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 blooms¹. 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,
reverse 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 bodies²⁻⁵. 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
lakes⁶⁻⁷. 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 N₂-fixing cyanobacteria which
differ dramatically in morphology and pigmentation but include species that are known to
produce the potent hepatotoxins microcystins⁸. 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
environments⁹,¹⁰. In contrast both Anabaena and Aphanizomenon are N₂-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. 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.](Image)

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