Spatiotemporal Variation Characteristics of 10 ℃ Accumulated Temperature in the Shiyang River Basin (Postprint)

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Abstract

Using daily mean temperature data from five meteorological stations in the Shiyang River Basin from 1960 to 2017, the threshold for 10 ℃ accumulated temperature was determined using the moving average method; subsequently, methods including multiple linear regression, standard deviation ( ), linear trend coefficient, cumulative anomaly, and signal-to-noise ratio were employed to analyze the spatiotemporal variation characteristics of 10 ℃ accumulated temperature in the Shiyang River Basin. The results indicate that the 10 ℃ accumulated temperature exhibits distinct regional characteristics in the Shiyang River Basin; the mean and extreme values are highest in desert areas, followed by oasis plain areas, and lowest in mountainous areas. The spatial distribution of 10 ℃ accumulated temperature is closely related to weather systems as well as longitude, latitude, and altitude. Normal years for 10 ℃ accumulated temperature occur most frequently, with a probability exceeding 65%, decreasing rapidly toward both ends. Both annual and decadal 10 ℃ accumulated temperature show significant increasing trends. 10 ℃ accumulated temperature occurs mainly from May to September, peaking in July. The climate abrupt change of 10 ℃ accumulated temperature occurred in 1996 for the entire basin, Minqin, and Tianzhu, and in 1997 for Yongchang, Liangzhou, and Gulang. The increase in 10 ℃ accumulated temperature in the Shiyang River Basin leads to reduced planting area and shortened growth period for cool-loving crops, which is unfavorable for high-yield formation; conversely, it results in expanded planting area and extended growth period for warm-loving crops, which is conducive to high-yield and high-quality formation. This study will be of significant importance for modern agricultural structure planning, crop variety adjustment, and quantitative assessment of agriculture.

Full Text

Preamble

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Abstract: Accumulated temperature is an important climate resource and crop growth and development index. In this paper, using daily average temperatures of five meteorological stations in Shiyang River basin, Gansu Province, China during 1960–2017, cumulative temperature limit of 10℃ was determined using the sliding average method. Spatiotemporal changes in cumulative temperature 10℃ were analyzed via multiple linear regression, mean square deviation ( ), linear trend coefficient, cumulative anomaly, and signal-to-noise ratio methods. The results showed that the cumulative temperature 10℃ of Shiyang River basin has obvious regional characteristics. In the desert area, the average and extreme values of cumulative temperature of 10℃ were higher than those in the oasis plain, and the temperature in the oasis plain was higher than that in the mountainous area. The regional distribution of cumulative temperature 10℃ was closely related to the weather system, longitude, latitude, and altitude. In normal years, a cumulative temperature 10℃ was the most common, the probability of which exceeded 65%, which was the ends of decline. Annual and decadal cumulative temperatures 10℃ showed a significant upward trend. The cumulative temperature 10℃ mainly occurs from May to September, with the highest peak in July. Abrupt changes in cumulative temperature 10℃ occurred in the entire basin, including Minqin and Tianzhu in 1996, and Liangzhou, Yongchang, and Gulang in 1997. When the cumulative temperature in the Shiyang River basin exceeds 10℃, the planting zones decrease and the growth period becomes shorter, which is not favorable for the high yields of cool-weather crops, while it is favorable for the warm-weather crops. This paper revealed new pattern of heat resources and its impacts on agriculture in Shiyang River basin. This is very important for modern agricultural planning, crop variety adjustment, and agricultural quantitative evaluation.

Keywords: 10℃ accumulated temperature; Spatiotemporal change; Multiple linear regression; Shiyang River Basin

2 Data and Methods

2.1 Data Source

Daily average temperature data from five meteorological stations in the Shiyang River Basin from 1960 to 2017 were used, including Wuwei, Minqin, Gulang, Yongchang, and Tianzhu stations. The data were provided by the Gansu Provincial Meteorological Information Center and had undergone quality control.

2.2 Methods

2.2.1 Calculation of 10℃ Accumulated Temperature The 10℃ accumulated temperature was calculated using the 5-day sliding average method. The sliding average method is a commonly used approach for determining the start and end dates of stable temperature periods. The start date is defined as the first day when the 5-day average temperature is 10℃, and the end date is the last day when the 5-day average temperature is 10℃. The accumulated temperature is the sum of daily average temperatures during this period.

2.2.2 Multiple Linear Regression Model A multiple linear regression model was established between 10℃ accumulated temperature and geographic factors (latitude, longitude, and altitude):

$$y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_k x_k$$

where b_0 is the constant term; $b_1, b_2, \ldots, b_k$ are regression coefficients; and y is the estimated value of 10℃ accumulated temperature. The actual observed value y can be expressed as:

$$y = \hat{y} + y'$$

where $\hat{y}$ is the regression estimate and y' is the residual.

The regression model for geographic factors is:

$$\hat{y}_j = b_0 + b_1 \theta + b_2 \varphi + b_3 \lambda$$

where θ represents latitude, φ represents longitude, and λ represents altitude.

2.2.3 Standard Deviation Method The standard deviation (σ) was used to classify anomaly levels. For a time series x_i of 10℃ accumulated temperature:

- When x_i falls within $\bar{x} \pm \sigma$, it is classified as a normal year
- When x_i falls within $\bar{x} \pm \sigma$ to $\bar{x} \pm 2\sigma$, it is classified as an abnormal year
- When x_i exceeds $\bar{x} \pm 2\sigma$, it is classified as a highly abnormal year

2.2.4 Trend Coefficient The linear trend coefficient was calculated using:

$$x_i = a + b t_i, \quad i = 1, 2, 3, \ldots, n$$

where x_i is the accumulated temperature, t_i is the year sequence, b is the trend coefficient, and $b \times 10$ represents the temperature change per decade. The significance of the trend was tested using the F-test at significance levels of $\alpha = 0.1, 0.05, 0.01$.

2.2.5 Signal-to-Noise Ratio Method The signal-to-noise ratio (SNR) method was used to detect abrupt changes in the accumulated temperature series. The SNR is defined as the ratio of the mean difference before and after a potential change point to the standard deviation. When SNR exceeds a threshold, an abrupt change is considered to have occurred.

3 Results

3.1 Spatial Distribution Characteristics

The spatial distribution of 10℃ accumulated temperature in the Shiyang River Basin showed significant regional patterns. The multiple linear regression models for different periods all passed the significance test at $\alpha = 0.01$ level, with correlation coefficients exceeding 0.999.

The regression equations for different periods showed that latitude had the greatest influence on accumulated temperature, followed by altitude and longitude. The negative coefficients for latitude and altitude indicate that accumulated temperature decreases with increasing latitude and altitude.

3.2 Temporal Variation Characteristics

3.2.1 Interannual Variation From 1960 to 2017, the 10℃ accumulated temperature in the Shiyang River Basin showed a significant increasing trend. The trend coefficients ranged from 52.433 to 110.42℃ · 10a ^{1} across different stations, all significant at the 0.01 level.

The decadal analysis revealed that the 1960s–1980s were predominantly normal or low years, while the 2000s–2010s were predominantly high years. The probability of normal years exceeded 65% across all stations.

3.2.2 Anomaly Years Abnormal years accounted for 29.3%–34.5% of the total, while highly abnormal years accounted for 0%–5.2%. The frequency of abnormal years increased after the 1990s.

The most significant positive anomalies occurred in 2010 and 2016, with anomalies exceeding 260℃ at most stations.

3.2.3 Monthly Distribution The 10℃ accumulated temperature primarily occurred from May to September, accounting for 87.8%–99.3% of the annual total. July contributed the most, accounting for 59.1%–89.6% of the summer accumulated temperature.

[Figure 3: see original paper]

The monthly distribution showed a single-peak pattern, with the peak occurring in July at all stations.

3.2.4 Extreme Values The extreme maximum accumulated temperature occurred mainly in July 2010, with values ranging from 398.4°C to 815.0°C across stations.

The signal-to-noise ratio analysis detected abrupt changes around 1996–1997. Minqin and Tianzhu stations showed abrupt changes in 1996, while Wuwei, Yongchang, and Gulang stations changed in 1997.

[Figure 4: see original paper]

The cumulative anomaly curves showed a clear transition from negative to positive phases around 1997, indicating a significant warming shift.

[Figure 5: see original paper]

3.3 Impact on Agricultural Production

The increase in 10°C accumulated temperature has significant implications for agricultural production in the Shiyang River Basin. The warming trend leads to: - Northward shift of crop planting boundaries - Extension of the growing season for warm-season crops - Reduction of suitable areas for cool-season crops - Increased heat stress in some regions

The accumulated temperature is a critical factor for crop variety selection and planting system optimization. The observed changes suggest that agricultural planning should adapt to the new thermal conditions.

4 Discussion and Conclusions

The analysis of 10°C accumulated temperature in the Shiyang River Basin from 1960 to 2017 revealed: 1. **Spatial patterns**: Clear vertical and horizontal zonation, with temperature decreasing from desert to oasis to mountainous areas 2. **Temporal trends**: Significant warming at rates of 52–110°C per decade, with an abrupt change around 1996–1997 3. **Seasonality**: Concentrated in May-September, peaking in July 4. **Agricultural implications**: The warming provides opportunities for expanding warm-season crops but challenges for traditional cool-season crops

The multiple linear regression models effectively captured the spatial variation, with latitude and altitude as primary controlling factors. The signal-to-noise ratio method successfully identified the climate shift in the mid-1990s, consistent with regional climate change studies.

These findings provide a scientific basis for agricultural adaptation strategies, including: - Adjusting crop varieties to match the new thermal conditions - Optimizing planting dates to maximize heat resource utilization - Developing heat-tolerant cultivars for sustainable production

The study demonstrates that the Shiyang River Basin has experienced significant thermal regime changes, requiring proactive agricultural planning to ensure food security and sustainable development.

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