Developing a PACE Hyperspectral Bio-Optical Algorithm Framework for Detection of Freshwater Harmful Algal Blooms

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PACE Plankton, Aerosol, Cloud, ocean Ecosystem

HARBOR BRANCH FLORIDA ATLANTIC UNIVERSITY

GLERL

Environment and Climate Change Canada

Project Overview

We are developing a new detection application for freshwater harmful blooms of cyanobacteria (cHABs) by integrating information from several different approaches, some of which expand upon current operational algorithms but are not based on hyperspectral data. Hyperspectral data is well suited to monitoring cHABs in freshwater, as there is more information available to differentiate phytoplankton groups and even large species assemblages based on unique spectral features. We are producing a suite of advanced bio-optical products, including from semi-analytic algorithms (SAAs). For the SAAs, we are developing separate products based on optical model inversion incorporating cHAB properties. CHABs have unique absorption and scattering properties, which make them difficult to invert using standard SAAs models, but our approach will use these characteristics to create a unique identification of cHAB populations, among other phytoplankton groups that are typically also present before, during and after cHAB events.

Overall Goal:

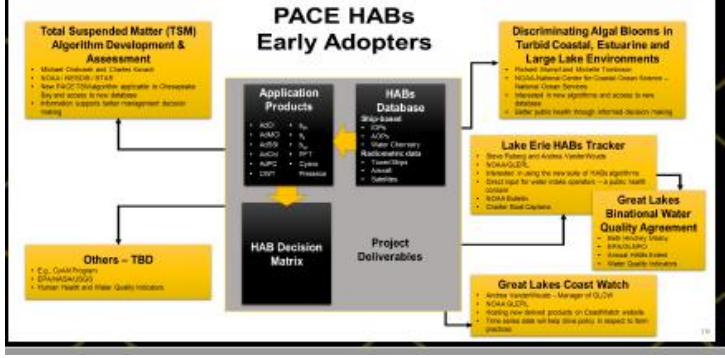
Generate a suite of validated hyperspectral HABs algorithms to support research and operational HAB monitoring applications such as the NOAA HAB Tracker

Project Objectives

The main application question we are addressing: **Can we improve CHAB detection and assessment including early stages with hyperspectral data?** Our ultimate application product will be a comprehensive CHAB assessment that includes confidence levels tied to bio-optical algorithm uncertainties. Our specific objectives are to:

1. Develop new adaptive CHAB indices based on present approaches but modified by dynamically selecting optimal bands per pixel depending on locations of spectral features expanding algorithm sensitivity and dynamic range.
2. Develop novel adaptive semi-analytic bio-optical models that use spectral libraries for inherent optical properties that themselves are associated with different algal groups and physiological conditions.
3. Develop a CHAB detection product application with confidence levels based on the combination of algorithm outputs and criteria established from objectives 1 and 2.
4. Generate demonstration products from the proposed scheme using PACE analog hyperspectral in situ and remote sensing data over the case study areas.

PACE Application Stakeholders



Optical and Biogeochemical Database

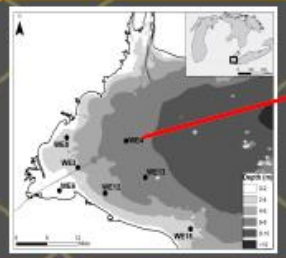


Figure 1. Weekly IOP/AOP measurements are made at standardized locations (left panel) in Lake Erie from May-October beginning in 2016. Additionally, high temporal frequency reflectance measurements are made from a fixed location hyperspectral radiometer system (LPR) co-located with a lake configured SeaPRISM (right panel).

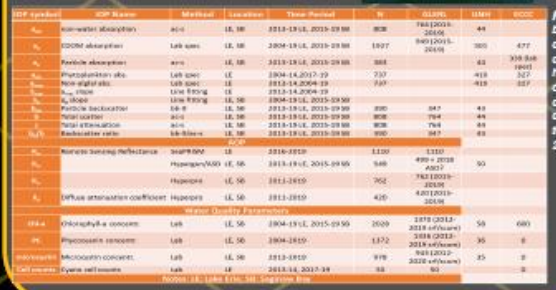


Figure 2. Summary of the bio-optical database being developed to support the development of hyperspectral freshwater cyanobacteria HAB detection algorithms. The database will be available to the community ~January 2022.

Optical Water Type Characterization

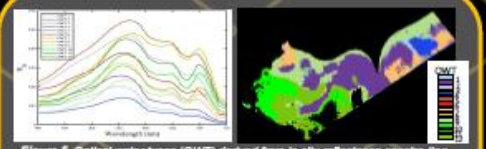


Figure 5. Optical water types (OWT) derived from in situ reflectance spectra (top left panel). OWTs mapped for a western Lake Erie HICO image (top right panel).

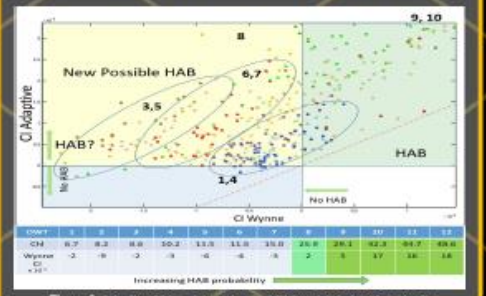
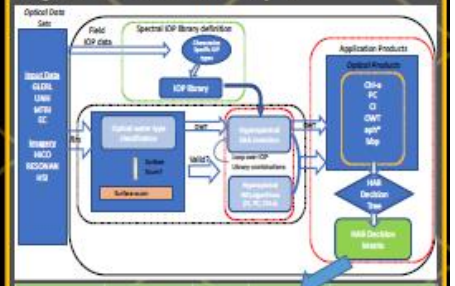


Figure 6. Adaptive CI (x-axis) vs standard CI (y-axis) derived from in situ reflectance spectra color coded by OWT.

CHABs Decision Framework

Development of a new hyperspectral bio-optical model to estimate more advanced cHAB properties for input into a cHAB decision matrix framework

New decision matrix classification and uncertainties will be integrated into the NOAA HAB Tracker system



Cyanobacteria Level	Description	Chl-a (µg/L)	Microcystin (µg/L)	Cyano counts (cells/mL)
BD	Below Detection level			
L	Low cyanobacteria	10-20	2-4	20,000
M	Medium cyanobacteria	20-50	20	20K-100K
H	High cyanobacteria	>50	>20	>100K
VH	Very High cyanobacteria	Scum		

Figure 7. New cHABs decision matrix framework using in situ data, adaptive algorithms, and an innovative hyperspectral semi-analytical model.

Hyperspectral Adaptive Algorithms

Documented multi-spectral HABs detection algorithms are being adapted to use hyperspectral data to account for shifts in spectral features with changing biomass

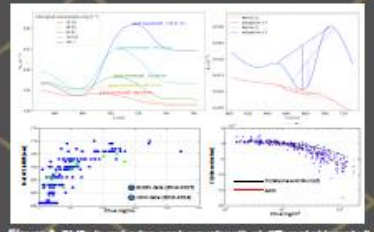


Figure 3. Shifts in red-edge peak wavelength at different chlorophyll concentrations (top left panel). Adaptive Cyanobacteria Index (CI) (dashed line) and standard multi-spectral CI (dotted line) for high (blue) and low (red) biomass (top right panel). Variations in peak wavelength as a function of chlorophyll concentration (bottom left panel). Adaptive CI improved sensitivity over a range of chlorophyll concentrations.

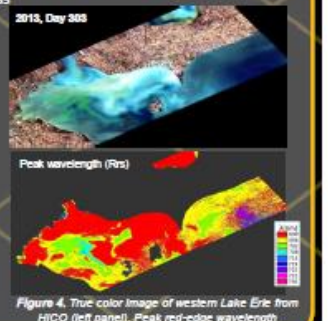


Figure 4. True color image of western Lake Erie from HICO (left panel). Peak red-edge wavelength mapped for same HICO image.

Pace Analog Data

Newly developed hyperspectral cHAB algorithms will be demonstrated using PACE analog data which includes spaceborne (HICO) and airborne (NASA HSI3, NOAA GLERL PIKA II) observations. Airborne data matchups (with in situ optics) will be included in the database

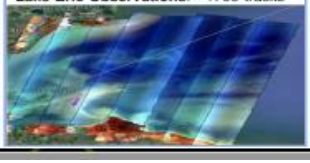
PACE Analog Hyperspectral Data to Support - Objective 4

Hyperspectral Imager for the Coastal Ocean (HICO)

Platform: International Space Station
Start: September 2009
End: September 2014
GSD: ~90m
Wavelength Range: 400-900 (87 bands)
Spec Resolution: 5.7 nm
SNR: >200:1 at 5%
Lake Erie Observations: 90 swaths, ~30 cloud free

NASA GRC Hyperspectral Imager

Platform: NASA Twin Otter, S3 Viking
Start: HSI2-May 2007, HSI3-May 2016
End: HSI2 - September 2018, HSI3 – September 2019
GSD: HSI2-3 ~1m (altitude dependent)
Wavelength Range: HSI2 - 400-900 (200 bands), HSI3 – 350-1000nm (325 bands)
Spec Resolution: HSI2 – 2.5 nm, HSI3 – 2nm
FOV: HSI2 – 12.4, HSI3 - 72
Lake Erie Observations: >1700 tracks



NOAA GLERL Resonon Pika II

Platform: Single Engine Aircraft
Start: May 2015
End: Ongoing
GSD: ~1m (altitude dependent)
Wavelength Range: 400-900 (240 bands)
Spec Resolution: ~2nm
FOV: 17.6
SNR – 198 max
Lake Erie Observations: > 1000 tracks