Global and Planetary Change 133 (2015) 141–148

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

A method to separate temperature and precipitation signals encoded in tree-ring widths for the western Tien Shan Mountains, northwest China

Wenhuo Liu [a,b], Xiaohua Gou [a,*], Jinbao Li [c], Yuxia Huo [a], Keyan Fang [d]

[a] Key Laboratory of Western China's Environmental Systems (MOE), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 73000, China
[b] Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, USA
[c] Department of Geography, University of Hong Kong, Hong Kong, China
[d] Key Laboratory of Humid Subtropical Eco-geographical Process (MOE), College of Geographical Sciences, Fujian Normal University, Fuzhou 350007, China

ARTICLE INFO

Article history:
Received 2 April 2015
Received in revised form 19 July 2015
Accepted 4 August 2015
Available online 5 August 2015

Editor: T.M. Cronin

Keywords:
Climate signals
Tree rings
Timberline
Climate reconstruction
Tien Shan Mountains
Dendroclimatology

ABSTRACT

Separating temperature and precipitation signals encoded in tree rings is a complicated issue. Here, we present a separation method by combining two tree-ring width chronologies of Schrenk's spruce (*Picea schrenkiana*) from the upper and lower timberlines in the western Tien Shan Mountains, northwest China. Correlation analyses show that both chronologies correlate positively with precipitation. However, temperature correlates positively with the chronology from the upper timberline, while negatively with the chronology from the lower timberline. This suggests that the two chronologies contain similar precipitation information but opposite temperature signals. In light of this, we calculated the average and difference of the two chronologies, and found that each of them has a much stronger correlation with precipitation or temperature alone. Finally, we reconstructed local precipitation and temperature variations over the past 201 years by using the average and difference of the two chronologies. The two reconstructions do not have a significant correlation, but they have significant positive and negative relationships on the high- and low-frequency band, respectively.

1. Introduction

Temperature and precipitation are the two most important factors affecting tree growth, and are often recorded in tree-ring width chronologies simultaneously. However, the correlation patterns of the chronologies with temperature and precipitation are different at different altitudes. For example, previous studies from the arid and semiarid areas in northern China have shown that the chronologies from the middle to lower forest zones are generally positively correlated with precipitation, but negatively with temperature (Chen et al., 2012, 2015; Fang et al., 2010, 2012; Li et al., 2006, 2007; Liang et al., 2006; Liu et al., 2009a; Shao et al., 2005; Sheppard et al., 2004; Song and Liu, 2011; Yang et al., 2011; Zhu et al., 2004). Although the chronologies from these altitudes are mainly used to study the precipitation variability (Chen et al., 2012; Liang et al., 2006; Liu et al., 2009a; Shao et al., 2005; Sheppard et al., 2004; Yang et al., 2011), more and more chronologies are found to have stronger relationships with the Palmer Drought Severity Index (PDSI) (Chen et al., 2015; Fang et al., 2010, 2012; Li et al., 2006, 2007; Song and Liu, 2011; Tian et al., 2007). The PDSI is a direct metric of moisture conditions taking both temperature and precipitation into account (Dai et al., 2004; Palmer, 1965). This suggests that temperature also has an important influence on tree growth in the middle to lower forest zones. By contrast, the chronologies from the upper timberline are generally correlated positively with both temperature and precipitation (Liu et al., 2005, 2006, 2009b; Yu et al., 2007; Zhang et al., 2014; Zhu et al., 2004, 2008). These chronologies were mainly used to study the temperature variability (Liu et al., 2005, 2009b; Yu et al., 2007; Zhang et al., 2014; Zhu et al., 2008). But some of them were also used to reconstruct precipitation (Liu et al., 2006), suggesting that precipitation also plays an important role on tree growth in the upper timberline. Obviously, we should separate the two climate signals encoded in tree rings in order to get more reliable precipitation and temperature reconstructions.

To our knowledge, there is no valid method to separate temperature and precipitation signals recorded in tree-ring width chronologies yet. The aforementioned studies showed that the chronologies from the middle to lower forest zones and the upper timberline are both positively correlated with precipitation, but have opposite relationships with temperature. Moreover, most of the chronologies showed similar response to temperature and precipitation in the same season (Chen et al., 2012, 2015; Fang et al., 2010, 2012; Li et al., 2006, 2007; Liang et al., 2006; Liu et al., 2009a; Shao et al., 2005; Sheppard et al., 2004; Song and Liu, 2011; Tian et al., 2007; Yang et al., 2011; Yu et al., 2007;

* Corresponding author.
E-mail address: xhgou@lzu.edu.cn (X. Gou).

http://dx.doi.org/10.1016/j.gloplacha.2015.08.002
0921-8181/

Zhang et al., 2014; Zhu et al., 2004). In view of this, here we propose to use the average and difference of the chronologies from the middle to lower forest zones and the upper timberline to separate the precipitation and temperature signals, so as to extract purer precipitation and temperature information.

In this paper, we present two chronologies from the lower and upper timberlines in the western Tien Shan Mountains, northwest China. As shown below, the climate responses of the two chronologies are similar to that of the above studies. Therefore, we combine them to identify whether the precipitation and temperature signals in the chronologies can be separated by statistical means.

2. Materials and methods

2.1. Tree-ring data

In China, the Tien Shan Mountains extend about 1300 km from the Hami district of Xinjiang province in the east to the national boundaries of China and Kazakhstan in the west. The Tien Shan Mountains block the humid air that is transported from the Atlantic and Arctic oceans under the influence of the westerlies, leading to more precipitation in the northern slope of the Tien Shan Mountains and a gradual decrease of rainfall from west to east. This is also the main factor responsible for the growth of coniferous forests on the northern slope of the Tien Shan Mountains. Generally, coniferous forests occur on shady and semi-shady slopes at 1400–2800 m a.s.l. The forest vegetation is primarily composed of *Picea schrenkiana*, while a mix of *P. schrenkiana* and *Larix sibirica* forests are present in the easternmost Tien Shan Mountains.

Tree-ring samples were collected from two sites, KUE and WUY, in the western Tien Shan Mountains (Fig. 1, Table 1). KUE is located at the lower timberline with an average elevation of 1499 m a.s.l. WUY is near to the upper timberline with an average elevation of 2763 m a.s.l. Increment cores were taken from *P. schrenkiana* at both sites. For cross-dating, at least 20 dominant trees were selected and two cores per tree were taken at breast height using 5-mm increment borers. In total, 46 (44) cores from 23 (23) trees were retrieved at the site of KUE (WUY), respectively.

In the laboratory, standard dendrochronological techniques were used to process the tree-ring cores. After air drying, mounting and sanding, all the samples were carefully cross-dated by visual comparison, and each ring-width was subsequently measured to 0.001 mm precision. The COFECHA program (Holmes, 1983) was further employed to check the quality of visual cross-dating. These methods ensure exact dating for each annual growth ring.

The chronologies were developed with the ARSTAN program (Cook, 1985) by removing biological growth trends while preserving variations that were likely related to climate. In most cases, we adopted negative exponential functions or linear functions to detrend the tree-ring series (83 series). A few of the series (7 series), which did not fit the negative exponential or linear models, were detrended by the cubic spline models. The detrended series were finally processed to produce the mean chronology using a bi-weight mean method. The variations of the two chronologies are shown in Fig. 2. Because the sample size declined in the early portion of the tree-ring chronology, the subsample signal strength (SSS) value of 0.85 (Wigley et al., 1984) was suggested to determine the reliable period of the chronology. In this study, the reliable period of the chronology with SSS values above 0.90 was used for further analyses. The final KUE and WUY chronologies extend from 1764–2004 AD and 1804–2004 AD, respectively.

2.2. Data analysis

Monthly mean temperature and precipitation records were obtained from three nearby meteorological stations, i.e. Tekesi, Xinyuan and Bayinbuluke (Fig. 1 & Table 1). Tekesi and Xinyuan are nearest to WUY and KUE, respectively. Tekesi and Bayinbuluke have the most similar elevations to KUE and WUY, respectively. As both sampling sites are located in the middle of the three meteorological stations, the mean values of climate variables from the three stations were calculated to better represent climate variations at the sample sites and to investigate the climate–tree growth relationships.

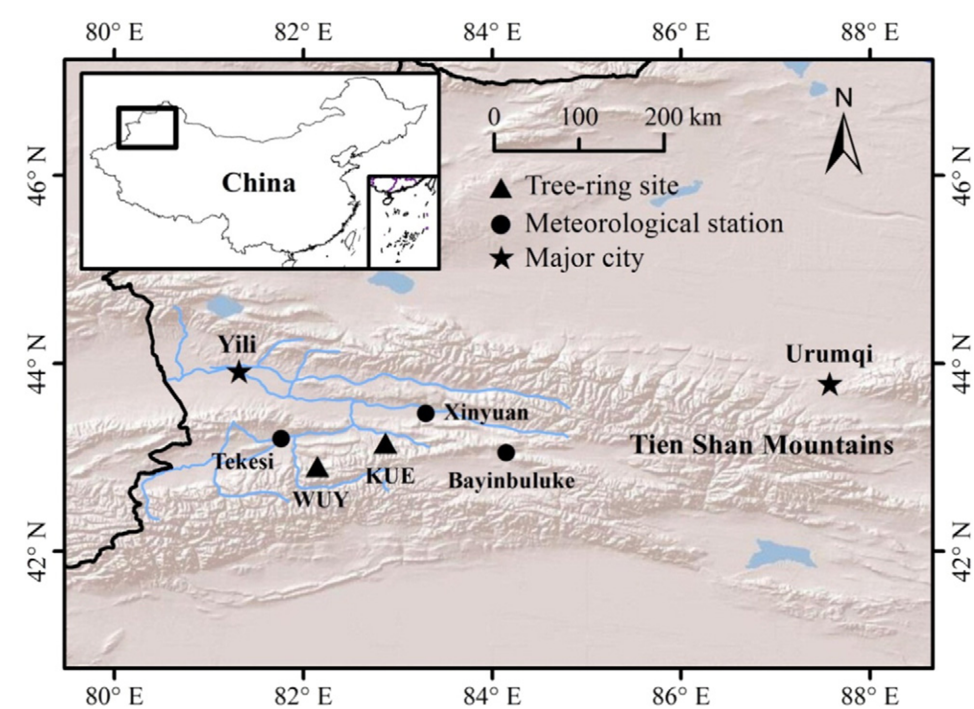

Fig. 1. Locations of tree-ring sampling sites (KUE and WUY) and the nearby meteorological stations (Tekesi, Xinyuan and Bayinbuluke).