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Evolution of Lake Ailike (northern Xinjiang of China) during past 130 years inferred from diatom data

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ABSTRACT

We have studied diatom assemblages of a 42-cm-long sediment core obtained from Lake Ailike in northern Xinjiang of China to reconstruct the hydrological and ecological variations of the past 130 years. Three environmental parameters of lake water (i.e., diatom-inferred pH, diatom-inferred total phosphorus and diatom-inferred conductivity) were estimated by comparing the fossil diatom assemblages from the Lake Ailike core with the modern diatom assemblages in the European Diatom Database. The reconstruction exhibited two major stages: stage A (1884–1960) was a “natural” stage and stage B (1960–2013) was a “human” stage. The “natural” stage can be further divided into two sub-stages: A-1 (1884–1920) was characterized by an averagely low lake area and A-2 (1920–1960) was a stably high lake-area period. The comparison between the reconstructed lake-area variations from Lake Ailike with the treering-recorded Palmer Drought Severity Index (PDSI) variations from nearby Hutubi shows that the low lake area from 1884 to 1920 was correspondent with a dry period and that the high lake area from 1920 to 1960 with a wet period. The similarity between PDSI from Hutubi and the Atlantic Multidecadal Oscillation (AMO) implies a climatic linkage. The linkage is revealed by the tight in-phase relationship between AMO and SWP (Siberian warm-season precipitation), that is, the AMO-promoted SWP might have extended its influence to northern Xinjiang. The “human” stage can also be divided into two sub-stages: B-1 (1960–2000) was a regressing stage and B-2 (2000–2013) was a transgressing stage. The man-made regression led to dramatic increases in TP of the lake water, TOC and TN of the sediments and also in the resulted decrease in lake water pH. Fortunately, the Irtysh-Karamay Canal started to inject water into the lake in 2001, resulting in a constant expansion of lake-covered area and also in a constant improvement of ecological conditions.

1. Introduction

The AR5 of IPCC (2014) pointed out that in the 21st century global warming will further intensify the Earth's water cycles, making the high-latitude areas even wetter and mid- and low-latitude areas even drier, melting more glaciers and reducing spring snow covers in the Northern Hemisphere. Situated in mid-latitudes, Arid Central Asia (ACA) is projected to face a variety of issues resulted from water resources shortage under the projected further warming conditions. That's because the water resources are primarily supplied by the mountain glaciers of ACA and those glaciers have experienced a pronounced retreat during the current warming period (Lioubimtseva and Henebry, 2009; Sorg et al., 2012; Zhang et al., 2014). However, the observed increase in precipitation and the warming-resulted increase in ice-melting runoff in Xinjiang region of China and the immediate adjacent areas, the core of Arid Central Asia (ACA), appear to be contradictive to the projected general drying trend of ACA (Li et al., 2012; Wang et al., 2010; Xu et al., 2015). It means that the increasing precipitation and the shrinking glaciers in Xinjiang region of China and the immediate adjacent areas highlight the uncertainty of future hydrological changes (Aizen et al., 2001; Sorg et al., 2012; Zhang et al., 2012; Wang et al., 2011; Xu et al., 2015). More importantly, human disturbances, superimposed on natural variability, have seriously altered the hydrological processes in recent decades, causing a series of water-related problems, such as water-resource shortage and ecological deterioration (Chen et al., 2011b; Tumur et al., 2013).

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Those water-related problems call for urgent attentions to the watershed hydrology and to the controlling or modulating mechanisms. This paper attempts to reconstruct the water-balance changes and the associated changes in aquatic ecology in Lake Ailike within the Dzungaria Basin of northern Xinjiang with a hope to improve our understanding of the atmospheric dynamics behind those changes and to assess the seriousness of human disturbances.

2. Physiographic settings

Lake Ailike (85°43′–85°51′E, 45°52′–45°59′N, 278 m a.s.l.), the studied lake, is situated in the western margin of the Dzungaria Basin of northern Xinjiang, the latter (i.e., the basin) being bounded by the Tianshan Mountains to the south and by the Altai Mountains to the northeast (Fig. 1a). Lake Ailike was a part of the well-known Lake Manas and became a completely independent lake before the Holocene (Cheng et al., 2006). Lake Ailike is hydrologically a closed lake (Fig. 1b), mainly fed by Baiyang River originated from the southeastern slope of Wurikexiayi Mountains (Ran et al., 2010). According to instrumental records at Karamay Meteorological Station which is only ~80 km from Lake Ailike, the mean annual temperature is 8.5 °C with the warmest-month (July) mean temperature of 27.6 °C and the coldest-month (January) mean temperature of −16.1 °C (Fig. 1c). The mean annual precipitation is only 116 mm, while the potential evaporation is up to ~3000 mm (Esqer et al., 2010).

Lake Ailike was historically described as a much larger lake about 1300 years ago (Tang, 2009), and it was reliably recorded to cover an area of ~80 km^2 in 1940s (Yao et al., 2007). However, it had been gradually shrinking since 1960s due to a large-scale man-made water diversion of the upstream Baiyang River to Karamay City and nearly completely desiccated in late 1990s due to water interception of Baiyang River Reservoir constructed in early 1970s (Ran et al., 2010). It should be mentioned that Lake Ailike started its transgression in 2001 and approached an area of ~65 km^2 in 2013 benefiting from the man-made water injection via the Irtysh-Karamay Canal.

3. Sampling and analytical methods

3.1. Sampling and laboratory methods

A gravity core of 42-cm-length was obtained in July of 2013 from the northeastern part of the lake (see Fig. 1b) at water depth of ~4.5 m using a modified Livingstone piston gravity corer (90 mm diameter) with additional hammer weight. It was sampled at 1 cm intervals using a scraper-plate. Samples from 0 to 35 cm were used for ^{137}Cs and ^{210}Pb dating after the pretreatments described by Yan et al. (2002). Diatom and other analyses were performed after the samples were freeze-dried in the laboratory.

Total organic carbon (TOC) and total nitrogen (TN) were analyzed after dissolving carbonates with 2 M H_3PO_4 using a Carlo

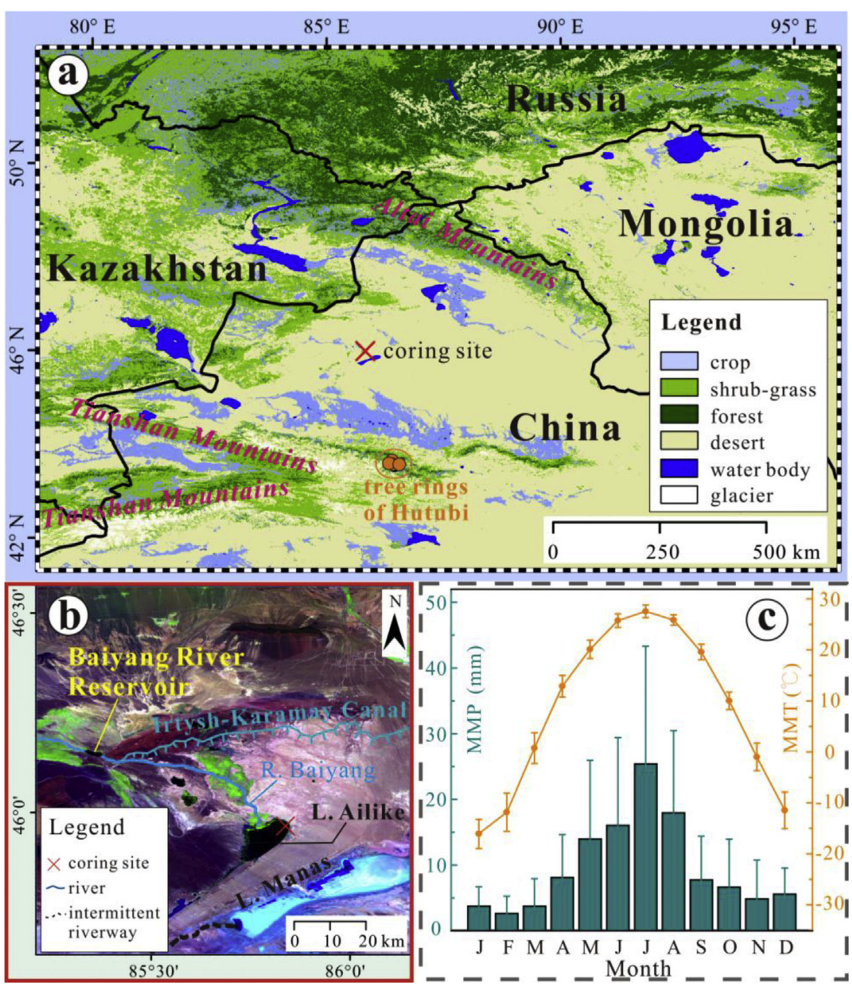

Fig. 1. Location of Lake Ailike and climate at nearby Karamay City. a: a larger-scale vegetation background; b: hydrological systems around Lake Ailike; c: monthly mean precipitation (MMP) and monthly mean air temperature (MMT) over past five decades in Karamay City.

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