Geophysical Research Abstracts
Vol. 17, EGU2015-13178, 2015
EGU General Assembly 2015

Composition and structure of varves in Lake Żabińskie, northeastern Poland: a potential for high-resolution reconstruction of meteorological conditions

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Reconstructions of paleoclimatic and paleoenvironmental data from sediment records require a detailed knowledge of the physical, chemical and biological factors which influence sediment-formation processes and signal preservation in lake sediments. This can be achieved by process studies and high-resolution analysis of sediments that provide an opportunity to calibrate varves and paleolimnological proxies against instrumental hydrological and meteorological data.

Here we present results from Lake Żabińskie located in northeastern Poland with the aim to understand the relationship between meteorological conditions, sedimentation processes and climate signal preservation in varve structure and chemical composition. This eutrophic and hardwater lake exhibits well preserved biogenic varves with high sedimentation rates (5-8 mm/yr). We conducted a three-year long observation of limnological conditions within the water column and recent sediment fluxes as well as analyzed a 70-cm long sediment core from the deepest part of the lake basin covering the last 125 years. Thin sections were prepared and analyzed microscopically for individual laminae composition. We also measured chemical variability within varves using high-resolution XRF scanning of impregnated sediment slabs.

We demonstrate that different mixing patterns may occur in Lake Żabińskie, from dimictic to meromictic depending on the meteorological conditions. Sediment fluxes varied substantially during the observation period with characteristic spring maxima and, optionally, a second late fall maxima. Considerable variability was also observed for the fluxes of total organic carbon, biogenic silica and calcite. Microscopic investigation of the topmost sediments revealed a complex varve structure showing a distinct spring calcite lamina followed by one or more fine calcite laminae interbedded with diatom-rich laminae and, finally, by an organic-rich lamina with minerogenic admixtures deposited during winter. This seasonal variability was also reflected in the chemical composition inferred from high-resolution XRF measurements which allowed for the recognition of individual seasons within one varve. Comparison with long series of meteorological measurements indicates that the length of winter (ice cover duration) and temperature gradients in spring and fall may have major implications for sediment accumulation rates and characteristics of individual varves.