Climate Change Characteristics in Northern Xinjiang over the Past 56 Years (Postprint)

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Abstract

Based on daily temperature and precipitation data from 40 stations in northern Xinjiang from 1961 to 2016, and employing methods such as mathematical statistics, trend analysis, Mann-Kendall mutation test, and wavelet analysis, this study investigates the characteristics, trends, and spatial differences of climate change in northern Xinjiang over the past 56 years. The results show that: during the study period, the climate exhibited an overall warming and wetting trend characterized by rising temperature and increasing precipitation, with the annual mean temperature increasing at a rate of 0.34 ℃·(10a)-1 and annual precipitation increasing at a rate of 12.05 mm·(10a)-1; Mann-Kendall mutation test reveals that temperature increased after an abrupt change in 1991, while precipitation gradually increased after an abrupt change in 1987; annual mean temperature variation exhibits periodic patterns of 6 a, 14 a, and 28 a, while precipitation variation shows periodic patterns of 4 a, 12 a, and 22 a; spatially, the temperature increase rate is greater in the east-west direction than in the north-south direction, precipitation increment is larger in mountainous areas than in plains and basins, and larger in the west than in the east.

Full Text

Preamble

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2 Data and Methods

2.1 Data Sources

The study utilized daily temperature and precipitation data from 40 meteorological stations in Northern Xinjiang spanning 1961–2016 [FIGURE 1]. The data were obtained from the Xinjiang Meteorological Information Center. To ensure data quality and continuity, missing values were interpolated using the linear regression method based on data from neighboring stations. The digital elevation model (DEM) data were extracted from the SRTM dataset with a spatial resolution of 1000 m × 1000 m [17–18].

2.2 Methods

The study employed mathematical statistical methods, linear trend analysis, the Mann-Kendall (M-K) mutation test, and Morlet wavelet analysis to investigate climate change characteristics.

Linear trend analysis was performed using the least squares method to calculate climate tendency rates. The **M-K non-parametric statistical test** was used to detect mutation points in the time series, with the significance level set at $= 0.05$. The **Morlet wavelet analysis** method was applied to examine periodic oscillations in temperature and precipitation series.

Spatial interpolation was conducted using a hybrid interpolation method combining multiple regression based on geographical factors (latitude, longitude, elevation) with residual kriging correction [MATH_0005]. This approach effectively improved interpolation accuracy by incorporating topographic influences on climate variables.

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3 Results

3.1 Temporal Variation Characteristics

3.1.1 Temperature The annual average temperature in Northern Xinjiang during 1961–2016 was 5.8°C. The warmest year was 2015, with an anomaly of +7.5°C, while the coldest was 1970, with an anomaly of -3.3°C [FIGURE 2]. The overall temperature trend showed a significant increase at a rate of 0.34°C · (10a) ^{1}, which exceeds the national average warming rate of 0.25°C · (10a) ^{1} [19].

During 1961–1970, temperatures were relatively low, with the minimum occurring in 1969. From the 1970s onward, temperatures began to rise gradually.

The period 1991–2016 exhibited the most pronounced warming, with an average temperature of 5.8°C. Notably, the 1960s showed a cooling trend of -2.06°C · (10a)^{1}, while the 1990s displayed the strongest warming at 0.89°C · (10a)^{1}, followed by the 1970s (0.61°C · (10a)^{1}), 2001–2010 (0.38°C · (10a)^{1}), and the 1980s (0.36°C · (10a)^{1}).

Seasonal analysis revealed that summer contributed most to annual warming (21.01°C average), followed by spring (7.94°C), autumn (6.73°C), and winter (-11.42°C) [FIGURE 3]. The warming rates varied by season: winter showed the highest increase (0.34°C · (10a)^{1}), followed by spring (0.28°C · (10a)^{1}), summer (0.16°C · (10a)^{1}), and autumn (0.13°C · (10a)^{1}).

3.1.2 Precipitation The 56-year average annual precipitation was 195.5 mm, with the maximum of 333.3 mm occurring in 1971 and the minimum of 116.6 mm in 1962 [FIGURE 2]. Precipitation exhibited an overall increasing trend at a rate of 12.05 mm · (10a)^{1}, though the trend was not statistically significant. The interannual variability was substantial, with a coefficient of variation of 0.31.

The 1960s–1980s represented relatively dry periods, while the 1990s–2010s were comparatively wet. The 1970s showed the most significant increase at 54.5 mm · (10a)^{1} [TABLE 2]. Seasonal precipitation patterns indicated that summer contributed the largest share (96.75 mm), followed by spring (71.40 mm), autumn (55.93 mm), and winter (30.26 mm) [FIGURE 4]. All seasons showed increasing trends, with summer precipitation rising at 4.10 mm · (10a)^{1}, spring at 3.86 mm · (10a)^{1}, autumn at 2.38 mm · (10a)^{1}, and winter at 1.22 mm · (10a)^{1}.

3.2 Mutation and Periodicity Analysis

3.2.1 M-K Mutation Test The M-K test statistic for annual temperature (UF) exceeded the critical value (U . = 1.96) beginning in 1963, indicating a significant warming trend [FIGURE 5a]. The intersection point of UF and UB curves in 1991 marked a significant mutation point, after which temperatures increased abruptly. For precipitation, the UF curve remained within the confidence interval until 1987, when it crossed the critical line, indicating a mutation toward wetter conditions. The post-mutation average precipitation increased by 59.9 mm compared to the pre-mutation period.

3.2.2 Wavelet Analysis Morlet wavelet analysis revealed that temperature variations exhibited significant periodicities of 6, 14, and 28 years [FIGURE 6a]. The 6-year and 14-year cycles were prominent during 1961–1981 and 1990–2016, while the 28-year cycle dominated the entire study period. Precipitation showed primary periodicities of 4, 12, and 22 years [FIGURE 6b], with the 4-year and 12-year cycles being significant throughout the series.

4 Discussion

The climate of Northern Xinjiang has undergone a significant warming and wetting trend over the past 56 years, with temperature increasing by $0.34^{\circ}C \cdot (10a)^{1}$ and precipitation by $12.05\ mm \cdot (10a)^{1}$. These findings align with regional climate change studies [22-23]. The spatial distribution showed that temperature increases were more pronounced in the eastern and western regions than in the northern and southern areas, while precipitation increases were greater in mountainous regions compared to plains and basins, and higher in the west than in the east.

The warming trend is consistent with global climate change patterns [24] and regional responses to Arctic oscillation [25]. The increased precipitation may be attributed to enhanced water vapor transport under warming conditions and the influence of large-scale atmospheric circulation patterns. The identified periodicities correspond to quasi-biennial oscillations and decadal climate cycles, reflecting the complex interactions between regional and global climate systems.

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Climate Change in Northern Xinjiang in Recent 56 Years

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Abstract:
Mathematical statistics, trend analysis, Mann-Kendall mutation test, and wavelet analysis were employed to investigate the characteristics, trends, and spatial differences of climate change in Northern Xinjiang over the past 56 years, based on daily temperature and precipitation data from 40 stations from 1961 to 2016. The results showed a general warming-wetting trend during the study period. The annual average temperature increased by 0.34°C · (10a) ^{1}, while the precipitation increase rate was 12.05 mm · (10a) ^{1}. The Mann-Kendall mutation test indicated that temperature increased significantly after 1991, and precipitation increased gradually after its mutation in 1987. Wavelet analysis

revealed 6-, 14-, and 28-year periodic changes in annual mean temperature, and 4-, 12-, and 22-year periodicities in annual precipitation. Spatially, temperature increases were higher in the east and west than in the north and south, while precipitation increases were greater in mountainous regions than in plains and basins, and higher in the west than in the east.

Keywords: climate change; linear trend analysis; M-K mutation test; Morlet wavelet analysis; hybrid interpolation; Northern Xinjiang