

Climatic Characteristics of Diurnal Precipitation in Inner Mongolia During the Growing Season, 1961-2018: A Postprint

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Abstract

Based on daily surface precipitation data from 103 meteorological observation stations in Inner Mongolia from 1961 to 2018, and using trend analysis, Mann-Kendall test, and wavelet analysis methods, the spatiotemporal distribution characteristics of daytime and nighttime precipitation amount and precipitation days during the growing season in Inner Mongolia over the past 58 years were analyzed, to provide scientific guidance for future agricultural development and ecological restoration projects in Inner Mongolia. The results show that: (1) The multi-year average daytime precipitation amount and daytime precipitation days during the growing season in Inner Mongolia are generally greater than nighttime precipitation amount and nighttime precipitation days, with significant monthly characteristic differences. Both daytime and nighttime precipitation amounts and days exhibit different periodic variation characteristics, but the total regional daytime and nighttime precipitation amount has basically remained unchanged, while daytime and nighttime precipitation days show a decreasing trend. (2) The spatial distribution of average annual precipitation amount and precipitation days during the growing season in Inner Mongolia both exhibit a uniform decreasing characteristic from northeast to northwest, but in central-southern and eastern Inner Mongolia, daytime precipitation contributes significantly to daily precipitation, with large differences between daytime and nighttime precipitation amounts and between daytime and nighttime precipitation days, while in the western region, the differences between daytime and nighttime precipitation amounts and precipitation days are small. (3) The spatial changes in daytime and nighttime precipitation amounts during the growing season are similar, i.e., decreasing in the central region and increasing in the western and northeastern regions. However, the spatial changes in daytime and nighttime precipitation days differ significantly: daytime precipitation days remain basically unchanged in the western region and show a decreasing trend in the central and northeastern regions, while nighttime precipitation days show

an increasing trend in the central-western and western parts of the northeast, and a decreasing trend from southeast to northeast.

Full Text

Climatic Characteristics of Day and Night Precipitation During the Growing Season in Inner Mongolia from 1961 to 2018

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Abstract

Based on daily surface precipitation data from 103 meteorological observation stations in Inner Mongolia from 1961 to 2018, this study analyzes the spatiotemporal distribution characteristics of day and night precipitation amounts and days during the growing season using trend analysis, Mann-Kendall test, and wavelet analysis. The results provide scientific guidance for future agricultural development and ecological restoration projects in Inner Mongolia. The findings indicate that: (1) The multi-year average daytime precipitation amount and number of daytime precipitation days during the growing season are generally greater than their nighttime counterparts, with significant monthly variations. Both day and night precipitation exhibit different periodic characteristics, though the total day-night precipitation amounts remained essentially unchanged while precipitation days showed decreasing trends. (2) The spatial distribution of average annual precipitation amount and days during the growing season both show a uniform decreasing pattern from northeast to northwest. However, daytime precipitation contributes more to daily precipitation totals in south-central and eastern Inner Mongolia, where differences between day and night precipitation amounts and days are large, while these differences are small in western regions. (3) The spatial variation trends of day and night precipitation amounts are similar, showing decreases in central areas and increases in western and northeastern regions. However, the spatial variation patterns of precipitation days differ substantially: daytime precipitation days remained essentially unchanged in the west, decreased in central and northeastern regions, while nighttime precipitation days increased in central-western and western parts of the northeast but decreased from southeast to northeast.

Keywords: day and night precipitation; night precipitation rate; change trend; oscillation period; Inner Mongolia

1 Data and Methods

Precipitation data were obtained from the China Meteorological Data Sharing Network (<http://data.cma.cn/>), with all data standardized, quality-controlled, and verified by the National Meteorological Information Center. Based on principles of station homogeneity and data completeness, daily surface precipitation data from 103 meteorological stations in Inner Mongolia during the growing season (May–September) from 1961 to 2018 were selected [Figure 1: see original paper]. According to Chinese meteorological observation standards, precipitation occurring between 20:00 and 08:00 Beijing Time is recorded as a nighttime precipitation event, with accumulated precipitation during this period defined as nighttime precipitation amount; precipitation occurring between 08:00 and 20:00 is recorded as a daytime precipitation event, with accumulated precipitation defined as daytime precipitation amount. Precipitation intensity is defined as the ratio of total precipitation amount to precipitation days. Analysis shows that the multi-year average growing season precipitation total in Inner Mongolia exhibits a distribution pattern of high values in the northeast and low values in the northwest.

The Mann-Kendall test was used for trend analysis of day and night precipitation changes, and wavelet transform methods were employed to analyze periodic characteristics of growing season precipitation. For convenience, the decades 1960s, 1970s, 1980s, 1990s, 2000s, and 2010s are referred to as 1960s, 1970s, 1980s, 1990s, 2000s, and 2010s respectively.

2.1 Temporal Variation Characteristics of Growing Season Precipitation

The multi-year average growing season precipitation total is approximately 281 mm, accounting for over 85% of annual precipitation. Daytime precipitation totals are generally greater than nighttime totals, with daytime precipitation of about 157 mm (55.9% of growing season total) and nighttime precipitation of about 124 mm (44.1%). Trend analysis shows no significant trends in either daytime or nighttime precipitation totals, and consequently no significant change in the contribution rate of nighttime precipitation to the growing season total ($P = 0.98$). The overall growing season precipitation total also shows no significant trend ($P = 0.64$). Decadal statistics reveal that both daytime and nighttime precipitation totals were highest in the 1990s (about 30 mm above the multi-year average) and lowest in the 2000s (about 20 mm below average). Mann-Kendall mutation tests indicate that daytime precipitation had increasing and decreasing mutations in 1990 and 2002 respectively, while nighttime precipitation had similar mutations in 1990 and 2005, though none passed the 0.05 significance level.

The multi-year average number of daytime precipitation days (22.7 days) exceeds that of nighttime precipitation days (20.4 days). Both show decreasing trends, but only the nighttime trend is statistically significant ($P < 0.05$), with an average decline of about 0.3 days per decade. Decadal variations show the fewest daytime precipitation days occurred in the 2000s, while the most nighttime precipitation days occurred in the 1960s and 1990s.

2.2 Periodic Analysis of Growing Season Precipitation

Wavelet analysis reveals that daytime precipitation exhibits multi-timescale characteristics with a dominant 15–25 year periodicity controlling its variation throughout the study period [Figure 3: see original paper]. Within this timescale, alternating wet-dry periods occurred mainly after 1980, with three oscillations observed. A secondary periodicity of 5–10 years shows more frequent alternations. Wavelet variance analysis shows two significant peaks corresponding to 18-year and 8-year scales, with the 18-year scale representing the primary period.

Nighttime precipitation shows different periodic characteristics, with a 23–29 year cycle dominating its variation [Figure 3: see original paper]. This timescale exhibited four oscillations before 1990. An 11–18 year timescale shows frequent alternations. Wavelet variance indicates nearly equal peaks at 25-year and 15-year scales, suggesting these two periodic fluctuations jointly control nighttime precipitation variation.

Both day and night precipitation days show similar multi-timescale characteristics [Figure 4: see original paper]. Their evolution exhibits periodic patterns at 6–10 year and 15–29 year scales. The 6–10 year scale shows stable performance across the entire study period with four oscillations, while the 15–29 year scale shows multiple oscillations. For daytime precipitation days, the primary period is 18 years, while for nighttime precipitation days, both 18-year and 25-year scales show nearly equal peaks, indicating they jointly control the periodic characteristics.

2.3 Spatial Variation Characteristics of Growing Season Precipitation

The spatial distribution of average annual day and night precipitation amounts during the growing season is similar, showing a uniform decreasing pattern from northeast to northwest [Figure 5: see original paper]. High-value areas in the northeastern Hulunbuir region receive over 200 mm, accounting for more than 60% of growing season totals. Precipitation contribution rates and day-night differences show that daytime precipitation contributes most to daily totals at the junction of Xilingol League and Chifeng City in south-central Inner Mongolia, reaching 42 mm—over 50 mm higher than nighttime precipitation. This difference gradually decreases outward. Generally, daytime precipitation exceeds

nighttime precipitation in south-central to northeastern regions, while day and night amounts are nearly equal in northwestern Inner Mongolia.

The spatial trends of day and night precipitation amounts are also similar [Figure 5: see original paper]. Precipitation decreased in Hulunbuir's western region, Hinggan League, Tongliao City, Chifeng City, Xilingol League, and Ulanqab City, while increasing elsewhere. Among daytime precipitation, 57% of stations show decreasing trends and 43% show increasing trends. The fastest decrease occurred in Hinggan League ($-1.1 \text{ mm} \cdot \text{a}^{-1}$), while the fastest increase was in Ordos City ($0.8 \text{ mm} \cdot \text{a}^{-1}$). For nighttime precipitation, 55% of stations decreased and 45% increased, with the fastest decrease in Tongliao City ($-0.8 \text{ mm} \cdot \text{a}^{-1}$) and fastest increase in Ordos City ($0.8 \text{ mm} \cdot \text{a}^{-1}$).

The spatial distribution of average annual day and night precipitation days is similar, decreasing from northeast to northwest [Figure 7: see original paper]. In the high-value area of northeastern Hulunbuir, daytime days exceed nighttime days by more than 2 days. The largest differences occur near the junction of Xilingol League and Chifeng City, while the smallest differences appear in Tongliao City of southeastern Inner Mongolia and Alxa League in the west. The Horqin Sandy Land at the junction of Chifeng and Tongliao shows fewer precipitation days than its surroundings.

Station-level trends differ markedly [Figure 7: see original paper]. For daytime precipitation days, 65% of stations show decreasing trends (with 15% passing significance tests, concentrated in Xilingol League and Chifeng City), while only 5% show increasing trends. The fastest decrease occurred in central Xilingol League ($-1.6 \text{ d} \cdot (10\text{a})^{-1}$, $P < 0.05$), while the fastest increase was in Ordos City ($0.5 \text{ d} \cdot (10\text{a})^{-1}$). For nighttime precipitation days, 45% of stations decreased and 55% increased. The fastest decrease was in eastern Hulunbuir ($-1.9 \text{ d} \cdot (10\text{a})^{-1}$), while the fastest increase was in western Hulunbuir ($2.1 \text{ d} \cdot (10\text{a})^{-1}$). In western Hulunbuir, Xilingol League, and Baotou City, daytime precipitation days decreased while nighttime days increased.

2.4 Monthly Variation Characteristics of Growing Season Precipitation

Monthly analysis shows that from May to July, precipitation amounts at most stations decreased, with the most significant decreases occurring in June. From August to September, most stations showed increasing trends, with the most significant increases in September. Precipitation days showed similar patterns: most stations decreased from May to July, with the most significant decreases in June, while August to September showed mixed trends with similar numbers of increasing and decreasing stations.

3 Discussion

Precipitation in Inner Mongolia shows clear regional differences, decreasing uniformly from southeast to northwest with large east-west variations. This pattern results from both the East Asian monsoon's influence (which weakens from southeast to northwest) and topographic effects, particularly mountain ranges. Yu et al. noted that nighttime precipitation is closely related to local atmospheric dynamics and thermodynamic conditions caused by topography. From a topoclimatic perspective, east-west oriented mountain basins and valleys facilitate nighttime precipitation, while north-south oriented ranges promote daytime precipitation through valley circulation.

In Inner Mongolia, the Greater Khingan Mountains extend from northeast to southwest along the border between Hinggan League, Tongliao City, Chifeng City, and Xilingol League. Both day and night precipitation reach maxima along this range, with daytime precipitation exceeding nighttime precipitation and large day-night differences. Precipitation days decrease uniformly from the mountains to both sides.

Research indicates that nighttime precipitation, with lower temperatures and reduced evaporation, increases soil moisture infiltration and enhances humidity. Clear days with rainy nights increase diurnal temperature ranges, benefiting photosynthesis and vegetation biomass accumulation. This study shows that nighttime precipitation totals in western Inner Mongolia's arid and semi-arid regions have increased, benefiting vegetation growth and ecological restoration. However, large spatial spans and uneven precipitation intensity distribution, combined with decreasing precipitation days in some areas, have increased precipitation intensity and the risk of flood and geological disasters.

Analysis of precipitation intensity anomalies in the 2010s shows that intensity increased significantly in western Alxa League and eastern Hulunbuir, with anomaly percentages averaging 20-50%. This suggests that western sandy areas are prone to soil erosion and flash floods. Future work should balance benefits and risks, implementing scientific ecological protection to minimize damage from heavy precipitation, especially nighttime events.

4 Conclusions

Based on daily precipitation data from 103 meteorological stations in Inner Mongolia from 1961 to 2018, this study analyzed spatiotemporal variation characteristics of growing season day and night precipitation using climate tendency rate, Mann-Kendall test, wavelet analysis, and spatial interpolation. Main conclusions are:

- 1) Interannually, multi-year average daytime precipitation amounts and days during the growing season exceed nighttime values. While precipitation amount trends are insignificant, precipitation days show decreasing trends.
- 2) Wavelet analysis indicates daytime precipitation has 15-25 year periodicity,

while nighttime precipitation shows 23–29 year cycles. Both day and night precipitation days exhibit 6–10 year and 15–29 year periodicities.

- 3) Spatially, average annual day and night precipitation amounts and days both decrease uniformly from northeast to northwest. Day-night differences in both amounts and days are large in south-central to northeastern regions but small in western Inner Mongolia.
- 4) Monthly variations show most stations had decreasing precipitation amounts and days from May to July, particularly in June, while August–September showed increasing trends. Precipitation day trends were mixed in late summer.

This study only analyzed the distribution and variation patterns of growing season day-night precipitation. Observed precipitation changes represent combined effects of various processes at different timescales. Inner Mongolia's large span and complex local climate factors create uncertainties, and the impact of recent ecological restoration projects on local precipitation distribution remains unclear. Future research should investigate the causes and mechanisms of growing season day-night precipitation changes in Inner Mongolia.

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