CHAPTER 7

Conclusions

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The multiple proxies investigation from the Wah Shikar and Mawmluh caves from NE Himalaya and the Tso Moriri Lake from NW Himalaya indicate large variability in Indian summer monsoon strength during last ~34kyr. ISM was strong during late MIS 3, Bølling-Allerøid, Early Holocene, Medieval Warm Period and Current Warm Period. The weak ISM conditions appeared in the intervals of Last Glacial Maximum, Henrich Events, Younger Dryas, 8.2kyr BP, ~4.3-3.4kyr BP and Little Ice Age. Based on the multi-proxy studies from caves and lake deposits, following conclusions have been drawn:

Objective 1: To reconstruct history of the Indian Summer Monsoon in the Himalayan region with an emphasis on extreme monsoon events (droughts and floods) during the last 1000 years

Our multiple proxy records suggest several decadal to centennial scale changes in the ISM intensity during the last millennium. The ISM was strong between AD 1,000 and 1,320 due to warming of earth's in MWP interval followed by weak summer monsoon conditions between AD 1320 and 1710, the colder phase of LIA. After AD 1,710 and till present, the ISM again become strong with a rise in global temperature due to industrial revolution and anthropogenic factors. The intervals of MWP, LIA and CWP are recorded in both northeast and northwest Himalaya. Our records also indicate more frequent abrupt and extreme rainfall events during the warmer intervals of MWP and CWP than the cold phase of LIA. The amplitude of climatic fluctuation was highest during the MWP. The frequency of the extreme precipitation events have been increased during the last three centuries with the onset of CWP which suggests further rise in the intensity and occurrence of climatic surprises in the form of flash floods especially in high altitude Himalayan regions, and droughts in very near future.

Objective 2: To understand a relationship between Indian summer monsoon and mid latitude westerlies

The strength of Mid Latitude Westerlies (MLW) put a negative impact on the intensity of the ISM. The changes in MLW is itself controlled from the climate in North Atlantic Ocean. The cooling in the North Atlantic Ocean intensify the MLW in the northern hemisphere which cause more snow deposition in the Himalaya and Europe. The higher snow deposition in the Himalayan regions restricts the development the low pressure system in the Ganga plain and western India due to cooling in atmosphere and eventually weaken the ISM winds. The weakening of ISM during the Henrich events, Younger Dryas and Last Glacial Maximum indicate impact of cooling in the North Atlantic Ocean and intensified MLW associated with it. The weak phases of ISM between 4,350 and 3,450 yrs BP, and Little Ice Age also witnessed the enhanced MLW during that time span.

Objective 3: To understand forcing factors that drove changes in the Indian summer monsoon on short time scale

Our multiple proxy records indicate several forcing mechanisms to Indian summer monsoon on different time scales. The changes in solar insolation, sea surface temperature in the Atlantic Ocean and El Niño Southern Oscillation (ENSO) have been the major factors controlling the intensity of the ISM during last 35,000 years.

Our records from all three sites indicate the solar insolation and North Atlantic Oscillations are the major controlling factors on centennial to millennial scale. The weak ISM during Last Glacial Maximum, Younger Dryas and strong summer monsoon during the Early Holocene was influenced by these two factors. In last 4,500 years, the occurrence of ENSO activity also greatly affected the ISM strength. The weakening of ISM after 4,350 yrs BP was caused by modern El Niño kind conditions and southward migration of the Inter Tropical Convergence Zone. On decadal to multidecadal time scales during the last millennium, the solar insolation and ENSO have been the major factors in determining ISM rainfall. The Solar insolation is the major influencing factor during the colder intervals e.g. LIA, and ENSO have been the major factor during warmer intervals like MWP and CWP.

Objective 4: To investigate the role of climate in driving major socio-economic changes in south Asia

The strength of the ISM greatly affected the socio-economic changes of society in south Asia. The Indus-Sarasvati civilization flourished in Indian subcontinent during the strong summer monsoon during 10,000 to 5,000 cal yrs BP. The weak ISM conditions appeared after 4,350 cal yrs BP devastated the agriculture in the areas of Indus-Sarasvati civilization and population had to migrate towards east and south in the search of water availability. This societal changes during the last millennium also hints towards the strong cultural-climate link in India and surroundings. The abrupt weakening of ISM in 12th and 13th century AD induced the collapse of several well established Indian Empires due to the collapse of agriculture based economy. The large empires of Maratha, Vijayanagar, and

Mughal were established during the strong summer monsoon conditions in India and disintegrated with weakening of ISM. The loss of millions of lives due to rainfall failure induced famines also indicate the criticality of ISM rainfall for the society in south Asia.

6.2. Future Prospective

Owing to the importance of the Indian summer monsoon for the society on Indian subcontinent, the prediction of its variability in the future and occurrence of extreme precipitation events in effect of changing global climatic scenario will be a major challenge for us. We have to extend our climatic database with high resolution paleoclimatic records from all through the Indian summer monsoon regime along with the modelling studies. Our studies in northeast and northwest Himalaya have highlighted several important point to be perused in future. An extensive database of well dated, long term climate record is essential to reduce uncertainty in climate predictions by testing and refining climate models.

- Increasing the spatial coverage of the palaeoclimatic data in the Indian subcontinent and especially in central Himalaya and NE Himalaya to better understand the climatic variability in the past
- Making the precise chronology of the palaeoclimatic datasets to constraints the timing of climatic events and asynchronity of various palaeoclimatic records
- Making the high resolution datasets from the Arabian Sea and Bay of Bengal and their comparison with the terrestrial datasets.

- Making the climatic models for the Indian subcontinent using the high resolution palaeoclimatic datasets for ISM and its teleconnections
- Paleoclimate simulations of different duration and different time slices are needed to understand the typical circulation anomalies responsible for the occurrence of extremes (floods and droughts) and identify the physical causal mechanisms.