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Climate changes reconstructed from a glacial lake in High Central Asia over the past two millennia

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ABSTRACT

Climatic changes in Arid Central Asia (ACA) over the past two millennia have been widely concerned. However, less attention has been paid to those in the High Central Asia (HCA), where the Asian water tower nurtures the numerous oases by glacier and/or snow melt. Here, we present a new reconstruction of the temperature and precipitation change over the past two millennia based on grain size of a well-dated glacial lake sediment core in the central of southern Tianshan Mountains. The results show that the glacial lake catchment has experienced cold-wet climate conditions during the Dark Age Cold Period (~300–600 AD; DACP) and the Little Ice Age (~1300–1870 AD; LIA), whereas warm-dry conditions during the Medieval Warm Period (~700–1270 AD; MWP). Integration of our results with those of previously published lake sediment records, stalagmite $\delta^{18}O$ records, ice core net accumulation rates, tree-ring based temperature reconstructions, and mountain glacier activities suggest that there has a broadly similar hydroclimatic pattern over the HCA areas on centennial time scale during the past two millennia. Comparison between hydroclimatic pattern of the HCA and that of the ACA areas suggests a prevailing 'warm-dry and cold-wet' hydroclimatic pattern over the whole westerlies-dominated central Asia areas during the past two millennia. We argue that the position and intensity of the westerlies, which are closely related to the phase of the North Atlantic Oscillation (NAO), and the strength of the Siberian High pressure (SH), could have jointly modulated the late Holocene central Asia hydroclimatic changes.

1. Introduction

Global warming since the mid-19th century has been well recognized (IPCC, 2007; Moberg et al., 2005; PAGES 2k Consortium, 2013; Neukom et al., 2014), but hydrological response shows a spatial heterogeneity (Chen et al., 2015; Xu et al., 2016). Owing to the limit of instrumental records, the knowledge of climate changes and its mechanisms during the late Holocene, especially over the past two millennia, are crucial for understanding the contemporary climate dynamics, predicting possible climate changes in future, and researching the past global climate changes. Numerous studies have been carried out to shed light on the climate changes over the past two millennia based on variable proxy indices (Diaz et al., 2011; Graham et al., 2011; PAGES 2k Consortium, 2013; Neukom et al., 2014; Schurer et al., 2014; Sigl et al., 2015; Xu et al., 2016), which have largely improved our understanding of the details in climatic changes and the related mechanisms. However, hydroclimatic changes and impacts are variable among different regions, and the mechanisms are not fully understood; further research on spatial-temporal pattern of different regions is necessary.

As one of the most arid areas in the world, central Asia is primarily dominated by the westerlies, and its climatic change and dynamic mechanisms have been widely concerned (Aizen et al., 1997, 2001, 2006; Yang et al., 2009; Chen et al., 2010; Cheng et al., 2012; Song et al., 2015). However, investigation of climatic

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change under global warming is seriously impeded by the limit of the instrumental record. Furthermore, the limited paleoclimate archives are mostly located at low-elevated areas (Chen et al., 2006, 2010; Sorrel et al., 2006; Kroonenberg et al., 2007; Huang et al., 2011; Ma et al., 2011). A series of mountains (e.g., Tianshan Mt., Altai Mt., and Pamir Plateau) are located at the central Asia; and the climate over those mountainous regions may be largely different with that of the low-elevated ACA areas. Because of the scarce of well-dated high resolution paleoclimate records in the HCA areas over the past two millennia, development of the geological proxies for temperature and precipitation records covering longer time spans would be a significant step forward for understanding of the climate changes over the HCA and their relationship with those over the ACA areas.

Here we reconstruct climatic changes over the past two millennia at Lake Harnur, a glacial lake of the central Tianshan Mt., based on ^{137}Cs, ^{210}Pb, AMS ^{14}C dating and sedimentary grain size analysis. We focus on hydroclimatic pattern in the HCA areas, and compare them with those over the extended ACA areas, and finally discuss the possible driving forces.

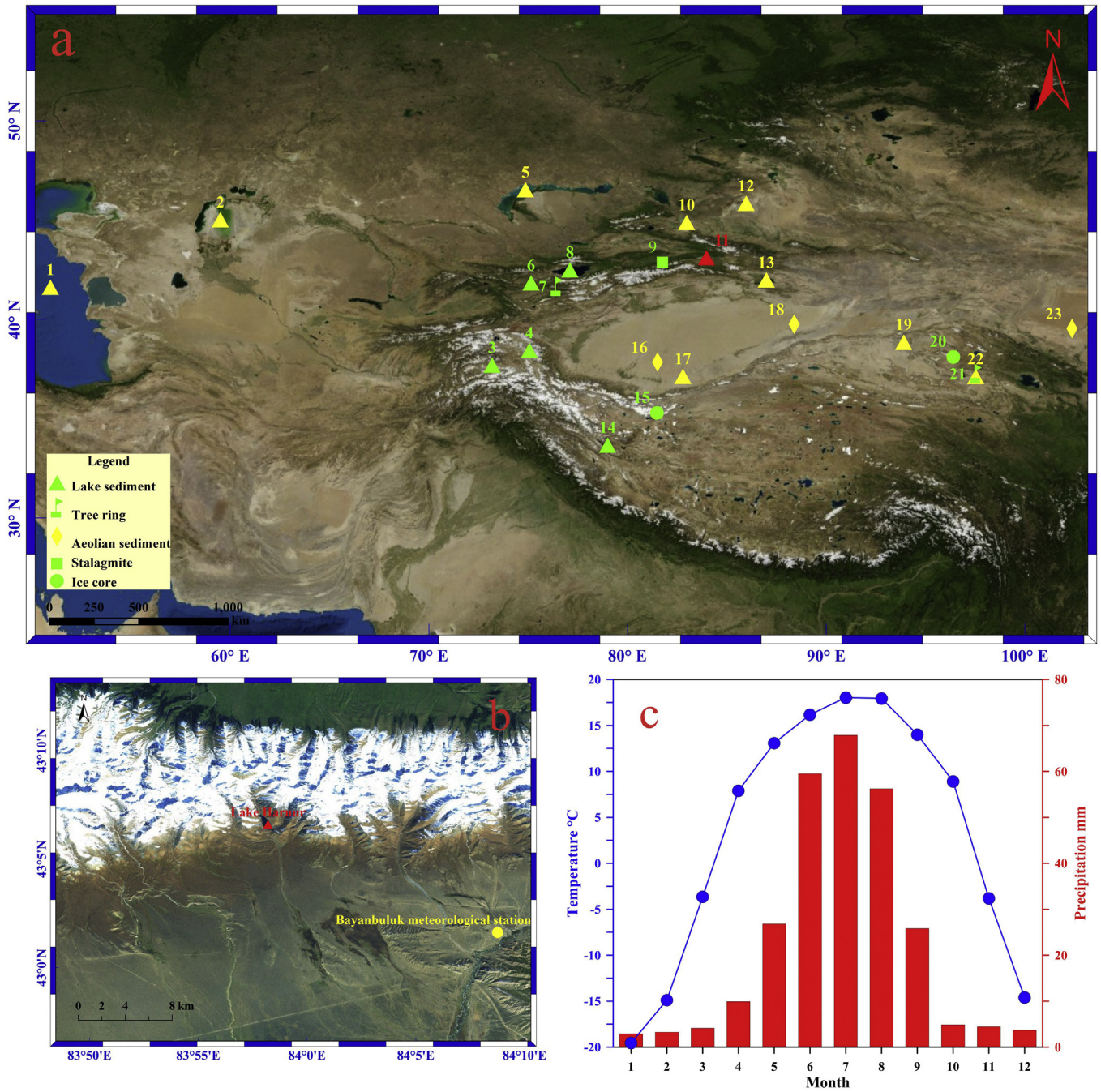

Fig. 1. (a) Locations of Lake Harnur (red triangle) and other sites (see numbers of other sites in Table 1) mentioned in the text. The green color sites note the HCA and the yellow sites present the ACA. (b) Locations of Lake Harnur and Bayanbuluk meteorological station. White color denotes the glacier distribution. (c) Mean monthly precipitation (red histogram) and temperature (blue dot line) at Byanbuluk meteorological station (data from 1958 to 2008). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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