Spatial and Temporal Distribution Characteristics of Snowstorm in Ulanqab City in Recent 30 Years

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Abstract Based on the data of daily snowfall and weather phenomena of 11 national meteorological stations in Ulanqab City from 1991 to 2020, the spatial and temporal distribution characteristics of snowstorm were analyzed. The results show that the snowstorm in Ulanqab had obvious seasonal distribution characteristics, mainly happening in spring (March - May) and autumn (September - November). It also had obvious regional distribution in space, and the snowstorm center appeared in Chahar Right Wing Middle Banner and Jining District, namely the east side of the Yinshan Mountain. In the past 30 years, the amount of snowstorm in the whole year in Ulanqab showed a certain fluctuation trend, and the number of snowstorm days had shown an obvious upward trend since 2011.

Key words Ulanqab City; Snowstorm; Spatial and temporal distribution characteristics

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Ulanqab City is located in the middle of Inner Mongolia Autonomous Region, and has a temperate continental monsoon climate, with distinct seasonal changes. In spring, the climate is dry, and there is less rain and more wind. The summer is short and warm, and precipitation is concentrated. The autumn is cool with less rain and early frost. The winter is long and cold, and there is more cold wave weather. However, Ulanqab City is also frequently affected by extreme weather, of which snowstorm is the most prominent one in the winter half. snowstorm not only seriously affects the local traffic, agriculture and animal husbandry, but also poses a threat to people's lives and property safety[1]. In this paper, based on the data of daily precipitation and weather phenomenon of 11 national stations in Ulanqab City from 1991 to 2020, the snowstorm standard was defined as follows: daily precipitation is ≥10 mm, and the weather phenomenon at the end of the precipitation is recorded as snow. Meanwhile, the number of snowstorm days and amount of snowstorm in Ulanqab City were analyzed, and then the spatial distribution, seasonal, annual and long-term changing trend of snowstorm were studied to provide a useful reference for local disaster prevention and mitigation work.

1 Spatial and seasonal distribution characteristics of snowstorm

1.1 Spatial distribution characteristics of snowstorm Fig. 1 shows the spatial distribution of snowstorm days and the total amount of snowstorm in Ulanqab City. From the spatial distribution of snowstorm days in Ulanqab (Fig. 1a), it can be seen that the spatial distribution of snowstorm days in Ulanqab had obvious regional characteristics. The area with the largest number of snowstorm days mainly appeared from Chahar Right Wing Middle Banner to Chahar Right Wing Front Banner through Jining District, and snowstorm days gradually decreased from the large-value area to the northeast and southwest. Snowstorm days in the past 30 years from Chahar Right Wing Middle Banner to Chahar Right Wing Front Banner through Jining District exceeded 20 d. Snowstorm days in Xinghe County and Fengzhen City in the south of Ulanqab were relatively less, generally less than 13 d. Snowstorm days in most other counties in Ulanqab City were between 13 and 16 d in the 30 years. As shown in Fig. 1b, the total amount of snowstorm in Ulanqab City was very similar to snowstorm days in spatial distribution. That is, the total amount of snowstorm from Chahar Right Wing Middle Banner to Chahar Right Wing Front Banner through Jining District was over 300 mm in the past 30 years. The total amount of snowstorm in the east of Chahar Right Wing Rear Banner, Shangdu County, Huade County, the east of Xinghe County, and the south of Fengzhen City was small, basically below 200 mm. It was between 200 and 300 mm in the rest of Ulanqab City in the past 30 years.

1.2 Seasonal distribution characteristics of snowstorm In the past 30 years, the snowstorm in Ulanqab started on September 25, 1997, and ended on May 26, 2000. The distribution characteristics of snowstorm days and the total amount of snowstorm in Ulanqab City in each month are shown in Fig. 2. As can be seen from the figure, both the percentage of snowstorm days (Fig. 2a) and the total amount of snowstorm (Fig. 2b) showed a bimodal distribution. That is, the peak period of snowstorm occurred in spring (March - May) and autumn (September - November), in which snowstorm days (total amount of snowstorm) accounted for 96.0% (97.6%) of the whole year. On the contrary, at the time of bitter winter (December - February), the frequency of snowstorm was very small, and the amount of snow was not large. In the early spring and late autumn, snowstorm happened frequently

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in Ulanqab, while snowstorm rarely occurred at the time of bitter winter.

As for Ulanqab City, there was less snowstorm in winter, mainly because warm and cold air should meet here to produce heavy snowfall. In severe winter, Ulanqab is controlled by the strong surface cold high pressure, and the cold air mass is dominant. Moreover, there is no or very little warm and humid air activity, so it is difficult to form heavy snowfall. In spring and autumn, trough and ridge activities in Ulanqab City are frequent, and the cold and warm air forces are similar, which is conducive to the production of heavy snowfall[2].

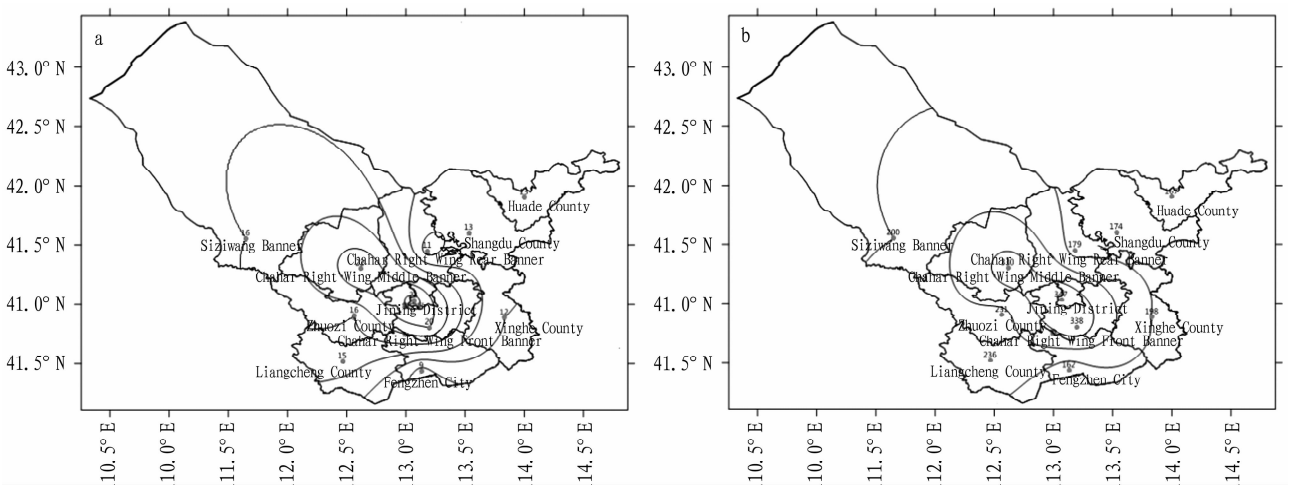


Fig. 1 Spatial distribution of snowstorm days (a, unit: d) and the total amount of snowstorm (b, unit: mm) in Ulanqab City

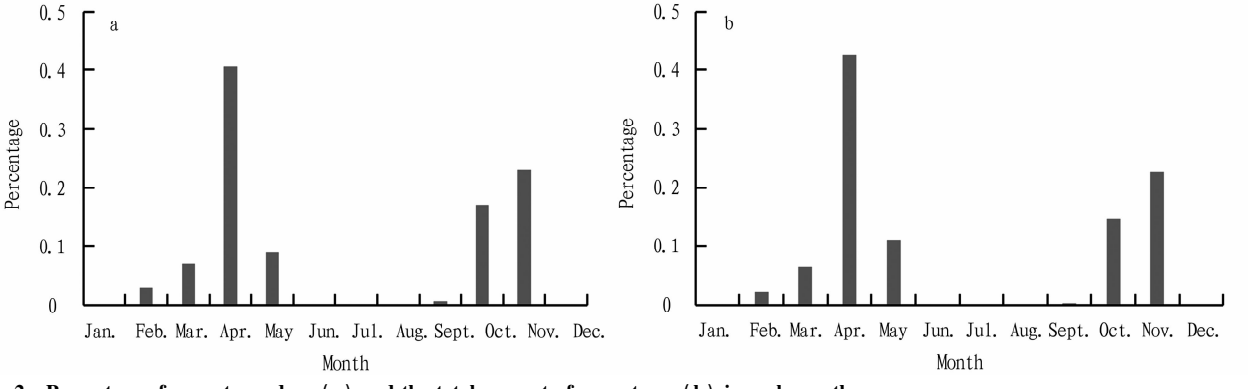


Fig. 2 Percentage of snowstorm days (a) and the total amount of snowstorm (b) in each month

2 Annual change and long-term changing trend of snowstorm

2.1 Annual variation of snowstorm The annual variations of snowstorm days and the total amount of snowstorm in Ulanqab City in the past 30 years are shown in Fig. 3. Seen from the annual variations of snowstorm days (Fig. 2a), there was an obvious periodic oscillation of 2 – 3 a, and it showed an upward trend in the past 30 years. In the first decade of the 21st century, it fluctuated more obviously than before, and the maximum (minimum) appeared in 2006 (2003). The annual variation of the total amount of snowstorm changed stably (Fig. 2b), and also has a periodic oscillation of 2 – 3 a. At the beginning of the 21st century, the frequency of extreme weather events has shown an increasing trend with global warming. From the annual variation characteristics of snowstorm in Ulanqab in spring and autumn (the figure is omitted), it is seen that the amount of spring snowstorm before 2006 accounted for 76% of the annual amount of snowstorm, and the fluctuation was small after 2006, but the amount of spring snowstorm reached the peak in 2003. On the whole, it showed a decreasing trend. Different from the evolution of the amount of spring snowstorm, the amount of autumn snowfall after 2006 accounted for 58% of the annual amount of snowstorm, and there was a significant increasing trend in autumn snowfall (the figure is omitted).

2.2 Long-term changing trend of snowstorm

2.2.1 The whole year. The linear trend of the amount of snowstorm in Ulanqab City in the past 30 years was analyzed. Fig. 4 shows the spatial distribution of regression coefficient of snowstorm. Seen from Fig. 4a, the regression coefficient of Chahar Right Wing Middle Banner, Chahar Right Wing Rear Banner, Shangdu County and Chahar Right Wing Front Banner was negative, indicating that the total amount of snowstorm in these counties showed a decreasing trend, among which the linear trend rate of Chahar Right Wing Rear Banner and Chahar Right Wing Front

Banner exceeded 3.5 mm/10 a. In particular, the decreasing trend of Chahar Right Wing Rear Banner and Chahar Right Wing Front Banner was unusually significant (passing the significance test at 0.05 level). Except for Chahar Right Wing Middle Banner, Chahar Right Wing Rear Banner, Shangdu County and Chahar Right Wing Front Banner, the regression coefficient of other stations was positive, revealing that the total amount of snowstorm in all stations showed a linear increasing trend, among which the linear trend rate was more than 3.5 mm/10 a in the north of Siziwang Banner and the east of Huade County.

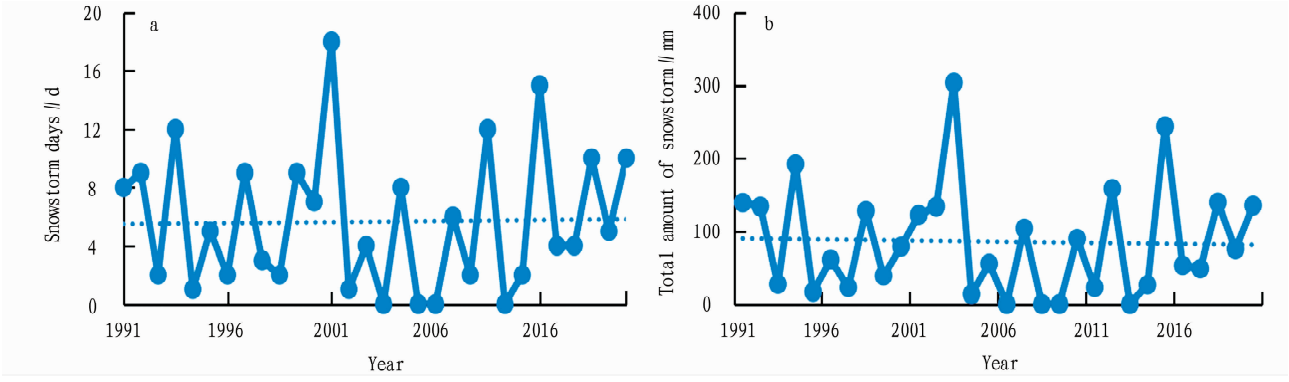
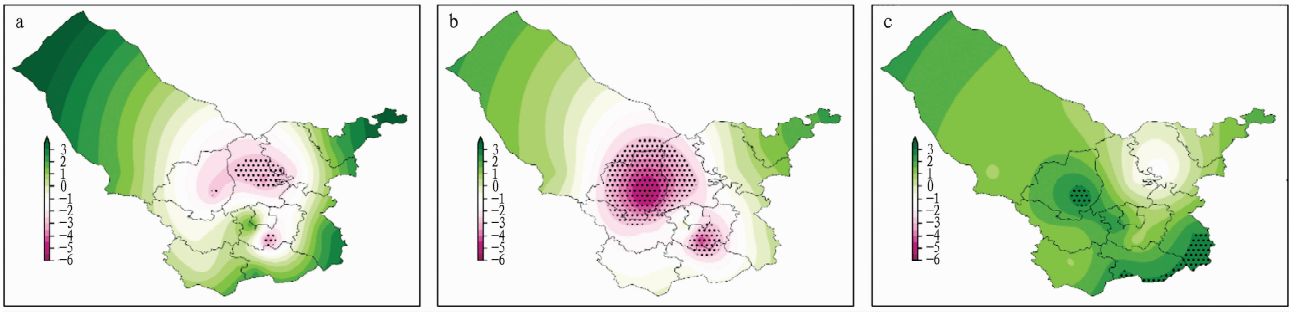


Fig. 3 Annual variations of snowstorm days (a) and the total amount of snowstorm (b)

2.2.2 Spring. As shown in Fig. 4b, the spatial distribution of the linear trend of spring (March to May) snowstorm in Ulanqab in the past 30 years was similar to that of the whole year, that is, it was more in the periphery and less in the middle. It decreased by 6 mm/10 a in Chahar Right Wing Middle Banner, but increased by above 4 mm/10 a in the north of Siziwang Banner and the east of Huade County.

2.2.3 Autumn. From Fig. 4c, the spatial distribution of the linear trend of autumn (from September to November) snowstorm in Ulanqab City was completely opposite to that of the whole year and spring. Except for a weak decreasing trend in Shangdu County, autumn snowstorm in most areas shows an increasing trend, among which it showed an abnormal increasing trend in the center of Chahar Right Wing Middle Banner, the south of Fengzhen City and the south of Xinghe County, with a linear trend of 3.5 mm/10 a.



Note: In the dot region, the reliability of linear trend exceeds the significance test at 0.05 level.

Fig. 4 Spatial distribution of linear trends of total snowstorm (a), spring snowstorm (March – May, b) and autumn snowstorm (September – November, c) in Ulanqab (unit: mm/10 a)

3 Conclusions

Based on the data of daily temperature and snowfall in Ulanqab City in recent 30 years, the spatial and temporal variation characteristics and linear variation trend of snowstorm in Ulanqab City were analyzed.

(1) The snowstorm in Ulanqab showed significant seasonal distribution characteristics. That is, in spring (from March to May) and autumn (from September to November), the frequent interaction of warm and cold air was conducive to the occurrence of snowstorm. During this period, snowstorm occurred frequently in Ulanqab, with a large amount of snow, while snowstorm rarely happened in winter (from December to next February).

(2) The distribution of snowstorm in Ulanqab City had obvious spatial differences, and snowstorm appeared frequently from Chahar Right Wing Middle Banner to Chahar Right Wing Front Banner through Jining District.

(3) There were obvious oscillations in the amount of snowstorm and snowstorm days in Ulanqab, and there was a quasi-3-year oscillation period in general.

(4) In the past 30 years, the amount of snowstorm in the whole year and spring in Chahar Right Wing Middle Banner, Chahar Right Wing Rear Banner and Chahar Right Wing Front Banner showed a decreasing trend, while the snowstorm in other counties showed an obvious increasing trend. In autumn, the snowstorm in

most areas showed an increasing trend.

Due to the vast area of Ulanqab and the large span of north and south latitudes, the standard of snowstorm was determined to facilitate the calculation of the amount of snowstorm. However, for Ulanqab, which has a high temperature in spring and autumn, the process of snowstorm defined in this way includes three phases: rain, sleet and snow, so it is necessary to determine different standards of snowstorm in the future according to the climatic characteristics of different regions.

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(From page 10)

On September 6, 1945, Mr. Yu Youren, a veteran of the Kuomintang and the most renowned calligrapher in China at the time, hosted a luncheon for Mao Zedong and others. During the banquet, he praised the concluding line of the poem *Qinyuan Spring · Snow*. That afternoon, Mao Zedong, along with Zhou Enlai and Wang Ruofei, visited two literary and ink friends, Liu Yazi and Zhang Boling, at Nankai Middle School in Shapingba. At that time, Mao Zedong gifted Liu Yazi with the book *Qinyuan Spring · Snow*. Mao Zedong's letter to Liu Yazi on October 7, 1945 also confirmed this statement: "when I first arrived in northern Shaanxi and saw heavy snow, I filled in a poem that seemed to be slightly similar in style to your poem, and submitted it for review"[6].

3 Influence of weather and climate on calligraphy works

Calligraphy theorist Sun Guoting in the Tang Dynasty proposed the theory of subject – object relationship of "Five Obedience and Five Harmony" in his book *Shupu*.

"Shi He Qi Run" refers to clear skies, moist air, pleasant climate, and excellent climatic conditions are conducive to writing. "Feng Zao Ri Yan" refers to the hot wind blowing, scorching sun, and dryness of the air. Li Yangbing talked about the "Nine Life Methods" in the *Hanlin Forbidden Scripture*, which includes "nine, life scenery, clear sky, and pleasant human heart". In the Song Dynasty, Gu Junzhi also said, "when the scenery is bright and clear, it could write; when there is a hint of darkness in the sky and earth, it does need to use writing brush". Wang Xizhi's *Prologue to the Collection of Poems Composed at the Orchid Pavilion* is a masterpiece created in the context of "clear sky, gentle breeze, and smooth flow of time". It can be seen that the warm climate provides a good creative environment for calligraphers.

If writing is done under scorching sun and dry weather, one often feels that the writing brush is stiff and unsmooth, disturbing the writer's mood, affecting their physical and mental state, and causing them to stutter.

The Chinese people said that "man and nature are one". The four seasons of nature overlap, and the weather changes. The ancient people had already felt the impact of weather on their body and mind. What environment can the best state of writing be achieved? As Zhuangzi said in the *Great and Venerable Teacher*, people and their surroundings are as suitable, harmonious, and unified as the four seasons of nature. Heaven, earth, and human form a harmonious whole. This situation is also the best result that matches the environment and the creativity of the calligrapher. So, writing in a physiological and psychological environment that is suitable for the creative subject can achieve the best state of creation[3].

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