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Generating quantitative palaeoflood data from homogeneous lake sediments: a case-study from Brotherswater, northwest England

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The scarcity of long-term hydrological data is a barrier to reliably determining the likelihood of floods becoming more frequent and/or intense in a warmer world. Lakes and their sediments are increasingly being used to reconstruct long-term, highly-resolved datasets of past floods but the ultimate goal, generating quantitative palaeohydrological data to augment flood frequency analyses, is a persistent challenge.

To this end, ascertaining the autogenic and allogenic processes influencing the character and preservation potential of palaeoflood laminations and determining the minimum discharge at which a sedimentary imprint will be deposited in a particular system are two key precursors. Some success has been achieved at lakes containing annually-laminated sequences or where event layers exhibit well-defined lithological contacts. Many non-alpine and non-polar lakes, especially those in temperate regions, are instead characterised by visually-homogeneous, organic-rich sediments from which discrete flood laminations are difficult to discriminate. Working at Brotherswater, a small upland lake in northwest England, we have successfully demonstrated an approach to obtain flood frequency and magnitude data from this type of lake system by integrating a 16 month sediment trap deployment (CE 2013-2014) with the recent (CE 1962 – 2014) depositional record.

The geochemical composition and end-member modelling of the trap data shed light on the seasonal variation in background sedimentation dynamics, specifically enhanced sediment supply during winter, spring diatom blooms and heightened summer productivity, which alter the signature of coarse-grained deposition in response to higher flows. Having pinpointed the characteristic flood end-member, comparison of the short-core palaeoflood reconstruction to local river discharge data was able to reveal the hydrological thresholds of this system: flood magnitudes calculated to have a four year recurrence interval are preserved in delta-proximal sediments but the central basin was less sensitive, declining to nine years. These results have been further contextualised through comparison with the sedimentological signature of a recent extreme flood captured by sediment traps and in short cores extracted immediately post-event. On the 5-6 December Storm Desmond delivered unprecedented rainfall and multiple gauging stations in the region surpassed record river flow, offering a unique opportunity to test a sediment-based palaeoflood record.

These data re-emphasise the need for systematic process monitoring and calibration of the depositional record to obtain a site-specific understanding of internal and external factors controlling event signature preservation. Wider implementation of this approach at equivalent lakes offers a vast, untapped archive of palaeohydrological data for hydrologists, climate modellers, engineers and policy makers addressing future flood risks.