# Tree-ring reconstruction of early summer mean temperature in the Altay Region, 1572-2014 (Postprint)

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## Abstract

Using tree-ring samples from three high-altitude Siberian larch (Larix sibirica) sampling sites in the Altay region, a regional standard chronology of tree-ring width (DKH) was established. Correlation analysis revealed that the DKH chronology is significantly correlated with June mean temperature of the same year from seven meteorological stations in the Altay region, with a correlation coefficient of 0.705 ($P<0.00001$), indicating that June mean temperature is the primary climatic limiting factor affecting tree radial growth. The DKH chronology can reliably reconstruct early summer mean temperature for the region over a 443-year period from 1572 to 2014, with an explained variance of 49.6%, and verification indicates that the temperature reconstruction series is credible. Analysis of temperature variation characteristics shows that the reconstructed early summer temperature experienced ten warm periods and nine cold periods, with 1605-1622 and 1682-1723 being the warmest and coldest periods, respectively, and 1875-1913 and 1753-1804 being the longest-duration warm and cold periods, respectively. Significant periodicities of 2.37-2.39 yr and 2.19 yr ($P<0.05$) and marginally significant periodicities of 73.50 yr, 14.00 yr, 7.30 yr, 2.29 yr, and 2.21 yr ($P<0.10$) were identified. Abrupt shifts from cold to warm conditions occurred around 1684 and 1719. Spatial correlation analysis indicates that the temperature reconstruction series in this study exhibits good spatial representativeness for temperature in the Altay region. The early summer temperature series reconstructed in this study shows good consistency when compared with the May-September mean temperature from western Altay and the temperature series from the southern slope of the Altai Mountains.

Full Text

# Reconstruction of Early Summer Temperature during 1572-2014 from Tree Rings in the Altay Prefecture

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## Abstract

Tree-ring width samples from three high-altitude sampling sites of Siberian larch (*Larix sibirica*) in the Altay region were used to establish a regional standardized chronology (DKH). Correlation analysis revealed that the chronology showed significant correlation with the June mean temperature of the same year from seven meteorological stations in the Altay region, with a correlation coefficient of 0.705 ($P < 0.00001$). June mean temperature was identified as the primary climatic limiting factor affecting radial tree growth. The DKH chronology was used to reconstruct the regional June mean temperature over the past 443 years, with an explained variance of 49.6%. Verification tests demonstrated the reliability of the reconstructed temperature series. Analysis of temperature variation characteristics indicated that the reconstructed early summer temperature experienced ten warm periods and nine cold periods. The warmest and coldest periods occurred during 1605-1622 and 1682-1723, respectively, while the longest warm and cold periods lasted from 1875-1913 and 1753-1804, respectively. Abrupt changes from cold to warm occurred around 1684 and 1719. Spatial correlation analysis showed that the reconstructed temperature sequence has good spatial representativeness for the Altay region. Comparison with other temperature reconstructions from western Altay and the southern slope of the Altai Mountains revealed good consistency.

**Keywords:** Altay Prefecture; *Larix sibirica*; regional standardized chronology; mean temperature change

## 1. Introduction

Dendrochronology has been widely applied in historical climate change research due to its unique advantages. High-altitude, high-latitude, and arid/semi-arid regions are particularly important for dendroclimatic studies because climate factors play crucial roles in tree radial growth in these areas. Since the 20th century, dendrochronologists worldwide have conducted extensive research. Li Jiangfeng et al. studied the information content of tree-ring chronologies from forest upper and lower limits on the southern slope of the Altai Mountains, noting correlations between ring-width indices and sunspot activity. Shao Xuemei et al. reconstructed winter mean minimum temperature anomalies in western Sichuan over the past 350 years using spruce tree-ring width data. Duan Jianping et al. reconstructed May–July temperature variations on Mount Gongga since AD 1387 using fir tree-ring latewood density data. Zhu Haifeng et al. revealed the main limiting factors for tree growth in the Qilian Mountains using forest-upper-limit *Sabina przewalskii* samples and reconstructed mean May–July temperature over the past 1000 years. Yu Shulong et al. analyzed the correlation between tree-ring width fields and minimum temperature fields in western Sichuan based on single correlation analysis methods. Zhang Ruibo et al. established width and gray-value chronologies using tree-ring image analysis and reconstructed April–May mean minimum temperature on the northern slope of the Wusun Mountains. Most current dendroclimatic and hydrological studies focus on small-scale and local regions. This study uses Siberian larch tree-ring width data collected from three sampling sites at the forest upper tree line on the Altai Mountains to construct a regional standardized chronology, aiming to reconstruct temperature variations and analyze characteristics of the reconstructed climate series. Understanding historical climate change facts, patterns, and characteristics in this region can provide a basis for climate prediction and economic development assessment, offering reference and guidance for agricultural and pastoral production planning.

### 1.1 Study Area

The Altai Mountains extend approximately 2100 km across the borders of China, Kazakhstan, Russia, and Mongolia in a northwest-southeast orientation across central Asia. The Altai Mountains are rich in virgin forest resources with diverse tree species. Siberian larch (*Larix sibirica*) is widely distributed between 1300–2600 m altitude. Its physiological characteristics include drought and cold tolerance. The growing season begins in May, with rapid growth during June–July, and leaf fall and dormancy beginning in September. This species is only distributed on the southern slope of the Altai Mountains and the eastern Tianshan Mountains in Xinjiang, China. Precipitation in this region mainly originates from the Atlantic westerlies and partial airflow from the Arctic Ocean crossing mountain passes. Due to orographic lifting, mountainous areas receive relatively abundant precipitation, which decreases from northwest to southeast. Temperature varies correspondingly with precipitation patterns across different localities.

## 1.2 Meteorological Data

Meteorological data were obtained from seven stations: Habahe (1957-2014), Burqin (1956-2014), Altay (1953-2014), Fuyun (1957-2014), Qinghe (1957-2014), Fuhai (1975-2014), and Jeminay (1956-2014). The average climate element values from these stations represent the study area' s climate. Due to varying degrees of missing data at individual stations, the common period 1960–2014 was selected for analysis. The Altay station, closest to the sampling sites, has a multi-year average precipitation of 191.3 mm and multi-year average temperature of 4.5°C. Climate elements (mean temperature, mean precipitation) from the previous October to September of the current year were arranged chronologically and correlated with the regional standardized chronology (DKH) to analyze the response between Siberian larch radial growth and climate factors.

## 1.3 Sample Collection and Chronology Development

Following fundamental dendrochronological principles, we collected tree-ring samples from three high-altitude forest upper tree-line sites in the Altay region during July 2014 (sampling site details in ). We avoided trees affected by fire, other disturbances, diseases, or pests, and selected sites with low canopy density where tree spacing exceeded 5-10 m. A total of 79 Siberian larch trees and 261 cores were collected. Sample pretreatment was completed at the Key Laboratory of Tree-Ring Physical and Chemical Research, Institute of Desert Meteorology, China Meteorological Administration, following standard dendrochronological procedures. After drying, mounting, and polishing, ring widths were measured. Cross-dating was performed using skeleton plot comparison and verified with the COFECHA program. The ARSTAN program was then used to develop three tree-ring width chronologies: standardized, residual, and autoregressive standardized chronologies. This study used the standardized chronology (DKH) for analysis. Due to high inter-correlation coefficients among the three chronologies (), width series from all three sites were combined for re-crossdating and used to develop a regional standardized chronology (DKH) for the Siberian larch forest upper tree line.

Statistical characteristics of the tree-ring width regional standardized chronology are shown in . The mean sensitivity is 0.181, first-order autocorrelation is 0.624, and the expressed population signal (EPS) exceeds 0.85, indicating strong common growth signals among trees. The chronology spans 493 years (1522–2014), with reliable chronology length of 443 years (1572–2014) based on the SSS $> 0.85$ threshold.

## 2. Results

### 2.1 Correlation between Tree-Ring Radial Growth and Climate Factors

To analyze the response of Siberian larch radial growth to climate, meteorological data were arranged chronologically and correlated with the regional standardized chronology (DKH). Results ([Figure 2: see original paper]) show significant positive correlation with June mean temperature of the current year ($r = 0.705$, $P < 0.00001$), indicating June temperature is the main limiting factor. Significant positive correlation also exists with May precipitation ($r = 0.421$, $P < 0.01$) and significant negative correlation with July precipitation ($r = -0.382$, $P < 0.01$). The positive correlation with May precipitation may reflect sufficient moisture availability during early growth, while negative correlation with July precipitation suggests that increased summer rainfall, often accompanied by cold air intrusion and reduced solar radiation, may limit photosynthesis and cell division, resulting in narrower rings.

### 2.2 Establishment and Verification of the Reconstruction Equation

Based on the above analysis, the regional standardized chronology (DKH) was used as the independent variable, and the average June mean temperature from seven meteorological stations as the dependent variable to establish a linear regression model:

$$T_{June} = 15.13779 + 4.87729 \times DKH$$

where $T_{June}$ is the regional June mean temperature and $DKH$ is the tree-ring width regional standardized chronology. The correlation coefficient is 0.705, with variance explanation of 49.6% ($F = 50.279$, $P < 0.00001$). Comparison of observed and reconstructed values ([Figure 3: see original paper]) shows good consistency in variation trends and amplitudes.

The stability of the reconstruction equation was tested using the leave-one-out cross-validation method. Cross-validation statistics () show that both the sign test and first-difference sign test exceed the 0.05 significance level, indicating good consistency between reconstructed and observed series at both high and low frequencies. The positive reduction of error ($RE = 0.48$) and coefficient of efficiency ($CE = 0.47$) values indicate the reconstruction passes validation. The product means test ($t = 4.877$) exceeds the 0.001 significance level. These statistics demonstrate high reliability of the temperature reconstruction.

### 2.3 Characteristics of the Reconstructed Temperature Series

Using the above equation, we reconstructed June mean temperature for the past 443 years (1572-2014) ([Figure 4: see original paper]). The reconstructed series shows ten warm periods and nine cold periods (). The warmest period (1605-

1622) was 0.55°C above the long-term mean (19.86°C), while the coldest period (1682-1723) was 0.54°C below the mean. The longest warm period lasted 39 years (1875-1913) and the longest cold period lasted 52 years (1753-1804).

Power spectrum analysis revealed significant periodicities of 2.37-2.39 a and 2.19 a ($P < 0.05$), and 73.5 a, 14.0 a, 7.3 a, and 2.29 a ($P < 0.10$). The 2.19 a cycle may relate to the quasi-biennial oscillation associated with ocean-atmosphere coupling. The 73.5 a, 14.0 a, and 7.3 a cycles likely reflect low-frequency climate variability.

Moving t-test analysis identified abrupt temperature changes from cold to warm around 1684 and 1719 ($\alpha = 0.005$).

## 3. Discussion

### 3.1 Tree-Ring Radial Growth and Climate Factor Relationships

The significant positive correlation between radial growth and June temperature has clear physiological meaning. Siberian larch growing season is May-September, with rapid growth in June-July. At the upper tree line, precipitation is relatively abundant, and under moisture-sufficient conditions, higher temperatures enhance photosynthesis and cambial cell division, producing wider rings. This relationship has been documented in other studies on the northern and southern slopes of the Altai Mountains and the western Sichuan Plateau.

### 3.2 Spatial Representativeness

Spatial correlation analysis between our reconstruction and CRU TS3.23 0.5°$×$0.5° gridded June temperature data shows good consistency. The reconstruction correlates best with northern Xinjiang (Altay, Hami, Turpan), western Mongolia, northeastern Kazakhstan, and southern West Siberia ($r > 0.6$), with moderate correlation ($r > 0.4$) across broader regions including northern Tianshan, eastern Kazakhstan, southern West Siberia, and western Mongolia. This demonstrates strong spatial representativeness of our reconstruction for large-scale temperature variations.

### 3.3 Comparison with Other Reconstructions

Comparison with other temperature reconstructions from western Altay and the southern Altai Mountains slope shows generally consistent trends and good correspondence of warm/cold periods ([Figure 5: see original paper]). Our reconstruction shows particularly strong agreement with Shang Huaming' s southern slope temperature series. Notable consistent cold periods (1585-1604, 1682-1723, 1809-1830, 1845-1874, 1950-1980) and warm periods (1605-1622, 1752-1804, 1914-1928, 1981-1992) appear across multiple reconstructions. Some differences likely arise from different chronologies used and specific site environmental conditions.

## 4. Conclusions

1) A regional standardized chronology (DKH) was developed from Siberian larch samples collected at three high-altitude forest upper tree-line sites in the Altay region. Correlation analysis identified June mean temperature as the primary limiting factor for radial growth, with a significant correlation coefficient of 0.705 ($P < 0.00001$).
2) The chronology was used to reconstruct June mean temperature for the past 443 years (1572-2014). The reconstruction explained 49.6% of temperature variance and passed rigorous statistical verification, demonstrating reliability.
3) The reconstructed temperature series experienced ten warm periods and nine cold periods. The warmest period was 1605-1622 (+0.55°C) and the coldest was 1682-1723 (-0.54°C). The longest warm period lasted 39 years (1875-1913) and the longest cold period lasted 52 years (1753-1804).
4) Power spectrum analysis revealed significant periodicities of 2.37-2.39 a, 2.19 a, 73.5 a, 14.0 a, 7.3 a, and 2.29 a. The 2.19 a cycle likely relates to quasi-biennial oscillation from ocean-atmosphere coupling, while longer cycles reflect low-frequency climate variability.
5) Moving t-test detected abrupt warming transitions around 1684 and 1719. Spatial correlation analysis demonstrates that the reconstruction has good representativeness for temperature variations across the Altay region and surrounding areas.
6) Comparison with other regional temperature reconstructions shows good consistency in overall trends and warm/cold phase correspondence, particularly with the southern Altai Mountains slope temperature series, further confirming the reliability of our reconstruction.

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