Laboratory hyperspectral imaging a powerful tool for a fast-high-resolution analysis of natural sample: application to sediment core

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Photography encouraged

Sedimentary cores are used, thanks to their physical, chemical and biological properties, to infer past climate and environment. Sampling methods (millimeter or centimeter) and routine analysis are destructive, non-spatially resolved, time-material consuming and can be expensive. Hyperspectral Imaging (HSI) merges the advantages of spectroscopy (non-destructive, fast analysis, structurally informative) and of imaging (high resolution, pixel spatially referenced, spatially informative). Coupling hyperspectral imaging with data mining methods can be used to monitor concentration variations of sediment compounds, classify or discriminate proxies at micrometric scale in each area of the core.

1. Material

A. Sediment core:

A core from Lake Le Bourget (Western Alps, France) was cored in 2009 at 145 m depth (53 cm long and 9 cm width). Two main areas are observed, the first half is characterized by strata ; no clear pattern is observed in the second half.

B. Hyperspectral imaging:

A hyperspectral image (HSI) is an image with high spatial resolution, in which each pixel contains a spectrum with a continuous spectral resolution.

Two hyperspectral sensors (Specim) from the M2C laboratory (Rouen, France) were used:

- Visible Near InfraRed
  VNIR, 400-1000 nm, pixel size: 60 µm
- Short Wave InfraRed
  SWIR, 1000-2500 nm, pixel size: 200 µm

The acquisition by each sensor takes 15 minutes for a 1.5 m core.

C. Sedimentological analysis:

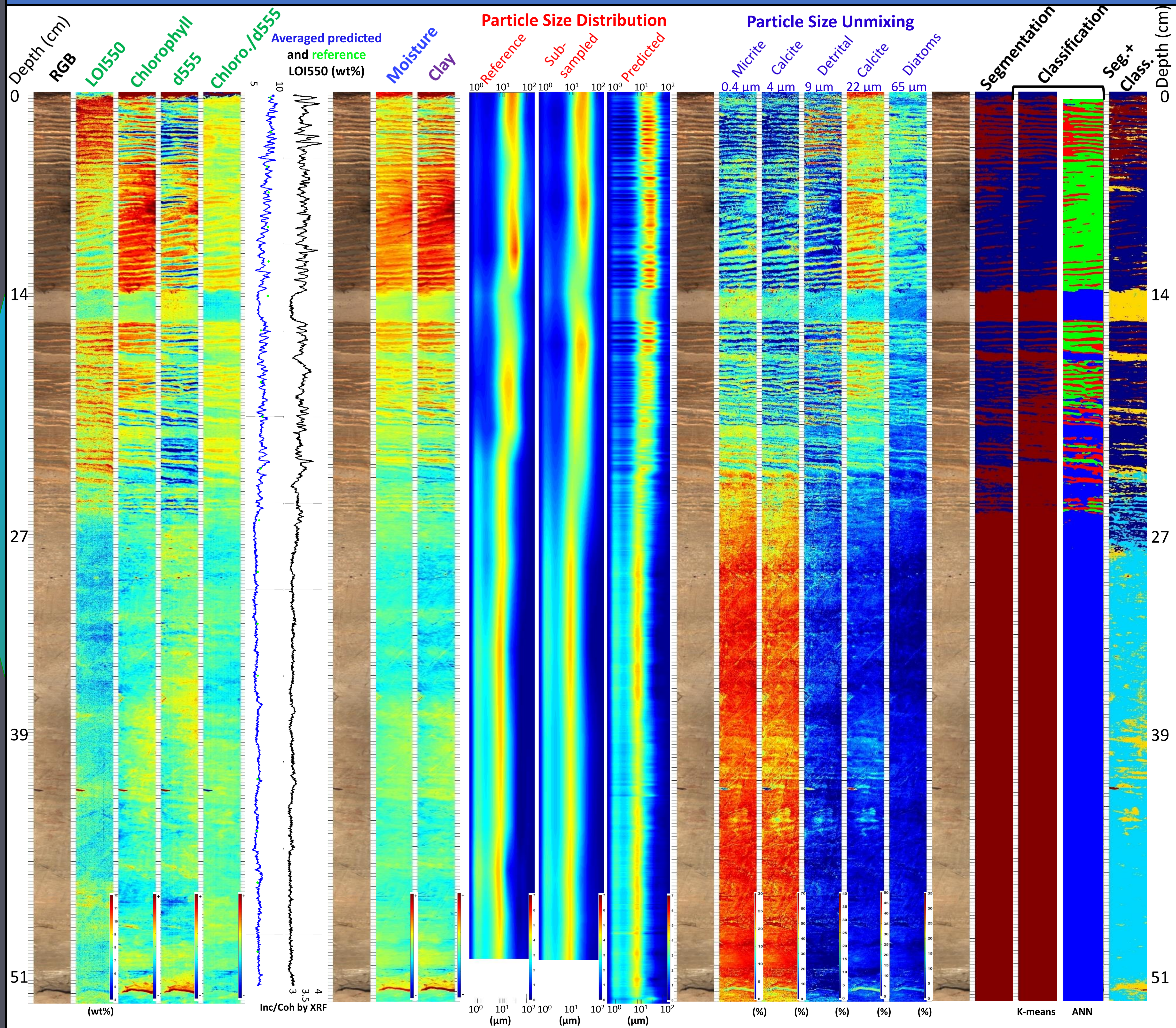
Some destructive analysis were made (Loss On Ignition, Grain Size, Thin Section, RockEval) and non-destructive (X-Ray Fluorescence). They are used to calibrate predictive models or qualitative indices.

2. Spatial registration

The hyperspectral images can be combined to homogenize the spatial resolutions with registration (low resolution: 200 µm) or data fusion (high resolution: 60 µm) methods. The combination of these sensors allows to improve prediction with an increase of spectral information that is linked to structural properties.

XRF can also be registered in the same hyperspectral area, to calibrate or compare both methods.

4. Results



3. Relevant information extraction

A. Qualitative indexes:

Several wavelengths are known to bring qualitative structural information on some compounds (2200 nm: clay, 1450 nm: moisture, 555 nm: iron oxide).

A combination of some wavelengths is also used as qualitative indices (RABA650-700: chlorophyll).

B. Quantitative model:

Partial Least Squares Regression (PLSR) is used to link reference values (PSD, LOI) with hyperspectral spectra to estimate spectral regression coefficients. Wavelength selections are also used to reduce the redundancy of wavelengths and increase the model robustness. This model is then used on all the spectra of the hyperspectral image to obtain an abundance map (Jacq and al., 2019).

C. Image processing:

The spatial dimension allows to segment the sediment structures of the different maps or images. Lamination of the Bourget core corresponds to a triplet of lamina (white, light-gray, dark-gray). Only two can be found (white-dark) by image processing that is better than classifications (k-means, artificial neural network). This was done with the contrast limited adaptive histogram equalization algorithm to enhance locally the contrast between the two sediment structures. The last difficulty to overcome is to discretize each laminae.

5. Future works

Property maps combination would allow to obtain a higher relevance information (depositional sediment sources with PSD, organic matter origins).

A spatio-spectral approach would allow to characterize each laminae at the chemical, biological, physical levels. It could also reveal lamina patterns.

Hyperspectral imaging and data mining show great possibilities to monitor proxies at high resolution, especially thanks to the two dimensions (spatial and spectral) to study variations down and cross core or structures (laminae, flood). Visible and Near Infrared spectral ranges allow to estimate some properties as particle size, organic matter, moisture, pigment, colored oxide… Using others spectral ranges as fluorescence, Raman could allow to increase the panel of estimated compounds with for example mineralogy, pollutant (PAHs), specific organic matter… All these sensors (VNIR, SWIR, fluorescence, Raman) will be gathered in a benchtop core logger that is under development at EDYTEM laboratory.

Jacq, K., Perrette, Y., Fanget, B., Sabatier, P., Coquin, D., Martinez-Lamas, R., Debret, M., Arnaud, F., 2019. High-resolution prediction of organic matter concentration with hyperspectral imaging on a sediment core. Sci. Total Environ. 663, 236–244. https://doi.org/10.1016/J.SCITOTENV.2019.01.320
Giguet-Covex, C., Arnaud, F., Poulenard, J., Enters, D., Reyss, J.-L., Millet, L., Lazzaroto, J., Vidal, O., 2010. Sedimentological and geochemical records of past trophic state and hypolimnetic anoxia in large, hard-water Lake Bourget, French Alps. J. Paleolimnol. 43, 171–190. https://doi.org/10.1007/s10933-009-9324-9