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Decadal/multi-decadal temperature discrepancies along the eastern margin of the Tibetan Plateau

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ABSTRACT

Knowledge of the synchronicity and discrepancy of temperature variations along the Eastern margin of the Tibetan Plateau (ETP) is critical in understanding the driving forcing of regional temperature variations. In this study, we established $\delta^{15}N$ timeseries in organic matter and $\delta^{13}C$ timeseries in ostracod shells from sediments of Lake Lugu and attributed their variations to decadal/multi-decadal temperature variations. We compared temperature variations along the ETP transect during the past four centuries based on our presently developed and previously developed temperature proxy indices, as well as temperature variations reconstructed by other researchers. We found that: (1) Over the north ETP area (N-ETP), the decadal/multi-decadal variations in temperature correlate well with each other. (2) Over the south ETP area (S-ETP), temperature variations correlate not so well with each other; while those at south to west portion of the Tibetan Plateau are rather local. (3) The decadal variations in temperature are generally synchronous with those in precipitation over the N-ETP area, and they are broadly anti-phase/out-of-phase with the corresponding ones over the S-ETP area. (4) The long term temperature and precipitation trends are coupling over the N-ETP but decoupling over the S-ETP. We speculate that because the N-ETP is located at the frontier of the Asian summer monsoon (ASM) region, temperature variations there are not as strongly influenced by the ASM; they are most likely dominated by changes in solar activities, and show general similarity to the average of the Northern Hemisphere. Over the S-ETP area, decadal temperature variations are obviously influenced by precipitation. Because the decadal/multi-decadal precipitation variations are anti-phase and/or out-of-phase between the N-ETP and S-ETP, the decadal/multi-decadal temperature variations between these two regions are also anti-phase and/or out-of-phase.

1. Introduction

Temperature variation, especially during the past millennium, is one of the most concerned issues worldwide. Its general trend during the last millennium has been reconstructed by numerous studies (e.g., Briffa et al., 2004; Jones and Mann, 2004; Mann, 2007), which have greatly improved our understanding of the climatic changes and the role of various natural and anthropogenic forcings. It is well known that temperature varies on different timescales and the corresponding forcings are also variable (e.g., Jones and Mann, 2004). This would reasonably result in variable temperature patterns in different regions on different timescales. Because most of the large scale temperature curves were generated from averages over wide geographic areas, differences in regional temperature variations could possibly be masked. This may limit our understanding of regional temperature variations and weaken the reliability of regional climatic predictions. Therefore, it is crucial to master the details in temperature variations for different regions and shed light on the underlying dynamics.

The Tibetan Plateau (TP) plays an important role in modulating the large-scale atmospheric circulation over Asia. Along the ETP transect, the East Asian summer monsoon (EASM), the Indian summer monsoon (ISM), the East Asian winter monsoon, and the westerly jet stream prevail (Liu and Chen, 2000; Yu and Kelts, 2002; Ji et al., 2005; Shen et al., 2005; Xu et al., 2007; An et al., 2012). Variations in precipitation over the S-ETP area are dominated by the ISM (as can be inferred from the streamlines in Fig. 1), while those over the N-ETP area are likely to be influenced both by the EASM and by the westerly (e.g., An et al., 2012). Therefore, the ETP

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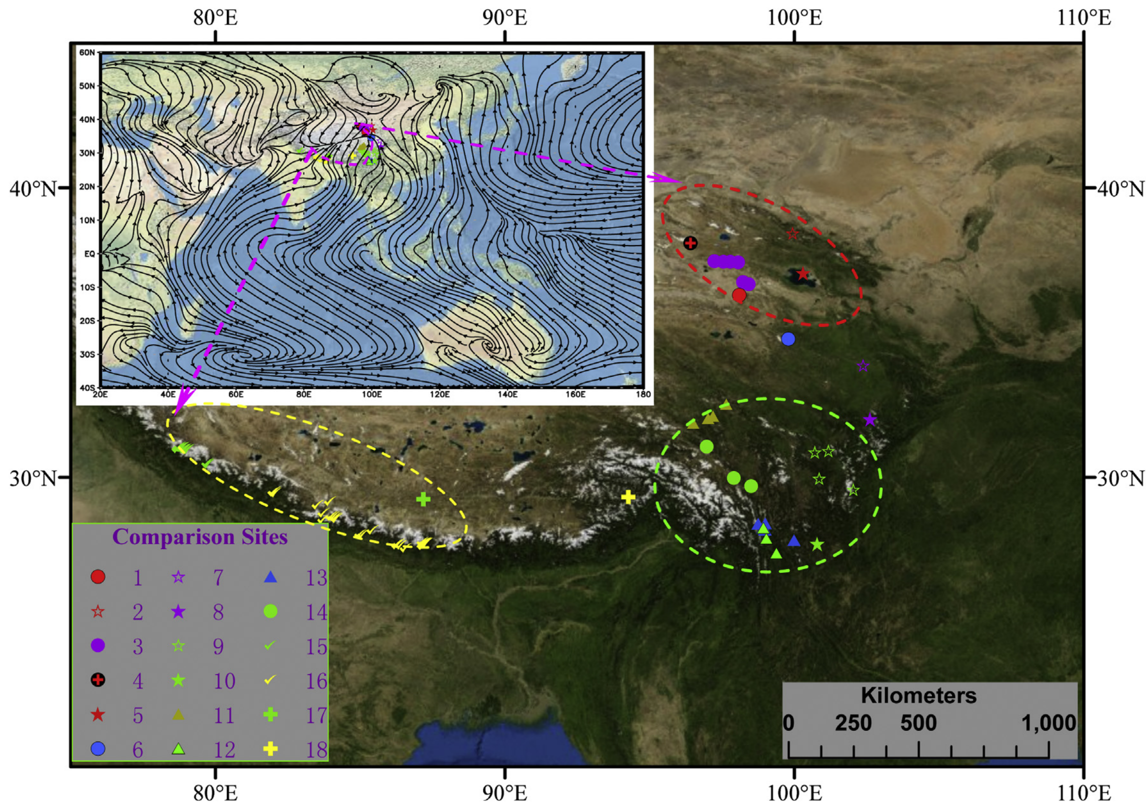

Fig. 1. Locations of the comparison sites along the Eastern margin of the Tibetan Plateau (ETP). Data of Lake Lugu are from this study. Data of tree rings in Hongyuan and those of sediments in Lake Qinghai are from the major author's previous work; other data are collected from literatures (see Table 1). Numbers in the legend (left lower corner) are corresponding to the site numbers listed in Table 1. The three dotted circles represent three typical regions (N-ETP, S-ETP, and south to southwest Tibetan Plateau) discussed in the text. Upper left corner shows the streamlines averaged from June to August at 850 hPa during 1968–1996 based on the NCEP/NCAR reanalysis data (Kalnay et al., 1996). The satellite images are from the basemaps in ArcGIS (ESRI data & maps).

transect is one of the most sensitive regions for studying global climatic changes. Mastering the similarities and differences in temperature variations along the ETP transect is thus vital to understand the mechanisms of temperature and precipitation variations.

Meteorological stations over the Tibetan Plateau are relatively scarce and the meteorological records are relatively short. Fortunately, various bio-geological paleao-climatic archives are widely spread along the ETP transect and scientists have made great efforts to reconstruct the paleoclimates through different approaches. For example, at the N-ETP area, Yao et al. (2006) studied temperatures during the last millennium based on $\delta^{18}O$ in ice cores. Kang et al. (2000) and Liu et al. (2005) reconstructed temperature variations during the past one to two millennia from tree ring widths at Dulan and Qilian Mt., respectively. Climatic changes over the N-ETP area have also been investigated from lake sediments by numerous previous studies (e.g., Liu et al., 2006; Xu et al., 2006a,b; He et al., 2013). Around the Mid-ETP area, Wu et al. (2002) studied climatic changes from proxy indices in gastropod remains (e.g., $\delta^{18}O$ and $\delta^{13}C$) of sediments in Xingcuo Lake, Zoige Plateau. Gou et al. (2006) reconstructed temperature variations at Animaqin Mt. from tree ring widths. Xu et al. (2010, 2012) reconstructed temperature and precipitation during the past 270 years at Hongyuan, Zoige Plateau, based on $\delta^{13}C$ and $\delta^{18}O$ in tree rings, respectively. At/near the S-ETP area, Shao and Fan (1999) reestablished temperature variations at the western Sichuan Plateau based on tree ring widths. Liang et al. (2008) reconstructed temperature variations based on tree ring width at the source region of the Yangtze River, south TP. Fan et al. (2008), Wang et al. (2010), and Li et al. (2012) reconstructed temperature variations in Hengduan Mt. inferred from different tree ring data (see location in Fig. 1). Although common features are seen between these previous reconstructions, notable discrepancies also exist both in timing and magnitude, which have not been well addressed previously. It is necessary to focus on these differences and examine the underlying physics.

In this study, we extracted temperature proxy indices from sediments in Lake Lugu. We compared the decadal/multi-decadal temperature variations along the ETP transect based on our newly and previously developed temperature proxy indices, as well as those from others. We focused on the phase relationship of decadal/multi-decadal climatic variations during the past about four hundred years between the N-ETP and S-ETP and the possible physics involved.

2. Methods

2.1. Climatic proxy indices extracted from sediments in Lake Lugu

Lake Lugu is a deep pull-apart basin located in northwestern Yunnan–southwestern Sichuan Province, the S-ETP. Climatic changes around Lake Lugu are mainly controlled by changes in Indian summer monsoon intensity. Mean annual air temperature is about 12.8 °C; while mean annual precipitation is about 1000 mm, with approximately 80%–90% concentrated during May to October (Zhang et al., 2013). The lake is a hydrologically semi-closed system, and the lake level therefore keeps relatively steady on short term timescales (e.g., decadal scale). Three surface sediment cores (27.70972°N, 100.78475°E; alt. 2694 m; water depth at the sampling site: ~45 m) were collected using a self-designed heavy corer, in September 2007. The lithologies of these three short cores