Heavy rainfall events recorded in sediments of the TT Lake (southern-central Tibetan Plateau) since AD 440

M. Ahlborn[1], T. Haberzettl[1], K. Henkel[1], T. Kasper[1], B. Reinwarth[1], J. Ju[2], L. Zhu[2], G. Daut[1] and R. Mäusbacher[1]

[1] *Institute of Geography, Friedrich-Schiller-University Jena, Germany*
[2] *Institute of Tibetan Plateau Research, Chinese Academy of Science, Beijing, P. R. China*
marieke.ahlborn@uni-jena.de

The Tibetan Plateau has experienced a gradual weakening of the summer monsoon systems during the Holocene. Although lake sediment records from the Tibetan Plateau are considered to be particularly sensitive to climate variations, a holistic picture of the spatial and temporal monsoon evolution is still missing due to the interplay of different moisture-transporting wind systems (Indian summer monsoon, East Asian summer monsoon, Westerlies). Especially the late Holocene is poorly understood and well-dated highly resolved records are lacking. Closing this data gap is important since the Tibetan Plateau is a key area for understanding the climate evolution and its impact on the availability of current and future water resources in Central Asia. Hence, well-dated and high-resolution records are essential to improve the understanding of the spatial and temporal monsoonal evolution.

To investigate the hydrological cycle indicating past monsoon variability and its spatial and temporal heterogeneities on the southern-central Tibetan Plateau, records of several lakes were studied along a W-E-transect including Nam Co, Tangra Yumco, Taro Co, and a small lake named TT Lake in the Tangra Yumco basin. In this study, a high-resolution sediment record from TT Lake (31.10° N, 86.57° E; 4,745 m asl) is presented to reveal climate dynamics since AD 440.

The terminal and 9 m deep TT Lake covers ~14,500 m^2 and has a catchment of 4.6 km^2. The lake is fed by a small stream (observed in June 2012) entering the lake in the west. This stream is surrounded by wetlands extending as a flat plain at the western shore. Vegetation around TT Lake is mainly limited to these wetlands and sparse in other parts of the catchment.

Three sediment short cores with 60 mm in diameter and lengths of 49.2 cm (TTL 11/1), 64 cm (TTL11/2), and 88.4 cm (TTL 12/3) were obtained in 2011 and 2012 from water depths of 8.2 – 8.8 m using a modified ETH-gravity coring device. By now data are available for lithology,a sedimentological core description, magnetic susceptibility (κ), XRF core scanning, statistical cluster analysis, CNS analyses, and grain size distribution. Additionally, seven radiocarbon dates were determined from bulk sediment material. Further, diatom and palynological analyses as well as ^{137}Cs measurements are in progress. Cores TTL 11/1, TTL 11/2, and TTL 12/3 were correlated based on lithological units and Ti patterns. Since core TTL 12/3 is the longest record retrieved from TT Lake it is considered as master core and serves as standard for all other cores. Possible event layers determined by macroscopic appearance, grain size, and XRF-data are omitted from further interpretation.

The macroscopic sedimentological description of the 88.4 cm long core TTL 12/3 revealed predominantly stratified, grayish-brown to black sandy mud. Four major sediment types were determined: 1) stratified, fine silty to fine sandy, light brown to dark olive gray sediments with laminae of mm-scale; 2) dark gray almost black, massive, fine silty to fine sandy sediments; 3) sediments with a noticeable internal grading from fine sand to very fine silt; 4) one light gray coarse silty to fine sandy layer at 86 – 85 cm. Layers with internal grading are distinguishable at 72.8 – 72.2 cm, 60.0 – 56.2 cm, 53.2 – 51.5 cm, 50.4 – 49.6 cm, 23.5 – 6.0 cm, and 1.8 – 0 cm, whereas the thickest one from 23.6 – 6.0 cm contains plant remains in the coarser section and occurs in all three obtained cores. Several age determinations from core TTL 12/3 show an offset to TTL 11/2 complicating the establishment of the age-depth model. However, age determinations at 55.2 cm, 33.6 cm (both TTL 11/2), and 86.4 cm (TTL 12/3) are considered as reliable and used to generate the age model for a event-layer-cleared record TTL 12/3. Linear interpolation of the mentioned calibrated age determinations revealed a basal age of AD 440 and an age of AD 1630 at the top of the record which is also cut off by a event-layer, i.e., the record covers a time span of 1,200 years with a sub-decadal resolution. The concentration of the elements K, Ca, Ti, Fe Zn, Rb, Mn, and Sr measured by

the XRF scanner with average counts >350 were used for interpretation and statistical analyses. The elements K, Ti, Fe, Zn, and Rb reveal a similar pattern and reproduce magnetic susceptibility pattern showing significant peaks in sediment sections with internal grading. A cluster analysis of the event-layer-cleared XRF data revealed a subdivision of the core into four zones (88.4 – 60.2 cm; 60.0 – 47.2 cm; 47.0 – 30.6 cm; 30.4 – 0.0 cm). TOC, TIC, TN, and TS show lowest values in sediment sections with internal grading. TOC is characterized by higher values from 88 – 61 cm and lower values in the upper section. Median particle diameters range from 3 – 82 µm, while values are variable but generally decreasing between 88.4 – 52 cm sediment depth, stable and increasing between 52 – 34 cm, with two prominent peaks at 32 and 30 cm, very high values at 22 – 16 cm, and almost constant thereafter. The macroscopically determined internal grading can be confirmed by grain size analyses for all aforementioned sediment sections, except for the layer at 72.2 – 72.8 cm sediment depth. Based on the abovementioned criteria seven event layers were defined and removed generating a event-layer-cleared sediment record of 53.2 cm length. The following sections are affected: 85.4 – 83.2 cm, 73.0 – 71.6 cm, 60.2 – 56.0 cm, 53.4 – 49.0 cm, and 23.6 – 0 cm sediment depth.

High concentrations of minerogenic elements, such as Ti, K, Fe, Rb, Mn, and Zn, are associated with high erosion rates resulting from increased surface runoff. Grain size distributions in lacustrine systems are mainly controlled by the prevalent hydrologic energy within the lake and its tributaries. Finer grain sizes represent reduced hydrologic energy during phases with higher lake levels, whereas coarser median grain sizes represent enhanced hydrologic energy during phases of lower lake levels. TOC values are considered to represent biological production within the lake with higher production, when temperatures are higher and vice versa. This leads to the following interpretation of the record:

Zone 1 (88.4 – 60.2 cm; ca. AD 440 – AD 1070)
Minerogenic input is generally low, but increases at AD 930, indicating increased surface runoff and thus, higher moisture availability in the catchment corresponding to rising lake level as inferred from grain sizes. TOC values suggest relatively high temperatures. Event-layers occur at AD 520 and AD 780 both matching phases with low temperatures and high lake level.

Zone 2 (60.0 – 47.2 cm; ca. AD 1070 – AD 1170)
Minerogenic input is highest in the entire record and well in phase with a high lake level. TOC values, i.e., temperatures are significantly decreasing. Three event-layers occur in this short interval probably triggered by enhanced runoff due to torrential precipitation events.

Zone 3 (47.0 – 30.6 cm; ca. AD 1170 – AD 1500
Minerogenic input decreases and shows lowest values in the record, while grain sizes increase both pointing to a falling lake level caused by reduced moisture availability. TOC, i.e., temperature values remain low. TOC and grain sizes start fluctuating at the top of the zone probably due to instable climatic conditions. No event-layers are recorded in this zone suggesting that event-layers might be triggered by precipitation events, i.e., enhanced surface runoff.

Zone 4 (30.4 – 0.0 cm; ca. AD 1500 – AD 1630)
Minerogenic input increases again and grain sizes are getting finer, indicating high runoff and a higher lake level. TOC values and temperature rise. A thick turbidite on top of zone 4 is supposed to have been erosive. As this event-layer occurs in all investigated cores this implies a dramatic precipitation event that probably triggered a mudflow in the catchment. Satellite images indicate that the event might have happened between AD 2004 – 2011. ^{137}Cs age determinations are in progress to test this hypothesis.

Key words: Tibetan Plateau, lacustrine sediments, multi-proxy approach, surface runoff, lake level variations, hydrologic extreme events