Introduction

Varved lake sediments have successfully been used to infer climatic and environmental conditions of the past (Trachsel et al., 2010). However, high resolution climate reconstructions at an annual scale for the last 1000 years are often very difficult and can be impossible for very thin varves. Furthermore, subsampling and analysing at annual scale resolution is very time consuming and requires months of intensive laboratory and analytical work. Thus, fast and non-destructive methods to achieve and analyse high resolution data from lake sediments are highly desirable.

We established non-destructive methods like X-ray fluorescence scanner only measure elements rather than substances and are therefore only of limited use. This study presents a new approach using a hyper-spectral camera and remote sensing techniques to infer climate data from reflectance spectra of lake sediments. Reflectance spectra differ according to sediment and to decompose different materials in the sediment. This can be used to map changes and to decompose different materials in the sediment.

Data acquisition & analysis

1. Hyper-spectral scans

The graph illustrates the output of several spectral indices that can be derived from a hyperspectral scan. The indices Min690, R570/630, R590/690 reflect the potential of chlorin concentration within the sediment. The graph shows mean spectra of groups with highest spectral differences (endmembers) Spectra characteristic reflect the sediment decomposition. Prominent spectral features for chlorin at 670 nm can be used to calculate the relative chlorin concentration within the sediment.

2. Spectral endmember extraction

The graph depicts the change of the relative absorption band depth at 670 nm (mean of 29 samples) in a profile through the sediment. The image is a distribution map of the chlorin concentration in the entire core.

3. Output of spectral index calculation

The graph shows the change of the relative absorption band depth at 670 nm (mean of 29 samples) in a profile through the sediment. The image is a distribution map of the chlorin concentration in the entire core.

Example Dataset

Lake Jaczno, Suwalki-region, Poland

- Coordinates: 54° 16′ 32″ N, 22° 52′ 20″ E
- Elevation: ~163 m a.s.l.
- Method: UWITEC gravity corer
- Core length [cm]: 145
- Water depth: ~1 m
- Varve thickness: <1 mm – 5 mm
- Temperature: 2°C
- Salinity: 13 g/l
- Oxygen: 8.5 ml/l
- pH: 7.5
- Chlorophyll-a: <0.01 mg/l
- Chl phaeophytin: <0.01 mg/l
- Total Phosphorus: 0.04 mg/l
- Total Nitrogen: 0.22 mg/l
- Depth [mm]: 550
- Chlorin concentration: 0.15

Summary & Outlook

In this study an example application has been presented to derive climate proxy data from a lake sediment core using remote sensing techniques. The method produces high resolution data on a subvarve-scale which allows annual scale climate reconstructions. The technique is very fast (~15 min/m), completely non-touching and non-destructive. In comparison to other techniques (e.g. Spectrolino) spectral sampling is done over the entire sediment which helps compensating for local anomalies.

The ongoing study is divided in 3 major parts:
1. Hyper-spectral imaging
   - Spectral unmixing
   - Spectral classification
   - Workflow / automation
2. Sediment analysis
   - Sedimentology
   - Geochemistry
   - Dating
3. Climate reconstruction
   - Proxy-proxy
   - Sediment proxy
   - Calibration-in-time

In the first part several techniques to unmix spectral endmembers are being investigated. The endmembers will then be used for classification. Additionally, a workflow how to produce data products will be established and automated where possible.

In a final step, all the information is put together to produce an annual scale resolution climate reconstruction.

References

REIN, B. (2003). In-er Robbinterkate Spektroskopie-und digitale Bildanalyse. Gewinnung hochauflösender Paläowasserstande mit fernerkundlichen Methoden, Heidelberg, 104 pp., Univ. of Mainz, Mainz, Germany