

List of Figures

- Figure 1.1** July mean 850mb pressure level using the 1981-2010 climatological base period based on International Research Institute for Climate and Society, Earth Institute, Columbia University. The arrows indicate the wind vectors, along with contours indicating the resultant wind speed (m/s). Vector orientation indicates the direction of the resultant wind, and the vector length indicates the wind speed (Source:http://iridl.ldeo.columbia.edu/maproom/Global/Climatologies/Vector_Winds.html) (After Dutt et al., 2015).....4
- Figure 1.2** January mean 850mb pressure level using the 1981-2010 climatological base period based on International Research Institute for Climate and Society, Earth Institute, Columbia University. The arrows indicate the wind vectors, along with contours indicating the resultant wind speed (m/s). Vector orientation indicates the direction of the resultant wind, and the vector length indicates the wind speed (Source:http://iridl.ldeo.columbia.edu/maproom/Global/Climatologies/Vector_Winds.html) (After Dutt et al., 2015).....6
- Figure 2.1** Geological map of the Shillong Plateau near the Wah Shikar and Mawmluh caves, Meghalaya, NE Himalaya (after Yin et al., 2010).....19
- Figure 2.2** Average monthly rainfall in Jaintia Hills district, Meghalaya, NE Himalaya during 1901 to 2000 (http://www.indiawaterportal.org/met_data/).....20

Figure 2.3	Geological map of the Tso Moriri Lake, Ladakh, NW Himalaya (after Mishra et al., 2014).....	23
Figure 2.4	Average monthly precipitation around the Tso Moriri Lake, Ladakh, NW Himalaya from 2010 to 2014 based on Tropical Rainfall Measuring Mission precipitation data (http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=TRMM_B42_Daily).....	25
Figure 3.1	Stalagmite sample WSS-3 in the Wah Shikar cave, NE Himalaya.....	29
Figure 3.2	Stalagmite sample MWS-1 in the Mawmluh cave, NE Himalaya.....	30
Figure 3.3	Sediment coring in the Tso Moriri Lake, NW Himalaya during Lake coring expedition in September-October 2012.....	31
Figure 3.4	Chronology of the stalagmite WSS-3 from the Wah Shikar cave, Meghalaya, NE Himalaya.....	32
Figure 3.5	Chronology of the stalagmite MWS-1 from the Mawmluh cave, Meghalaya, NE Himalaya.....	34
Figure 3.6	Age Depth plot of core TMC-1 from the Tso Moriri Lake, Ladakh, NW Himalaya, based on Bacon age model using calibrated mean ages. The main graph shows the 2-sigma (95%) confidence level of the calibrated weighted mean ages (blue dots) before the present (BP) with respect to AD 1950 plotted against depths. The shadowed area between the dotted lines shows the probability range of the ages	

	(minimum and maximum ranges). The red line in the middle of the shadowed area is the best fit used for age depth calculation.....	39
Figure 4.1	Indian summer monsoon proxy record of stable oxygen and carbon isotopes from Wah Shikar cave, Meghalaya, NE Himalaya for the period AD 1,026 to AD 2,012. The inverted black triangles in the bottom panel indicate the ^{230}Th ages.....	49
Figure 4.2	The Hendy test correlation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ proxy record from the Wah Shikar cave, NE Himalaya.....	51
Figure 4.3	$\delta^{18}\text{O}$ proxy record from the Wah Shikar cave with the homogenous rainfall data in NE India from year 1871 to 2012.....	51
Figure 4.4	Spectral analysis of $\delta^{18}\text{O}$ time series from the Wah Shikar cave, Meghalaya, NE Himalaya from AD 1026 to 2007.....	52
Figure 4.5	Spectral analysis of $\delta^{18}\text{O}$ time series from the Wah Shikar cave, Meghalaya, NE Himalaya from AD 1026 to 1320.....	53
Figure 4.6	Spectral analysis of $\delta^{18}\text{O}$ time series from the Wah Shikar cave, Meghalaya, NE Himalaya from AD 1320 to 1710.....	53
Figure 4.7	Spectral analysis of $\delta^{18}\text{O}$ time series from the Wah Shikar cave, Meghalaya, NE Himalaya from AD 1710 to 2007.....	54
Figure 4.8	Spectral analysis of IITM homogenous rainfall data for NE India from years 1871 to 2012 (http://www.tropmet.res.in/Data%20Archival-51-Page).....	54
Figure 4.9	Indian summer monsoon proxy record from Wah Shikar cave, Meghalaya, NE Himalaya compared with cave records from India,	

China and Turkey; ice record from China and marine record from Arabian Sea. (a) $\delta^{18}\text{O}$ record from Wah Shikar cave, India (present study), (b) $\delta^{18}\text{O}$ record from Jhumar cave, India (Sinha et al., 2011), (c) $\delta^{18}\text{O}$ record from Wanxiang cave, China (Zhang et al., 2008), (d) $\delta^{18}\text{O}$ record from Dongge cave, China (Wang et al., 2005), (e) $\delta^{18}\text{O}$ record from Dunde ice core, China (Thompson et al., 2000), (f) $\delta^{18}\text{O}$ record from Sofular cave, Turkey (Fleitmann et al., 2009) and *G. bulloides* (%) in marine core RC 2730 from the Arabian Sea (Anderson et al., 2002). The inverted black triangles in the bottom panel indicate ^{230}Th ages. Light grey bar shows the Little Ice Age (LIA). The Medieval Warm Period (MWP) has also been shown.....56

Figure 4.10 Correlation of Indian summer monsoon proxy record from the Wah Shikar cave with the major events in the Indian history during last the last millennium.....62

Figure 5.1 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ proxy record of Indian summer monsoon strength from speleothem MWS-1, from the Mawmluh cave, NE Himalaya.....66

Figure 5.2 Hendy test correlation of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values from a single lamina from the speleothem MWS-1 from the Mawmluh cave, NE Himalaya.....67

Figure 5.3 Spectral analysis of $\delta^{18}\text{O}$ time series from speleothem MWS-1 from

the Mawmluh cave, NE Himalaya for the period between 33,800 and 5,500 yrs BP.....68

Figure 5.4 Indian summer monsoon (ISM) proxy record from the Mawmluh Cave, Meghalaya, India, compared with cave and lake records from China, and marine records from the Bay of Bengal and Cariaco Basin. (a) Mawmluh Cave $\delta^{18}\text{O}$ record for the interval 33,800 to 5500 yrs B.P. (dated intervals are marked by diamonds with error bars in blue color); also superimposed is the published $\delta^{18}\text{O}$ record from the Mawmluh Cave (Berkelhammer et al., 2012). (b) Dongge Cave $\delta^{18}\text{O}$ record (black color) (Yuan et al., 2004) combined with Hulu Cave $\delta^{18}\text{O}$ record (green color) (Wang et al., 2001). (c) SST values from Cariaco Basin core PL07-39PC (cyan color) (Lea et al., 2003). (d) Bay of Bengal planktic foraminifer $\delta^{18}\text{O}$ record as proxy for precipitation change (Govil and Naidu, 2011). (e) Huguang Maar Lake record of Ti counts/s (Yancheva et al., 2007). Broken vertical black lines mark the boundaries between marine isotopic stages (MIS). Light grey bars mark the Younger Dryas (YD) period and Last Glacial Maximum (LGM), whereas the dark grey bar indicates the Bølling-Allerød (B-A) period.....70

Figure 5.5 Mawmluh Cave $\delta^{18}\text{O}$ data (blue color) compared with Greenland Ice Sheet Project 2 (GISP2) core $\delta^{18}\text{O}$ data (orange color) (Stuiver and Grootes, 2000). Also superimposed are maximum solar insolation at

25°N (cyan color) (Huybers, 2006) and orbital precession (black color) (Berger and Loutre, 1991).....72

Figure 6.1 Location of sites of the Harappan civilization in India, Pakistan and Afghanistan in yellow circle and red triangle (Madella and Fuller, 2006). Also shown are the location of the Tso Moriri Lake, NW Himalaya in blue circle.....78

Figure 6.2 Optimal end-member modelling (EM1-EM-3) using grain size data of core TMC-1 from the Tso Moriri Lake, Ladakh, NW Himalaya. End-member loadings represent sedimentologically interpretable unmixed grain-size distributions of three end members; EM1(lacustrine deposition of clay under slack water conditions near the river mouth, indicating very low or even temporary absence of river discharge, EM2 (high energy fluvial flow, and EM2(low energy fluvial flow).....80

Figure 6.3 Indian summer monsoon proxy records of extracted end members from grain size variations (EM1: fluvial-lacustrine deposition of clay under slack water conditions, EM2: fluvial high energy flow, and EM3: fluvial low energy flow), $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ ratios in bulk carbonate, elemental ratios of Al/Ca and Rb/Sr and TOC (Wt. %) in core TMC-1 from the Tso Moriri Lake, Ladakh, NW Himalaya. Light green-grey bars indicate prolonged arid phase during ~4,350-3,450 cal yrs BP and the Little Ice Age (LIA). A potential commencement of the arid phase until 2,800 cal yrs BP is marked

by the shaded bar. Medieval Climate Anomaly (MCA) is marked in light orange.....82

Figure 6.4 Spectral analysis of Al/Ca time series from core TMC-1, Tso Moriri Lake, Ladakh, NW Himalaya for the period 4,500 to -62 cal. yr BP showing the strongest periodicity at 140, 80, 63, 58 and 45 yrs (90%) using PAST Red Fit and Monte Carlo methods.....85

Figure 6.5 Indian summer monsoon proxy records from the Tso Moriri Lake, Ladakh compared with lake record from eastern tropical Pacific Ocean region, and marine records from the eastern Pacific Ocean and Cariaco Basin. (a) EM3 (low energy fluvial) from the Tso Moriri Lake, NW Himalaya (present study), (b) EM2 (high energy fluvial) from the Tso Moriri Lake, NW Himalaya (present study), (c) percent Ti from the ODP site 1002, Cariaco Basin (Haug et al., 2001), (d) percent sand in sediment core from the El Junko Lake, Galapagos, eastern tropical Pacific (Conroy et al., 2008) and (e) 10 years running mean of lithics percentage from marine core SO147-106KL, eastern Pacific Ocean (Rein, 2007).....88