Exploring the potential of hyper-spectral imaging for the biogeochemical analysis of varved lake sediments

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Varved lake sediments have successfully been used to make inferences about past environmental and climate conditions from annual to multi-millennial scales. Among other proxies, concentrations of sedimentary photopigments have been used for temperature reconstructions. However, obtaining well calibrated annually resolved records from sediments still remains challenging. Most laboratory methods used to analyse lake sediments require physical subsampling and are destructive in the process. Hence, temporal resolution and number of data are limited by the amount of material available in the core. Furthermore, for very low sediment accumulation rates annual subsampling is often very difficult or even impossible.

To address these problems we explore hyper-spectral imaging as a new method to analyse lake sediments based on their reflectance spectra in the visible and near infrared spectrum. In contrast to other fast and non-destructive methods like X-ray fluorescence, VIS/NIR reflectance spectrometry distinguishes between biogeochemical substances rather than single elements. Rein (2003) has shown that VIS-RS can be used to detect relative concentrations of sedimentary photopigments (e.g. chlorins, carotenoids) and clay minerals.

This study presents an advanced approach using a hyper-spectral camera and remote sensing techniques to infer climate proxy data from reflectance spectra of varved lake sediments. Hyper-spectral imaging allows analysing an entire sediment core in a single measurement, producing a spectral dataset with very high spatial ($30x30\mu$m/pixel) and spectral resolutions ($\sim$1nm) and a higher spectral range (400-1000nm) compared to previously used spectrophotometers. This allows the analysis of data time series at sub-varve scales or spatial mapping of sedimentary substances (e.g. chlorophyll-a and diagenetic products) at very high resolution.

The method is demonstrated on varved lake sediments from northern Poland showing the change of the relative concentrations of chlorin pigments within individual varve years. In a next step absolute concentrations of chlorins derived from HPLC measurements have been calibrated to the spectral data using a linear regression model. This results in a very high-resolution dataset of absolute sedimentary pigment concentrations.
In a second example μXRF measurements are used to validate a spectral index for clay mineral detection.