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Reconstructed precipitation on a centennial timescale from tree rings in the western Tien Shan Mountains, Central Asia

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A B S T R A C T

July–June precipitation has been reconstructed to 1756 AD for the western Tien Shan Mountains, Central Asia, using the *Picea schrenkiana* tree-ring width. The reconstruction explains 31% of the variation in the observed precipitation from 1933 to 2009. Some extremely dry signals in the historical documents are captured precisely in this new reconstruction. Wet periods occurred during the periods of 1811–1828, 1843–1880, 1893–1915, 1929–1934, and 1983–2002, while the periods 1766–1810, 1829–1842, 1881–1892, 1916–1928, and 1935–1982 were relatively dry. Power spectral and wavelet analyses demonstrated the existence of significant 32-, 17-, and 2.6–7.4-year cycles of variability. An assessment of spatial correlation analysis and the significant correlation coefficients between the reconstructed precipitation series and three precipitation reconstructions indicate that our reconstruction might contain multiple large-scale climatic signals in the low-frequency domain. A wetting trend in the eastern Central Asia since the 1970s decades was also captured by this reconstruction.

1. Introduction

The Eurasian Tien Shan Mountains span China, Kazakhstan, Kyrgyzstan, and Uzbekistan, extending >2500 km from south to north and 250–300 km from east to west, and play an important role in determining the climatic processes in northern Central Asia (Aizen et al., 1997). Understanding the history of climate change within a given region could provide insights into the underlying climate-forcing mechanisms. However, most meteorological records available for the Tien Shan Mountains span less than 60 years and limited historical documents do not adequately describe past climatic changes. Fortunately, the widespread pine forests of the Tien Shan Mountains, comprising mostly *Picea schrenkiana*, *Juniperus turkestanica*, and *Pinus wallichiana*, provide a good opportunity for dendroclimatic studies (Esper et al., 2001).

Systematic dendroclimatic studies for the Central Asian region of the Tien Shan Mountains were started in 1990 (Esper et al., 2007). Esper et al. (2003) established two-millennia-length juniper ring-width chronologies for the western Tien Shan Mountains in Kyrgyzstan, which likely reflect summer temperature variation. Winter et al. (2009) investigated the relationship between climatic data and the ring-with series of Persian walnuts (*Juglans regia* L.) from more than 200 trees. Fang et al. (2010) contribute spatial reconstructions of the Palmer Drought Severity Index for central High Asia based on a tree-ring network that included some chronologies from the western Tien Shan Mountains. Five tree-ring-width chronologies from the western Tien Shan Mountains were used to reflect variances in the January–May Palmer Drought Severity Index from 1580 to 2005 for this region (Chen et al., 2013). Zhang et al. (2014) studied the relationships between the ring-width of spruce trees and local gridded climatic data in the mountains surrounding the Issyk-Kul Lake (Northeast Kyrgyzstan), suggesting

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that three chronologies at the different elevations mainly contain an annual precipitation signal. However, previous dendroclimatic studies in the Tien Shan Mountains in China have focused on tree-growth response and climatic reconstructions for this part of Central Asia remain limited.

In this study, a dendrochronological approach was used to construct ring-width chronologies from spruce trees in the western Tien Shan Mountains. Based on the tree growth–climate responses, a long-term record of precipitation was reconstructed, derived from tree-ring-width data from the study region. This new reconstruction was compared with a gridded meteorological dataset and other proxy records to assess common climatic signals.

2. Material and methods

2.1. Sample collection

Our sampling targeted the western Tien Shan Mountains, a mountainous area of Northeast Kyrgyzstan, Central Asia (Fig. 1). The samples used in this study came from spruce trees (*P. schrenkiana*), which are distributed widely in this region, can often grow up to 40-m high, and frequently live for more than 200 years. The forest stands are rather open and canopy densities low. The trees generally grow under poor soil conditions. The soil type at the sampling sites is a Leptosols (Soil unit symbol: LPe), which is thin and contains considerable gravel. The information regarding the soil type was developed by the Harmonized World Soil Database (version 1.2) (FAO et al., 2012).

Table 1 provides the information from these sampling sites including latitude/longitude, number of trees/cores, elevation, aspect, slope, maximum tree age, and the rate of absent rings. To minimize non-climatic effects on tree growth, only healthy trees exhibiting little evidence of fire or human disturbance were selected for sampling. To collect tree-core samples that contained consistent climate signals, the altitude difference between the highest and lowest locations of each sample site was 200 m. For most trees at the sites, two cores were extracted from different directions for cross-dating purposes. Overall, 235 cores (5.15-mm diameter) from 124 trees were collected at breast height from five sites: Akebulake (AKB), Hunanzhong (HSZ), Kezersun (KZE), Kezersunxia (KZX), and Tubeshu (TBX) in October 2012. One 409-year-old tree was found at the KZE site (Table 1).

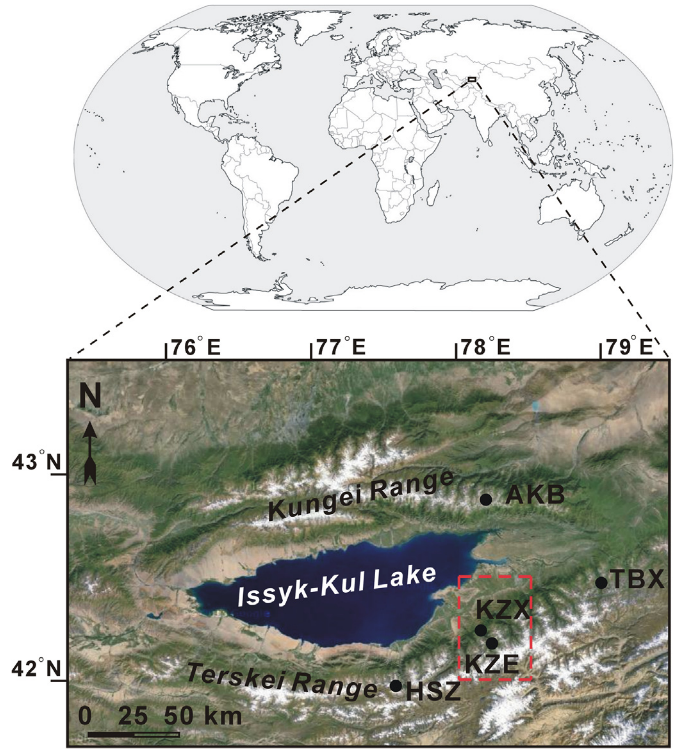

Fig. 1. Locations of the *Picea schrenkiana* tree-ring sampling sites. Red dash block diagram is the location of the selected CRU grid (42.25°N and 78.25°E). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Information regarding sampling sites.

Site code	Latitude (N)	Longitude (E)	Number of trees/cores	Elevation (m)	Aspect	Slope	Maximum tree age	The rate of absent rings (%)
AKB	42.83°	78.23°	21/41	~2750	E	20°	175 (1838–2012)	0.00
HSZ	41.98°	77.62°	33/60	~2450	NW	10°	268 (1745–2012)	1.42
KZE	42.17°	78.20°	25/46	~2800	NE	40°	409 (1604–2012)	0.12
KZX	42.25°	78.13°	20/40	~2210	N	15°	129 (1884–2012)	0.00
TBX	42.42°	78.95°	25/48	~2900	NW	40°	362 (1651–2012)	0.06

2.2. Tree-ring-width measurements and chronology developments

All the tree-ring cores were dried naturally, mounted, surfaced, and cross-dated following standard dendrochronological procedures (Speer, 2010). Each ring width was measured with a resolution of 0.001 mm using a Velmex Measuring System. The cross-dating quality control was performed using the COFECHA program (Grissino-Mayer, 2001). The ARSTAN program (Cook and Krusic, 2005) was used for detrending and developing the tree-ring chronologies. The age- and size-related variations of the tree-ring widths were removed by a single detrending process applied to each tree-ring measurement, i.e., a 170-year cubic smoothing spline (Cook and Peters, 1981). The detrended data from individual tree cores were processed to produce a standard chronology using a bi-weight robust mean to minimize the influence of outliers, extreme values, or biases (e.g., from spurious trends) in the tree-ring indices.

For each tree-ring-width series, temporal autocorrelation was removed using autoregressive moving average time-series models to produce a residual chronology. The pooled model of autoregression was reincorporated into a residual chronology to develop an Arstan chronology containing the persistent, common, and synchronous signals among a large proportion of the series from the sampled tree cores. Finally, three types of chronologies from the sample sites were obtained (Cook and Kairiukstis, 1990). Generally,