Evaluating the efficacy of five chlorophyll algorithms in the Chesapeake Bay (USA) for operational monitoring and assessment

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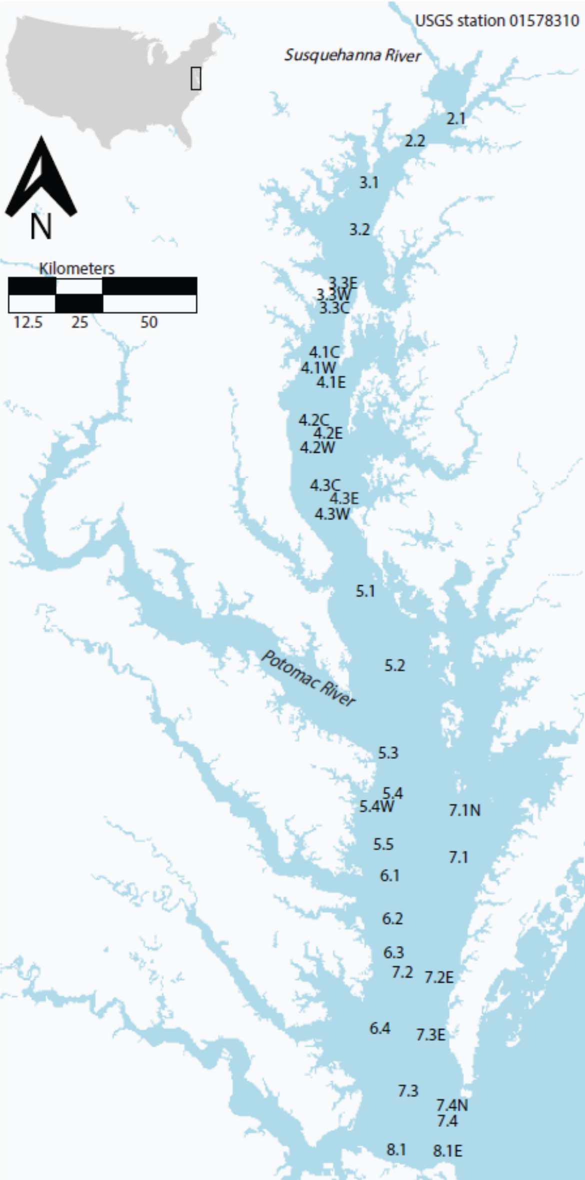
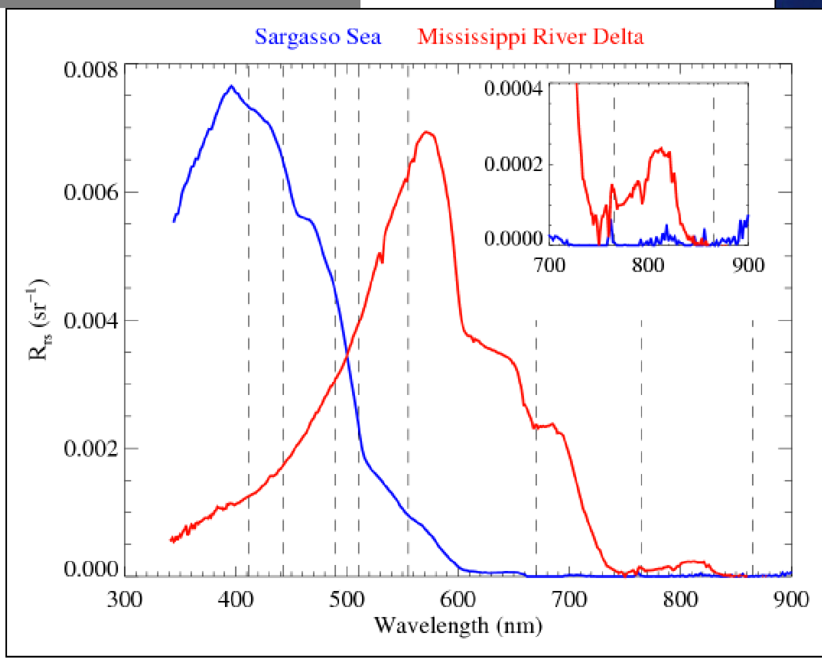


Methods

- 38 Stations along the center of the Bay were selected for analysis
- A red-edge chlorophyll (chl-a) algorithm was compared with 4 other algorithms (1 open ocean OC4 algorithm), and 3 operational algorithms (OCx) delivered at CoastWatch East Coast Node)
- A median of a 3x3 pixel box surrounding the field sample were used in the analysis
- All pixels at a station were extracted and a time-series analysis was conducted to assess stability
- The degree of agreement between field and satellite chl-a was evaluated using the multiplicative median and mean bias as well as absolute error

Case-1 versus Case-2 water

Case 1
water where the optical properties are determined primarily by phytoplankton and their derivative products



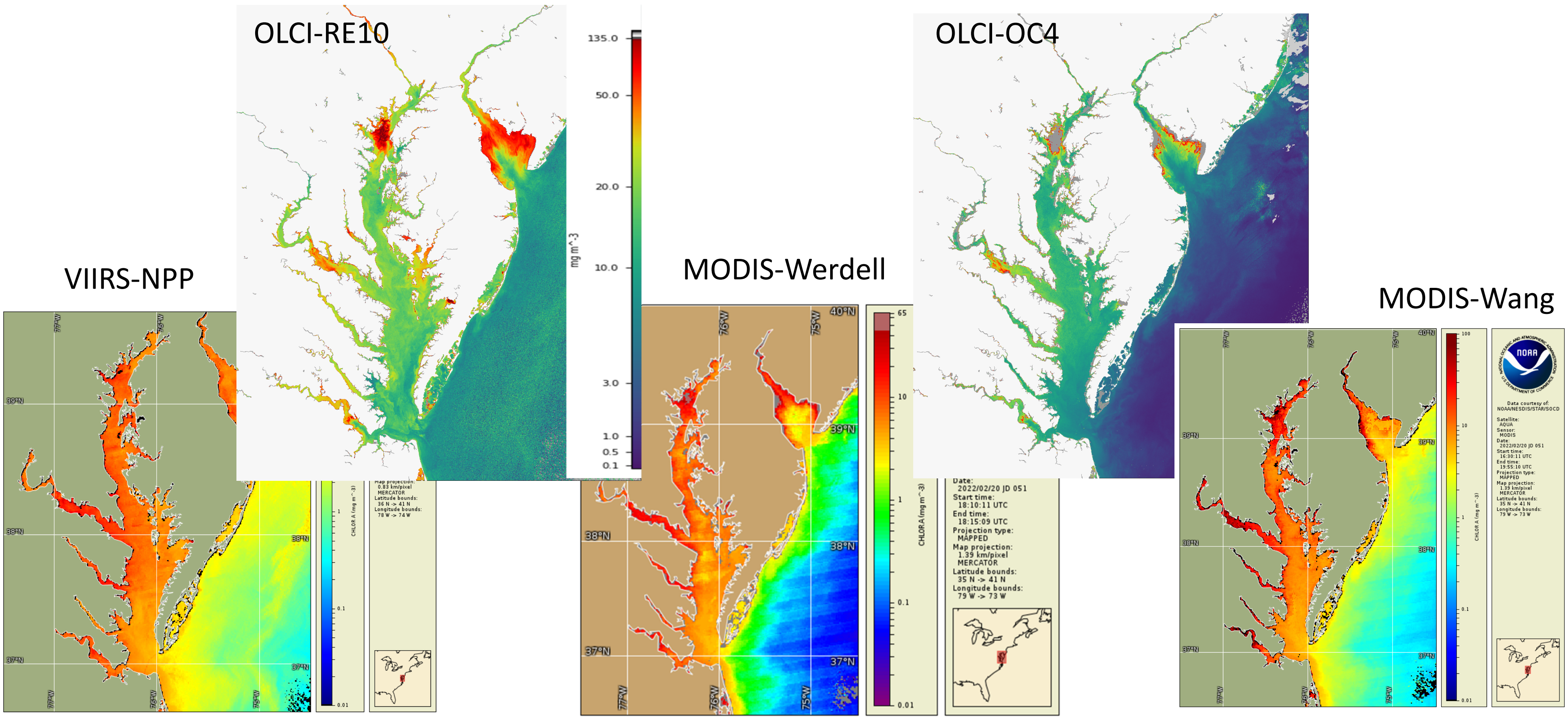
Case 2
everything else, namely water where the optical properties are significantly influenced by other constituents, such as mineral particles, CDOM, or microbubbles, whose concentrations do not covary with the phytoplankton concentration

The algorithms

Algorithm	Sensor	Spatial Resolution	Optical bands	Input	Reference
RE10[a] (formerly Gilerson)	OLCI	300 m	Red edge with NIR correction	Rhos	Gilerson et al. (2010)
OC4[a]	OLCI	300 m	OC4 (blue-green) applied to OLCI with NIR correction	Rhos	O'Reilly (1999)
Wang[b]	MODIS	1 km	OC3 (blue-green) with SWIR-NIR Atmospheric Correction	nLw	Wang et al. ATBD (2017)
Werdell[b]	MODIS	1 km	OC3 (blue green) bias adjusted for Chesapeake Bay	Rrs	Werdell et al. (2009)
Science Quality[b]	VIIRS	750 m	OC3 (blue green) open ocean (blue-band calibration), 14-day lag	nLw	O'Reilly (1999)

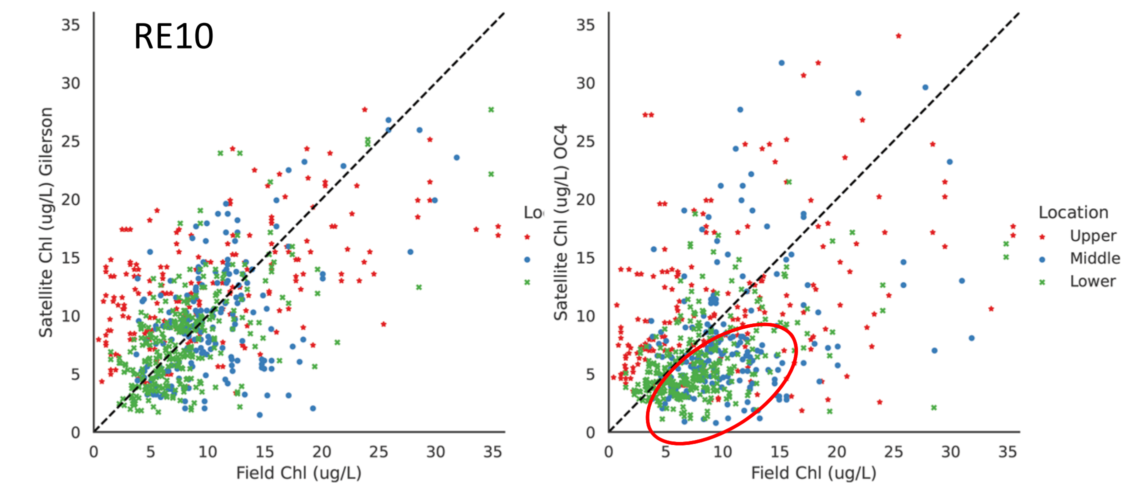
[a]https://coastwatch.noaa.gov/cw_html/NCCOS.html
[b]https://eastcoast.coastwatch.noaa.gov/cw_data_types.php

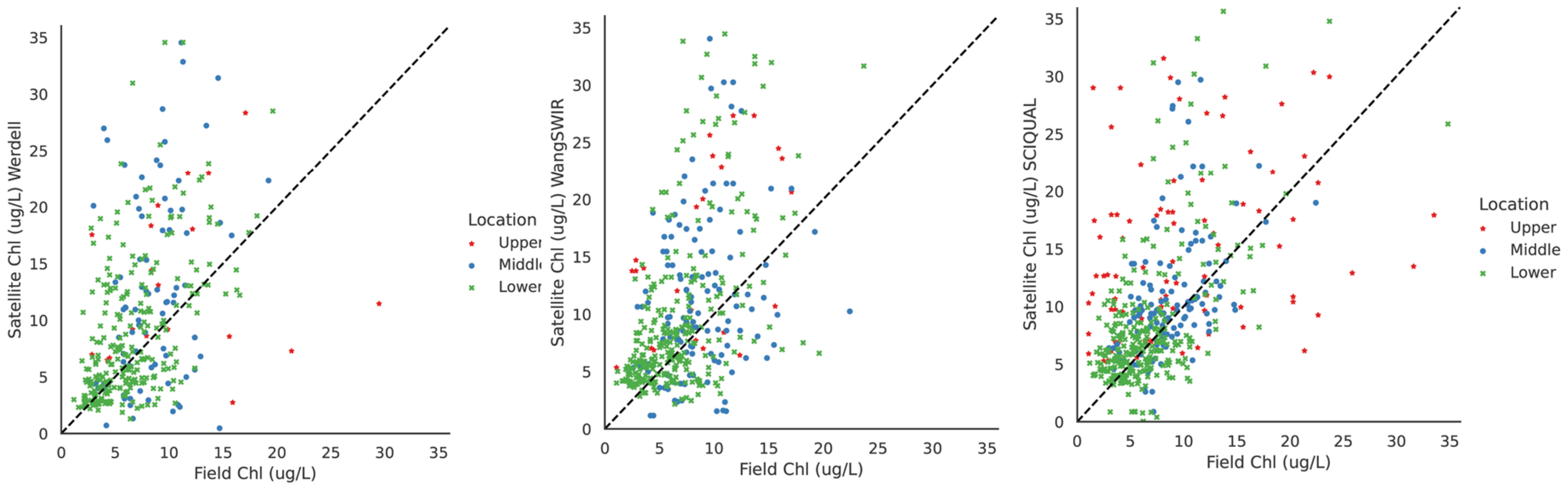
Imagery from 2/20/2022



Field to Extracted Chl Match ups

- RE10 fell along 1:1 line best, less scatter
- OC4 is underestimating chl-a
- All operational algorithms overestimate chl-a
- Due to resolution and atmospheric correction, less upper Bay pixels





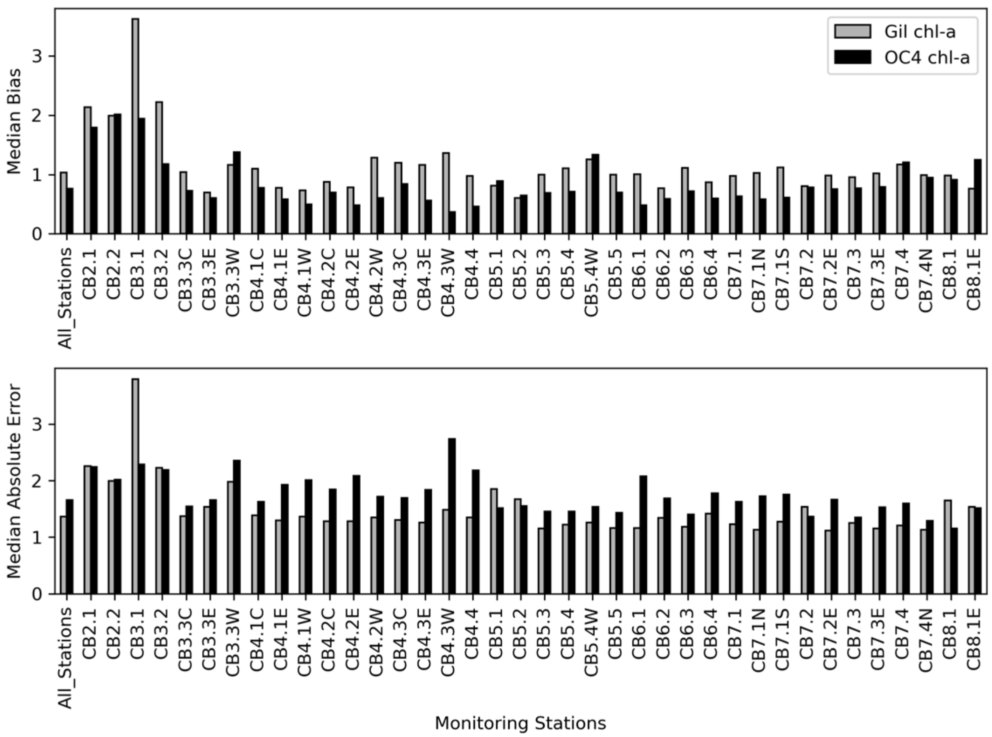
Bulk Statistics

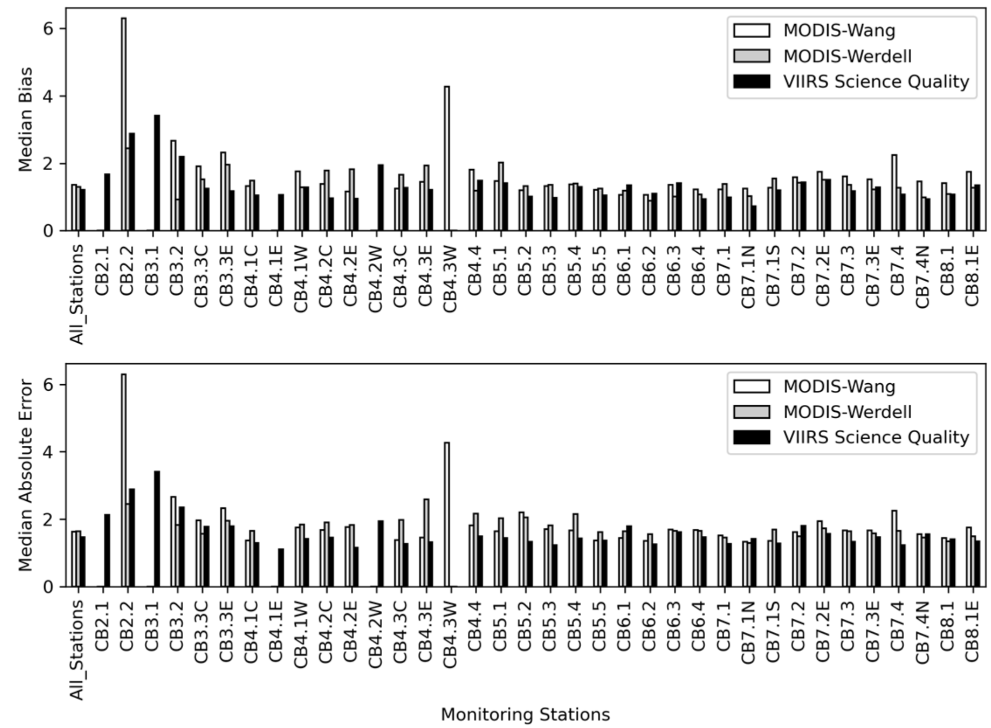
Metrics	Gilerson	OC4	Science Quality	Werdell	Wang
n	1679	1679	518	383	467
Linear Bias	-0.419	-2.756	16.431	5.715	5.05
Multiplicative Mean Bias	1.044	0.791	1.29	1.328	1.394
Multiplicative Median Bias	1.037	0.765	1.209	1.294	1.358
Linear MAE	4.499	5.86	18.632	7.717	6.894
Multiplicative MAE	1.596	1.87	1.745	1.866	1.839
Multiplicative MDAE	1.36	1.655	1.465	1.637	1.63

- The Multiplicative Median Bias of 1.037 indicates very little bias (< 4%) where 0.765 indicates higher bias (>23%).
- The Multiplicative Median Absolute Error (MDAE) shows a median error of 36%

For Methods see: Seegers et al, 2018 Optics Express

Error estimates by station for 5 algorithms

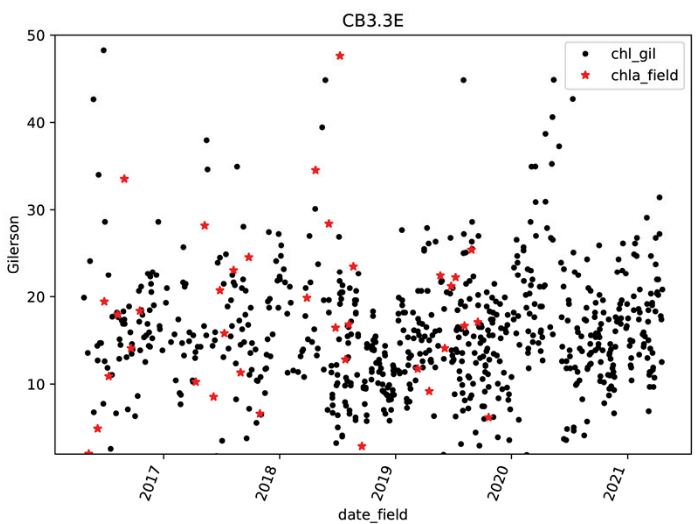




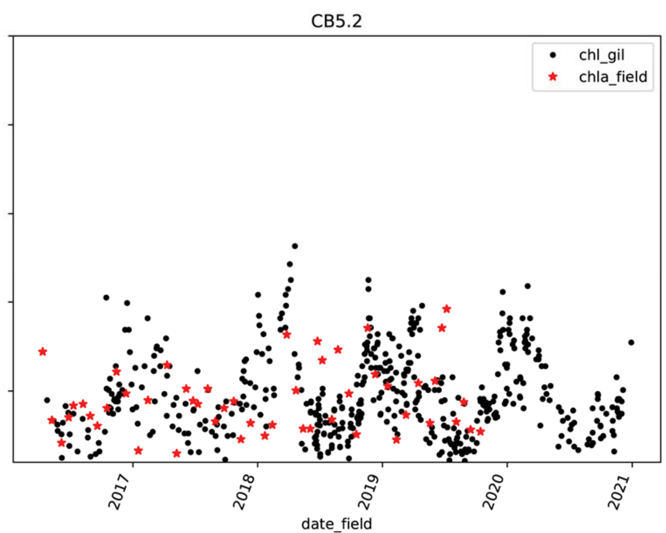
- Overall, Median Multiplicative Bias and MAE varies with location and chlorophyll concentration.
- Upper Bay stations on left, with lower Bay stations on the right

Time-series analysis

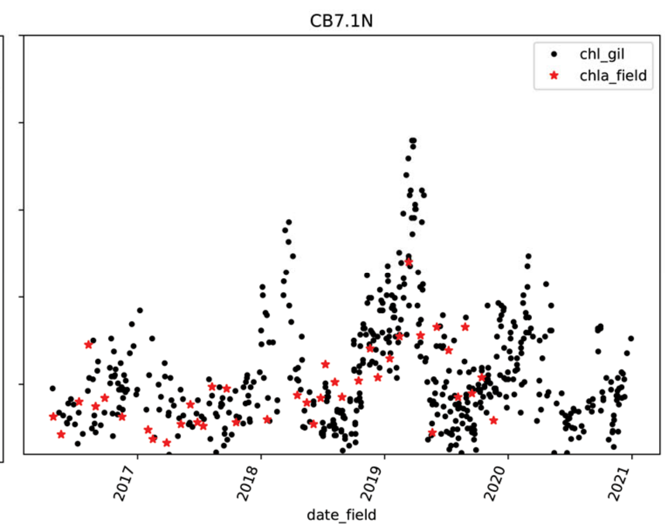
Upper Bay



Middle Bay



Lower Bay



- All available pixels were extracted at each CBP monitoring station
- Overall, tighter relationship in the Middle and Lower Bay regions, with good alignment with field estimates

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MDPI

Article

Evaluating the Efficacy of Five Chlorophyll-*a* Algorithms in Chesapeake Bay (USA) for Operational Monitoring and Assessment

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Abstract: This manuscript describes methods for evaluating the efficacy of five satellite-based chlorophyll-*a* algorithms in Chesapeake Bay, spanning three separate sensors: Ocean Land Color Imager (OLCI), Visible Infrared Imaging Radiometer Suite (VIIRS), and MODerate Resolution Imaging Spectroradiometer (MODIS). The algorithms were compared using in situ chlorophyll-*a* measurements from 38 separate stations, provided through the Chesapeake Bay Program (CBP). These stations span nearly the entire 300 km length of the optically complex Chesapeake Bay, the largest estuary in the United States. Overall accuracy was examined for the entire dataset, in addition to assessing the differences related to the distance from the turbidity maximum to the north by grouping the results into the upper bay, middle bay, or lower bay. The mean bias and the Mean Absolute Error (MAE) as well as the median bias and Median Absolute Error (MedAE) were conducted for comparison. A two-band algorithm, that is based on the red-edge portion of the electromagnetic spectrum (RE10), when applied to OLCI imagery, exhibited the lowest overall MedAE of 36% at all stations. As a result, it is recommended that the RE10 algorithm be applied to OLCI and provided as an operational product through NOAA's CoastWatch program. The paper will conclude with results from a brief climatological analysis using the OLCI RE10 algorithm.

Keywords: remote sensing; Chesapeake Bay; chlorophyll; OLCI; MODIS; VIIRS

check for updates

Citation: Wynne, T.T.; Tomlinson, M.C.; Briggs, T.O.; Mishra, S.; Meredith, A.; Vogel, R.L.; Stumpf, R.P. Evaluating the Efficacy of Five Chlorophyll-*a* Algorithms in Chesapeake Bay (USA) for Operational Monitoring and Assessment. *J. Mar. Sci. Eng.* **2022**, *10*, 1104. https://doi.org/10.3390/jmse10081104

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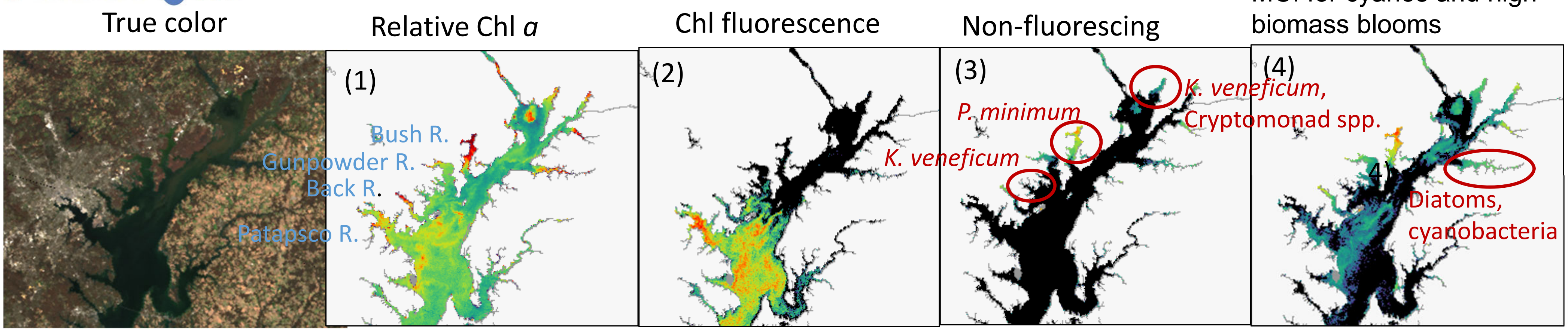
1. Introduction

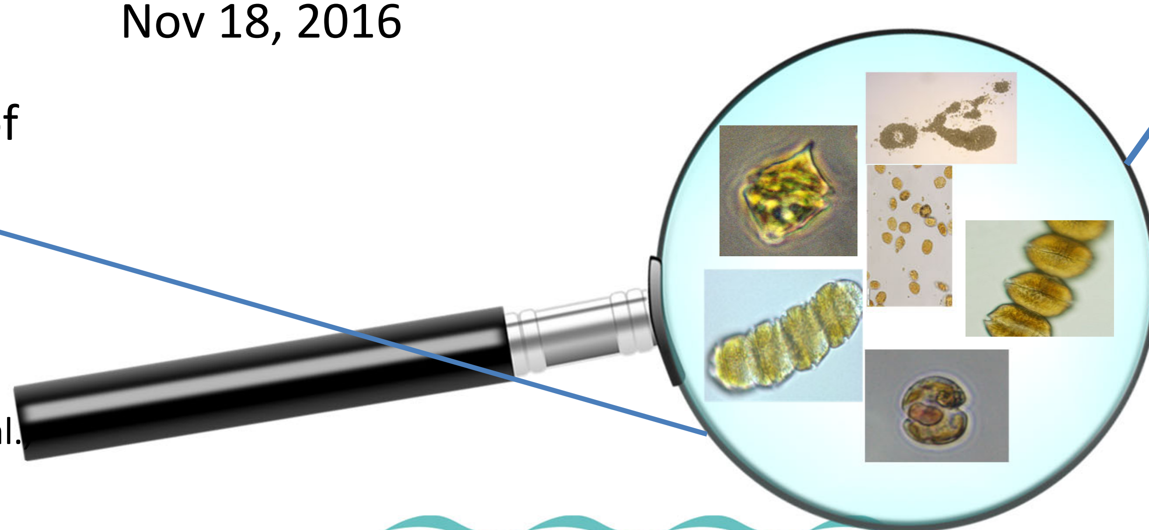
Satellite-derived products for algal bloom monitoring in Chesapeake Bay



Nov 18, 2016

Developing and providing algorithms for bloom monitoring routinely to MD DNR, MDE, VA Dept. of Health and VIMS from OLCI since 2016

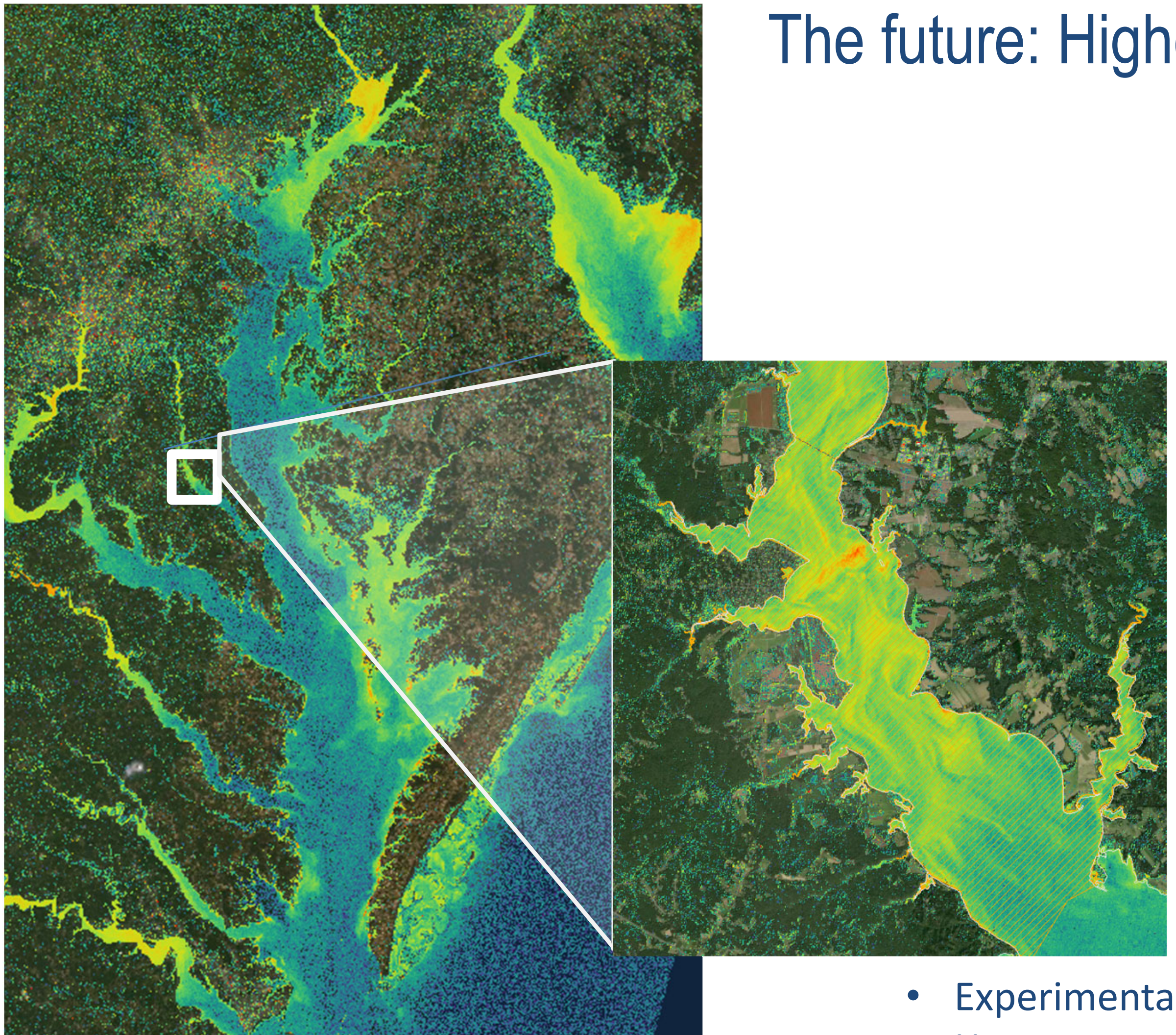
(1) Red Band Difference (RBD) (Amin et al., 2009)
(2) Red-Edge (Gilerson, 2010)
(3) Cyanobacteria Index (Wynne et al., 2008) modified by a negative shape at 620 nm
(4) Maximum Chlorophyll Index (MCI) (Gower et al. 2008, 2010)

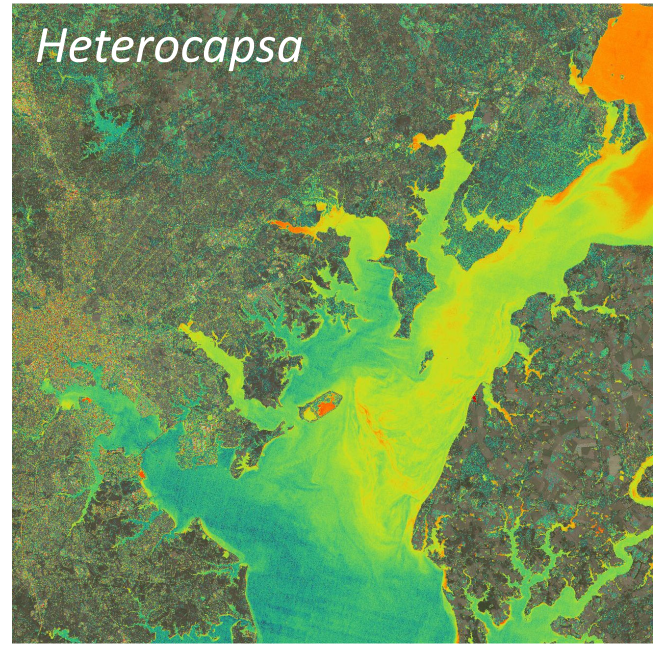


NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

https://coastwatch.noaa.gov/cw_html/NCCOS.html

The future: Higher spatial resolution Sentinel 2





Sentinel-2A February 9, 2022
MCI Composited (6 daily tiles) 20 meter pixels
Approximately 5 day repeat with 2 satellites

- Experimental Maximum Chl Index and true color available
- Hyperspectral imagery coming online through PACE, GLIMR, GEO-XO

https://coastwatch.noaa.gov/cw_html/NCCOS.html

Sentinel-2

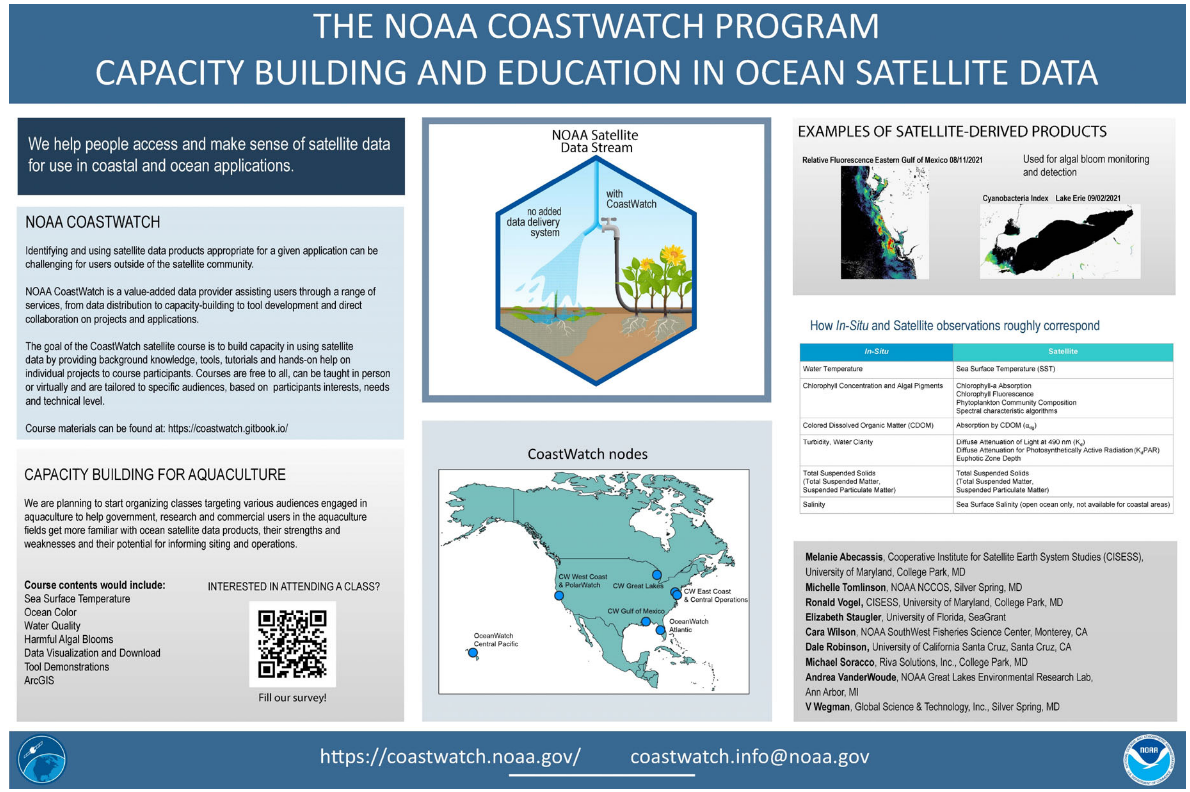
- 10 meter spatial resolution
- 5-day revisit time
- 13 spectral bands

Sentinel-2 bands
Band 1 – Coastal aerosol
Band 2 – Blue
Band 3 – Green
Band 4 – Red
Band 5 – Vegetation red edge
Band 6 – Vegetation red edge
Band 7 – Vegetation red edge
Band 8 – NIR
Band 8A – Narrow NIR
Band 9 – Water vapour
Band 10 – SWIR – Cirrus
Band 11 – SWIR
Band 12 – SWIR

CoastWatch Satellite Training Module for Water Quality

Interested in Attending a Class

Fill out our survey!



THE NOAA COASTWATCH PROGRAM
CAPACITY BUILDING AND EDUCATION IN OCEAN SATELLITE DATA

We help people access and make sense of satellite data for use in coastal and ocean applications.

NOAA COASTWATCH

Identifying and using satellite data products appropriate for a given application can be challenging for users outside of the satellite community.

NOAA CoastWatch is a value-added data provider assisting users through a range of services, from data distribution to capacity-building to tool development and direct collaboration on projects and applications.

The goal of the CoastWatch satellite course is to build capacity in using satellite data by providing background knowledge, tools, tutorials and hands-on help on individual projects to course participants. Courses are free to all, can be taught in person or virtually and are tailored to specific audiences, based on participants interests, needs and technical level.

Course materials can be found at: https://coastwatch.gitbook.io/

CAPACITY BUILDING FOR AQUACULTURE

We are planning to start organizing classes targeting various audiences engaged in aquaculture to help government, research and commercial users in the aquaculture fields get more familiar with ocean satellite data products, their strengths and weaknesses and their potential for informing siting and operations.

Course contents would include:
Sea Surface Temperature
Ocean Color
Water Quality
Harmful Algal Blooms
Data Visualization and Download
Tool Demonstrations
ArcGIS

INTERESTED IN ATTENDING A CLASS?

Fill our survey!

NOAA Satellite Data Stream
no added data delivery system
with CoastWatch

CoastWatch nodes
CW West Coast & PolarWatch
CW Great Lakes
CW East Coast & Central Operations
CW Gulf of Mexico
OceanWatch Atlantic
OceanWatch Central Pacific

EXAMPLES OF SATELLITE-DERIVED PRODUCTS

Relative Fluorescence Eastern Gulf of Mexico 08/11/2021

Used for algal bloom monitoring and detection

Cyanobacteria Index Lake Erie 09/02/2021

How *In-Situ* and Satellite observations roughly correspond

In-Situ	Satellite
Water Temperature	Sea Surface Temperature (SST)
Chlorophyll Concentration and Algal Pigments	Chlorophyll-a Absorption Chlorophyll Fluorescence Phytoplankton Community Composition Spectral characteristic algorithms
Colored Dissolved Organic Matter (CDOM)	Absorption by CDOM (α_{dg})
Turbidity, Water Clarity	Diffuse Attenuation of Light at 490 nm (K_d) Diffuse Attenuation for Photosynthetically Active Radiation (K_dPAR) Euphotic Zone Depth
Total Suspended Solids (Total Suspended Matter, Suspended Particulate Matter)	Total Suspended Solids (Total Suspended Matter, Suspended Particulate Matter)
Salinity	Sea Surface Salinity (open ocean only, not available for coastal areas)

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