An Operational Algorithm to Retrieve Chlorophyll, DOC, and Suspended Minerals from Satellite Data of the Great Lakes

3rd MERIS – SENTINEL-3 WORKSHOP

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Abstract

A set of algorithms have been developed for the five North American Great Lakes that utilizes MERIS, MODIS, or SeaWiFS satellite data to estimate chlorophyll (chl), dissolved organic carbon (doc), and suspended minerals (sm), the three primary Color Producing Agents (CPAs). The algorithms utilize a specific hydro-optical (HO) model for each lake. The HO models provide absorption functions for all three CPA components as well as backscatter relationships for the chl, and sm and were generated using in situ optical (IOP/AOP) data collected with coincident water chemistry (concentration) measurements. These new algorithms provide more accurate chl values then those obtained using the standard OC3 NASA MODIS retrieval when compared to in situ cruise observations, as well as providing the additional information on doc and sm. The suite of atmospheric correction algorithms for MODIS was also evaluated. In general the standard NASA algorithm does an adequate correction all of the time. The in situ optical data are housed in a geospatial database and will be made available via a web portal to support other investigations.

CPA Algorithm

Remote Sensing Reflectance (RSR) can be calculated from the specific absorption and backscattering coefficients, along with concentrations of each CPA:

$$RSR_i = f(a_i, b_i)$$

$$a_i = a_{H2O,i} + C_{chl}a_{chl,i} + C_{doc}a_{doc,i} + C_{sm}a_{sm,i}$$

$$b_i = b_{H2O,i} + C_{chl}b_{chl,i} + C_{sm}b_{sm,i}$$

C = Vector representing concentration of each CPA
a_i = Bulk absorption coefficient at band i
b_i = Bulk backscattering coefficient at band i
$a_{CPA,I}$ = Specific absorption coefficient for each CPA at band i
$b_{CPA,I}$ = Specific backscattering coefficient for each CPA at band i

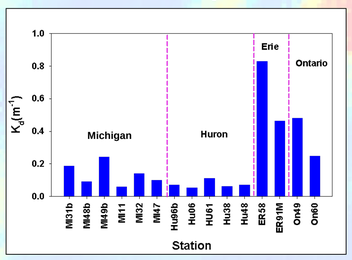
$$\sum_{i=1}^{total\_bands} \left(\frac{S_i - RSR_i}{S_i} \right)^2 = Error$$

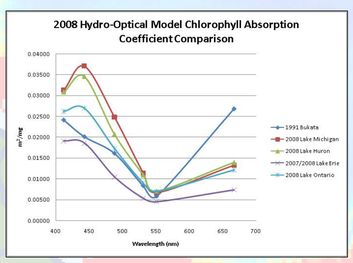
S = Measured Remote Sensing Reflectance from satellite
RSR = Calculated remote sensing reflectance from CPA concentrations, HO-model
After an initial guess for the CPA concentrations, the LM Procedure converges on a minimum in the error function:

Hydro-optical Model

- **The table of specific backscattering and absorption coefficients is also referred to as a Hydro-optical (HO) model.**
- **HO models depend on what type of CPAs are in the water.**
- **Given a HO-model for a body of water, CPA concentration images can be produced from satellite reflectance images using multivariate inverse procedures.**
- **Different bodies of water have different HO models.**
- **Similar types of water bodies have similar HO-models, such as Lake Michigan and Lake Huron.**

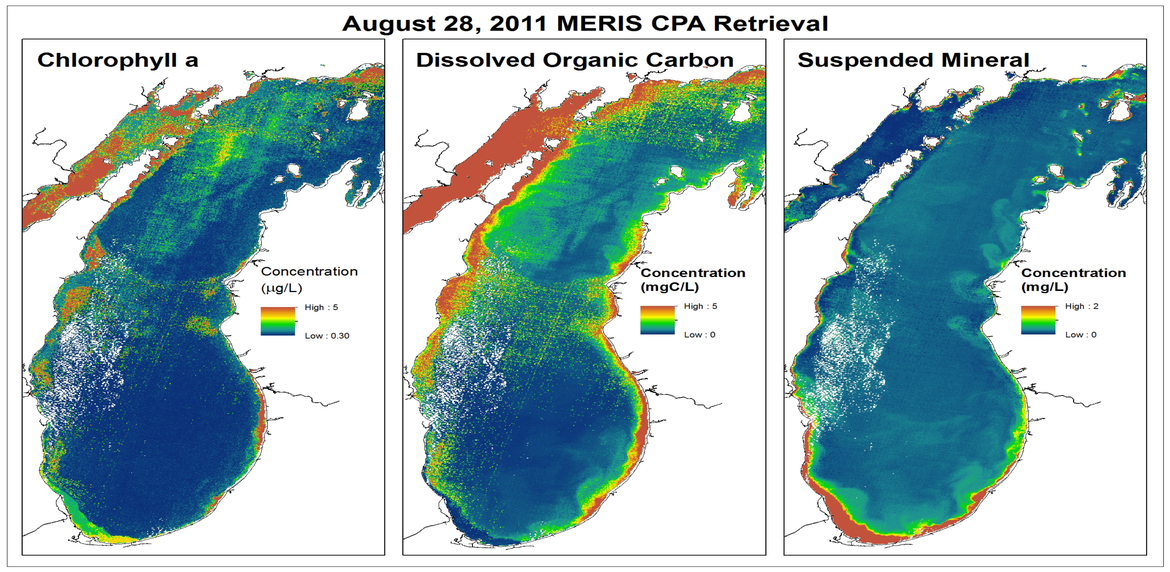
Kd variation by Lake





Lake Michigan MERIS Derived CPA Retrievals

True Color

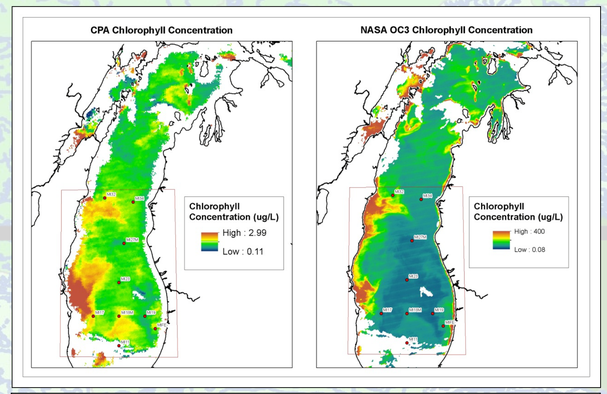


Chlorophyll Algorithm Validation and Comparisons to Case I Methods

Cruise data from 8/6/2010 - 8/8/2010, Satellite image from 8/8/2010.

GLERL sampling station average = 0.66 ug/L versus CPA algorithm (in boxed area) = 0.74 ug/L, OC3 = 0.76 ug/L

Individual station comparison (3x3 km buffer)
Max difference
CPA = 0.51 ug/L
OC3 = 0.56 ug/L
Min difference
CPA = 0.01 ug/L
OC3 = 0.14 ug/L
Avg difference
CPA = 0.15 ug/L
OC3 = 0.24 ug/L



Station	EPA CHL (µg/L)	CPA CHL (µg/L)	CPA vs. EPA (µg/L)	OC3 CHL (µg/L)	OC3 vs. EPA (µg/L)
MI 17	0.51	0.81	0.30	0.37	-0.14
MI 18M	0.61	0.80	0.19	0.43	-0.18
MI 19	0.54	0.55	0.01	0.28	-0.26
MI FE	0.63	0.73	0.10	0.49	-0.14
MI 23	0.55	0.59	0.04	0.30	-0.25
MI 27M	0.55	0.56	0.01	0.30	-0.25
MI 34	0.60	0.68	0.08	0.44	-0.16
MI 32	1.27	0.76	-0.51	0.71	-0.56
Averages	*0.66*	*0.69*	*0.03*	*0.42*	*-0.24*

Moving Forward…

- **Robust Hydro-optical models have been created for all five Great Lakes and validated with in situ measurements. HO models will continue to be refined where necessary.**
- **Decadal time series CPA estimates have been generated for cloud free images in all five of the Great Lakes to better understand climate change, invasive species, and anthropogenic forcing effects on water quality.**
- **A Great Lakes Primary Productivity Model (GLPPM) has been developed and tested on Lake Michigan.**
- **The GLPPM uses chlorophyll concentration retrievals from the CPA retrieval algorithm as input.**

March 2008 Lake Michigan GLPPM Primary Productivity From CPA Chlorophyll Retrieval.