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A 400-year record of hydroclimate variability and local ENSO history in northern Southeast Asia inferred from tree-ring $\delta^{18}O$

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ABSTRACT

We present here a chronology of tree ring cellulose $\delta^{18}O$ for the period 1588–2002 based on individual measurements of seven *Fokienia hodginsii* trees growing in northern Laos. Response function analysis of meteorological data revealed that this oxygen isotope chronology has a significant negative correlation with monsoon season precipitation, the water level of the Mekong River, and the Palmer drought severity index (PDSI). Our reconstructed monsoon season PDSI, which accounts for 41.5% of PDSI variance, showed that wetter phases occurred during the periods AD 1660–1695 and AD 1705–1790, that the main drier periods were AD 1630–1660, AD 1900–1940, and AD 1954–2002, and that there has been a trend of decreasing moisture during the monsoon season over the last 200 years. A reduction in monsoon activity can also be seen in various tree ring oxygen isotope records from the Himalaya, Tibet Plateau, and Southeast Asia. Rising sea surface temperatures over the tropical Pacific and Indian Ocean could be responsible for this reduction in the Asian summer monsoon. By combining proxies sensitive to the El Niño–Southern Oscillation (ENSO) in northern Laos and Vietnam, we were able to reconstruct the annual multivariate ENSO index (MEI) and local ENSO event history, and so improve our understanding of long-term variations in ENSO and its influences on Southeast Asia.

1. Introduction

The climate of Southeast Asia during the monsoon season is governed by the Indian summer monsoon (ISM), western north Pacific summer monsoon (WNPSM), and East Asian summer monsoon (EASM) (Wang and LinHo, 2002). Summer monsoon variability has an important effect on the agrarian economy of the densely populated regions of Southeast Asia (Lau and Yang, 1997), and has also influenced population movement over the past several hundred years (Buckley et al., 2010). The El Niño–Southern Oscillation (ENSO) has been widely shown to modulate the ISM and WNPSM over interannual to interdecadal timescales (Kumar et al., 1999; Wang et al., 2001). ENSO also affects the onset of the monsoons (Zhou and Chan, 2007). Variations in precipitation related to ENSO have significant effects on the inhabitants of Southeast Asia. For example, the severe drought of 2010 in Thailand and Vietnam led to a significant drop in rice production, while the floods of 2011 in Thailand resulted in significant economic losses. However, instrumental meteorological data from this area are spatially and temporally limited, and monsoon variability here has not been studied as widely as its counterparts on the Indian sub-continent and in China. Therefore, additional high-resolution and long-term proxy records are necessary if we are to improve our understanding of Asian monsoon variability and ENSO.

Recent research (Buckley et al., 2007a,b, 2010; Sano et al., 2009; D'Arrigo et al., 2011; Pumijumnong and Eckstein, 2011) has found increasing success using the width of annual tree rings in tropical trees (both evergreen and deciduous) to reconstruct a comprehensive picture of past climate variability over several centuries in Southeast Asia. However, the ring widths studied in these previous reconstructions (Buckley et al., 2007b, 2010; Sano et al., 2009; Pumijumnong and Eckstein, 2011) mainly reflect the signal from the pre-monsoon period (March–April–May), and hence cannot provide a clear record of summer monsoon variability.

Tree ring cellulose $\delta^{18}O$ from North China has been used successfully as an indicator of the strength of the East Asian summer monsoon (Liu et al., 2008). In addition, previous studies have revealed that tree ring cellulose $\delta^{18}O$ from *Fokienia* in Northern Laos mainly preserves the climatic signal from the monsoon season, and is very sensitive to ENSO (Xu et al., 2011), while tree ring cellulose $\delta^{18}O$ from *Pinus kesiya* in northern Thailand has been used to reconstruct monsoon strength (Zhu et al., 2012). However, both records are shorter than 100 years. Recently, a tree ring cellulose $\delta^{18}O$ record from *Fokienia* in Northern Vietnam was used to reconstruct a 300-year hydroclimate history and multivariate ENSO index (MEI), and this single-proxy reconstruction was robust, even when

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compared with those based on multi-proxy data (Sano et al., 2012). However, the accuracy of the reconstructed MEI must be tested against other records from the surrounding area.

In this paper, we present a 415-year tree ring cellulose $\delta^{18}O$ chronology from *Fokienia hodginsii* in Northern Laos. Our $\delta^{18}O$ chronology preserves low-frequency signals and was used to reconstruct the long-term Palmer drought severity index (PDSI) for the monsoon season in Southeast Asia, and also to evaluate variations in the Asian summer monsoon by comparison with other tree ring oxygen isotope records from the Himalaya and Southeast Asia. In addition, we extended the tree ring cellulose oxygen isotope chronology of Sano et al. (2012), obtained from the Mu Cang Chai (MCC) site in northern Vietnam (Fig. 1), from 1605 to 2004 by obtaining data from two additional cores (AD 1605–1704) and using tree ring cellulose $\delta^{18}O$ time series from Laos and Vietnam to reconstruct the annual MEI and local ENSO event history.

2. Methods and materials

2.1. Sampling sites and cross-dating

The tree-ring samples in this study were derived from 5-mm-increment cores collected from old growth *Fokienia hodginsii* (>300 rings). These trees grow in the Phu Leuy mountain area

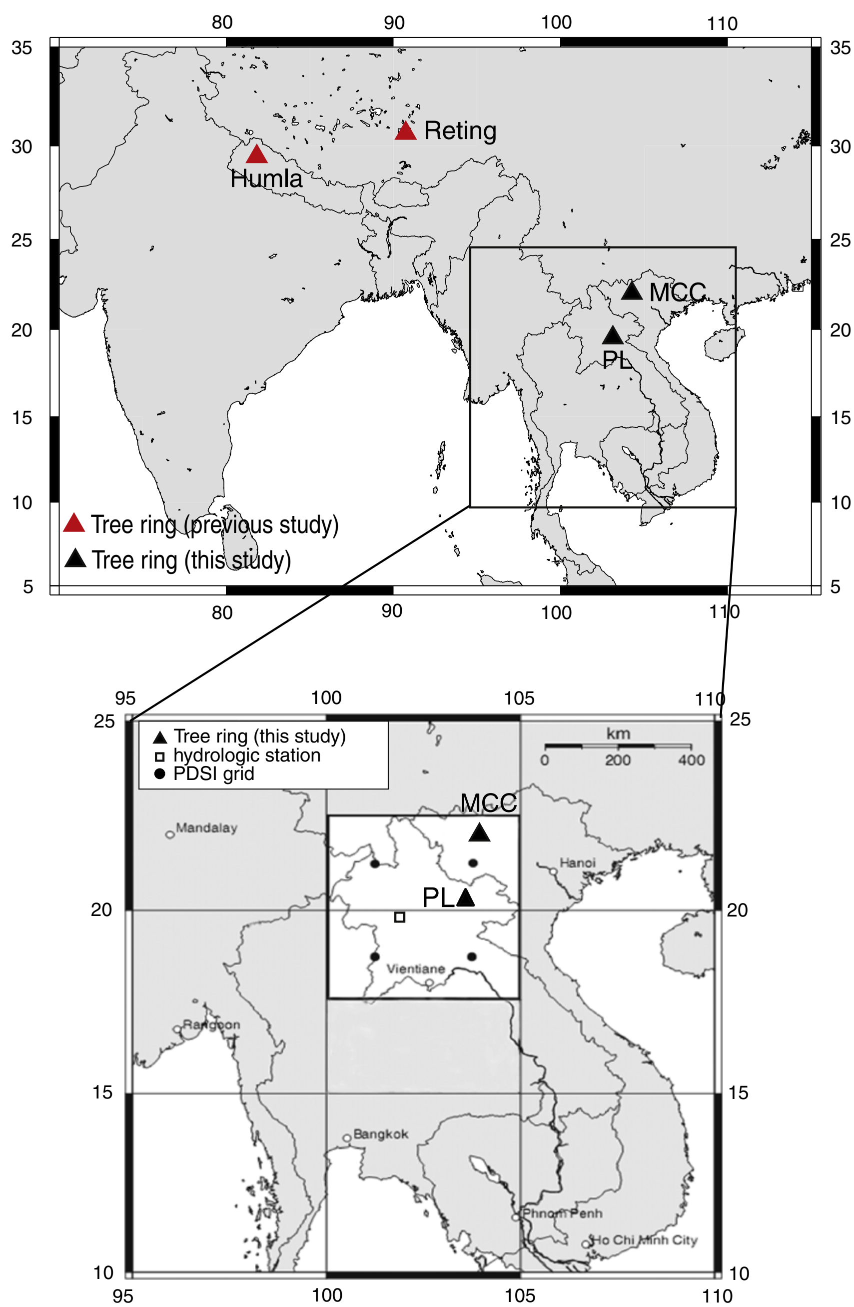

Fig. 1. a: The study region showing the sampling site Phu Leuy (PL) mountain area (19.9°N, 101.2°E) and tree ring sites in Vietnam (MCC, Sano et al., 2012), in Tibet (Reting, Grießinger et al., 2011) and in Himalaya (Humla, Sano et al., 2011), b: the Luang Prabang meteorological and hydrological station, the area of the grid box averages of the CRU TS3.1 and PDSI data sets used in this study are enclosed by the thick solid line, c: monthly mean temperature (black circles) and precipitation (gray bar) (1961–1990) at the Luang Prabang instrumental station.