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Holocene extreme hydrological events and their climatic implications: evidence from the middle Satluj valley, western Himalaya, India

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Extreme hydrological events and associated climatic processes are investigated and inferred through palaeoflood deposits preserved in the middle Satluj valley, India. Satluj River is the largest tributary of the Indus River having third largest catchment area in the Himalaya. Both Indian summer monsoon (ISM) and the mid-latitude westerlies contribute to the hydrological budget of the river. The steep southern orographic front prevents the northward penetration of ISM, while the mid-latitude westerlies bring moisture in form of winter snow to the orogenic interiors.

It has been observed that the floods in the Himalaya are intimately associated with the variability in the above climate systems. The optical chronology indicates that floods were clustered around three time domains. The oldest flood phase-1 is dated to ∼14-12 ka which climatically occurred during the initiation of the ISM after the Last Glacial Maximum. The second phase-2 is dated between 8-5 ka and is attributed to the moderate ISM. Whereas, the youngest phase-3 is assigned the Little Ice Age (LIA) and were associated with the variability in the mid-latitude westerlies. Geochemical analyses suggest that floods were generated in higher Himalayan crystalline (HHC) zone, as the extreme precipitation destabilised the precipitous slopes creating Landslide induced Lake Outbursts Floods (LLOFs). Further, the average interval between floods has decreased since 14 ka from 500 years, to 250 years and 100 years during respective flood phases.

The southern slopes of Himalaya are influenced by both the monsoon and mid-latitude westerlies and any abrupt changes in the circulation pattern were found to associate with heavy rainfall events in this region. Although an interaction between the westerlies and the monsoon is implicated for extreme floods in the western Himalaya. However, exact mechanism of these interactions is still illusive except for the observational based studies which state that extreme floods occurred during moderate monsoon. This observation corroborates well with the chronology of the flood sequences of the middle Satluj valley. We ascribe the floods to the transient monsoon/westerlies phases in the western Himalaya. Such phases are known to modulate the temporal changes in the pattern of the Rossby waves which in turn dictate the southward penetration of the cold arctic air masses during the Arctic Oscillations (AO). Finally, a steady decrease in the flood intervals probably suggests more frequent and rapid interaction between the monsoon and mid-latitude westerlies trough over the western Himalaya. With the anticipated global warming, the extreme flood events are likely to increase both in magnitude and frequency. Hence, emphasizes on the re-evaluation of ongoing infrastructure developmental activity, particularly the river valley projects in the Satluj river.