Hyperspectral imaging for lake sediment cores analysis

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Sampling methods (millimeter or centimeter) and routine analyses of cores are destructive and non-spatially resolved. Furthermore, these methods are time consuming and can be expensive. Hyperspectral Imaging merges the advantages of spectroscopy (non-destructive, fast analysis) and of imaging (high resolution, pixel spatially referenced). Coupling hyperspectral imaging with data mining methods makes possible to study several proxies at micrometric scale in each area of the core. This global process is able to monitor concentration variations of major sediment compounds, classify or discriminate proxies. The versatility of this methodology is illustrated by two applications on a core from the lake Le Bourget (Western Alps, 53cm long and 9cm width).

Hyperspectral imaging:

The acquisition was made at the M2C laboratory (Rouen, France) with two hyperspectral cameras: Visible Near InfraRed (VNIR, 400-1000nm, pixel size: 60µm) and Short Wave InfraRed (SWIR, 1000-2500nm, pixel size: 189µm) in less than 5 minutes each for a 53cm core. VNIR image is composed of 8643x813 pixels and SWIR image of 2801x271.

Grain size and LOI predictions by PLS:

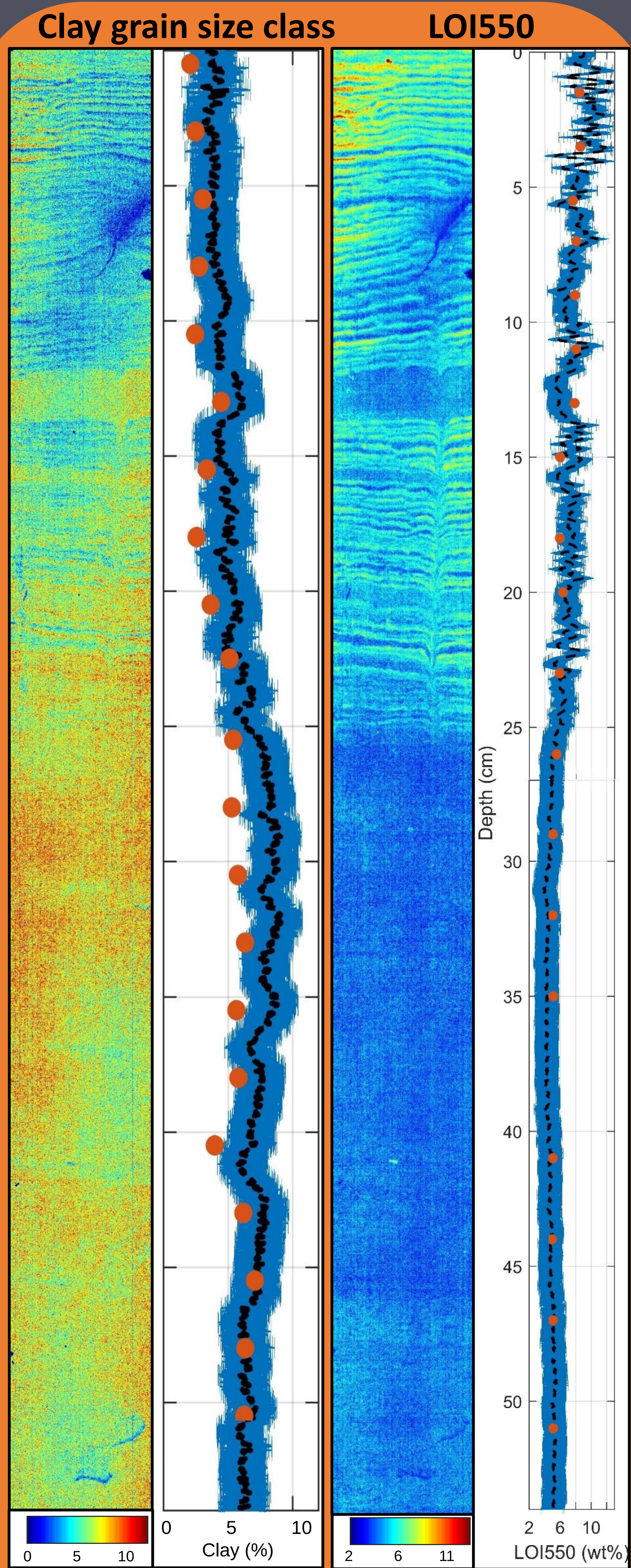
Partial **L**east **S**quares is a chemometric method based on the extraction of orthogonal predictor variables (also called latent variables LVs) corresponding to the maximum of variability in the spectra linked to one or several predicted variable(s) (Wold and al., 1984).

To create a model, 2/3 of the reference values (grain size classes, LOI…) are linked to SWIR spectra of the corresponding sampling depth to estimate regression coefficients. Prediction performances are then calculated with the remaining data. Spectral pretreatments may be used to correct scattering effects. Wavelength selections are used to reduce the redundancy of the spectra and increase the robustness. This model is then used on all the spectra of the hyperspectral image to obtain an abundance map.

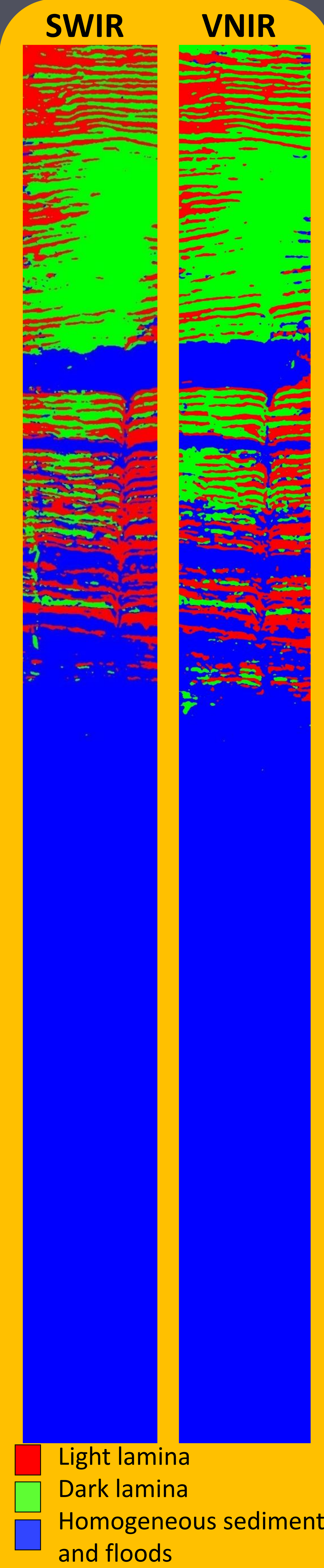
Laminae discrimination and counting by Artificial Neural Network ANN:

This algorithm is composed of connected artificial neurons that process the data and share it to next neurons to resolve a problem. For our study, ANN search spectral information to discriminate a number of groups defined by a user for the creation of a classification model.

It is created with less than 1% of the images (VNIR or SWIR) labeled in some group. In these examples, three groups are characterised (light and dark lamina, homogeneous sediment or floods). The created models are used on all the spectra to obtain a labeled map. Then, image processing is used to take into account the neighborhood, that can correct miss-classification. These maps can be used to count the lamina in each column of the image.



Determination coefficient R^2 of the two SWIR models are 0.79 (Clay grain size class, n=21, 5LVs) and 0.76 (LOI550, n=19, 5 LVs). Average predictions (dark) are compared to the reference values (orange point) and seems to follow the same trend. Variations inside each stratigraphic unit event at the scale of laminae can be studied at 189µm.



Accuracy of the 2 camera lithology classification models are 97.3% (SWIR) and 98.4% (VNIR). Then, it is possible to estimate the number of lamina : 136±2 (SWIR), 140±2 (VNIR), with eye counting it is 134±5.

Hyperspectral imaging and data mining show great possibilities to monitor proxies at high resolution down and cross core. These two types of hyperspectral images can be combined with data fusion methods to improve prediction with an increase in spectral information that is linked to chemical and physical properties. Other imaging techniques (fluorescence, Raman…) can be used with them to add other variabilities. After model creations, prediction results can also be combined to have informations inside each stratigraphic unit to infer paleoenvironment and paleoclimate.

Some studies on scale effects (pixel size ~µm, sampling resolution ~cm), calibration range and uncertainty maps are still to perform.

Wold, S., Ruhe, A., Wold, H., & Dunn, III, W. J. (1984). The Collinearity Problem in Linear Regression. The Partial Least Squares (PLS) Approach to Generalized Inverses. *SIAM Journal on Scientific and Statistical Computing*, *5*(3), 735–743. http://doi.org/10.1137/0905052