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Reconstructing climate variability during the last four millennia from trans-Himalaya (Ladakh-Karakoram, India) using multiple proxies

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ABSTRACT

In this communication we reconstruct climate variability of Ladakh, Trans-Himalaya region, on sub-century timescale spanning the last four millennia (~4130 to 260 cal yr 'before present' (BP)). To achieve this objective, we measured a suite of physical, biotic and inorganic proxies of a lacustrine sequence. In general, between ~4130 to ~2640 cal yr BP proxy records reveal climate variability following a typical pattern of the northern hemispheric climate and appear to be dominated by westerlies. Thereafter, the Indian Summer Monsoon (ISM) forcing appears to dominate regional climate. The former period appears to have experienced human presence as evidenced by an invasive species of diatom –*Didymosphenia* and charcoal, likely originating from human activities on trading routes with Central Asia, China and Tibet. After ~2640 cal yr BP, when ISM started governing the climate of the Ladakh- Karakoram region, it probably induced high-frequency climate variability leading to disasters related to landslides, debris flows, avalanches etc., eventually reducing the intra-boundary trade. A similar situation appears to be gripping the region again as meteorologically recorded precipitation data from Ladakh reveals arrival of high-frequency monsoonal variability in the region with recurrent flash floods (e.g., 2010, 2013).

1. Introduction

The monsoonal precipitation over the Indian subcontinent is largely controlled by the thermal gradient i.e., the net effect of differential heating of the Tibetan Plateau and the Indian subcontinent during summer. Highly variable and often contrasting precipitation patterns can be seen from east to west and north to south. And, the degree of rainfall variability over the Himalaya is even higher due to variable orography and this high-spatial variability is projected to gain magnitude due to the concurrent anthropogenic warming (Dimri et al., 2016; Srivastava et al., 2017; Ali et al., 2018, 2020; Kumar et al., 2020). In the Indian part of the Himalaya, hydro-climatology of the central and northeastern parts is largely influenced by ISM (i.e., composite precipitation in June, July, August and September). However, in the western Himalaya, westerly winds or westerlies bring moisture and determine the hydro-climate of the region (Yadav and Bhutiyani, 2013; Yadav et al., 2017; Dimri et al., 2015, 2016). The bulk of the precipitation over Ladakh-Karakoram region is received as snow from November to April, which is crucial to regulate the water budget of ten major rivers that originate from this area and supply a water source for ~1.4 billion human population (i.e. ~20% of the world's human population).

Outside the icecaps of Polar regions, this mid-latitude and high-altitude glaciated region is one of the most susceptible regions to modern-day anthropogenic climate warming and related uncertainties. Global surface temperatures over land and oceans show a clear and discernible warming trend in the last 50–60 years (IPCC Climate Change, 2012). These high-altitude glaciated terrains will respond inadvertently to these changes, and the recent increase in frequency and intensity of flash floods and intense precipitation events in the high-altitude Himalaya are already serving early signals. As a matter of fact, five major flood events have occurred in the Indian part of Himalaya in just last ten years, including the Leh-Ladakh flood 2010 and

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