Spatiotemporal Characteristics of Climate Change at Different Altitudes in Xinjiang over the Past 60 Years: Postprint

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Abstract

Global warming represents one of the prominent topics in current global climate change research. Xinjiang, situated deep in the interior of the Eurasian continent, features complex topography and climate. Investigating the relationship between climate change and altitude in this region carries significant reference value for global climate change research. Based on monthly and annual mean climate data from 41 meteorological stations across Xinjiang during 1958–2017, this study employed simple linear regression, Mann-Kendall (M-K) trend analysis, and mutation test to examine the relationship between the spatiotemporal distribution of climate change and altitude. The results demonstrate that from 1958 to 2017, both annual mean temperature and annual mean precipitation in Xinjiang exhibited increasing trends, though the magnitude of increase varied temporally and spatially. Temporally, the warming amplitude of seasonal mean temperature in Northern Xinjiang exceeded that of Southern Xinjiang (except in winter), while the increase in seasonal precipitation was greater in Northern Xinjiang than in Southern Xinjiang (except in summer); spatially, the increases in both temperature and precipitation were greater in Northern Xinjiang than in Southern Xinjiang. Temperature at individual stations displayed a spatial pattern of higher values in the south and lower values in the north, whereas annual mean precipitation showed higher values in the north and lower values in the south. The temperature tendency rate generally decreased with altitude across stations, while the change rate of annual mean precipitation increased with altitude, with internal variations observed across different altitude zones. In summary, influenced by global climate warming, Xinjiang has experienced increasing trends in both annual mean temperature and annual mean precipitation over the past 60 years, with Northern Xinjiang demonstrating particular sensitivity to global climate warming.

Full Text

Preamble

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Abstract: Global warming is one of the hotspots in global climate change research. Climate is an important part of nature, the basis for human survival and development, and an important condition for sustainable social development. But in recent years, with the intensification of human activities, the global climate is getting warmer. Located in arid and semi-arid regions, Xinjiang, China, has complex topography and more obvious climate change. In recent years, the average annual temperature and precipitation in Xinjiang have been on the rise, which has aroused widespread concern of domestic and foreign experts and scholars. Therefore, the discussion of the relationship between climate change and altitude in this region has important reference significance for global climate change research, as well as guiding significance for promoting sustainable development of local economy and rational utilization of resources. Based on the long-term temperature and precipitation data of 41 meteorological stations in Xinjiang from 1958 to 2017, and using ArcGIS, Matlab and other software, this paper uses regression analysis, climate trend method, Mann-Kendall (M-K) trend analysis and mutation test and other methods to analyze the time and space characteristics of climate change in different altitude zones in the research area in the past 60 years. The results show that from 1958 to 2017, the average annual temperature and precipitation of Xinjiang show an upward trend, but the increase range has time and space differences. In terms of time, the average temperature increase range of four seasons in northern Xinjiang is greater than that in southern Xinjiang (except winter), and the increase rate of four seasons in northern Xinjiang is greater than that in southern Xinjiang (except summer). Spatially, the increase of temperature and precipitation in northern Xinjiang was greater than that in southern Xinjiang. The temperature of each station in the study area showed a spatial pattern of high in the south and low in the north, with the highest average annual temperature of the meteorological stations around the Tarim Basin in the south and low average annual temperature in the north. However, the range of temperature increase was not consistent. In general, the range of temperature increase in northern Xinjiang was larger than that in southern Xinjiang, showing regional differences. The average annual

precipitation is high in the north and low in the south. The trend rate of temperature decreases with the increase of altitude, and the change rate of annual precipitation increases with the increase of altitude. The results showed that the average annual temperature in the middle and low altitude zone increased greatly, and the average annual precipitation in the middle and high-altitude zone increased greatly. To sum up, under the influence of global warming, the average annual temperature and precipitation in Xinjiang have been on the rise in the past 60 years. In particular, northern Xinjiang is more sensitive to global warming than southern Xinjiang.

Keywords: Xinjiang; different elevation zones; climate change; regression analysis; Mann-Kendall test

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3.1.2 Climate Tendency Analysis

Analysis of temperature and precipitation data from 1958–2017 reveals distinct trends across different elevation zones. The average temperature increase rates were 0.29°C · (10a) ^{1}, 0.33°C · (10a) ^{1}, and 0.27°C · (10a) ^{1} for different altitudinal bands, while precipitation increased at rates of 8.09 mm · (10a) ^{1}, 7.69 mm · (10a) ^{1}, and 5.49 mm · (10a) ^{1} respectively. The most pronounced warming occurred in the mid-altitude zones, with temperature increases in the 500–1000 m elevation band reaching 0.44°C · (10a) ^{1} for temperature and 7.69 mm · (10a) ^{1} for precipitation, both exceeding those in lower zones.

The year 2015 recorded notable temperature anomalies, with average annual temperatures reaching 9.55°C, 7.37°C, and 12.08°C across different zones. Abrupt climate changes were detected in 1984, 1984, and 1967 respectively, with corresponding temperature shifts of 6.66°C, 3.91°C, and 9.57°C. These mutation points align with significant regional climate transitions identified through Mann-Kendall analysis.

Table 1. Climatic tendency rate of different elevation gradients in the study area

Elevation (m)	Temperature trend (°C · (10a) ^{1})	Precipitation trend (mm · (10a) ^{1})
0–500	0.35	1.06
500–1000	0.26	1.34
1000–1500	0.39	2.01
>1500	0.38	1.98

Note: Based on 60-year data from 41 meteorological stations in Xinjiang

3.2 Temporal Variation Characteristics

[Figure 2: see original paper]

Figure 2. Variation trend of annual average temperature and annual precipitation in the study area

The temporal analysis reveals that temperature and precipitation trends exhibit significant interannual variability superimposed on long-term increasing trends. The M-K test statistic shows that most stations experienced significant warming trends, particularly after the mid-1980s. Precipitation trends display greater spatial heterogeneity, with northern stations showing more consistent increases than southern stations.

3.3 Spatial Variation Characteristics

3.3.1 Temperature Trends by Elevation

[Figure 3: see original paper]

Figure 3. Average annual temperature (a) and its variation trend (b) and average annual precipitation (c) and its variation trend (d)

Spatial analysis indicates a clear south-north gradient in temperature baseline values, with the Tarim Basin region recording the highest annual averages. However, the rate of temperature increase demonstrates an inverse relationship with elevation, with lower altitude zones (0–500 m) showing greater warming rates ($0.35°C \cdot (10a)^{-1}$) compared to high-altitude zones (>1500 m: $0.38°C \cdot (10a)^{-1}$). This elevation-dependent pattern is statistically significant across all zones.

3.3.2 Precipitation Trends by Elevation

[Figure 4: see original paper]

Figure 4. M-K test of climate factors in different elevation zones in northern Xinjiang (a–d: average annual temperature; e–h: average annual precipitation)

Precipitation trends exhibit the opposite elevation relationship, with increasing rates amplifying at higher altitudes. The 1000–1500 m zone shows the greatest increase rate at 2.01 $mm \cdot (10a)^{-1}$, while the lowest zone (0–500 m) shows the smallest increase at 1.06 $mm \cdot (10a)^{-1}$. The M-K test confirms these trends are significant at the 95% confidence level for most high-elevation stations.

The spatial distribution of precipitation change shows northern Xinjiang experiencing more substantial increases than southern Xinjiang, consistent with regional circulation pattern changes. Abrupt precipitation increases were detected around 1987 in low-elevation zones and 1997 in mid-elevation zones, indicating differential responses to large-scale climate forcing across altitudinal gradients.

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Note: Figure translations are in progress. See original paper for figures.