HICO Data User's Proposal

Exploring the Potential for Harmful Algal Bloom Species Discrimination Using HICO Hyperspectral Imaging

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Abstract

Lake Erie and Lake Winnipeg are two North American inland waters heavily impaired by the effects of intense, recurring, and potentially harmful algal blooms. Satellite monitoring of these blooms is currently in place using the broad spectral and spatial resolution of MODIS-Aqua. The spectral resolution of MODIS allows for a robust indicator of total algal biomass through the chlorophyll-a absorption band. Knowing the composition of these blooms, however, is of considerable value to water resource managers. HICO presents the opportunity to investigate the potential for algal bloom composition discrimination using its enhanced spectral resolution to detect specific pigment absorption features attributable to particular algal/cyanobacterial groups of interest. We aim to combine in situ measurements of optical properties, biogeochemical constituents, and algal assemblages, with radiative transfer modeling and statistical analyses, in the deconvolution of the hyperspectral reflectance signature to retrieve algal bloom composition on these lakes.

Statement of Work

Excessive growth of nuisance/harmful algae in inland waters gives rise to significant socioeconomic and ecological impact, with concerns such as taste & odour, toxicity, fouling (nets, water intakes), anoxia, fish/wildlife mortality, and influencing recreational/tourist industries and property values. Lake Erie is the most severely impaired of the Great Lakes, with the western basin in particular being prone to intense algal blooms. Lake Winnipeg is also noted for its deteriorating water quality driven by recurring intense algal blooms[1]. Both are the focus of new Environment Canada initiatives to work towards improving water quality and particularly reducing the frequency and extent of these potentially harmful algal blooms. Environment Canada's aquatic optics and remote sensing group have developed methods for satellite monitoring of water quality (algal blooms, suspended minerals, water clarity). Empirical, inverse modeling and multivariate statistical procedures applied to MODIS and MERIS imagery have enabled both assessments of historical change and prompt near-real-time observations of water quality over these water bodies[2-5]. The value that HICO offers is in its enhanced spectral resolution which will allow the exploration of methods for discriminating algal bloom composition. Not all algal blooms are necessarily harmful and certainly not all are toxic, and so methods that allow such discrimination offer significant advances in our ability to manage risks to our environment and health.

Four cyanobacterial genera (*Microcystis, Planktothrix, Anabaena* and *Aphanizomenon*) are of key interest and relevance to this work and dominate the blooms in the study lakes[6,7]. All are buoyancy controlling cyanobacteria which can potentially form surface scums or subsurface layers and include a range of morphologies which influence their optical properties. *Microcystis and Planktothrix* are non N_2-fixing cyanobacteria which differ dramatically in morphology and pigmentation but include species that are known to produce the potent hepatotoxins microcystins[8]. *Microcystis,* one of the most prevalent bloom-forming taxa in the more eutrophic areas of the Great Lakes, is typically characterized by macroscopic colonies of individual cells embedded in a spherical or lobed mucilaginous matrix ranging up to ~500mm in size. *Planktothrix* is a filamentous cyanobacteria which occurs as single strands and is well adapted to low light environments[9,10]. In contrast both *Anabaena* and *Aphanizomenon* are N_2-fixing filamentous taxa, they include species that occur as single filaments or as large, often macroscopic coiled or raft-like colonies. Species of *Anabaena* can produce hepatotoxins

and neurotoxins, and have been linked to taste and odour events through the production of the earthy-muddy metabolite geosmin[11]. *Aphanizomenon* is extremely common across all these lakes. While largely non-toxic, blooms of *Aphanizomenon* can produce thick surface accumulations under favourable conditions, the decay of which contribute significantly to anoxia.

The intention of this project is to explore the potential of hyperspectral imagery for extracting information on algal bloom composition within both Lake Erie and Lake Winnipeg. Satellite observations of algal biomass rely on quantifying spectral changes in the water-leaving radiance brought about by the absorption and scattering properties of the algal cells and pigments. One method of detecting cyanobacterial biomass from satellite aquatic colour imagery is based on the absorption features of phycocyanin, a light-harvesting pigment found in many strains of cyanobacteria. Phycocyanin absorption has a unique peak around 620 nm which can be seen clearly in particulate absorption spectra of eutrophic waters (Figure 1). Phycoerythrin, the pigment responsible for the red coloration of *Planktothrix*, has an absorption peak at 495 nm. These specific pigment absorption signals result in notable depressions in the remote sensing signal (Fig. 2) which may be quantified to infer algal composition.

We have 2-3 field surveys scheduled each year for the next three years in order to acquire in situ optical properties, biogeochemical constituents, and algal assemblage information, under varying bloom conditions. In addition, quantifying the optical cross sections on lab-grown cultures of individual strains will contribute to the development of inverse modeling approaches to extract bloom composition from HICO spectral reflectance.

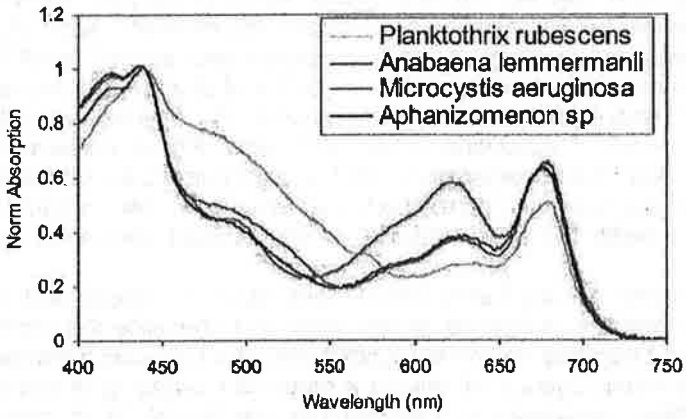

Figure 1: Spectral absorption signatures of key cyanobacteria species of interest.

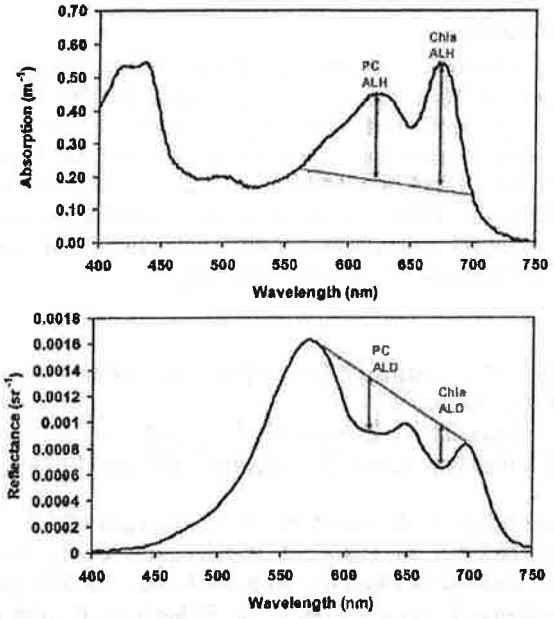

Figure 2: Spectral absorption and coincident reflectance signatures during an aphanizomenon bloom showing phycocyanin absorption and associated depression of the reflectance spectrum.

Biography & Facilities

The aquatic optics and remote sensing team with Environment Canada's Watershed Hydrology and Ecology Research Division conducts research on aquatic colour remote sensing for water quality applications relevant to EC's mandate to protect and conserve the resources of freshwater ecosystems. Dr Caren Binding completed her PhD in remote sensing of shelf sea suspended sediments after which she was invited on a NSERC visiting fellowship to study in a Canadian Government Laboratory. Dr Binding has 13 peer-reviewed publications on satellite remote sensing of aquatic colour and aquatic optics and has extensive experience in satellite image processing, having developed a dedicated image processing workstation for fully autonomous near-real-time processing of MODIS and (until recently) MERIS for inland water quality applications. The team is experienced in the use of SeaDAS, IDL, BEAM and MATLAB for image processing and maintains sufficient server capacity to allow for HICO image processing.

We have available to us a suite of research vessels allowing field surveys on Lakes Erie and Winnipeg to acquire in situ optical property and biogeochemical data under varying algal bloom conditions. The group operates Wetlabs AC9 and spectral bb sensors, Satlantic HyperPRO, as well as algal species discrimination instrumentation based on spectral fluorescence unmixing algorithms.

Output & Deliverables

With the successful acquisition of in situ IOPs, AOPs, biogeochemical and algal constituents, the project will provide a comprehensive database for validation of HICO imagery and processing steps over optically complex, turbid, eutrophic waters. In addition the project aims to develop methods to discriminate algal assemblages from hyperspectral reflectance, these methods and final mapped products would be made available to the HICO team. Results and developed methodologies will be prepared for publication in peer-reviewed journals. Funding and availability permitting, results will also be presented at the annual HICO team meeting.

References

[1]Environment Canada. 2011. State of Lake Winnipeg: 1999 to 2007 – Highlights. Cat. No. En4-149/2011E. 28pp.

[2]Binding, C. E., Greenberg, T. A., Bukata, R. P. 2012. An analysis of MODIS-derived algal and mineral turbidity in Lake Erie. *Journal of Great Lakes Research*, 38 (2012), pp. 107-116

[3]Binding, C. E., Greenberg, T. A., Jerome, J. H., Bukata, R. P. 2011b. Time series analysis of algal blooms in Lake of the Woods using the MERIS maximum chlorophyll index. *Journal of Plankton Research*, doi: 10.1093/plankt/fbr079.

[4]Binding, C. E., Greenberg, T. A., Jerome, J. H., Bukata, R. P. and Booty, W. G. 2011a. An assessment of MERIS algal products during an intense bloom in Lake of the Woods. *Journal of Plankton Research*, 33(5):793-806.

[5]Binding, C. E., Jerome, J. H., Bukata, R. P. and Booty, W. G. 2009. Suspended particulate matter in Lake Erie derived from MODIS aquatic colour imagery. *International Journal of Remote Sensing*, in press.

[6]Watson S B., Ridal J. & Boyer, G. 2008 Taste and odour and cyanobacterial toxins: impairment, prediction, and management in the Great Lakes. Can. J. Fish. Aquat. Sci. 65(8): 1779-1796

[7]Kling HJ, Watson SB, McCullough GK, Stainton MP 2011. Bloom development and phytoplankton succession in Lake Winnipeg: a comparison of historical records with recent data. Aquat. Ecosyst. Health Mgmt. 14 (2, 2011) : 219-224

[8]Huisman J, Matthijs HC, Visser PM. (eds) (2005) Harmful Cyanobacteria. Springer, Dordrecht, The Netherlands

[9]Davis, P.A., Dent, M., Parker, J., Reynolds, C.S. and Walsby, A.E. (2003), The annual cycle of growth rate and biomass change in *Planktothrix* spp. in Blelham Tarn, English Lake District. Freshwater Biology, 48: 852–867.

[10]Bonilla, S., Aubriot, L., Soares, M. C. S., González-Piana, M., Fabre, A., Huszar, V. L.M., Lürling, M., Antoniades, D., Padisák, J. and Kruk, C. (2012), What drives the distribution of the bloom-forming cyanobacteria *Planktothrix agardhii* and *Cylindrospermopsis raciborskii*?. FEMS Microbiology Ecology, 79: 594–607.

[11]Watson, S.B. 2003. Chemical communication or chemical waste? A review of the chemical ecology of algal odour. Phycologia 42: 333-350