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Short Communication

A short note on linkage of climatic records between a river valley and the upper timberline in the Sygera Mountains, southeastern Tibetan Plateau

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ABSTRACT

Tree-ring data from timberlines have been widely used to reconstruct past temperature variability. High-quality reconstructions depend on successful calibrations in which tree-ring records are compared with instrumental observations of climatic factors to establish quantitative relationships between tree growth and climate. Climatic data used in the calibrations are mostly from nearby meteorological stations, located generally in the valleys near human settlements of mountainous areas, regardless of whether climatic records at low elevations are representative for the upper timberline. In order to better understand the characteristics of the alpine environment at the upper timberline of blackseed juniper (*Juniperus saltuaria*) in the eastern side of the Sygera Mountains, southeastern Tibetan Plateau, an automatic weather station was established. We found that the variation in the daily/5-day/10-day/monthly mean temperatures and sums of precipitation on the valley bottom (3000 m a.s.l.) as well as the daily/seasonal sums of precipitation from the TRMM (Tropical Rainfall Measuring Mission) are highly correlated with the measurements at the upper timberline (4400 m a.s.l.). Thus, the variations of the valley bottom temperature and precipitation records are confident indicators of the conditions at the upper timberline on the southeastern Tibetan Plateau and hence can be used for the calibration in the dendroclimatic reconstructions based on timberline tree-ring data. For 5-day mean temperature pooled by individual months, the R^2 values of the regression models>0.60 between the valley bottom and timberline in February–August and October, and <0.40 in December. For 5-day total precipitation, the R^2 values>0.60 in March–July and October–December, and <0.40 in January, February, August and September. This study represents a small step towards fixing problems regarding to dendroclimatic calibrations.

1. Introduction

As the upper- and northern-most occurrence of forests, the alpine and arctic timberlines are likely the forested ecosystems to register climatic impacts at first (Holtmeier, 2003; Körner, 2003). With this context, timberline tree-ring data have been playing an important role in retrieving information of past climate changes, in particular of temperature variability (Bradley, 2000; Hughes, 2002). Such reconstructions are commonly based on the calibration between tree-ring time series and climatic records measured at meteorological stations (Cook and Kairiukstis, 1990), which are normally located in river valleys near human settlements of mountainous areas, such as the Tibetan Plateau and other remote highland regions. As for timberline studies, Holtmeier (2003) emphasized that one of the problems is the use of valley bottom climate records to predict phenomena at higher elevations. Unfortunately, few uninterrupted *in situ* micrometeorological field measurements are available for the upper timberlines, due primarily to difficulties of poor access and bad weather conditions throughout much of the year (Körner, 2003; Richardson et al., 2004; Cui et al., 2005; Biondi et al., 2009). This is certainly true for the upper timberline in the highly heterogeneous mountainous terrain of the Tibetan Plateau (Schickhoff, 2005; He et al., 2009; Liu et al., 2011; Liu and Luo, 2011). To date, few efforts have been made to test the representativeness of the variations patterns of meteorological records in river valleys for the upper timberline. Clearly, it is an issue deserving highest research priority.

The Tibetan Plateau, as the third pole on earth, influences climatic and environmental changes in Asia and elsewhere in the Northern Hemisphere and is one of the most sensitive regions to global change (Zheng and Yao, 2004). However, long-term climatic records for an enhanced understanding of the climatic variability on the Tibetan Plateau still remain lacking. With the current global warming, studies on past climate must rely on proxy records, such as tree rings, ice cores or lake sediments because of generally short instrumental records and their sparse spatial distributions on the Tibetan Plateau (Yao et al., 1997; Shao et al., 2005; Zhu et al., 2008). On the southeastern part of it, there is the highest natural timberline in the Northern Hemisphere (Li, 1985; Miehe et al., 2007), showing a great potential to reconstruct past

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temperature variability (Bräuning and Mantwill, 2004; Liang et al., 2008, 2009; Zhu et al., 2011). However, whether the variation in the instrumental climatic records of meteorological stations located generally in the valleys is representative for the upper timberline is a question not having received the attention it deserves, given the importance of the calibration process for the past climate reconstructions.

The objective of this study is, therefore, to test the linkages between the climatic records at Nyingchi (3000 m a.s.l.) in the Yarlung Zangbo River valley and those from an automatic weather station (AWS) at the upper timberline (4400 m a.s.l.) in a blackseed juniper (*Juniperus saltuaria*) forest in the Sygera Mountains. As precipitation shows strong spatial and temporal variations in mountainous regions, we considered the multi-satellite precipitation analysis product mainly based on the Tropical Rainfall Measuring Mission (TRMM) (Huffman et al., 2007) in the Sygera Mountains. Furthermore, we tested how to estimate the timberline climate conditions based on meteorological data from a station in the nearby valley. We hypothesize that the variations of temperature may be relatively consistent and those in precipitation could be quite different between the two sites, although the differences may decrease as the time interval for data summary becomes longer.

2. Study area

The study area is situated in the Sygera Mountains (with a peak of 5200 m a.s.l.) (29°10′–30°15′ N, 93°12′–95°35′ E) in the southeastern Tibetan Plateau, China (Fig. 1). It is characterized by a sub-humid climate caused by the South Asian monsoon reaching this area through the valley of the Yarlung Zangbo River, resulting in ample summer rainfall. Records from the meteorological station in Nyingchi (Linzhi) (29°34′ N, 94°28′ E, 3000 m a.s.l), located in the river valley on the western side of the Sygera Mountains, show an average sum of annual precipitation from 1960 to 2006 of 676.7 mm, of which 72% occurs from June to September. July (mean temperature of 15.8 °C) and January (0.5 °C) are the warmest and the coldest month, respectively.

In order to improve the understanding of the land-surface processes and environments over the Tibetan Plateau, the "Southeast Tibet Station for Alpine Environment Observation and Research, Chinese Academy of Sciences (CAS)" was established in the Sygera Mountains by the Institute of Tibetan Plateau Research, CAS, in 2005, where a typical natural alpine timberline exists. It is one of the stations in the Tibetan Observation and Research Platform (TORP) network (Ma et al., 2008). A 3-m automatic weather station (AWS) (Campbell CR1000) at the upper timberline of a blackseed juniper forest (29°39.420′ N, 94°42.427′ E, 4390 m a.s.l.) on a south-facing slope on the eastern side of the Sygera Mountains has been in operation since November 6, 2006 (Liu et al., 2011). It has a linear distance of 53 km from the closest meteorological station at Nyingchi on the valley bottom (Fig. 1). Half-hour meteorological parameters, including air temperature, air humidity, wind speed and direction, rain, and snow depth, are collected automatically. It is an initial attempt to have a long-term and uninterrupted *in situ* monitoring of the timberline environment on the Tibetan Plateau.

3. Materials and methods

The daily, 5-day, 10-day and monthly records of mean temperature and sum of precipitation from the AWS at the upper timberline and from the national meteorological station at Nyingchi on the valley bottom were compared over a three-year observation period from January 1, 2007 to December, 31 2009. Their mean values were checked by paired sample t tests, the data distributions by two-sample Kolmogorov–Smirnov tests, standard deviation, and Pearson's correlation analysis. The air temperature mean lapse rate with altitude was also evaluated.

The 0.25° × 0.25° gridded precipitation data in the Sygera Mountains area derived from the Tropical Rainfall Measuring Mission (TRMM) 3B42, Version 6, daily multi-satellite precipitation analysis (Huffman et al., 2007) for the same period were used to compare with daily, 5-day, 10-day and monthly sums of precipitation at the upper timberline. This dataset is a merged product based on the TRMM Microwave Imager (TMI) and other satellite rainfall estimates. The relevant documentation of the TRMM 3B42 V6 data can be obtained at http://disc2.nascom.nasa.gov/Giovanni/tovas/TRMM_V6.3B42_daily.shtml#description. As the TRMM dataset covers the entire study region, we used it to represent the regional precipitation regime.

To quantify the relationships between the timberline AWS data and data at the meteorological station, regression analyses were performed on the daily mean temperature and daily precipitation by months between the timberline and valley bottom sites. The

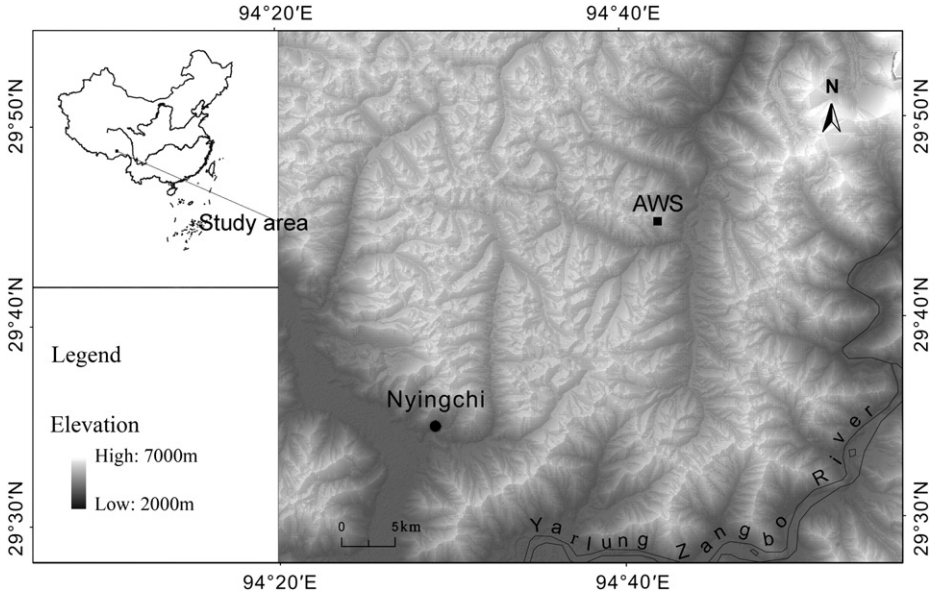

Fig. 1. Map of China (inset) showing the location of the meteorological station at Nyingchi on the river valley bottom and the automatic weather station (AWS) (black square) at the upper timberline of a balckseed juniper forest in the Sygera Mountains, southeastern Tibetan Plateau.