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Temperature variations at Lake Qinghai on decadal scales and the possible relation to solar activities

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Abstract

Temperature variations at Lake Qinghai, northeastern Qinghai–Tibet plateau, were reconstructed based on four high-resolution temperature indicators of the $\delta^{18}O$ and the $\delta^{13}C$ of the bulk carbonate, total carbonate content, and the detrended $\delta^{15}N$ of the organic matter. There are four obvious cold intervals during the past 600 years at Lake Qinghai, namely 1430–1470, 1650–1715, 1770–1820, and 1920–1940, synchronous with those recorded in tree rings at the northeast Qinghai–Tibet plateau. The intervals of 1430–1470, 1650–1715, and 1770–1820 are consistent with the three coldest intervals of the Little Ice Age. These obvious cold intervals are also synchronous with the minimums of the sunspot numbers during the past 600 years, suggesting that solar activities may dominate temperature variations on decadal scales at the northeastern Qinghai–Tibet plateau.

Introduction

It is well known that the Earth's temperature is influenced by variable factors, such as solar activity, atmospheric circulation, the complex topography, different land cover, and the greenhouse gases. The dominating factor that controls local temperature variation is different between different regions. Therefore, although the general trend of temperature variations over wide geographic areas has been figured out by numerous works, it is still urgent to make clear the details of regional temperature variations and the causes behind them.

The northeastern (NE) Qinghai–Tibet plateau is very sensitive to global climatic changes, with four planetary scale atmospheric circulations prevailing over there, namely the East Asian summer monsoon, the Indian summer monsoon, the Westerly, and the Asian winter monsoon. Temperature variations at this region have aroused wide attention. Yao et al. (2006) studied the temperatures during the last millennium based on $\delta^{18}O$ in ice cores. Kang et al. (2000) reconstructed the temperature variations from tree ring width. Liu et al. (2004) carried out a study of dendrochronology and discussed temperature variations at this region. Although similarities exist between those various proxy indices, there are also some differences both in timing and in magnitudes, which seriously limits the understanding of the temperature mechanisms. Much more evidence is necessary to shed light on the details of temperature variations at the NE Qinghai–Tibet plateau.

On the other hand, previous work has suggested that climates on different timescales at the Qinghai–Tibet plateau may be driven by different forces. For example, based on the comparisons between climates recorded in ice cores in the Tibet plateau and those in Greenland, Yao et al. (2001a) pointed out that the climatic variations at the Tibet plateau on orbital timescales are dominantly controlled by solar irradiance. According to a temperature indicator of $\delta^{18}O$ in peat cellulose, Xu et al. (2006a) suggested that the quasi-100-year solar activity may be responsible for temperature variations on centennial timescales at Hongyuan, NE Qinghai–Tibet plateau. However, as revealed from ice cores (Wang et al., 2003, Wang et al., 2003) and tree rings (Xu et al., unpublished data), temperature variations on annual scales are primarily influenced by atmospheric circulations, like the “El Niño–South Oscillation” (ENSO). Our question is: what is the controlling factor of temperature variations on decadal scales at the NE Qinghai–Tibet plateau?

In this study, we studied temperature variations on decadal scales during the past 600 years based on temperature indicators extracted from Lake Qinghai, NE Qinghai–Tibet plateau. We compared the temperature indicators at Lake Qinghai with the proxy indices from tree rings nearby, and with the reconstructed solar activities. The results show that temperature variations at Lake Qinghai are synchronous with those at the NE Qinghai–Tibet plateau, and the main temperature events are generally in-phase with solar activities during the last 600 years.

Section snippets

Temperature indicators from Lake Qinghai

Lake Qinghai (36°32′–37°15′N, 99°36′–100°47′E; Fig. 1) is located at the NE Qinghai–Tibet plateau. The meteorological records of the Gangcha station from 1958 to 2000 show that the temperature around this region varies between 8.9 °C and 13.7 °C in July, and between −16.4 °C and −10.74 °C in January, with a mean annual value of about −0.4 °C. Lake water is relatively cold, with an average temperature of about 10 °C for surface water and about 4 °C for bottom water in summer. The lake is frozen between …

Temperature variations during the last 600 years at Lake Qinghai

As shown in Fig. 2, the long-term trend of temperature variations is increasing, inferred from tree ring widths and isotopic indices in tree rings. This long-term trend can also be detected in $\delta^{18}O$ of Dunde ice core, Guliya ice core, and Dasuopu ice core (refer to Fig. 2 in Yao et al. (2006)), suggesting an increasing temperature trend during the past 600 years at the NE Qinghai–Tibet plateau. The $\delta^{18}O$ of the bulk carbonate in Lake Qinghai also shows an increasing trend (See Fig. 3 in Xu et al. …

Solar activity and temperature variations on decadal scales at NE Qinghai–Tibet plateau

As pointed out by Eddy (1977), the Maunder minimum, during which nearly no sunspots were detected, corresponded to the coldest period of the LIA. After that, a large amount of evidence has been supplied for the solar–Earth climate relationship. For example, the sea surface temperatures (SSTs) of the Atlantic, the Pacific, the Indian Ocean, and that of the global average correlate well with the sunspot numbers (see Fig. 1 in Reid, 2000). The concentration of ^{10}Be in Dye3 correlated well with…

Summary

Temperature variations are similar in trends at the NE Qinghai–Tibet plateau. The three strong decreases in temperature corresponded with the three coldest intervals of the LIA during the past 600 years. These three coldest intervals also correspond with the three solar minimum during the past 600 years, namely the Spörer, the Maunder, and the Dalton minimums. Such a relationship suggests that solar activities are possibly the controlling factor of temperature variations at the NE Qinghai–Tibet …

Acknowledgements

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…Furthermore, this area represents a transition region among the eastern monsoon area, the northwestern arid area and the cold alpine regions of the TP. The QLB is located in the northeastern part of the TP and is sensitive to climate change and human activity (Ji et al., 2005; Shen et al., 2005; Li et al., 2006; Xu et al., 2008; An et al., 2012). Due to climate change and enhanced human activity, environmental problems such as the drying up of rivers and lakes, grassland degradation and desertification have become increasingly prominent over the last 100 years (Cui and Li, 2015).…

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…The Daotang pollen record begins at 850 CE within the favourable and rather wet climate phase often attributed to the MWP. Corresponding studies suggest that it started in the 9–10 century AD on the north-eastern QTP (Yang et al., 2002; Shi et al., 1999; Paulsen et al., 2003) and ended sometime during the 13–14 century CE (Xu et al., 2008). The north-eastern QTP is dominated by strong monsoonal winds and constant moisture input from the EASM (Wernicke et al., 2015).…

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…When precipitation is higher, the input of terrestrial organic matter increases and the C/N ratio of the bulk organic matter of the lake sediment will increase, resulting in a positive "C/N–precipitation" relationship. Fig. 3 shows comparisons of temperature proxy indices (and/or reconstructed temperature variations) over the N-ETP area, namely at Dulan (a; Kang et al., 2000), Qilian (b; Liu et al., 2005), Lake Xingcuo (c; Wu et al., 2002), Hongyuan (d; Xu et al., 2010), and Lake Qinghai (e; Xu et al., 2006a, 2008). The decadal/multi-decadal temperature variations are broadly consistent and most of the curves show generally increasing trends.…

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…Xu et al. (2006) observed that the temperature responded to quasi-100-year solar variability during the past 6000 years from δ18O of cellulose in a peat core at Hongyuan of eastern Qinghai–Tibet Plateau. At Lake Qinghai in the northeast Qinghai–Tibet Plateau, Xu et al. (2008) found that the cold intervals recorded in tree rings were synchronous with the minimums of the sunspot numbers during the past 600 years. These findings could be explained by a study by Li (2006), who reported that the decrease of surface heating fields in Qinghai–Tibet Plateau corresponded to low solar activity.…

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