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Timing the Little Ice Age Advance and Fluctuations of a Glacier in the Eastern Alps - a multi-proxy Lake Sediment Study

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Abstract

In order to investigate the variation of glacier extent during the Little Ice Age (LIA) and Holocene in the Eastern Alps, we studied a multi-proxy sediment record from a small high alpine lake spanning over 10 kyr. The lake is located at 2790 m a.s.l. in Southern Tyrol, Italy, in a terrain with active glaciers. Proxies include organic carbon and nitrogen content, dry-weight and wet-density; sediment geochemistry at 1 cm resolution measured on ground dry samples with ED-XRFA, and at 1 mm resolution on core halves with ITRAX-XRF core-scanner; P-wave velocity, gamma density, and magnetic susceptibility measured at 1 mm resolution with a GEOTEK Multi-Sensor Core Logger; biological microfossils. With the Bayesian age-depth modelling software Bacon, we established an age-depth model based on 15 radiocarbon dates using plant macrofossils, and ^{210}Pb and ^{137}Cs dating of the top sediment layers. Due to turbidites and visible changes in sediment accumulation rate, establishing a robust chronology remained challenging. In the age-depth model we considered turbidites >1 cm thickness and a boundary layer caused by the shift in sediment properties due to glacier reconnection.

While the lake has currently lost its fluvial connection to the local glaciers, the periods of glacier meltwater input are evident in the sediment record. Before 10 000 cal. yr BP the lake first lost its connection to the glaciers; around 9500 ± 500 cal. yrs BP the lake shifted from a turbid to a clear water lake, and sediment layers became very homogenous and dominated by organic sedimentation for the major part of the Holocene. After 1100 ± 220 cal. AD, we observed another clear system shift; distinct changes in sediment organic content, density, turbidites, and geochemical composition separated several periods with glacier meltwater input of variable intensity and frequency and thus marked the onset of the LIA in this region, and the subsequent fluctuations in glacier extent. Around 1880 ± 20 cal. AD the glaciers started to retreat, and by 1950 ± 7 cal. AD the lake again became a clear water lake without direct glacier meltwater inflow, thus indicating a major retreat of the glacier that is currently still ongoing.

Despite highly variable meltwater input and connectivity to the local glaciers, the lake's sediment record itself was not disturbed or repositioned by glacier movements during the LIA. However, during LIA glacial maxima, the catchment area increased almost eightfold. The resulting vast water volume caused lake outbursts recorded in chronicles from a village in the lower valley which was affected by floodings and landslides. The unique position of the lake at the fringe of a glacier during LIA maximum glacier extent makes this lake's sediment a sentinel for glacier fluctuations and climate variations, especially during the Little Ice Age.