Challenges for mapping cyanotoxin patterns from remote sensing of cyanobacteria

cyanobacterial toxins

Cyanotoxins are toxins produced by cyanobacteria (also known as blue-green algae). Cyanobacteria are found almost everywhere, but particularly in lakes and in the ocean where, under high concentration of phosphorus conditions, they reproduce exponentially to form blooms.

goal & challenges

Using satellite imagery to quantify the spatial patterns of cyanobacterial toxins

challenges: cyanotoxins cannot be directly detected by remote sensing

state-of-the-art: A dual-model strategy

chlorophyll-a (Chl-a) or phycocyanin (PC) collected in situ as a surrogate to estimate the MC concentration + remote sensing algorithm to estimate the concentration of the surrogate pigment.

To detect pigments by satellite, three classes of algorithms (analytic, semi-analytic, and derivative) have been used…derivatives are more commonly used

Surrogate identification

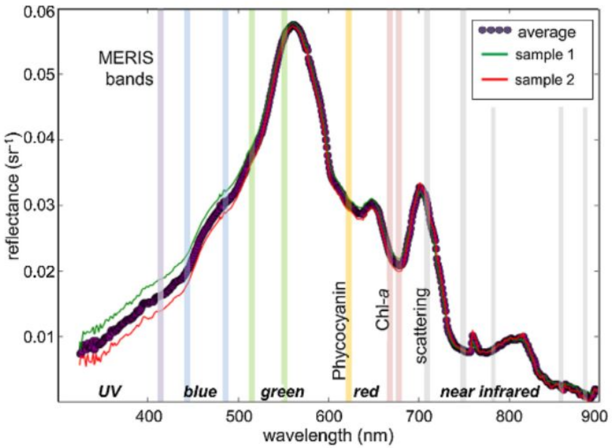
Chl-a is a common metric for algal biomass and is used as a reference for cyanobacterial blooms

Phycocyanins

(PC) are recognized as indicators of cyanobacterial presence

The decision on whether to use Chl-a or PC depends on three

factors: availability, specificity, and sensitivity.



Modeling microcystin–pigment relationships

the specific concentration of MC to pigment (the ratio of concentrations) can be expected to vary for many reasons (environment,...)

The stability of these MC-pigment ratios for toxin estimation warrants closer inspection !

These variations indicate that the relationships cannot be assumed to be fixed throughout the season and also that the two pigments can have different behaviors relative to MC.

Capturing the temporal variability in order to establish and maintain accurate models between MC and the pigments will require routine monitoring programs in the lakes of interest.

Modeling pigments from satellite

Analytical approaches

Analytical approaches solve simplified forms of the radiative transfer equation to extract the spectral absorption of the various constituents (phytoplankton, CDOM, sediment) from the calculated water reflectance.

quite effective with field data collected by radiometry., The challenge in applying analytical approaches to satellite data is the need for accurate water reflectance as an input, which requires an accurate atmospheric correction ⇒ difficult task

semi-analytical approaches

still requiring an accurate atmospheric correction

more robust than analytical solutions in that the calculation is a ratio

Failure still occurs with negative reflectances, and large biases will occur when the input water reflectance is severely underestimated

Ratio algorithms have particular value to sensors with few bands such as Landsat

Derivative approaches

These algorithms are all take the form of second derivatives

that second derivatives implicitly remove most of the atmospheric signal, making them more robust than the analytical and ratio methods.

The methods can be applied under conditions of mild sun-glint, because glint is spectrally flat

these algorithms have become the most common method used for bloom analyses and routine monitoring

$$SS(\lambda) = R(\lambda) - R(\lambda_-) + (R(\lambda_-) - R(\lambda_+)) \frac{(\lambda - \lambda_-)}{(\lambda_+ - \lambda_-)}$$

Conclusion

Cyanotoxins cannot be directly measured with remote sensing

a dual-model strategy for remote sensing

A relationship between MC and either

Chl-a or PC can remain constant for days to weeks within a lake.

Over longer time intervals, a fixed parameterization may lead to large errors in estimated MC concentrations, therefore the parameterization should be validated every few weeks and adjusted as necessary. While PC is the better surrogate for mixed blooms, Chl-a is the superior surrogate for blooms dominated by cyanobacteria. Chl-a has a stronger optical signature than PC, it is more stable within the cells, the laboratory methods are standardized, and it is more frequently measured.