Regional paleoclimate simulations:

a) ECHAM5 Atmosphere only General Circulation Model Simulations:

The focus was on the 200-yr-long time slices of the Medieval Climate Anomaly (900-1100 AD) and the Little Ice Age (1515-1715). Limitations in available computing resources have compelled us to focus on a single higher-resolved calculation of the millennium experiment. Our analysis is based on comparison of moisture signal in Central Asia between different simulations of the Millennium project (Jungclaus et al., 2010), revealed that the ensemble member mil014 shows the most robust signal compared to reconstructions. A two-step approach is used to simulate the past millennium: (i) the fully coupled Community Earth System Models (COSMOS) from Max Planck Institute for Meteorology with spatial resolution of T31 (ca. 3.75°×3.75°) with 19 vertical levels and coupled to the ocean model MPIOM (horizontal resolution of GR3.0 (ca. 3°×3°)), 40 vertical levels; and (ii) the atmosphere-only general circulation model ECHAM5 with spatial resolution of T63 (ca. 1.8°×1.8°) and 31 vertical levels. The simulated moisture changes between the MCA and LIA are compared with 9 reconstructed paleo-data (Ely et al., 1996; Chauhan et al., 2000; Denniston et al., 2000; Kar et al., 2002; Bhattacharya et al., 2007; Sinha et al., 2011a; Ponton et al., 2012; Anoop et al., 2013; Menzel et al., 2013; Sanwal et al., 2013; Prasad et al., 2014; Sarkar et al., 2014) derived from different archives like lake and ocean sediments, peat, and stalagmites using various proxies as pollen, isotopes, mineralogy, and sedimentology. Simulated and reconstructed annual moisture signals agree over the Himalaya and Central India. The numerous archives in the Himalaya region exhibit a high consistency with the model data in describing past moisture changes. In Central India, where less proxy data are available to describe the moisture distribution in the heterogeneous topography, the agreement is only prominent in summer. The proxy data are anchored around the new Lonar Lake record, which due to its long chronology and multi-proxy reconstruction is representative for the paleo-hydrological changes in Central India. This record has been cross-validated with historical data for the investigated time interval (Prasad et al., 2014). We tested the hypothesis that a warmer (cooler) climate leads to stronger (weaker) ISM as proposed by Rehfeld et al. (2013) and analyzed the physical processes connected to this response. We extended Rehfeld's theory and identified three larger regions within the ISM region which have pronounced moisture anomalies in summer and winter: (i) western and central Himalaya, which is influenced by variations in intensity of extra-tropical Westerlies during winter, (ii) the eastern Himalaya which in summer is affected by changes in thermal gradient between the Bay of Bengal and the Indian subcontinent as well as by the zonal band of strengthened ISM–EASM link, and (iii) Central India whose summer moisture anomalies are affected by the SST pattern in northern Arabian Sea. As Prasad et al. (2014) pointed out, the strength in the large-scale advection of moist air masses toward India and the Indo Pacific Warm Pool–ISM link varies on a multi-centennial time scale. Compared to Rehfeld et al. (2013) our “MCA minus LIA” anomalies showed a northern shift in ISM activity leading to weakening (enhancement) of ISM rainfall over Central India (eastern Himalaya) during warmer climate. Our results indicate that the combination of proxy and model data leads to an improved understanding of the paleo-climate. Proxy data are used to validate model simulations of climates of the past. The model data can then be analyzed to investigate the mechanism behind the changes (Polanski et al., 2014).

b) Regional Climate Model simulations with COSMO-CLM:

As the result of environmental complexity in Asia, an RCM model is employed to study the moisture changes across the past millennium. We focus on the regional moisture variability for
the recent past (past millennium) in Asia. The aim of this investigation is to study the evolution of moisture changes during the past millennium over ACA and identify the dynamical origins behind it. Here the sensitivity of extreme moisture events to climate forcing of the past millennium is tested with a focus over Central Asia. The COSMO-CLM (CCLM) model version 4.8 clm17 [Steppeler et al., 2003, Dobler and Ahrens, 2008, Asharaf et al., 2012] developed by the German Weather Service (http://www.cosmo-model.org) is applied in this study to simulate the high resolution regional climatic changes in Central Asia. Further details about the models can be found in previous studies [Marsland et al., 2003, Roeckner et al., 2006, Wetzel et al., 2006, Raddatz et al., 2007]. Our model experiments cover different possible climate behaviors throughout the past millennium could be clustered into wet and dry spells in three different historical epochs. By comparing the dynamical drivers of the moisture changes over ACA in the selected time-slices, we studied the differences of internal unforced variations of climate system between extreme dry and wet spells. Summing up the results, it can be concluded that during the wet phases of the past millennium, there is an extensive positive annual rainfall anomaly during LIA compared to MCA. This pattern is extended from ACA to the monsoon-dominated Asia, showing an in-phase relation between these two regions. This signal can be split into summer monsoon and winter ACA rainfall. The Asian summer monsoon activity is linked to a flavor negative central Pacific and positive North Atlantic SST anomaly conditions. During winter of wet phases, cooler North Atlantic leads to enhanced rainfall over ACA. During dry phase of LIA, annual moisture regime exhibits positive rainfall anomalies over Northeast of Asia coincident with drier monsoon-dominated Asia compared to MCA. Similarly, this pattern is divided into strengthened summer Westerlies during dry LIA and El Niño-like SSTA over Pacific coincident with equator-ward shifted Westerlies during the dry MCA. An intensified westerly during the summer of dry MCA leads to enhanced rainfall over west Central Asia (an area within 30° N–40° N and 60° E–80° E).

Finally, we note that our simulations are based on a single driving model and the timing in the model may be uncertain, preventing us to make any conclusion about a specific year in the simulations. However, for longer 30-year time periods within MCA, LIA and PI, the results depict the averaged internally produced climate variability under external natural climate forcings within these epochs. Using different driving GCMs for dynamical downscaling with RCMs will largely improve the certainty of the results. Regarding this, we suggest that considering more realizations using ensemble of driving GCMs and nested RCMs will produce a lot of added value in the results. This will lead to a larger coverage of the sample space. However, the computational costs will extremely increase in such approaches.

**Sensitivity test concerning the Tibetan Plateau:**

Simulations using the ECHAM5/MPIOM coupled atmosphere-ocean model with and without the Tibetan Plateau have been performed to study the large scale effects of orographic forcing on the behaviour of the Asian summer monsoon system. Our analysis emphasizes the significant impact of plateau forcing on the atmospheric circulations. It is argued that, in addition to the direct feedbacks of Tibetan Plateau orography on the climate of Asia such as sensible heat pumping and thermal insulation, other significant direct processes exist, which link the Asian summer monsoon to the sea surface temperatures in the North Atlantic Ocean. A removal of the Tibetan Plateau modifies the wind-driven ocean circulations over the North Atlantic, leading to a decrease of surface heat advection over the North Atlantic Ocean and a decrease of the Atlantic Meridional Overturning Circulation. This, in turn, affects via teleconnections both the monsoon rainfall and the position of the intertropical convergence zone. The results are accepted but not published yet for the journal of “Climate Dynamics”.