An Operational Algorithm for the Retrieval of Water Quality Parameters in the Great Lakes from Satellite Data

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Abstract

Water quality parameters provide unique observations of the lower food web, including primary production, to help better understand ecological changes due to anthropogenic forcing and climate change. The Color Producing Agent Algorithm (CPA-A) is a semi-analytical inverse radiative transfer bio-optical model to retrieve water quality parameters from satellite observed reflectance. The CPA-A requires knowledge of the inherent optical properties of a given water body to produce accurate retrievals of the primary color producing agents (CPAs) namely chlorophyll (CHL), suspended mineral (SM), and CDOM. An all season, multi-year measured set of inherent optical properties with concurrent CPA concentrations, known as a hydro-optical (HO) model, has been generated for all of the Great Lakes that produce robust retrievals annually and intra-annually from satellite ocean color data. The optimized HO model was used to generate long-term time series estimates of several water quality parameters including CHL, SM, CDOM, DOC, attenuation, absorption, backscatter, and photic depth from the MODIS mission (2002-2013). The diffuse attenuation coefficient (Kd) and photic depth are functions of CPA concentration and are therefore inherently retrievable with the CPA-A. Retrieved concentrations of CPA-A derived water quality parameters compare favorably with in situ measurements. The CPA-A algorithm is currently being vetted by NOAA NESDIS (National Environmental Satellite, Data, and Information Service) for operational use in the Great Lakes and distribution to the user community by Great Lakes CoastWatch.

CPA Algorithm

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

$$Rrs_i = -0.00036 + 0.110(b_i/a_i) - 0.0447(b_i/a_i)^2$$

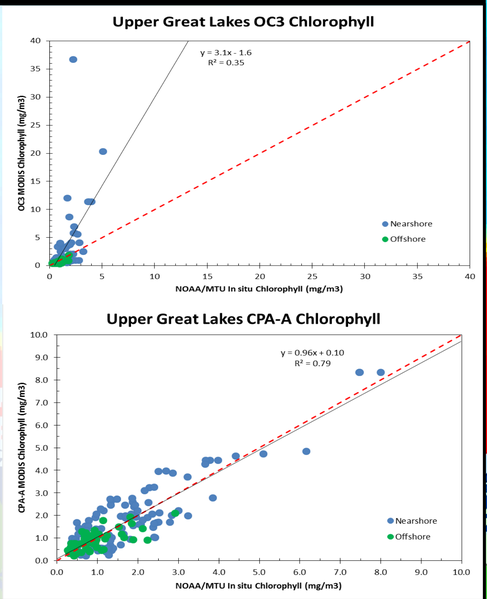
$$a_i = a_{H2O,i} + C_{chl}a^*_{chl,i} + C_{sm}a^*_{sm,i} + a_{CDOM@443}e^{-s(i-443)}$$

$$b_i = b_{H2O,i} + C_{chl}b^*_{chl,i} + C_{sm}b^*_{sm,i}$$

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
$a_{CDOM@443}$ = Absorption of CDOM at 443nm
s = The wavelength independent CDOM exponential spectral slope

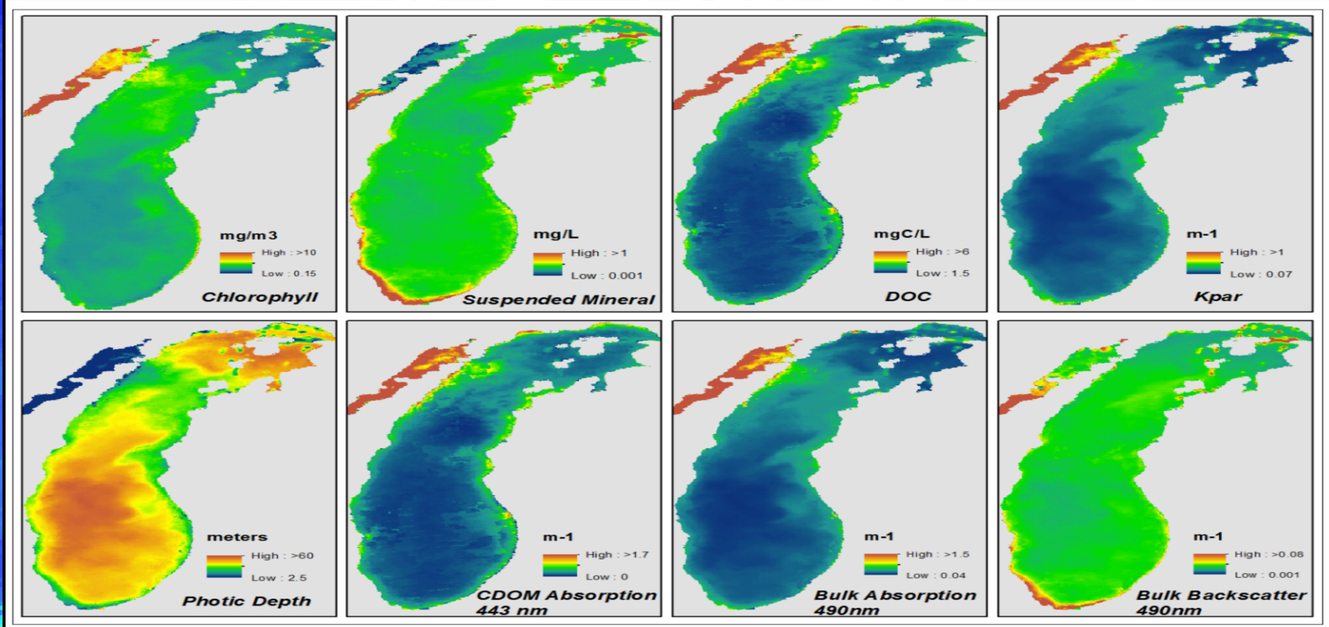
CPA-A Time Series Evaluation in the Great Lakes

- Comparison between MODIS-derived OC3 and CPA-A chlorophyll product and NOAA/MTRI in situ chlorophyll measurements
- In situ data from 2009-2012
- Comparisons were made against satellite retrievals collected within 24 hours of in situ measurements
- CPA-A produces more accurate chlorophyll in both nearshore and offshore
- Good agreement for all five lakes over varying concentration levels



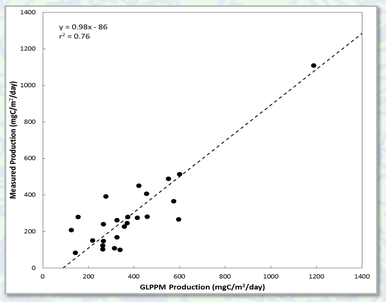
Lake Michigan CPA-A Outputs

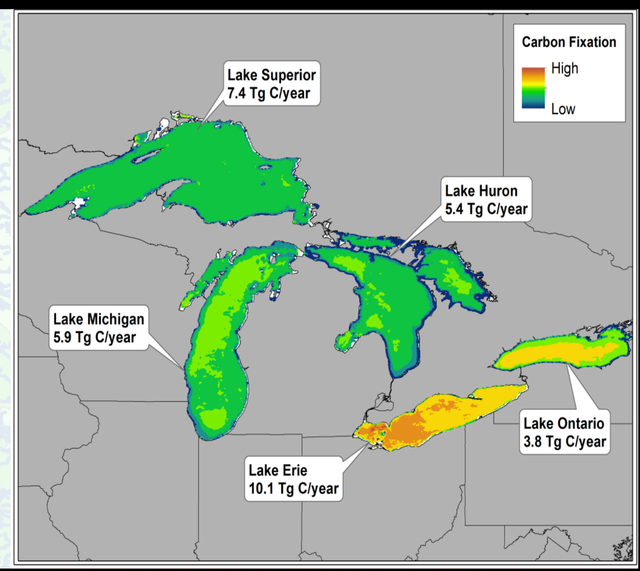
- 8 products
- Snapshots, weekly, and monthly products
- Some overlap with MODIS OC3 products
- Data record dates to 2002



Primary Productivity

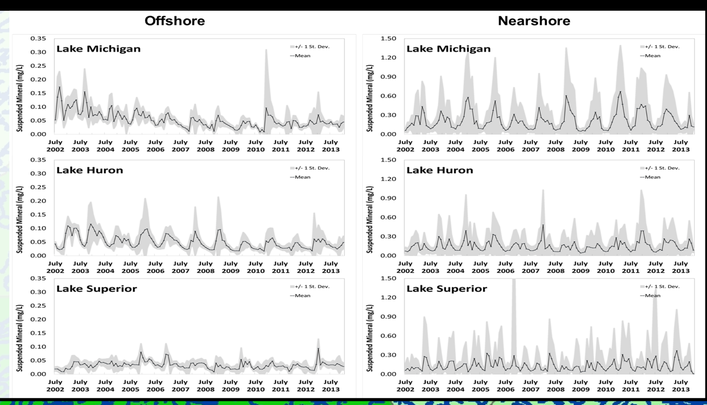
- Uses CPA-A satellite-derived (chl, Kd, PAR, temperature) and other (Julian day, latitude) inputs
- Weekly, monthly, and annual estimates for each lake
- Validated against Upper 3 lakes





Moving Forward

- Refining daily products using a moving average method and aggregating to weekly and monthly levels
- Implementing VIIRS as a data source
- Posting provisional CPA-A Upper 3 lake products on CoastWatch website
- Completing weekly and monthly time series from 2002-present for all five lakes



Reference

Shuchman, R.A., G.A. Leshkevich, M.J. Sayers, T.H. Johengen, C.N. Brooks, and D. Pozdnyakov. An algorithm to retrieve chlorophyll, dissolved organic carbon, and suspended minerals from Great Lakes satellite data. Journal of Great Lakes Research 39(Supplement 1):14-33 (DOI:10.1016/j.jglr.2013.06.017) (2013).