Anomalous Variation Characteristics of Warm and Cold Indices Before and After Abrupt Temperature Change in Inner Mongolia (Postprint)

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Abstract

Through analysis of the warmth index (WI) and coldness index (CI) in Inner Mongolia during 1961–2016, this study derived the spatiotemporal distributions of the regional mean and the indices before and after the abrupt change. The results demonstrate that prior to the abrupt change, the trend rates of WI and CI exhibited a locally mosaic pattern, with an overall upward trend predominating; subsequent to the abrupt change, the WI trend rate was primarily characterized by an upward trend, whereas CI was dominated by a downward trend. Against the backdrop of climate warming, CI in eastern Inner Mongolia displayed an overall decreasing trend following the temperature abrupt change, indicating that while the climate is warming, the cold season in the eastern region is concurrently becoming colder. This reveals a pronounced polarization trend in regional climate and a distinct phenomenon of 'abrupt cold-warm transition'. The 5-year moving average results indicate that the increase in warm-season heat is relatively stable, whereas fluctuations in cold-season heat are substantial. CI exhibited a decreasing trend after the turn of the 21st century, entering the declining phase 10 years earlier than WI. The CI trend rate in eastern Inner Mongolia showed a significant regional decreasing trend after the temperature abrupt change, while the central and western regions manifested a mosaic pattern of both increases and decreases.

Full Text

Abnormal Change of Warmth Index and Coldness Index before and after Temperature Mutation in Inner Mongolia

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Abstract

In this paper, the warmth index (WI) and coldness index (CI) in Inner Mongolia from 1961 to 2016 were analyzed, and the spatiotemporal distribution of these indexes and their changes before and after the temperature mutation were examined. The results showed that the tendency rates of WI and CI were distributed in an inlaid pattern before the temperature mutation; after the temperature mutation, the tendency rate of WI was mainly in an increasing trend, while that of CI was mainly in a decreasing trend. In the context of climate warming, the CI in Inner Mongolia was holistically decreased after the temperature mutation, which revealed that it also became colder in the cold season in eastern Inner Mongolia under climate warming, and there were sharp changes in both warmth and coldness. The five-year moving average results showed that the heat increase in the warm season was relatively stable, but the heat increase or decrease in the cold season fluctuated obviously. The CI was in a decreasing trend since the 21st century, and this decrease occurred 10 years earlier than that of WI. The tendency of CI in eastern Inner Mongolia was significantly decreased after the temperature mutation, and the tendency rates of WI and CI were distributed in an inlaid pattern in the central and western parts of Inner Mongolia.

Keywords: climate change; warmth index; coldness index; spatiotemporal variation; Inner Mongolia

1 Introduction

The IPCC Fifth Assessment Report indicates that global surface temperatures increased by (0.85±0.20)℃ from 1880 to 2012, and climate warming has significantly impacted natural ecosystems and human societies. Under this background of global climate change, the Inner Mongolia region has experienced notable temperature changes. The warmth index (WI) and coldness index (CI), developed by Kira, are effective indicators for quantifying the thermal conditions of ecosystems and have been widely applied in vegetation-climate relationship studies and agricultural climate zoning.

Previous studies have analyzed the spatial distribution characteristics of WI and CI in China and their correlation with vegetation boundaries. However, research specifically focusing on the spatiotemporal variation of WI and CI in Inner Mongolia, particularly before and after temperature mutation, remains limited. This study utilizes meteorological data from 106 stations in Inner Mongolia from 1961 to 2016 to analyze the changing trends of WI and CI and their spatial distribution patterns, providing a scientific basis for understanding regional climate change impacts.

2 Data and Methods

2.1 Data Source

The study employed daily mean temperature data from 106 meteorological stations in Inner Mongolia covering the period 1961-2016. Data quality control and homogenization were performed to ensure reliability.

2.2 Warmth Index and Coldness Index

Following Kira' s definitions, the warmth index (WI) and coldness index (CI) were calculated as:

- **Warmth Index (WI):** $WI = \sum(t_i - 5)$, where t_i is the monthly mean temperature above 5℃
- **Coldness Index (CI):** $CI = -\sum(5 - t_i)$, where t_i is the monthly mean temperature below 5℃

These indexes quantify the cumulative thermal conditions during growing seasons (WI) and cold seasons (CI).

2.3 Mann-Kendall Trend Test

The Mann-Kendall (M-K) non-parametric test was used to detect monotonic trends in the WI and CI time series. This method is robust against outliers and does not require data to follow a specific distribution.

2.4 Linear Trend Analysis

Linear trends were calculated using the least squares method: $x(t) = a + bt$, where b represents the trend rate and its significance was tested at the 95% confidence level.

3 Results

3.1 Temporal Variation Characteristics

The analysis revealed a temperature mutation occurring around 1988-1989 in Inner Mongolia. Before this mutation, the tendency rates of WI and CI showed an inlaid distribution pattern. After the mutation, WI demonstrated a predominantly increasing trend, while CI showed a decreasing trend.

The five-year moving average indicated that the warm season heat increase remained relatively stable, whereas cold season temperature fluctuations were more pronounced. Notably, CI began decreasing in the early 21st century, approximately 10 years earlier than the significant increase in WI.

3.2 Spatial Distribution Patterns

Fig. 1 shows the temperature change trend and mutation analysis for Inner Mongolia from 1961 to 2016. The spatial distribution of WI and CI trends before and after the temperature mutation is presented in **Fig. 2**.

After the temperature mutation, eastern Inner Mongolia exhibited a significant decreasing trend in CI, suggesting that despite overall warming, cold season temperatures became more severe in this subregion. The central and western regions displayed an inlaid pattern of WI and CI tendency rates, indicating complex spatial heterogeneity in thermal condition changes.

4 Discussion

The decreasing trend of CI since 2000, preceding WI changes, suggests that cold season warming in Inner Mongolia has been inconsistent, with some areas experiencing enhanced cold conditions. This phenomenon may be related to changes in atmospheric circulation patterns and the intensification of extreme cold events under global warming.

The spatial differentiation between eastern and western Inner Mongolia reflects the influence of topography and monsoon systems. The eastern region, more affected by East Asian monsoon variability, shows sharper CI decreases, while the western inland region exhibits more stable warming trends in WI.

5 Conclusion

The study demonstrates that temperature mutation significantly altered the thermal regime in Inner Mongolia. While WI has increased overall, the decreasing CI trend, particularly in eastern Inner Mongolia and its earlier onset compared to WI changes, highlights the complexity of regional climate warming. These findings have important implications for agricultural planning and ecological adaptation strategies in the region.

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