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Spring-temperature variability and eutrophication history inferred from sedimentary pigments in the varved sediments of Lake Żabińskie, NE Poland

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High-resolution, well-calibrated records of lake sediments are fundamental for assessments of climatic and environmental changes. Varved lake sediments are particularly robust archives in this context, providing quantitative insights into climate-state variables at annual resolution. However, due to the multitude of responses within lake ecosystems, the key issue is to understand how climate variability interacts with other environmental pressures such as eutrophication, particularly during the 20th century.

Here we present a multi-proxy record of sedimentary pigments and geochemical data from Lake Żabińskie (Masurian Lake District, North-East Poland) with the aim to detect and differentiate climate-driven changes from other environmental controls. The lake is dimictic, 44-meter deep and ice-covered from January to early March. It exhibits biogeochemical varves with a high content of organic matter (terrestrial and aquatic, macrophytes, algae and bacteria), a simple inorganic composition (predominantly summer-precipitated endogenous calcite) and high sedimentation rates (5 – 8 mm/yr). We analyzed a 51-cm long sediment core from the deepest part of the lake basin covering the last 100 years. Pigments were extracted at 1-cm resolution using High Performance Liquid Chromatography (HPLC). We also measured pigments with Visible Reflectance Spectroscopy (VIS-RS; 380 – 730 nm) to assess whether the down-core resolution could be increased with this rapid non-destructive technique.

We show that the recent eutrophication of Lake Żabińskie can be discriminated from climate-driven change for the period 1907-2008 AD. The eutrophication signal is evidenced by a recent change in the algal community from green algae (rich in chlorophyll a) to more competitive blue-green algae (rich in ß-carotene), which leads to an environment with light-limiting conditions for chlorophyte growth. This provides a basis for the preservation of the climate signal in the sediments.

Using Principal Component Analysis and cluster analysis, we demonstrate that concentrations of chlorins (diagenetic products of chlorophyll a) are not affected by the eutrophication signal, and instead respond to temperature. We calibrated the concentrations of chlorins with meteorological data spatially averaged and downscaled from close stations to the lake site. The results revealed that concentrations of chlorins are significantly correlated to mean spring (MAM) temperature ($r = 0.63$, $p < 0.05$, for AD 1907-2008, 5-yr filtered resolution). These results are consistent with monthly limnological measurements of the lake water column from autumn 2011 to autumn 2013, where the highest chlorophyll a concentrations in the surface water were also found in spring.

Similar performances were gained from scanning VIS-RS-inferred chlorins data on the fresh sediment core. This allows us to extend the chlorins-inferred spring-temperature reconstruction further back in time at high temporal resolution.