Hyper-spectral imaging of lake sediments

Christoph Butz[1], Martin Grosjean[1], Wojciech Tylmann[2]

[1]Oeschger Centre, University of Bern, Switzerland, [2]Gdansk University, Poland

Introduction

Varved lake sediments have sucessfully 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.

Well 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 decomposition. This can be used to map changes and to decompose different materials in the sediment.

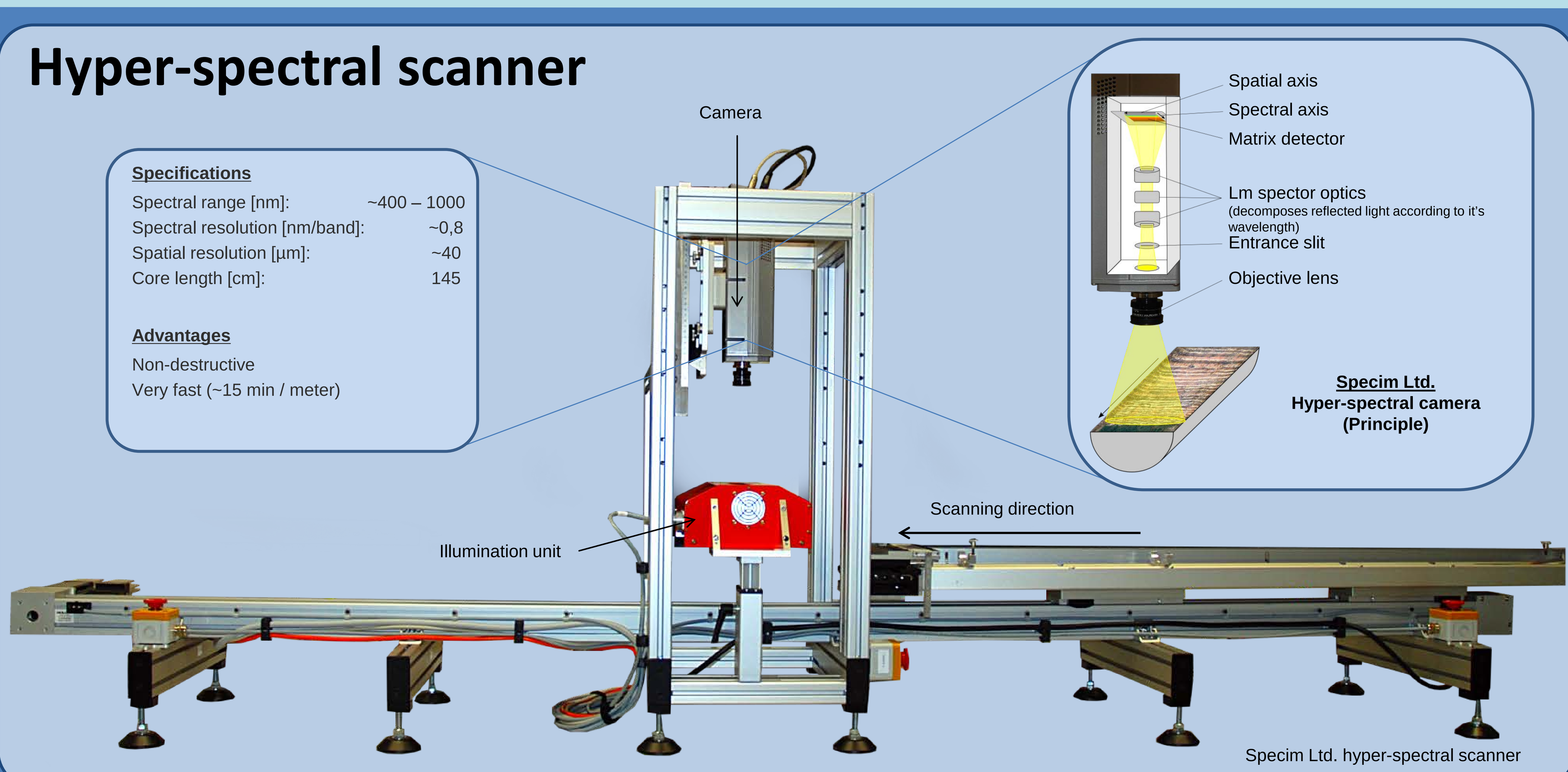
Hyper-spectral scanner

Specifications

Spectral range [nm]:	~400 – 1000
Spectral resolution [nm/band]:	~0,8
Spatial resolution [µm]:	~40
Core length [cm]:	145

Advantages

Non-destructive
Very fast (~15 min / meter)



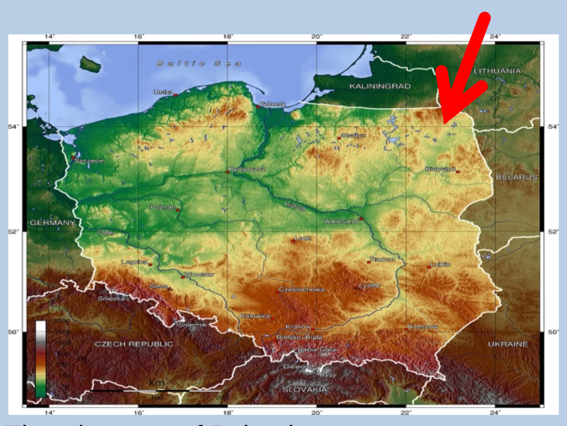
Specim Ltd.
Hyper-spectral camera
(Principle)

Specim Ltd. hyper-spectral scanner

Study site

Lake Jaczno, Suwalki-region, Poland

Coordinates:	54° 16'26.3"N 22° 52'20.3"E
Elevation:	~163 m a.s.l.
Method:	UWITEC gravity corer
Varve thickness:	<1mm – 5mm
Waterdepth:	22.6 m

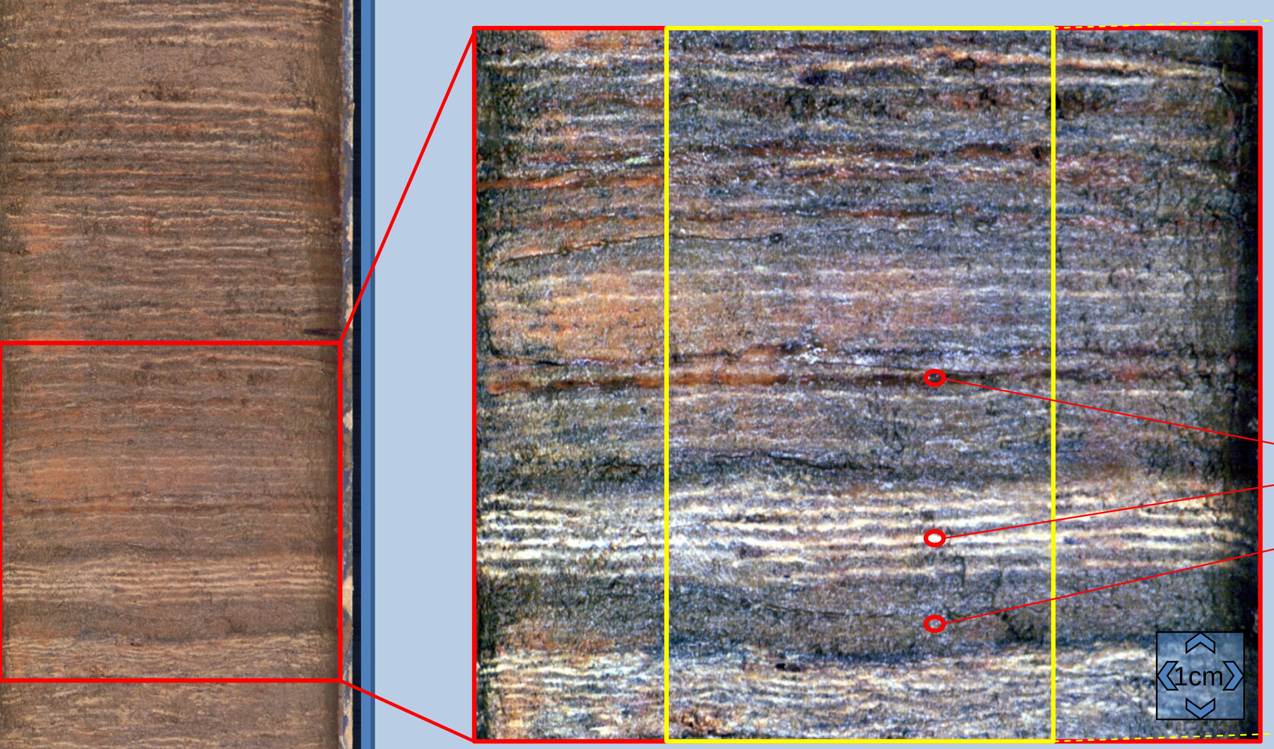


Elevation map of Poland,
The red arrow marks the study site

Photography of lake Jaczno, northern basin,
View is roughly south

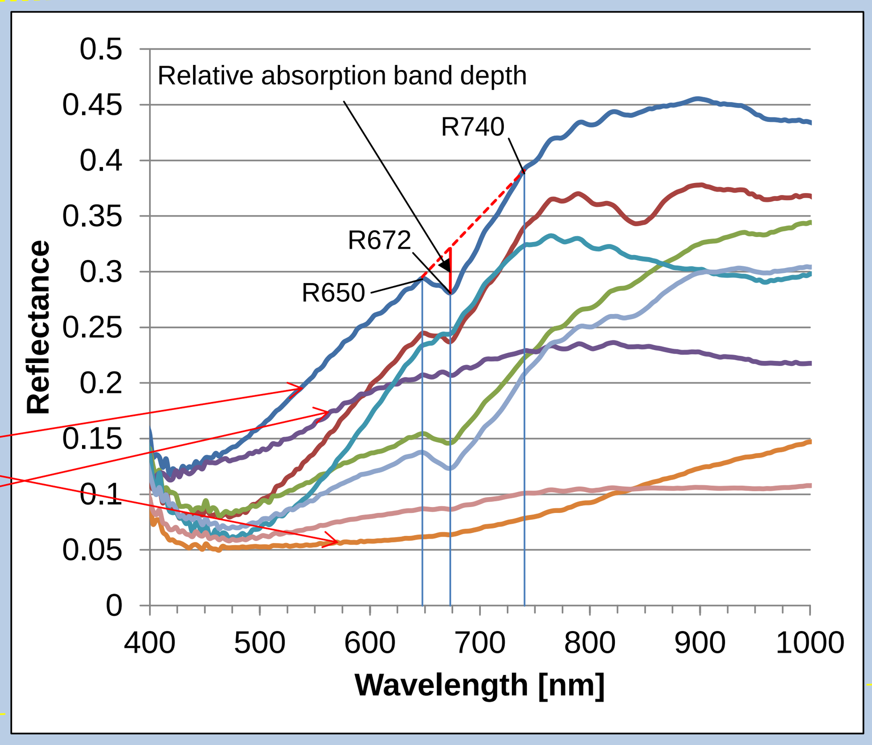
Recovery of the sediment core, southern basin

Data acquisition & analysis



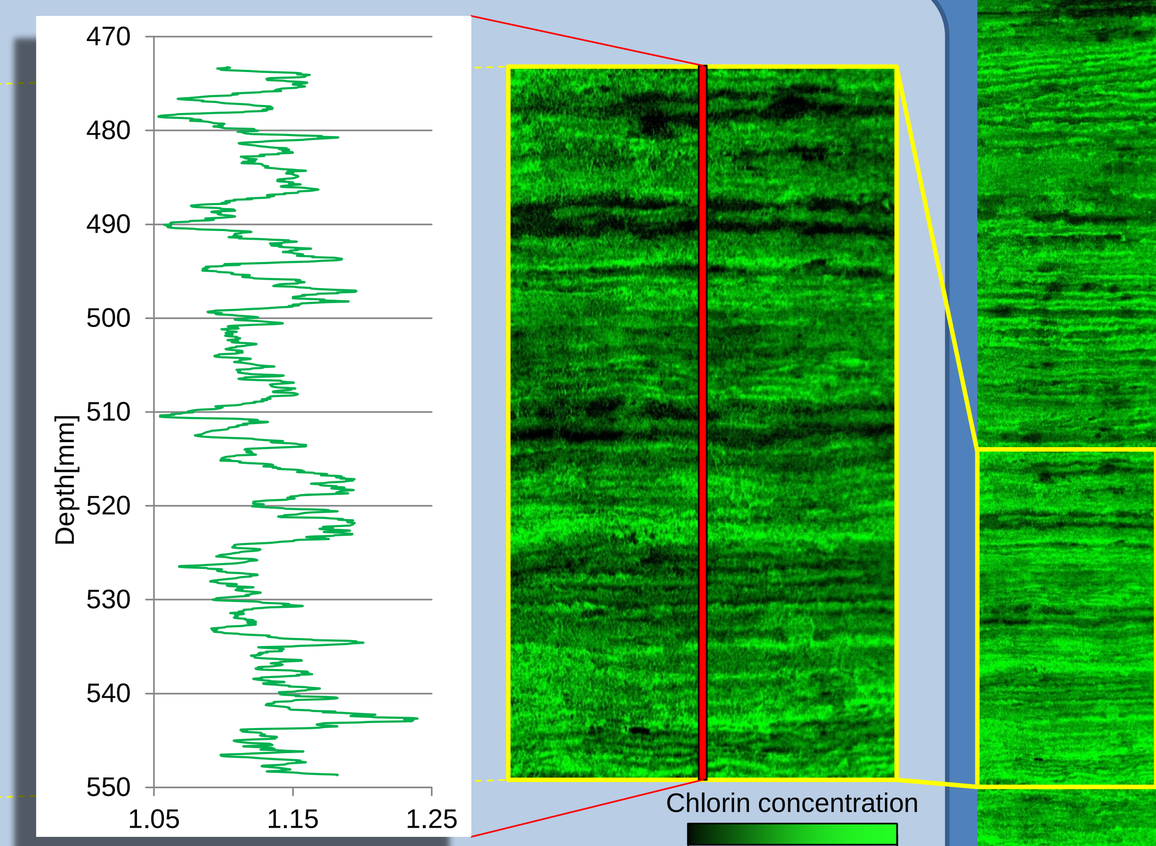
1. Hyperspectral scans

Magnified and contrast enhanced sample of a hyper-spectral scan in truecolor configuration.
Within a spectral range of 400 – 1000 nm 196 measurements were taken. Spatial resolution is ~70µm/pixel.



2. Spectral endmember extraction

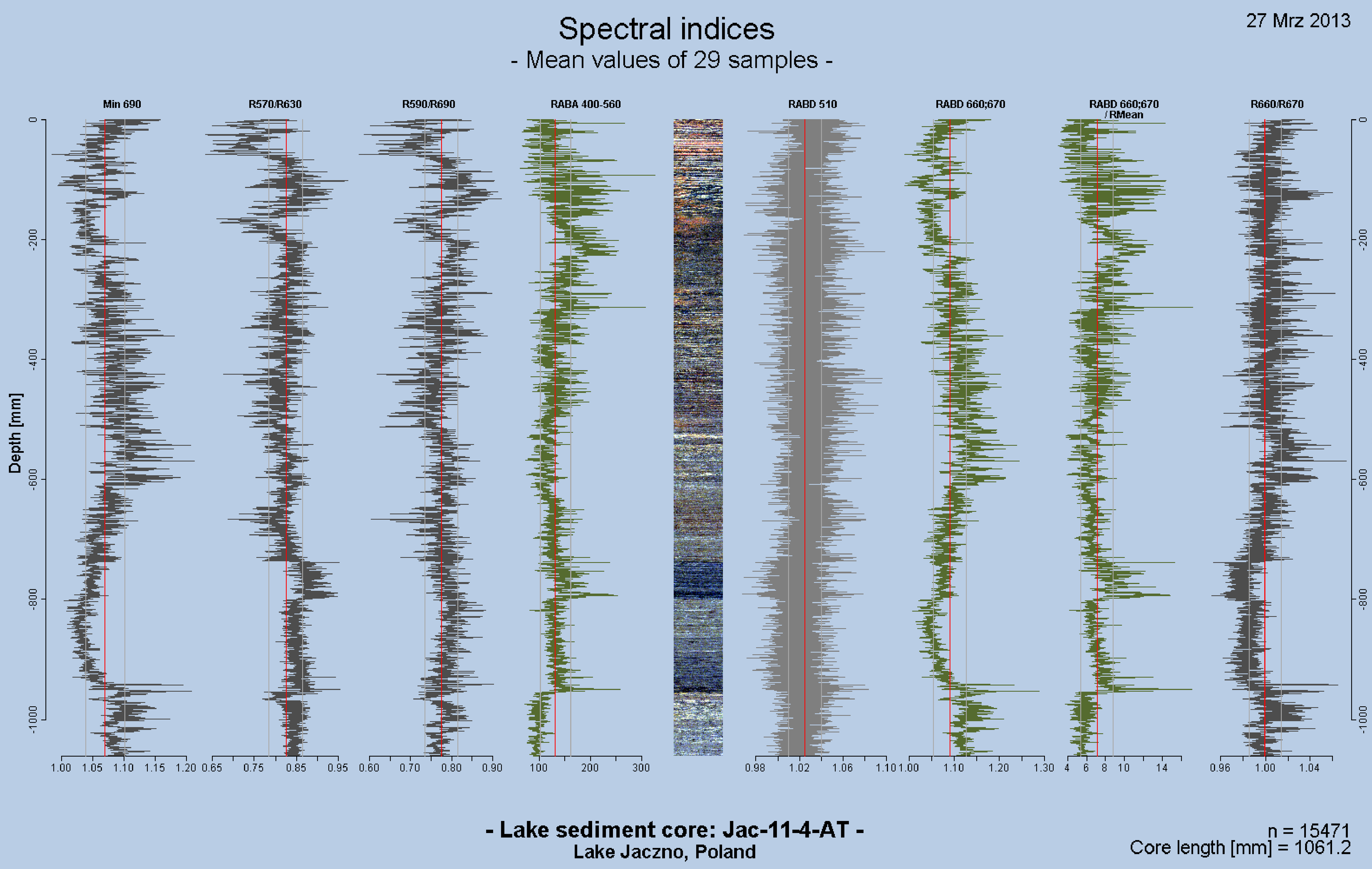
The graph shows mean spectra of groups with highest spectral differences (=> endmembers)
Spectra characteristics reflect sediment decomposition. Prominent absorption features like the one for chlorins at 670 nm can be used to calculate the relative chlorin concentration within the sediment.



3. Output of spectral index calculation

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.

Example Dataset



This 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 influences of clay minerals. The indices $RABA_{400\text{-}560}$, $RABD_{660;670}$ & $RABD_{660;670}/R_{mean}$ are highly correlated to the variance in total organic carbon and can also be linked to chlorphyll. $RABD_{510}$ explains variances in the carotenoid concentration and the Ratio $R_{660/670}$ explains the degree of diagenesis.

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 (~15min/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.

The second part consists of «traditional» sediment analysis. The sedimentological and geochemical properties are determined and will be compared with the hyper-spectral signal in a proxy-proxy approach.

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

References

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TRACHSEL, M., GROSJEAN, M., SCHNYDER, D., KAMENIK, C., REIN, B, 2010. Scanning reflectance spectroscopy (380–730 nm): a novel method for quantitative high-resolution climate reconstructions from minerogenic lake sediments. Journal of Paleolimnology 44, 979-994. doi 10.1007/s10933-010-9468-7.

Contact

christoph.butz@giub.unibe.ch

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