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Calibrating detrital layers in varved lake sediments for quantified flood reconstruction

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Based on generalizing assumptions, recurrence times of flood triggered detrital layers in lake sediments are commonly interpreted to reflect flood frequency changes and the thickness of a flood deposit is often expected to represent the intensity of a triggering flood. However, recent results from detailed process studies suggest a more complex relation between river discharge and flood layer deposition. Calibrating time-series of flood layers against discharge data of the tributary river of a lake allows testing the significance of a flood layer record and correcting for potential non-flood induced biases.

Therefore, time-series of even sub-mm thick flood layers have been established at seasonal resolution from two varved surface sediment cores from Lakes Mondsee (MO) and Ammersee (AS) and at annual precision from non-varved surface sediment cores from the Pallanza sub-basin of Lago Maggiore (LM) located in a proximal and distal position towards the tributary rivers integrating microfacies analyses and X-ray fluorescence scanning (μ-XRF) at 200 μm resolution.

Calibrating flood layers from the proximal coring locations against floods of different magnitudes reveals an empirical discharge threshold of about 40 m^3/s for MO, 125 m^3/s for AS and 600 m^3/s for LM above which the deposition of a flood layer is very likely (MO: 13 floods >40 m^3/s, 92% coverage, 12 of 16 layers; AS 17 floods >125 m^3/s, 71% coverage, 12 of 22 layers LM: 18 floods >600 m^3/s, 78% coverage, 14 of 15 layers). However, the flood layer time-series also include additional layers associated to floods below the evaluated discharge thresholds. While four additional flood layers in MO and one additional flood layer in LM sediments do not bias the flood time-series substantially and the records represent changes in the frequency of floods above the evaluated threshold through time, ten additional flood layers in AS sediments associated to lower magnitude floods might induce a considerable bias. Evaluating the seasonality of these deposits reveals that six of ten additional layers in AS sediments are all fall flood layers detected during the calibration period. Consequently, these deposits have to be removed from the record and the AS flood frequency time-series is significant only for spring and summer.

The relation between flood layer thickness in the proximal sediment cores and the magnitude of a triggering flood is more complex. A significant empirical correlation between flood layer thickness and flood magnitude was found at the three study sites for on average 28% of all flood layers that are triggered by the most extreme discharge events (MO >60m^3/s, AS >250 m^3/s, LM >1500 m^3/s). For the remaining 72% flood layers related to floods below these discharge thresholds the statistical link between flood magnitude and layer thickness is weak or very weak (r=0.41 for MO, r=0.03 for AS, r=0.19 for LM). This suggests that the most important factor for detrital sediment deposition during lower magnitude floods is internal variability in the lake/catchment setting, while during the most extreme discharge events it is the intensity of the turbidity current.

These results underline the great potential of calibrating flood layer frequency and thickness time-series from varved lake sediments against local discharge data for improved and quantified flood reconstructions and evaluating the significance of a time-series at up to seasonal precision.