Tree-Ring Width Records of 160-Year Average Minimum Temperature Variations in Northern Tajikistan: Postprint

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Abstract

Correlation analysis between the tree-ring width standard chronology of Juniperus turkestanica in northern Tajikistan and regional climate variables reveals a significant relationship between the February-March mean minimum temperature of the current year and tree radial growth. Based on this, the February-March mean minimum temperature for the region from 1857 to 2016 was reconstructed, with the reconstruction equation explaining 39.5% of the variance, and 37.5% after adjusting for degrees of freedom. The study indicates that over the past 160 years, the region has experienced six warm phases: 1857-1878, 1885-1890, 1907-1915, 1926-1931, 1960-1967, and 1994-2016; and five cold phases: 1879-1884, 1891-1906, 1916-1925, 1932-1959, and 1968-1993. Spatial analysis results demonstrate that the reconstructed February-March mean minimum temperature for the study area can represent the variations in February-March mean minimum temperature across Tajikistan over the past 160 years.

Full Text

Tree-Ring-Based Reconstruction of Minimum Temperature in North Tajikistan in Recent 160 Years

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Abstract:
Correlation analysis between the normalized tree-ring width chronology of

Juniperus turkestanica and regional climatic elements in northern Tajikistan showed that the mean minimum temperature in February and March of the same year was significantly correlated with radial tree growth. Based on this relationship, the average minimum temperature in the region from February to March, 1857-2016, was reconstructed. The reconstruction equation could explain 39.5% of the variation in minimum temperature, and the interpretation amount after adjusting the degrees of freedom was 37.5%. The results showed that, in the recent 160 years, the study area experienced six high-temperature periods including 1857-1878, 1885-1890, 1907-1915, 1926-1931, 1960-1967, and 1994-2016, and five low-temperature periods including 1879-1884, 1891-1906, 1916-1925, 1932-1959, and 1968-1993. According to spatial correlation analysis results, the reconstructed minimum temperature in February and March could be used to represent the actual situation in north Tajikistan.

Keywords: tree-ring width; chronology; monthly mean minimum temperature; *Juniperus turkestanica*; Tajikistan

2. Data and Methods

2.1 Climate Data The climate data used in this study were obtained from the Climate Research Unit (CRU) TS 4.0 dataset (Climate Research Unit, University of East Anglia, http://www.cru.uea.ac.uk) at a spatial resolution of 0.5°×0.5°. The dataset covers the period 1901-2016 for the region (66°75 - 72°25 E, 38°75 -41°75 N), including monthly temperature, precipitation, and other variables. Data processing and analysis were performed using MATLAB.

2.2 Tree-Ring Data Tree-ring samples were collected in October 2016 from a site located at 69°45 E, 40°37 N, at an elevation of 1485-1585 m. The sampling site is characterized by *Juniperus turkestanica* forest with trees aged 220-430 years. The terrain is steep with slopes of 0.2-0.5 m vertical drop per horizontal meter. The canopy height ranges from 7-12 m, and the diameter at breast height varies from 92-320 cm.

Sample processing followed standard dendrochronological procedures. The wood cores were mounted, sanded, and measured with a Lintab measuring system (precision 0.01 mm). Cross-dating quality was verified using the COFECHA program, which checks for measurement errors and ensures accurate dating. The ARSTAN software was used to develop the final tree-ring chronologies, including the standard chronology (STD), the residual chronology (RES), and the autoregressive standard chronology (ARS).

2.3 Statistical Methods Correlation analysis and response function analysis were employed to examine the relationships between the tree-ring chronology and monthly climate variables from the previous June to the current September.

The leave-one-out method was used for calibration and validation of the reconstruction model. Statistical parameters including the correlation coefficient (r), explained variance (R^2), standard error (SE), reduction of error (RE), and coefficient of efficiency (CE) were calculated to evaluate the model' s performance.

The reconstruction equation based on the STD chronology is:

$$Y = 5.42X + 25.3688$$

where Y represents the February–March mean minimum temperature and X is the tree-ring width index. The equation explains 39.5% of the temperature variance ($R^2 = 0.395$, adjusted $R^2 = 0.375$). The F-statistic is 49.12, significant at the 0.01 level.

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3. Results

3.1 Chronology Statistics The tree-ring chronology spans 177 years (1840–2016), with the reliable portion (EPS > 0.85) covering 160 years (1857–2016). The chronology contains 38 series with a mean inter-series correlation of 0.484 and mean sensitivity of 0.555. The standard deviation is 0.601, and the first-order autocorrelation is 0.897. The signal-to-noise ratio is 5.601, indicating a strong common signal among the samples.

[TABLE:N] Statistical characteristics of the tree-ring width chronology

Parameter	Value
Time span	1840–2016
Reliable period (EPS > 0.85)	1857–2016
Number of series	38
Mean correlation	0.484
Mean sensitivity	0.555
Standard deviation	0.601
First-order autocorrelation	0.897
Signal-to-noise ratio	5.601
Expressed population signal	0.897

3.2 Climate-Growth Relationships Correlation analysis revealed that the tree-ring width index was significantly positively correlated with the minimum temperature in February and March of the current year ($r = 0.62$, $p < 0.01$). The relationship with precipitation was weak and not statistically significant. Based on these results, the February–March mean minimum temperature was selected as the target variable for reconstruction.

3.3 Temperature Reconstruction The reconstruction model was calibrated using data from 1932-2016 and validated using the leave-one-out method. The validation statistics show:

[**TABLE:N**] Statistical characteristics of leave-one-out test

Statistic	Value
Standard deviation	0.35
RE/CE	0.17/0.17
F-statistic	49.12
Significance level	0.01
t-statistic	2.26

The reconstruction explains 37.5% of the variance after adjusting for degrees of freedom. The reduction of error (RE) and coefficient of efficiency (CE) values of 0.17 indicate acceptable model skill.

[**FIGURE:N**] The reconstructed monthly mean minimum temperature and 11-year moving average in north Tajikistan in February and March during 1857-2016

The reconstruction reveals six distinct warm periods (1857-1878, 1885-1890, 1907-1915, 1926-1931, 1960-1967, and 1994-2016) and five cool periods (1879-1884, 1891-1906, 1916-1925, 1932-1959, and 1968-1993). The warmest period occurred in 1994-2016, with temperatures 0.51°C above the long-term mean. The coolest period was 1932-1959, with temperatures 0.45°C below the mean.

[**FIGURE:N**] Spatial correlation fields of reconstructed and observed monthly mean minimum temperature in February and March with gridded CRU TS 4.0 during 1932-2016

Spatial correlation analysis indicates that the reconstruction is representative of north Tajikistan and adjacent regions, with significant positive correlations ($r > 0.4$, $p < 0.05$) across most of the study area.

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4. Discussion

The tree-ring chronology developed from *Juniperus turkestanica* in north Tajikistan shows a strong response to winter minimum temperatures, consistent with findings from other dendroclimatic studies in Central Asia. The explained variance of 37.5% is comparable to similar reconstructions in the region. The identified warm and cool periods align well with historical climate records and other proxy data from the Tien Shan Mountains and surrounding areas.

The recent warming trend since 1994 is particularly pronounced, representing the warmest period in the 160-year record. This finding is consistent with regional and global warming patterns observed in the late 20th and early 21st centuries.

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5. Conclusion

This study developed a 160-year tree-ring chronology from *Juniperus turkestanica* in north Tajikistan and used it to reconstruct February–March mean minimum temperatures. The reconstruction reveals significant inter-annual to decadal variability, with six warm periods and five cool periods identified. The recent period (1994–2016) represents unprecedented warmth in the context of the past 160 years. The reconstruction provides valuable insights into long-term temperature variability in Central Asia and can be used for climate change studies in the region.

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