# New MODIS Algorithm for Retrieval of Chlorophyll, Dissolved Organic Carbon, and Suspended Minerals for the Great Lakes

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## Overview

It has previously been found that the algorithms for chlorophyll retrieval from satellite data are not accurate for the Great Lakes. Although an algorithm has been produced and tested on Lake Michigan, its predictions currently underestimate the amount of chlorophyll. The algorithm does, however, successfully observe correct seasonal trends of all three color producing agents (CPAs):

- chlorophyll (chl)
- dissolved organic carbon (doc)
- suspended minerals (sm)

This proposal addresses a proposed collaboration between Michigan Tech Research Institute (Ann Arbor, MI), Nansen International Environmental and Remote Sensing Center (St. Petersburg, Russia) and GLERL to further develop the algorithm to produce accurate estimates of chl, doc, and sm from MODIS satellite data for all of the Great Lakes. The anticipated results of this proposed collaborative investigation will be a set of validated algorithms for the retrieval of color producing agents from all of the Great Lakes.

## Objectives

Increase number of regional, coastal, and marine ecosystems delineated with approved indicators of ecological health and socioeconomic benefits that are monitored and understood

Process and incorporate Lakes Michigan, Huron, Erie, Ontario data into the bio-optical model and test performance, update the current hydro-optical model with Lake Superior data, test using MODIS satellite data.

## Proposed Work

Process optical data taken on Lakes Michigan, Huron, Erie, Ontario during 2008 for use in modifying/updating the hydro-optical model. Process MODIS images using current hydro-optical model then test and validate new hydro-optical model for Lake Erie, Lake Michigan, Lake Superior and/or other Great Lakes to test algorithm performance.

**Accomplishments**

- Algorithm for the retrieval of CPAs from satellite data developed by the Altarum Institute (formerly the Environmental Research Institute of Michigan (ERIM) and currently MTRI) and the Nansen International Environmental and Remote Sensing Center (NIERSC) of St. Petersburg, Russia
- Tested algorithm on Lake Michigan
    - Operates on SeaWiFS or MODIS data to produce estimates of chl, doc and sm
- Preliminary validation of algorithm using both dedicated and historical in situ water chemistry measurements
- Inaccurate estimates of algorithm because hydro-optical model used in the algorithm was generated for Lake Ontario waters and measurements were taken on Lake Michigan
- Historical radiometric observations with in situ water chemistry used to update hydro-optical model used in algorithm
- Optical measurements and coincident water samples taken on Lake Erie in the summer of 2005 to advance hydro-optical model for Lake Erie
- In situ measurements made on Lake Superior during 2007 for use in modifying/updating the hydro-optical model

**Scientific Rationale**

Remote sensing is an important component of GLERL's new theme areas, particularly physical environmental and ecological prediction. Sensing provides data for model initialization, validation, monitoring, management, and decision making owing to:M

- the number and capabilities of current and future satellites
- the cost effectiveness of these satellites to provide synoptic and localized data (E.g. NASA EOS suite of satellites)
- the synoptic view provided only by satellite observation (real-time, high temporal and spatial resolution)

**Description of Algorithm**

(Note: A more detailed description is given in (Pozdnyakov et al. 2004). The new algorithm utilizes SeaWiFS or MODIS satellite data to retrieve the concentrations of chl, doc, and sm in surface case II waters.

The fast operating algorithm is based on a previously developed hydro-optical model developed for Lake Ontario (Bukata et al. 1995) and a combination of the Levenberg-Marquardt (L-M) multivariate optimization approach and neural network (NN) emulation technique. Although the L-M technique generally provides more accurate results and is more robust for noise-contaminated input data, it is slower than NN (Pozdnyakov et al. 2004) because it tests a wide variety of options of the CPA concentrations before reaching a final solution.

The NN emulator proceeds differently, providing the multivariate solution within a fraction of a second. However, being reasonably accurate for the mid-range value of the CPA concentrations, generally found in mesotrophic to moderately eutrophic waters (Petrova 1990), it is less accurate for the CPA concentrations less than 5 (in respective concentration units). Therefore, we linked the two tools, allowing the NN emulator to provide the L-M procedure with much narrower limits of the range of the CPA concentration vector, within which the final solution can be reached. This procedure appreciably accelerates algorithm performance.

The search for the solution can be further improved. If along with broad range NN, a specially trained narrow-range NN is used, should any of the CPAs determined by the broad range NN falls into the range 0-5 (in respective concentration units), L-M performance will be increased.

An example of the algorithm output is shown in Figure 1.

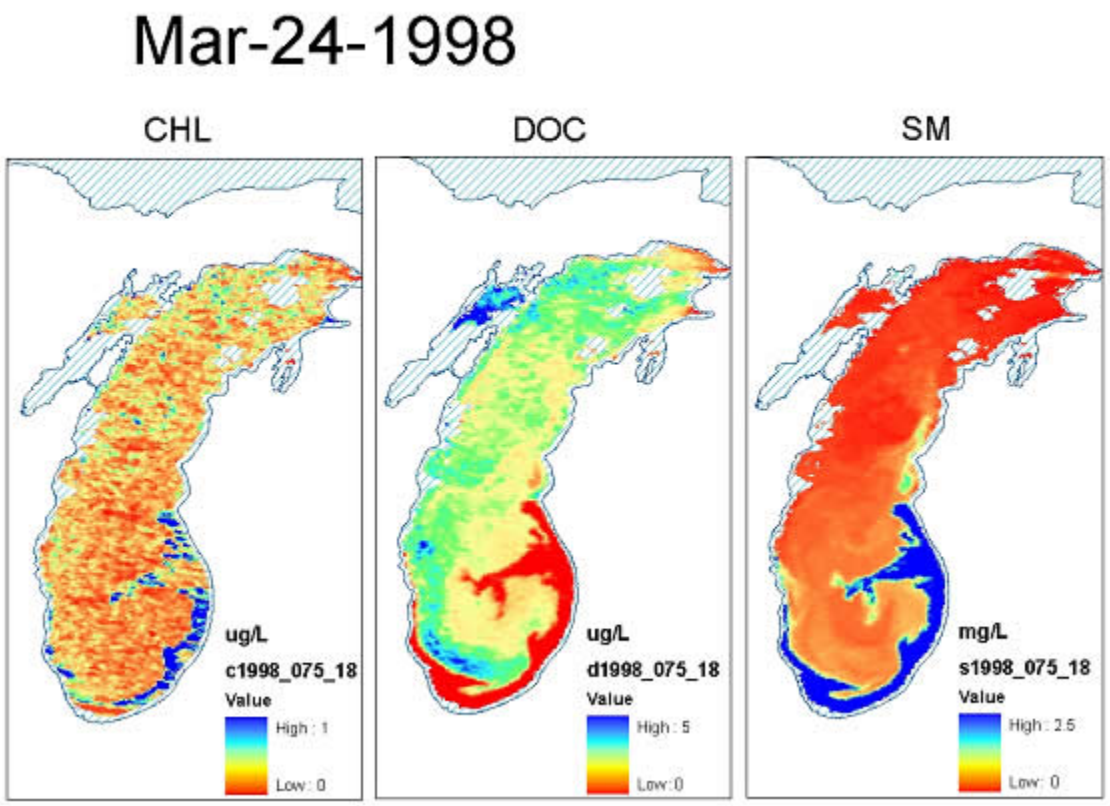


***Figure 1**: This Figure presents the spatial distributions of chl, doc, and sm as they are retrieved from a SeaWiFS image taken on March 24, 1998. The retrieved data quantitatively illustrates the influence of the 1998 springtime episodic event, which resulted in a considerable re-suspension of bottom sediments. As seen in the Figure, the re-suspension of sediments resulted in a notable growth of phytoplankton within the plume area, and very significant scavenging of doc from the water column produced by settling sm particulate matter.*

## Governmental/Societal Relevance

This project will produce a robust algorithm for the satellite detection and monitoring of water quality parameters including phytoplankton chlorophyll, suspended minerals, and dissolved organics in the Great Lakes. This data will be used to produce quantitative estimates useful to other ecological system modelers and forecasters. If the three major color producing agents (chlorophyll, dissolved organics, and suspended minerals) can be monitored from satellite data, the public, managers, and the scientific community will have near real-time data. Data will provide insight into current water quality, ecosystem vitality, economic and recreational potential, and quantitative estimates of primary productivity, transport and availability of toxic materials.

## Relevance to Ecosystem Forecasting

Providing near real-time mapping of chl, DOC, and SM can improve ecosystem forecasting in a number of areas including:

- improved prediction of primary production
- aid in the assessment of impacts of DOC and sediments in protecting harmful (*E. coli*) bacteria from UV radiation which impacts their demise
- help to track and evaluate the impacts of annual and inter-annual changes to ecosystems caused by episodic events and climate changes