference $D = \text{year} - B$, where year and B represent the data of the old and new sites, respectively[5].

2 Results and analysis

2.1 Average wind speed Fig. 1 showed the variation curve of the annual 2-min average wind speed at two stations from 1974 to 2023. Seen from Fig. 1, the annual average wind speed was 5.2 m/s from 1974 to 2006 and 2.2 m/s from 2007 to 2023 after station relocation, with a difference of 3 m/s between the two periods. Statistics showed that the maximum values before and after relocation were 5.7 and 2.4 m/s, and the difference in annual 2-min wind speed between the two periods was 3.3 m/s. There was a significant discontinuity in the historical data sequence of average wind speed between the current and old sites in 2007.

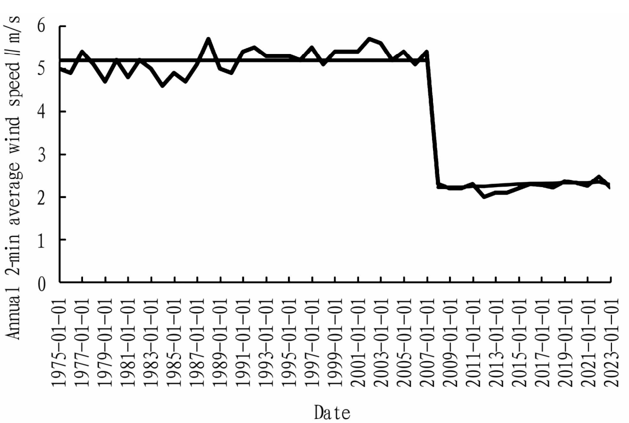

Fig. 1 Annual 2-min average wind speed at two stations from 1975 to 2023

Seen from Fig. 2, the daily 2-min average wind speed was 4.4 m/s at the old station and 2.3 m/s at the current site. The daily 2-min average wind speed at the new station was 2.1 m/s lower than that at the old station. The correlation coefficient between the daily 2-min average wind speed series of the two stations reached 0.42, indicating a high degree of correlation between the 2-min average wind speed data of the two stations. Analyzing the daily changes in average wind speed at the two stations within the year, it can be seen that the trend of the two stations was consistent, and the average wind speed at the old station was higher than that at the current station. The highest 2-min average wind speed was 5.2 m/s at the old station in April and 4.7 m/s at the new station in May. The average wind speed in August was the lowest (1.76 m/s for the old station and 0.9 m/s for the new station), with a difference of 0.8 m/s between the two stations.

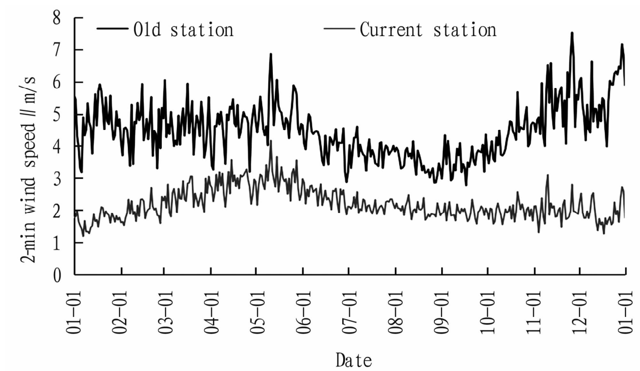

Fig. 2 Change in daily 2-min average wind speed at the new and old stations from 2009 to 2023

2.2 Extreme wind speed Comparing the extreme wind speed data of two stations, the average extreme wind speed of the old station was 3.3 m/s higher than that of the new station. The strong wind days at the new station has also significantly decreased compared to the old station, with a total reduction of 57.28% in the strong wind days compared to the original site.

The distribution of extreme wind speed in each month was roughly the same at the two locations, with the highest in November. The extreme wind speed of the old station was generally higher than that of the new station in each month, but the difference was smaller than the maximum wind speed difference. It can be seen that the instantaneous wind speed of the new and old sites is less affected by the terrain and urban factors than the 10-min average wind speed. The direction of extreme wind speed at the new station was mainly ENE, NE, and NW, while the direction of extreme wind speed at the old station was mainly SSW. The total strong wind days in the old station over the past 18 years was 611 d, while it was 261 d in the new station. Both stations had the most strong wind days in spring.

Statistical analysis was conducted on the wind direction of daily extreme wind speed at Urad Rear Banner Meteorological Station and Chaogewenduer Town Meteorological Station from 2009 to 2023, and a rose chart comparing the wind direction of extreme wind speed at the new and old stations was presented (Fig. 3). It can be seen that in the wind direction of extreme wind speed in the 15 years, WSW has appeared the most at Chaogewenduer Town Station, with 733 times; next was SSW, which appeared 626 times. The most wind direction of extreme wind speed at Urad

Rear Banner Meteorological Station was ENE, with 821 times, followed by NW, with 641 times. So N was the dominant wind direction after the station relocation.

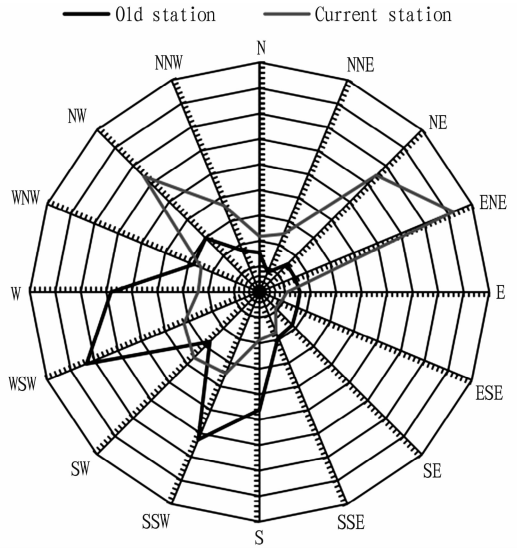

Fig. 3 Comparison of wind direction of daily extreme wind speed at new and old stations from 2009 to 2023

2.3 Monthly variation of strong wind days Fig. 4 showed the strong wind days in the old and new meteorological stations from 2009 to 2023. The monthly distribution of strong wind days was very uneven, and the monthly variation characteristics were very obvious. The strong wind days in Chaogewenduer Town Station was mainly concentrated from April to June and October to next January, while the strong wind days in Urad Rear Banner Station was mainly concentrated from March to June. Strong wind at Chaogewenduer Town Station was mainly in November, and monthly average strong wind days was 7.3 d, accounting for 17.7% of the total annual strong wind days. The second strong wind month was April, and monthly average strong wind days was 5.3 d, accounting for 13.6% of the total annual strong wind days. The third strong wind month was January, and monthly average strong wind days was 5.2 d, accounting for 13.2% of the total annual strong wind days. The monthly average strong wind days in August was only 1.6 d, which was the minimum. Strong wind at Urad Rear Banner Station was mainly in May, and monthly average strong wind days was 5.4 d, accounting for 23.8% of the total annual strong wind days. The second strong wind month was April, and monthly average strong wind days was 3.7 d, accounting for 16.1% of the total annual strong wind days. The third strong wind month was June, and monthly average strong wind days was 2.9 d, accounting for 12.8% of the total annual strong wind days. The monthly average strong wind days in January, August, and September was less than 1 d, which was the lowest.

3 Impact of wind changes on agricultural production

The changes in wind speed and direction have had a significant impact on agricultural production in Urad Rear Banner. With changes in climate conditions and adjustments in geographical environment, the dynamic characteristics of wind play an important role in the stability and yield of agricultural systems. In this paper, the specific impact of wind on agriculture is explored from three aspects: the positive effect of reduced wind speed on agriculture, the impact of dominant wind direction changes on irrigation systems, and the promoting effect of reduced strong wind days on crop growth.

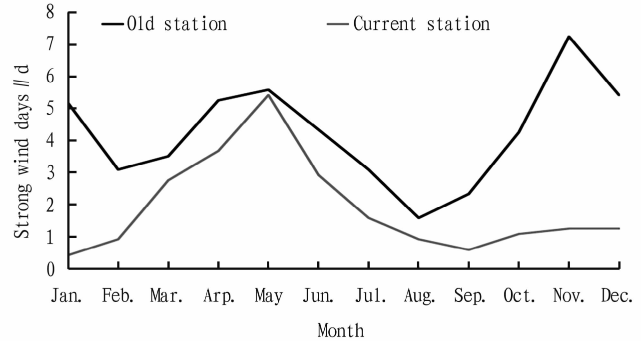

Fig. 4 Comparison of average strong wind days at new and old stations in each month from 2009 to 2023

3.1 Positive effect of reduced wind speed on agricultural production The decrease in wind speed is an important phenomenon worth paying attention to in agricultural production in Urad Rear Banner. In recent years, wind speed has shown a decreasing trend in monitoring data in agricultural areas with changes in climate conditions. This change has multiple positive impacts on agricultural production.

Firstly, the decrease in wind speed significantly reduces the threat of wind erosion to agricultural production. Strong winds can cause mechanical erosion of soil and crops in farmland, especially in arid or semi-arid areas. Wind erosion is of great significance in damaging soil structure and reducing fertility. Urad Rear Banner is located in a semi-arid climate zone, and soil water retention and nutrient content have always been important concerns for agricultural production. The decrease of wind speed can effectively reduce the damage of wind erosion to soil, and protect the structural integrity and fertility of soil, thereby providing a more favorable soil environment for crop growth.

Secondly, a decrease in wind speed can also reduce mechanical damage to crops. Strong winds can cause the stems of crops to be blown or broken, especially during the seedling stage. Excessive wind can have a serious impact on the growth and development of crops. The decrease of wind speed can effectively reduce mechanical damage to crops, and minimize interference with crop growth, thereby improving stress resistance and yield stability of crops.

In addition, a decrease in wind speed can also reduce the spread of crop diseases. Wind is an important medium for the spread of pathogens. Under high wind speed, pathogens are more likely to spread in farmland, causing the spread of crop diseases. The reduction of wind speed can effectively slow down the spread of pathogens and provide a healthier growth environment for agricultural production.

3.2 Impact of dominant wind direction changes on irrigation systems The change in wind direction not only affects the natural conditions of agricultural production, but also directly affects the layout and efficiency of irrigation systems. Recent observations in Urad Rear Banner have found that ENE has gradually become the dominant wind direction, which poses new requirements for the design and operation of irrigation systems.

Firstly, changes in the dominant wind direction can affect the distribution efficiency of irrigation water. Different wind directions will bring different patterns of water distribution. For example, ENE is usually accompanied by strong southeast water transport, which can cause a southeast tilt in water distribution in irrigation systems. Although this distribution pattern can meet the water needs of some crops, if the irrigation system is not adjusted accordingly, it may lead to uneven water distribution, and even local drought or waterlogging phenomena.

Secondly, changes in wind direction can also affect the layout and management of irrigation systems. In order to adapt to the water distribution characteristics brought by the dominant wind direction, the irrigation system needs to be adjusted accordingly. For example, the problem of uneven water distribution can be compensated for by changing irrigation time, adjusting irrigation density, or using coverings, to ensure balanced crop growth.

In addition, changes in dominant wind direction may also have an impact on the long-term stability of irrigation systems. For a long time, the irrigation system in Urad Rear Banner has mainly been based on observation data from old station. With the introduction of observation data from new station, changes in wind direction have brought new challenges to the design and operation of the irrigation system. Therefore, the irrigation system needs to be dynamically adjusted based on the latest meteorological data, to adapt to new conditions brought about by changes in wind direction.

3.3 Promoting effect of reduced strong wind days on crop growth The decrease in the strong wind days is a positive trend in agricultural production in Urad Rear Banner. Recent observation data from the new station in Urad Rear Banner have shown a significant reduction in the strong wind days compared to the old station, which is of great significance for agricultural production.

Firstly, the reduction in the strong wind days has lowered the risk of crop lodging. Strong winds are an important cause of crop lodging, especially during the seedling and growth stages. Excessive wind can cause serious damage to the stems and roots of crops. The reduction of wind speed and the decrease in the strong wind days can effectively reduce the risk of crop lodging and minimize interference with crop growth.

Secondly, the decrease in the strong wind days is beneficial for improving crop yield and quality. The growth and development of crops require certain stable conditions, and strong winds can interfere with the photosynthesis, transpiration, and growth and development of crops. The decrease in wind speed can provide a more stable growth environment for crops, thereby improving crop yield and quality.

In addition, the decrease of strong wind days can also reduce mechanical damage and disease transmission in farmland. Strong winds can cause mechanical damage to the branches, leaves, and stems of crops, especially during maturity period. Excessive wind can damage the fruits and seeds of crops. The decrease of wind speed can effectively reduce mechanical damage to crops and minimize the impact on crop yield and quality.

3.4 Comprehensive impact of changes in wind speed and direction The changes in wind speed and direction not only affect the natural conditions of agricultural production, but also have significant implications for the sustainable development of agricultural production. The agricultural production in Urad Rear Banner is facing multiple challenges, including climate change, land degradation, and water scarcity. The changes in wind speed and direction provide new opportunities for adaptive adjustments in agricultural production.

Firstly, a decrease in wind speed can effectively reduce the threat of wind erosion to soil and crops, providing a more stable soil environment for agricultural production. At the same time, the decrease of wind speed can also reduce mechanical damage and disease transmission of crops, and improve the stability of agricultural production.

Secondly, the change in dominant wind direction provides possibilities for optimizing irrigation systems. By adjusting the layout and management of the irrigation system, it is possible to better adapt to the water distribution characteristics caused by changes in wind direction, and improve irrigation efficiency and crop yield.

In addition, a decrease in the strong wind days can lower the risk of crop lodging, and minimize interference with crop growth, thereby improving crop yield and quality. At the same time, the decrease of strong wind days can also reduce mechanical damage and disease transmission in farmland, further improving the stability of agricultural production.

4 Conclusions

(1) The daily 2-min average wind speed in Urad Rear Banner over the past 47 years was 4.4 m/s, which was 2.7 m/s lower than the average value after the station relocation, showing obvious periodic interannual variation characteristics. After the relocation of the station, the annual average wind speed was 2.2 m/s from 2007 to 2023, with a difference of 3 m/s in average wind speed between the two periods.

(2) After the relocation of the station, the strong wind days at the new station decreased by 57.28% compared to the old station. The largest reduction was in winter, with a decrease of 55.25% compared to the original site.

(3) After the relocation, the dominant wind direction at Urad Rear Banner Meteorological Station was ENE.

(4) According to the statistics of the average strong wind days at two meteorological stations, it was found that strong wind at Chaogewenduer Town Station was mainly concentrated from April to June and October to next January, while strong wind at Urad Rear Banner Station was mainly concentrated from March to June. The average strong wind days in winter decreased significantly, while the decrease in spring was relatively little.

(5) The changes in wind speed and direction have a significant impact on local agricultural production, especially on the wind erosion risk and irrigation efficiency during crop growth season.

Analysis suggested that after the relocation of the meteorological bureau in Urad Rear Banner, the latitude of the current station has shifted southward, the altitude has decreased, and the surrounding environment has changed. The impact of urbanization is minimal, resulting in significant differences in wind speed and direction compared to the old station, which can no longer represent the wind conditions of the old station. Therefore, in the combination and use of historical data sequences from old site, especially in climate feature analysis, climate prediction, climate change and impact assessment research, and business services, the data should be corrected according to the actual situation. The application of other elements such as temperature and rainfall data from the two stations also requires error analysis, providing reference for weather forecasting, improvement of prediction accuracy, and disaster prevention and mitigation services.

The changes in wind speed and direction have had a significant impact on agricultural production in Urad Rear Banner. The decrease in wind speed reduces the risk of wind erosion and protects soil structure and fertility. The change in dominant wind direction has affected the layout of the irrigation system, which requires corresponding adjustments. The decrease in the strong wind days reduces the risk of crop lodging, which is beneficial for improving crop yield and quality. These changes have provided new development opportunities for agricultural production in Urad Rear Banner. Through scientific meteorological monitoring and dynamic adjustment, agricultural production can better adapt to changes in wind speed and direction, achieving sustainable development of agricultural production.

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sensitive elements for aquaculture needs (such as long wave radiation, short wave radiation, *etc.*) on the basis of existing configuration observation elements[10], in order to provide more comprehensive and refined data support for aquaculture activities, will become the key research work in the future.

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