Development of optical tools to quantify algal biomass and identify dominant taxa

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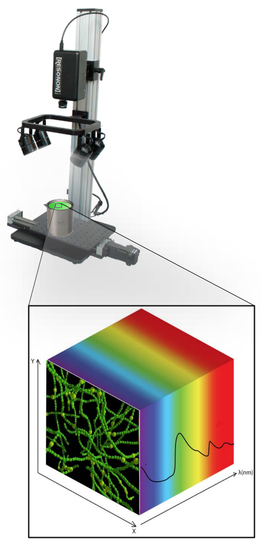
- To study the response of phytoplankton and particularly of bloom formers to changing environmental conditions, water sampling and standard laboratory analyses are often insufficient considering the spatiotemporal variability of this phenomenon.
- Airborne hyperspectral sensors could allow the mapping of algal biomass and HABs with a high spatio-temporal resolution at the local (drone) and regional (satellite) levels, with the distinction of different optical groups of algae.

The objectives of this study are to generate a library of spectral signatures by the three main optical groups of algae (blue-green, green and golden-brown taxa);
Test the interfering effect of the other optically active components (chromophoric dissolved organic matter or CDOM, inorganic particles or TSS) that are abundant in freshwaters;
Develop optical indicators and a deconvolution algorithm to quantify the algal biomass of each groups that can be exploited in hyperspectral imagery.

METHOD

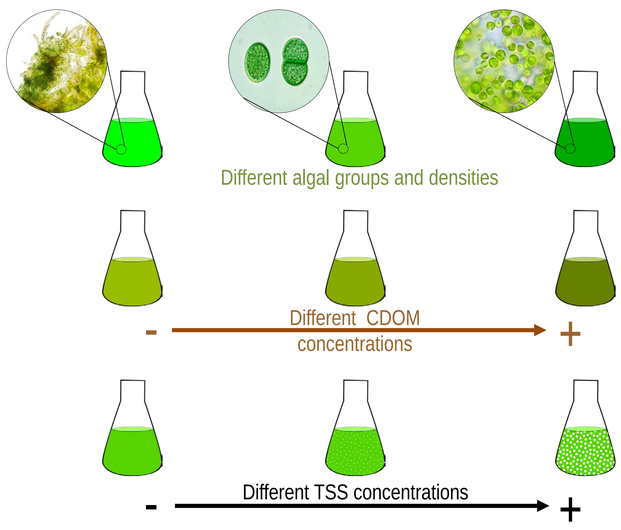
Using a laboratory-adapted device, a container with monospecific algal suspensions of variable densities and different proportions of interfering substances (inorganic particles, dissolved organic matter) is scanned to form a reflectance datacube, analyzed with the Spectronon Pro software. A datacube is defined as a three dimension image: two spatial dimensions (x,y) and one spectral (λ).

We are using two hyperspectral cameras from Resonon: Pika II (reflectance between 400 and 900 nm) and Pika NIR (reflectance in the near infrared, between 900 and 1700 nm).



BUILDING A SPECTRAL LIBRARY

The use of hyperspectral sensors is booming because of its high spectral resolution compared to multispectral remote sensing. However, no study has yet provided a library of spectral signatures for different phytoplankton groups (blue-green, green, golden-brown) with variable morphologies (unicellular/colonies, filamentous/picoplanktonic, small/large-cells) and physiological states (exponential growth, stationary phase). The signature is obtained for a range of cell densities, in presence of interference factors and for species mixtures.



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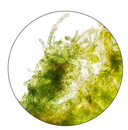
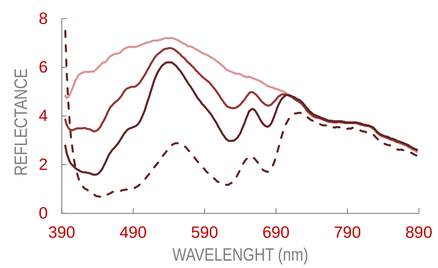
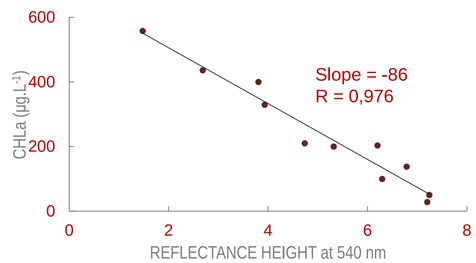
PRELIMINARY RESULTS

Below on the left, examples of spectral signatures from two cyanobacteria (continuous line: exponential growth phase, dotted line: stationary growth phase) and one green algae (only stationary growth phase) at different densities. The spectral shape between 610 and 655 nm is characteristic of cyanobacteria (phycobiliproteins) and allows to distinguish them from the other optical groups. A clear pattern in the signature appears for the stationary phase between 690 and 740 nm where the signal gets higher than at the 540 nm peak. We are testing the relationship between different reflectance indices and chlorophyll-a concentrations (Chla). Below on the right, the correlation between the reflectance height at 540 nm and Chla (fluorimetric quantification). The slopes differs between taxa, precluding the use of this too simple proxy to estimate the biomass from algal mixtures; more sophisticated indices will be developed.

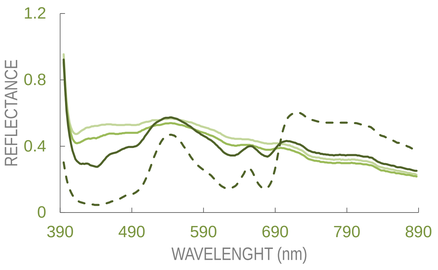


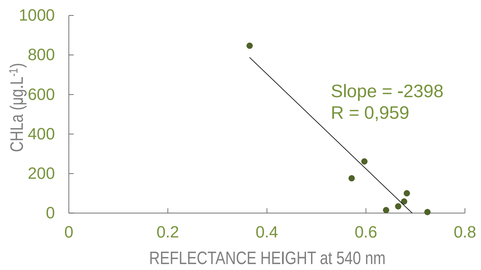
Anabaena sp

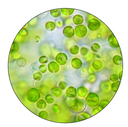




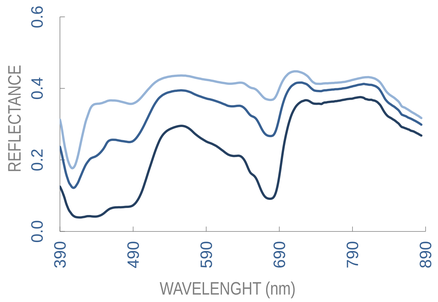
Synechococcus sp

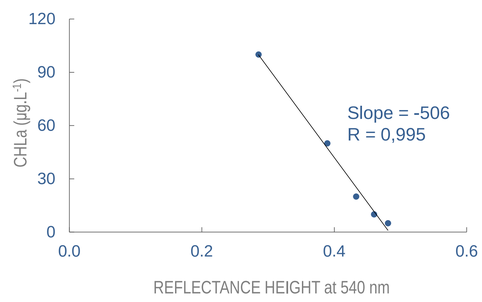






Chlorella sp





PERSPECTIVES

The project will ultimately lead to the development of a model to quantify algal biomass during the development of bloom episodes, and to identify its main actor (the algal group most contributing to the biomass). This innovative approach will contribute to better identify the controlling factors promoting the development of HABs in lakes and coastal marine systems, to map the progression of a bloom in sensitive areas like beaches, and potentially inform decision makers on most promising strategies for the restoration of lakes experiencing accelerated degradation.

The use of hyperspectral imagery will definitely improve the spectral and spatial resolution of HAB remote sensing. HAB monitoring needs to be done combining several tools, including the use of *in vivo* fluorescence probes that can improve the temporal resolution at a specific site, and detect biomass accumulation deeper in the water column (e.g. metalimnetic development). This is another part of my thesis that has not been presented here. A comparison in the performance of these tools will be done.