# Tree-ring reconstruction of May-September relative humidity variations in the Qingnan Plateau, AD 1639-2013: Postprint

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## Abstract

A tree-ring width residual chronology (RES) was developed using Juniperus tibetica collected from Angsai Township, Zaduo County, Qinghai Province. Correlation analysis reveals a significant positive relationship between average atmospheric relative humidity from May to September over the Southern Qinghai Plateau and the tree-ring width residual chronology, with a correlation coefficient of 0.65 (calibration period, 1969-2013). Using this residual chronology, a 375-year sequence of May–September average relative humidity variations for the Southern Qinghai Plateau was reconstructed, with the reconstruction equation explaining 42.3% of the variance and demonstrating stability. Within the reconstructed 375-year period, five significant wet periods were identified: 1694–1710, 1753–1778, 1830–1847, 1892–1908, and 1978–1989; and eight significant dry periods: 1646–1673, 1682–1693, 1711–1731, 1735–1752, 1796–1809, 1817–1829, 1848–1861, and 1873–1886. Multi-taper Method (MTM) spectral analysis indicates that the reconstructed series exhibits a long-term periodicity of 28–30 years and short-term periodicities of 6–9 years and 2–5 years. This reconstruction shows good low-frequency consistency with other tree-ring based dry-wet reconstructions for the Tibetan Plateau region, and its correlation coefficient with the summer Palmer Drought Severity Index (MADA) for corresponding grid points during the common period (1639–2005) reaches 0.489 ($P < 0.001$, $n = 367$), further validating the reliability of the reconstruction.

## Full Text

### Tree-Ring Based Reconstruction of Relative Humidity from May to September in Southern Qinghai Plateau during AD 1639–2013

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**Abstract**

The study of relative humidity is important for better understanding past climatic variations. However, there have been few long-term humidity reconstructions using tree-ring widths worldwide. In this paper, we established a reconstruction of mean relative humidity from May to September from AD 1639 to 2013 using *Sabina tibetica* from the southern Qinghai Plateau region in the northeastern Tibetan Plateau, China. In total, there were 56 tree cores from 28 trees collected at Angsai Township of Zaduo County of Qinghai Province (AS, 95°37.765 E, 32°42.856 N). All samples were surfaced, cross-dated and measured according to standard dendrochronology techniques. The reconstructed equation was stable and reliable and its variance interpretation quantity reached 42.3%. In the past 375 years, there were five wet periods (1694–1710, 1753–1778, 1830–1847, 1892–1908, and 1978–1989) and eight dry periods (1646–1673, 1682–1693, 1711–1731, 1735–1752, 1796–1809, 1817–1829, 1848–1861 and 1873–1886) in the reconstructed humidity sequence. The longest wet period is 1753–1778 (26 years), and the longest dry period is 1646–1673 (28 years). There were 12 extremely dry years: 1689, 1700, 1724, 1727, 1739, 1749, 1872, 1910, 1942, 1953, 1995 and 1998; and 5 extremely wet years: 1640, 1699, 1703, 1704 and 1873. The multi-taper method (MTM) spectral analysis indicates that there are 3 periodic changes of 28–30a, 6–9a, 2–5a. The 2–5a cycle may be related to the Quasi-biennial and Southern Oscillations influenced by the constant change between east wind and west wind in the equatorial stratosphere in a cycle of 26–30 months. The 6–9a cycle may be related to ENSO. By comparing the reconstructed sequence from this study with a few typical reconstructed series which can reflect the status of dry and wet in the Southern Qinghai Plateau, it is found that there were four curves which shared the same wet periods (1710s, 1830s–1840s and 1890s–1900s) and drought periods (1660s, 1680s–1690s, 1730s–1740s, 1820s and 1950s) at an inter-annual scale. The result shows that the series presented good consistency on the change of low frequency. Moreover, our relative humidity reconstruction was correlated well with the corresponding grids MADA dataset in the public section during the common period. All of these have proved the accuracy of the reconstruction sequence in this paper.

**Keywords:** southern Qinghai Plateau; tree-ring residual chronology; relative humidity; reconstruction

## 1. Data and Methods

Tree-ring samples were collected from *Sabina tibetica* trees growing at the Angsai Township sampling site in Zaduo County, Qinghai Province (95°37.765 E, 32°42.856 N). A total of 56 tree cores from 28 trees were obtained. All samples were processed, cross-dated, and measured following standard dendrochronological techniques. The residual chronology (RES) was developed using standard procedures.

Meteorological data were obtained from nearby weather stations. The reliability of the tree-ring chronology was assessed using several statistical parameters. The expressed population signal (EPS) exceeded the threshold value of 0.85, and the subsample signal strength (SSS) was also above 0.85, indicating a robust chronology. The variance explained by the reconstruction model was 42.3%.

The relationship between the tree-ring residual chronology and relative humidity was examined using correlation analysis. The results showed significant positive correlations between the RES and May–September relative humidity ($RH_{5\ 9}$). The highest correlation coefficient reached 0.65 ($P < 0.001$) for the period 1969–2013.

## 2. Reconstruction Model

Based on the strong relationship between RES and $RH_{5\ 9}$, a linear regression model was developed to reconstruct historical humidity:

$$RH_{5-9} = 6.32 \times RES + 58.58$$

The model explained 42.3% of the variance in the observed humidity data, with a standard error of estimate of 3.1%. Statistical validation tests, including the sign test, product-mean test, and reduction of error (RE) test, all passed at the 0.01 significance level, confirming the reliability of the reconstruction.

## 3. Historical Humidity Variations

The reconstruction revealed significant interannual to multi-decadal variability in relative humidity over the past 375 years (Fig. 4). Wet periods (defined as values exceeding $+1\sigma$) occurred during 1694–1710, 1753–1778, 1830–1847, 1892–1908, and 1978–1989. Dry periods (values below $-1\sigma$) were identified for 1646–1673, 1682–1693, 1711–1731, 1735–1752, 1796–1809, 1817–1829, 1848–1861, and 1873–1886.

Extreme events were also identified. Twelve extremely dry years (below $-2\sigma$) occurred: 1689, 1700, 1724, 1727, 1739, 1749, 1872, 1910, 1942, 1953, 1995, and 1998. Five extremely wet years (above $+2\sigma$) were recorded: 1640, 1699, 1703, 1704, and 1873.

## 4. Spectral Analysis

Multi-taper method (MTM) spectral analysis of the reconstructed humidity series revealed significant periodicities at 28–30 years, 6–9 years, and 2–5 years (Fig. 5). The 2–5 year cycle may be associated with the Quasi-biennial Oscillation (QBO) and the Southern Oscillation, reflecting the alternating easterly and westerly wind patterns in the equatorial stratosphere with a period of 26–30 months. The 6–9 year cycle likely reflects ENSO variability. The 28–30 year cycle may be linked to lower-frequency climate dynamics.

## 5. Comparison with Other Reconstructions

Comparisons with other paleoclimatic reconstructions from the Southern Qinghai Plateau region showed good agreement in the timing of major wet and dry periods (Fig. 6). Four independent records shared common wet periods in the 1710s, 1830s–1840s, and 1890s–1900s, and common dry periods in the 1660s, 1680s–1690s, 1730s–1740s, 1820s, and 1950s. This consistency across multiple proxies strengthens the reliability of our reconstruction.

Furthermore, the reconstructed humidity series correlated well ($r = 0.489$, $P < 0.001$, $n = 367$) with the Monsoon Asia Drought Atlas (MADA) grid data during the overlapping period of 1639–2005, providing additional validation of our results.

## 6. Conclusions

The tree-ring residual chronology from *Sabina tibetica* provides a robust proxy for reconstructing May–September relative humidity in the southern Qinghai Plateau. The 375-year reconstruction reveals substantial variability in humidity, with distinct wet and dry periods and significant periodicities at interannual to decadal timescales. The good agreement with independent reconstructions and the MADA dataset confirms the reliability of the record. These results contribute to a better understanding of long-term hydroclimatic variability in the Tibetan Plateau region.

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## References

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