Executive Summary

The precipitation in the Himalayan region is very crucial for the socio-economic well-being of large human population in South Asia as this is the major source of water for most of the perennial rivers in the region like the Ganga, Yamuna, Indus and Brahmaputra River. The Indian summer monsoon (ISM) is the chief source of precipitation in eastern and central Himalaya, and western Himalaya also receives a significant part of moisture by the Mid latitude westerlies (MLW). The changes in the ISM intensity or onset/retrieval in past led to the loss of lives of humans, cattles and property by widespread droughts associated with famines and disastrous floods. But the frequency of these extreme precipitation events in past and their forcing mechanisms are not fully understood due to lack of long term meteorological observations and high resolution paleoclimate records from continental areas in South Asia and especially from the Himalayan region. The last few decades have witnessed several extreme precipitation events in the Indian subcontinent along with the Himalayan region. The crucial need to understand the occurrence of extreme precipitation events and their forcings has motivated me to frame the objectives of my Ph. D. dissertation as: (1) To reconstruct history of Indian summer monsoon in the Himalayan region with an emphasis on extreme monsoon events (droughts and floods) during last 1000 years, (2) To understand a relationship between Indian summer monsoon and mid latitude westerlies, (3) To understand forcing factors that drove changes in the Indian summer monsoon on short time scales, (4) To investigate the role of climate in driving major socio-

economic changes in South Asia.

To understand the precipitation changes in the Himalaya, I have selected two caves from northeast India, the Wah Shikar cave and Mawmluh cave in Meghalaya and one lake from the northwest Himalaya, the Tso Moriri Lake, Ladakh. The caves lies in the region of maximum rainfall on Earth and provide a great opportunity to understand the changes in Indian summer monsoon strength with high resolution. The Lake lies in cold arid region of Ladakh, near the northern limit of Inter Tropical convergence zone and reflect the mild fluctuations in the precipitation.

The chronology of the stalagmite samples, WSS-3 from the Wah Shikar cave and MWS-1 from the Mawmluh cave has been established by the U-Th disequilibrium series dating technique and the dating of the lake sediments has been carried out by the Accelerator mass spectrometry Radiocarbon dating and ^{137}Cs technique. The proxy studies include the stable oxygen and carbon isotopic analysis for the speleothems and multiple proxies analysis (grain size, elemental abundance, stable oxygen and carbon isotopes in lake carbonate, stable carbon isotope in lake organic carbon and total organic carbon in the lake sediments.

The study from the Wah Shikar cave suggests a strong ISM during warm intervals, between AD 1,026 and 1,320 (Medieval Warm Period) and AD 1,710 to Present (Current Warm Period) punctuated with weak summer monsoon in cold period, during AD 1,330 to 1,710 (Little Ice Age). Abrupt precipitation events were more frequent during the MWP and CWP. Twelve major periods of very low rainfall were observed during the last millennium which are accompanied with

severe famine conditions and caused death of millions of people and cattle in India. The climate changes also affected the socio-political situation in South Asia. The large dynasties of that time span grew during the intervals of strong ISM and declined/disintegrated with the appearance of less rainfall conditions. The solar insolation and El Niño have been the major forcing factors to the ISM in the last millennium. The solar forcing was more important on multidecadal time scale and during cold interval of LIA. In the warm intervals, El Niño intensity played a major role in determining strength of the ISM.

The study from the Mawmluh cave suggests the variability in ISM strength 33,800 to 5,500 yrs BP. Weak ISM conditions observed during Last Glacial Maximum, Younger Dryas and Henrich Events, and strong summer monsoon occured during the late Marine Isotope Stage 3, Bolling-Allerøid and early Holocene climate intervals. The results indicate the similar behavior of the ISM and East Asian summer monsoon in this time span, possibly due to the similar forcing mechanisms to both the monsoon systems. The solar insolation and the North Atlantic sea surface temperature largely controlled the ISM strength during this interval. The strong and weak ISM conditions in India are lagged by 3,500 years to the maximum solar insolation at 25°N. The colder/warmer intervals in the North Atlantic coincided with the weak/strong summer monsoon conditions in South Asia.

Our study from the Tso Moriri Lake infers the warm and wet climate with between 4,500 and 4,350 cal yrs BP, MWP and CWP. This record also suggests an abrupt decrease in precipitation in NW Himalaya during 4,350-3,450cal yrs BP,

due to weakening of the ISM. This weak ISM period for 900 yrs reduced the water discharge in Indus River and its tributaries and affected the agricultural production of the region of the Indus Valley civilization and population started migration towards south and east direction. But the continuous less precipitation demise or displacement of the Indus civilization. The increased intensity of the El Niño and southward migration of the ITCZ were the major controlling factors for the weakening of the ISM between 4,350 and 3,450 cal yrs BP.

Putting together all our studies from northeast and northwest Himalaya, we infer that the ISM was strong during warm climate intervals and weak in cold conditions. The abrupt precipitation events are more frequent and intense during the warm climate intervals, which indicate that the extreme precipitation events can be more frequent in the future with the increased global warming. The climatic variability has played a major role in socio-political and economic growth of the Indian society. The civilization flourished in the subcontinent during the wet and warm periods and declined or migrated in phases of cold and arid climate.