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Tree-ring recorded hydroclimatic change in Tienshan mountains during the past 500 years

Feng Chen [a,b,*], Yu-jiang Yuan [a,b], Wen-shou Wei [a,b], Shu-long Yu [a,b], Tong-wen Zhang [a,b], Hua-ming Shang [a,b], Rui-bo Zhang [a,b], Li Qin [a,b], Zi-ang Fan [a,b]

[a] Key Laboratory of Tree-ring Physical and Chemical Research of China Meteorological Administration, Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, China
[b] Xinjiang Laboratory of Tree-Ring Ecology, Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, China

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ABSTRACT

In Central Asia, tree rings provide one of the best sources of paleoclimatological information. However, dendroclimatology has not been widely applied in the coniferous forests of Central Asia. Tree cores of *Picea Schrenkiana* from four sites in the Hutubi River Basin were developed into a 606-year tree-ring width chronology. The analyses showed that the tree-ring width indices highly correlate with mean April–May PDSI in the Hutubi River Basin. Mean April–May PDSI of the Hutubi River was reconstructed using the tree-ring data with 41.5% of the variance explained. The reconstructed series contains both high- and low-frequency climate signals. Our new PDSI reconstruction agrees reasonably well with the dry and wet periods previously estimated from tree rings in western Tien Shan. The results reveal common climatic extremes over much of Central Asia. Spatial analysis shows that the PDSI reconstructions have strong common signals for the Tien Shan. The first principal component of PDSI reconstructions in Tien Shan is significantly correlated with sea surface temperature in the eastern equatorial Pacific Ocean and Atlantic Ocean. The linkages to the Atlantic and Pacific Oceans suggest the connection of regional moisture variations to the Asian monsoon and the Westerlies.

1. Introduction

The Tien Shan in Xinjiang Province of western China, which is bordered by the Junggar Basin in the north and the Tarim Basin in the south, is one of the major sources of sandstorms in Central Asia. The oasis of the Junggar Basin and the Tarim Basin are nurtured by the mountainous rivers which originate in Tien Shan, including Ili River, Tarim River and Manas River. Thus, it plays an important role in the ecosystem and agriculture of Central Asia. It is increasingly clear that an anomalous wet period of the early 1980s caused an overestimation of available water resources, resulting in over-allocation of the mountainous rivers streamflow of Tien Shan (Chen et al., 2004, 2013a). Therefore, investigation of the climate variations in Tien Shan is a high research priority for the detection and attribution of hydroclimatic change. However, the meteorological records in Tien Shan are very short, generally begin in the 1960s. The poor temporal and spatial coverage of meteorological records limits our ability to examine current climate regimes in a long-term perspective.

In order to better understand the long-term history of hydroclimatic change, annually/seasonally resolved hydroclimatic proxy records are needed. The high-resolution, precisely dated tree-ring data are of considerable value for developing longer hydroclimatic reconstructions for analysis. By using tree-ring data, the long-term hydroclimatic history has been successfully reconstructed on local, regional, and hemispheric scales (Cook et al., 2010; Chen et al., 2013a). In recent years, numerous tree-ring based reconstructions of temperature, precipitation, streamflow and drought history have also been developed in Tien Shan (Yuan et al., 2007; Chen et al., 2010, 2013a; Yu et al., 2013). Considering that the tree-ring chronologies are still sparse in Central Asia, additional proxy data sets are needed. This study presents a new tree-ring-based spring drought reconstruction for the Hutubi River Basin in the central Tien Shan over the past 553 years, which is compared and assessed in the light of existing instrumental, documentary, and proxy records available for the Tien Shan region.

* Corresponding author. Key Laboratory of Tree-ring Physical and Chemical Research of China Meteorological Administration, Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, China.
E-mail address: feng653@163.com (F. Chen).

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2. Materials and methods

2.1. Study area

The study area is situated in the central Tien Shan area (Fig. 1), and lies on the present margin of the Westerlies (Chen et al., 2006). Regional climate of the study region is temperate continental arid climate, with peak warm and wet conditions in July and April, respectively. According to the nearest meteorological station, Hutubi (44°08′N, 86°49′E, 523.5 m a.s.l.) for the period 1961–2005, the annual average temperature and annual total precipitation are 6.7 °C and 167 mm, respectively (Fig. 2). The main tree species in the study areas is Schrenk spruce (*P. schrenkiana*).

2.2. Tree-ring data

Schrenk Spruce tree-ring samples were collected from living trees in the Hutubi River Basin in the central Tien Shan area during the 2004–2009 summer field seasons (Table 1). Cores were taken from the living trees by an increment borer at breast height using 5-mm-diameter increment borers, and two cores were obtained from each tree. In total, 44 cores were collected from 22 trees at the AYS site (43°34′N, 86°23′E, 2120–2250 m a.s.l.), 52 cores from 26 trees at the SRK site (43°32′N, 86°27′E, 2450–2650 m a.s.l.), 58 cores from 29 trees at the KYS site (43°34′ N, 86°25′E, 2065–2215 m a.s.l.) and 52 cores from 26 trees at the WZG site (43°43′ N, 86°39′E, 2264–2350 m a.s.l.). After air-dried, mounted and progressively sanded to >320 grit, the cores were cross-dated using standard methods (Cook and Kairiukstis, 1990). Tree-ring widths were measured to the nearest 0.001 mm using a Velmex measuring system. The quality of visual cross-dating was further checked by the computer program COFECHA (Holmes, 1983). As the four sampling sites were very close (mean distance among the four sites is about 20 km) and all tree-ring width series cross-dated well, all increment cores collected at the four sites were used to build a regional chronology.

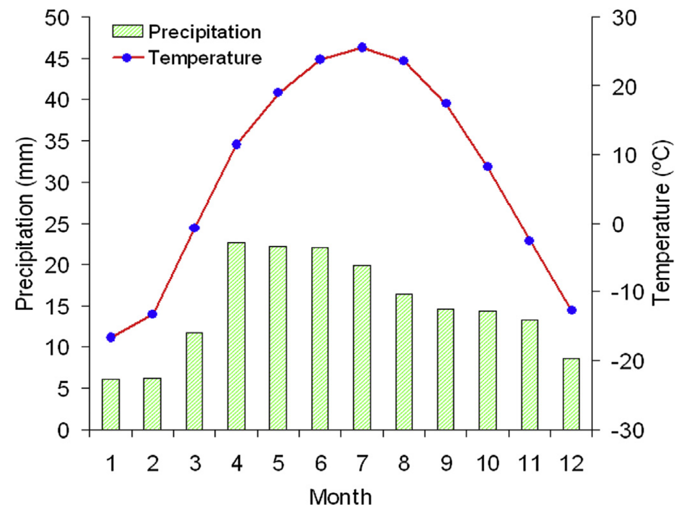

Fig. 2. Monthly mean temperature and sum of precipitation at the Hutubi meteorological stations (1961–2005).

Each cross-dated ring-width series was standardized with negative exponential curve fits in order to remove non-climatic trends due to age, size, and stand dynamics (Fritts, 1976). All detrended series were standardized into the regional chronology using the program ARSTAN (Cook and Kairiukstis, 1990). The variance in chronologies was stabilized in the chronology compilation process using the Briffa RBAR-weighted method, which uses average correlations between series in combination with the sample size each year to make adjustments in the variance for changes in sample size (Osborn et al., 1997). We used the expressed population signal (EPS), which represents the degree to which a particular sampling portrays a hypothetically perfect chronology (Wigley et al., 1984), as a guide in evaluating chronology reliability. An EPS value of 0.85 is a widely accepted threshold for adequate sample size in chronology development.

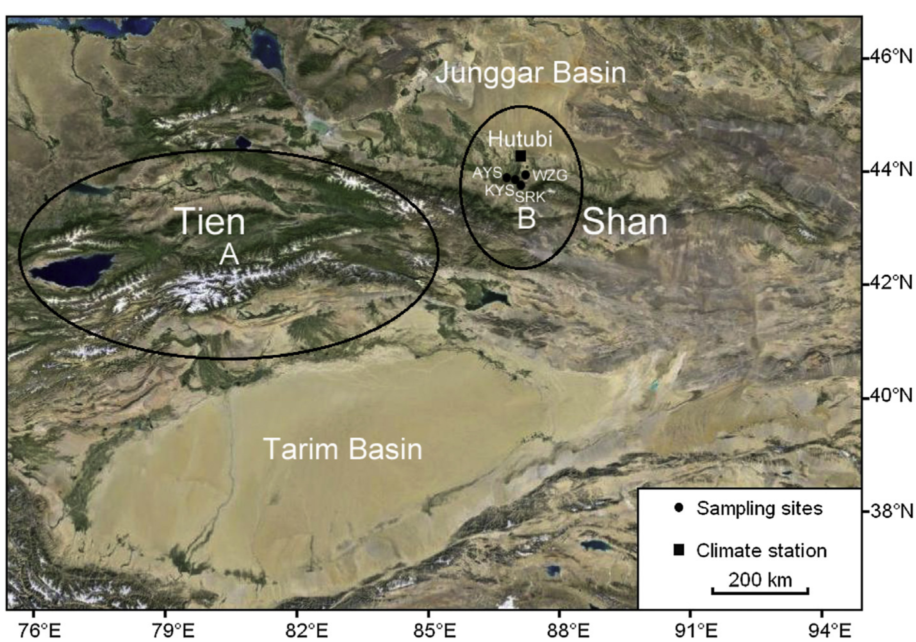

Fig. 1. Sampling sites in the Hutubi River Basin (A region) and meteorological stations nearby. The map contains another tree-ring based drought reconstruction for western Tien Shan (B region, Chen et al., 2013a) which compared with the drought reconstruction for the Hutubi River Basin in this paper. The ellipses denote the Hutubi River Basin (A region) and western Tien Shan (B region).