

Remote Sensing of Algal Blooms

Rick Stumpf NOAA

Michelle Tomlinson, Andrew Meredith

And help from a number of other people

Danielle Dupuy, Jennifer Wolny, Kim Reese, Todd Egerton.



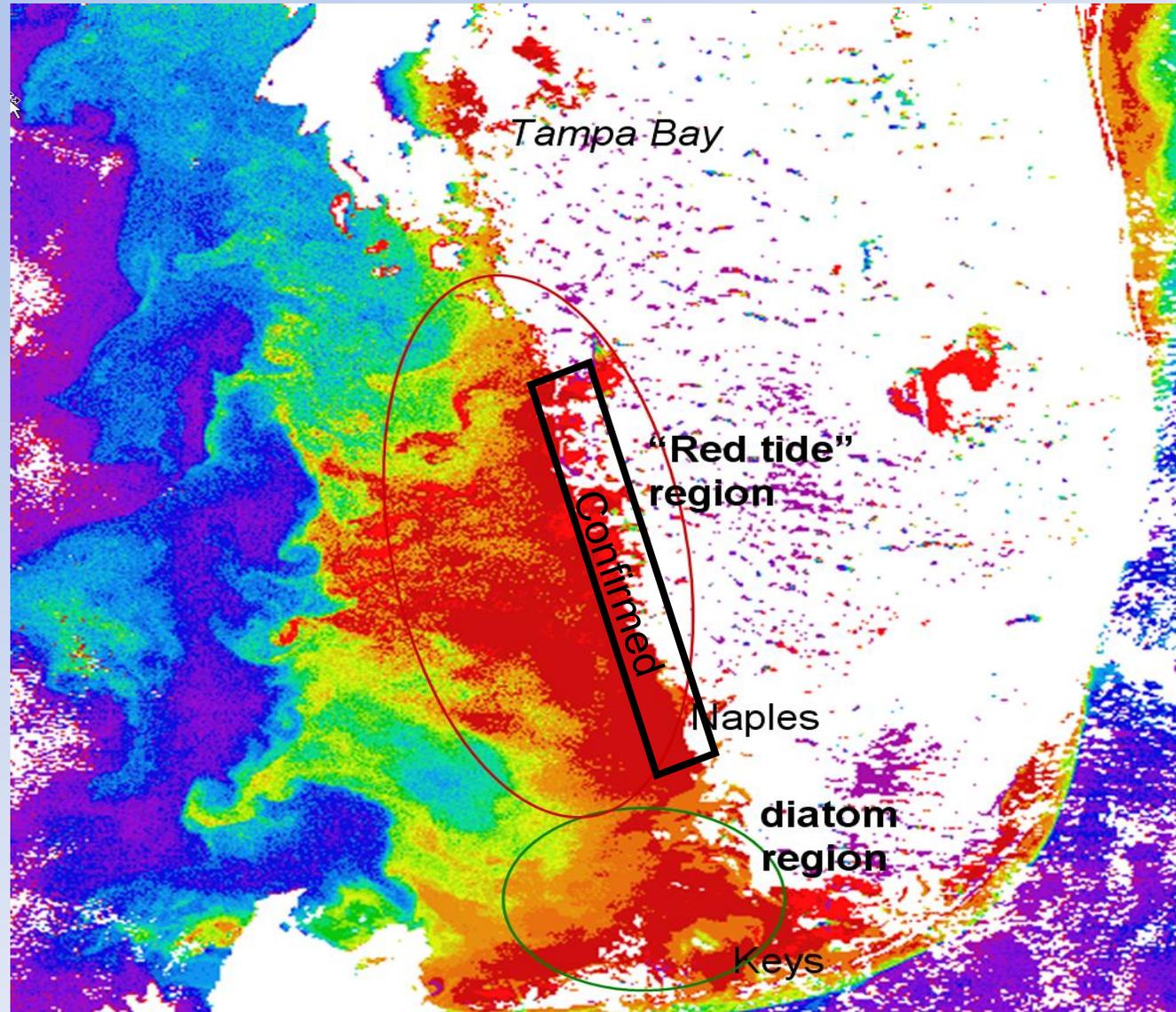
Satellite optics and HABs, *the image*

Coastal Zone Color Scanner, launched in Sept; image Nov 14, 1978

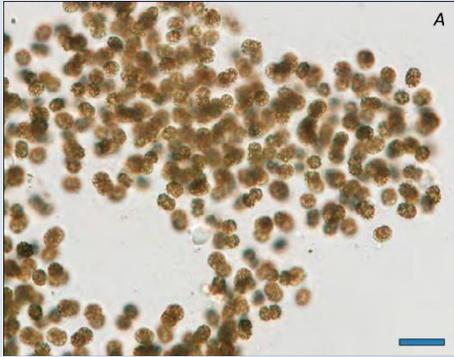
“Red Tide” HAB of *Karenia brevis*
(then *Gymnodinium breve*)

Demonstrated the potential
value of ocean color (Used by
Steidinger and Haddad, 1981)

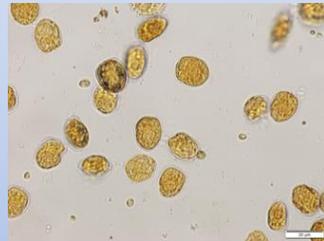
(a year earlier Jim Mueller flew
CZCS simulator over Florida “red
tide”)



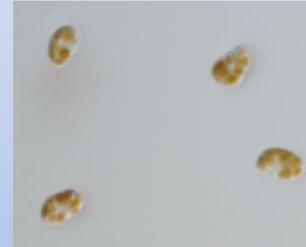
Marine Algal Blooms, and freshwater cyanobacteria



Microcystis aeruginosa
Cyanobacteria (usgs.gov)



P. minimum



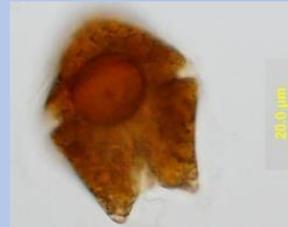
H. akashiwo



K. veneficum



M. aeruginosa



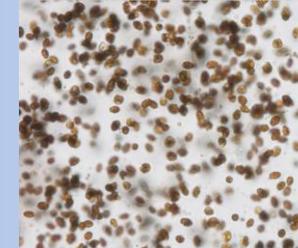
A. sanguinea



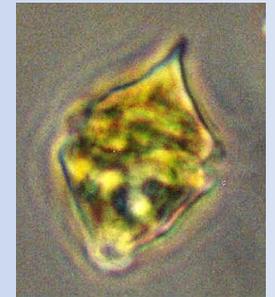
A. monilatum



M. polykrikoides

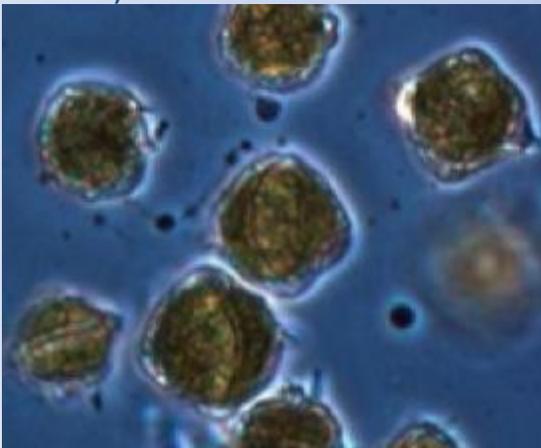


H. rotundata



H. triquetra

Pyrodinium bahamense
(photo myfwc.com)



L. minimus

Photos MD DNR



Cryptomonad



K. Brevis
(photo myfwc.com)

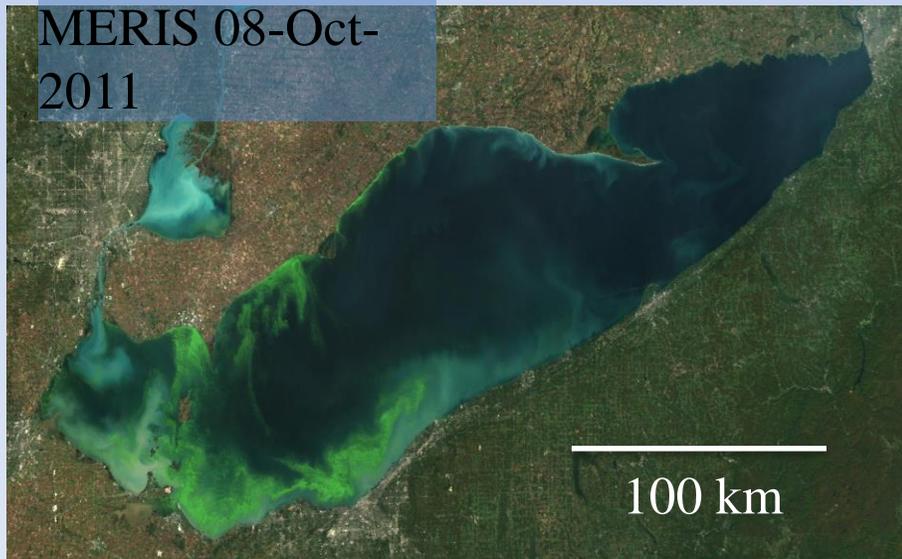
Cyanos in many areas

Baltic (*Nodularia spumigena*)

Freshwater in estuaries

(*Microcystis aeruginosa*)

Lakes (e.g. Lake Erie)



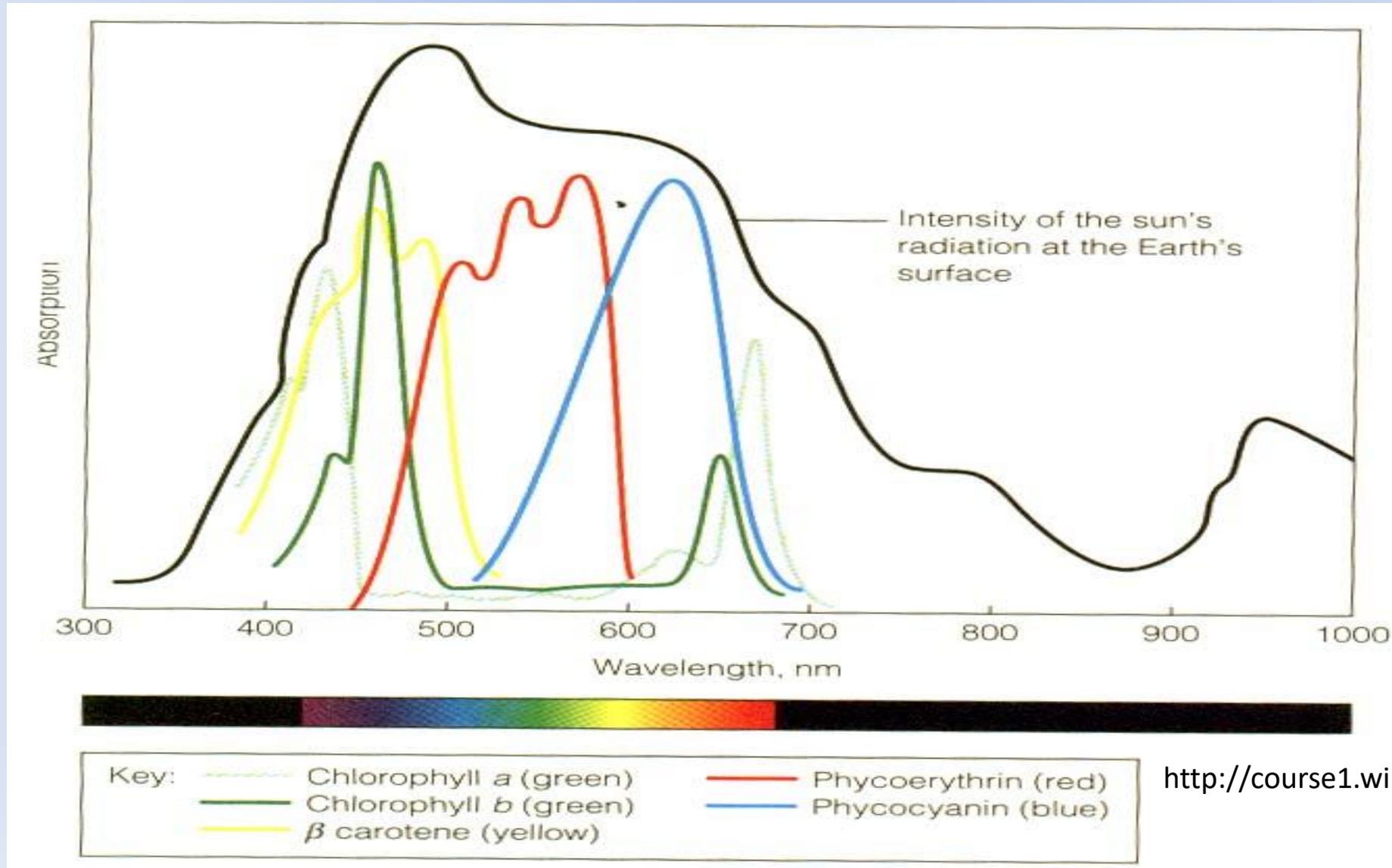
Satellite Comparison for bloom applications

Satellite	Spatial	Temporal	Key Spectral
MERIS 2002-12 OLCI Sentinel-3 2016-present 	300 m <i>OK</i>	2 day <i>good</i>	10 (5 on red edge) <i>good</i>
MODIS high res Terra 1999; Aqua 2002	250/500 m <i>OK</i>	1-2 day <i>good</i>	4 (1 red, 1 NIR) <i>marginal</i>
MODIS low res	1 km <i>poor</i>	1-2 day <i>good</i>	7-8 (2 in red edge) <i>OK</i>
Landsat	30 m <i>good</i>	8 or 16 day <i>poor</i>	4 (1 red, 1 NIR) <i>marginal</i>
Sentinel-2a (2015) 2b (2017) MSI	20 m <i>good</i>	10 day each 5 day with 2 satellites <i>Potential with 2</i>	5 (1 red; 2 NIR, 1 in red edge) <i>potential</i>

Some sunglint is not a problem for our algorithms

Minimum resolution, 3 pixels across (2 mixed land/water)

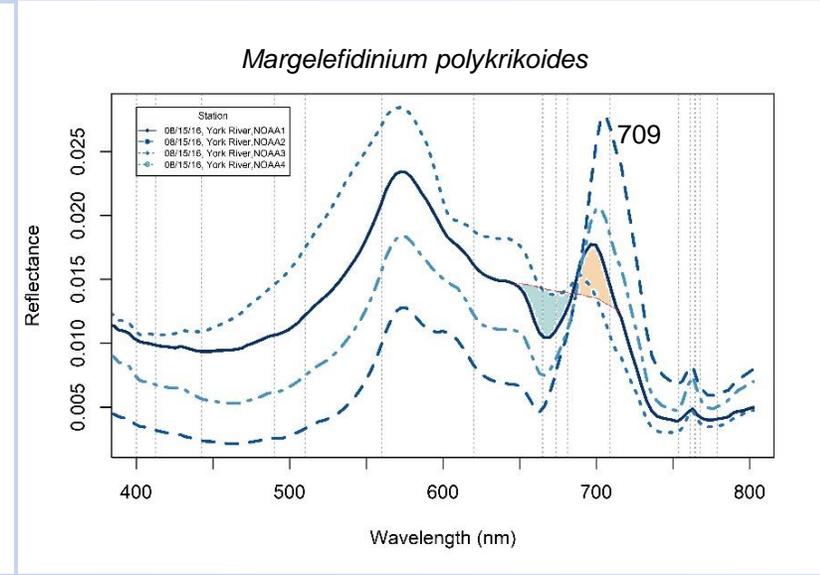
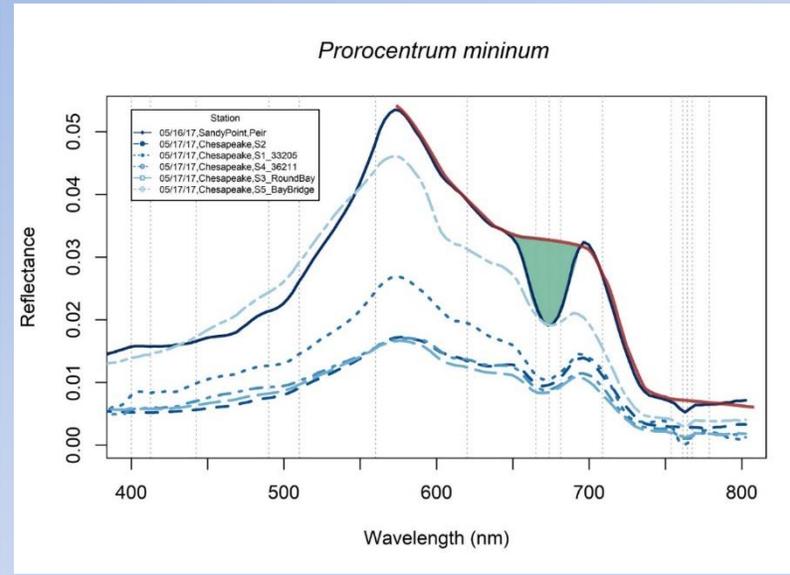
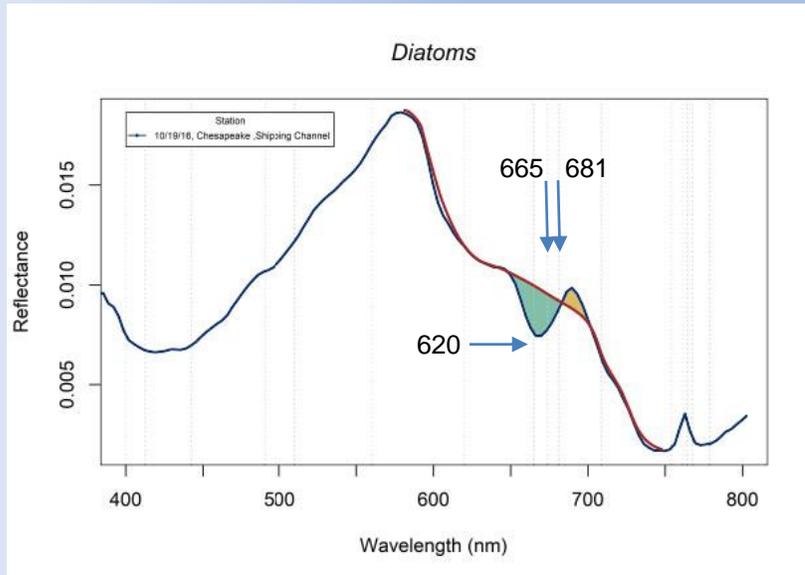
Spectra: various pigments in algae



S. Berg Winona State

http://course1.winona.edu/sberg/Fac_sb.htm

Radiometry for various bloom types, “red” light is most useful.



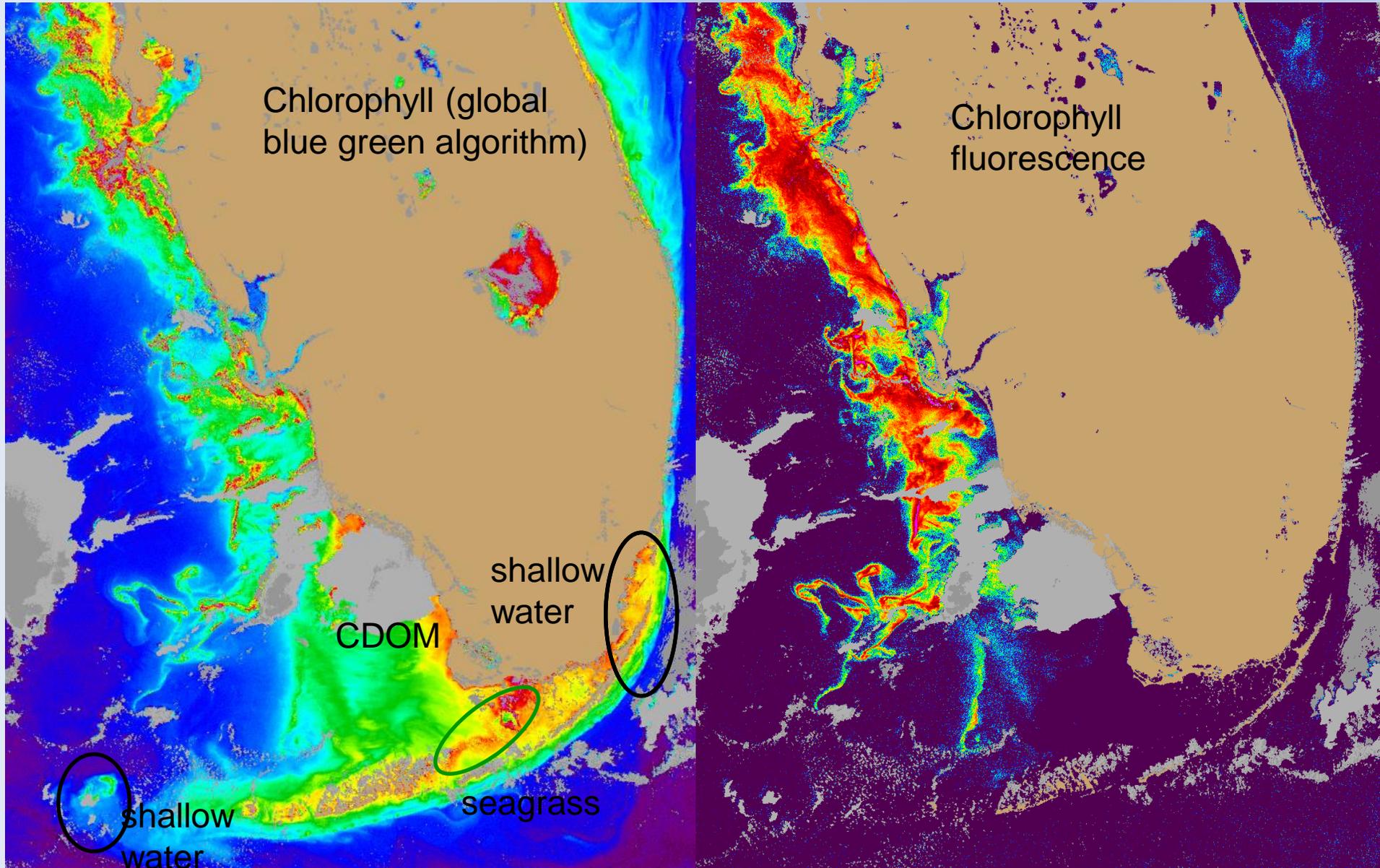
CI Non-Cyano: No reflectance peak at 665 nm as there is no phycocyanin absorption at 620 nm
Negative shape at 681 nm, plus <0 at 665 nm (a modification of Wynne et al., 2008)

Red Edge: $R_{rs}(708)/R_{rs}(665)$ as a chl estimate (Gilerson, et al., 2010)

RBD: Shift in minimum from phytoplankton absorption at 678 to shorter wavelengths (667 nm) with significant chl fluorescence in the red (Amin et al., 2009)

Standard "blue green" ratio algorithm for chlorophyll has challenges

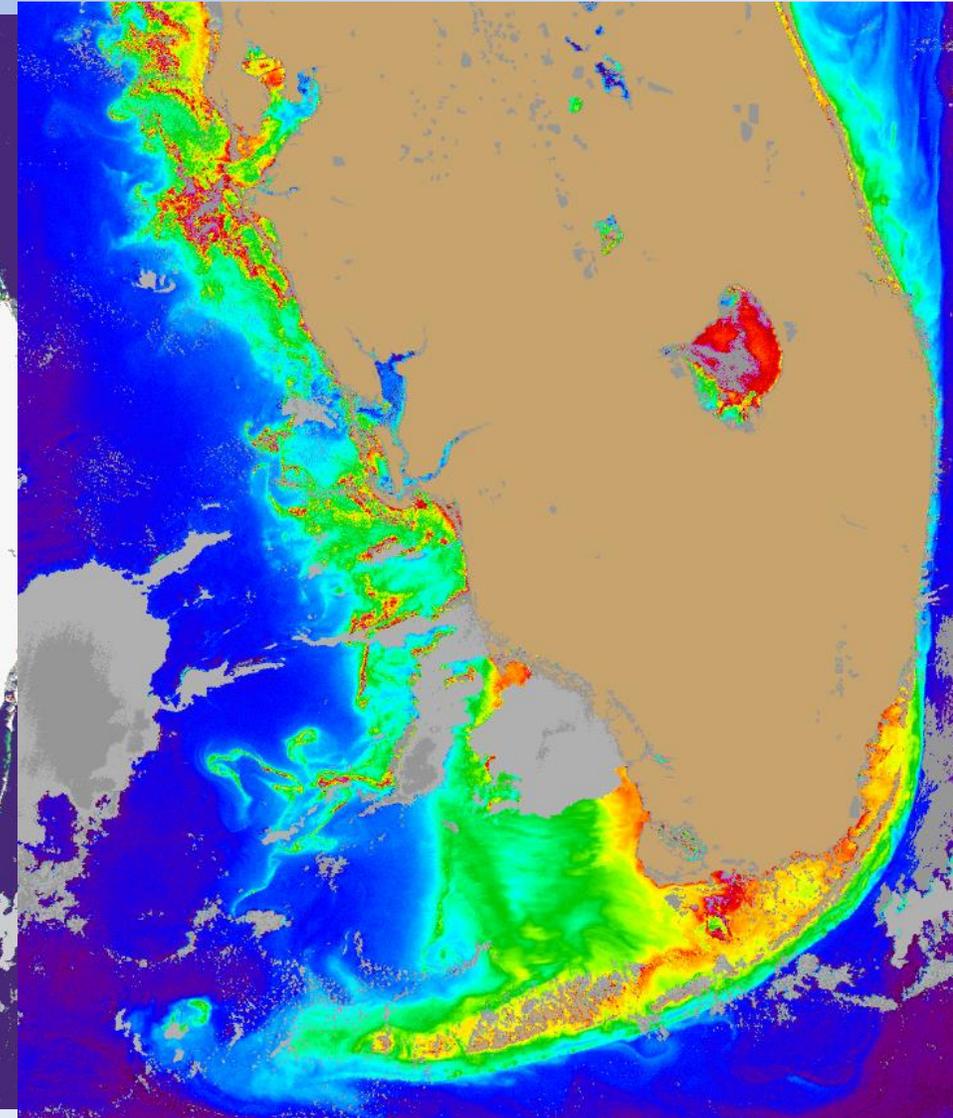
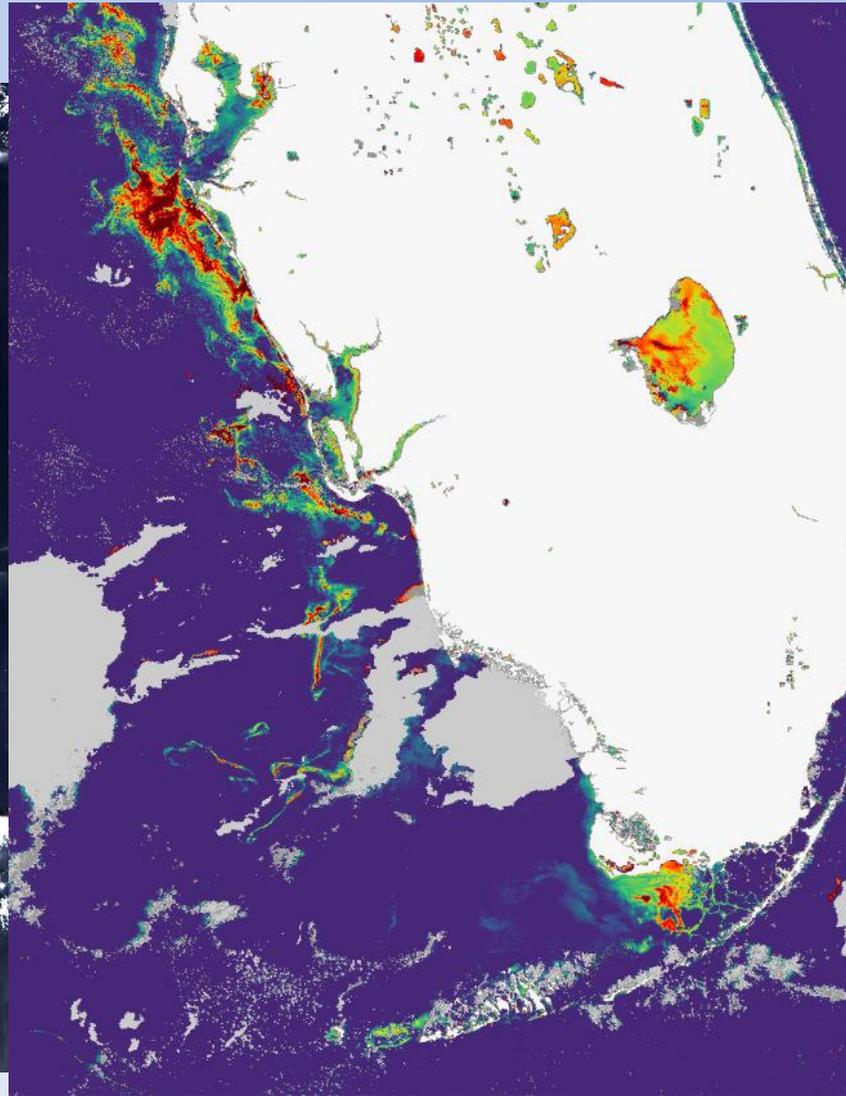
Other means of finding chlorophyll



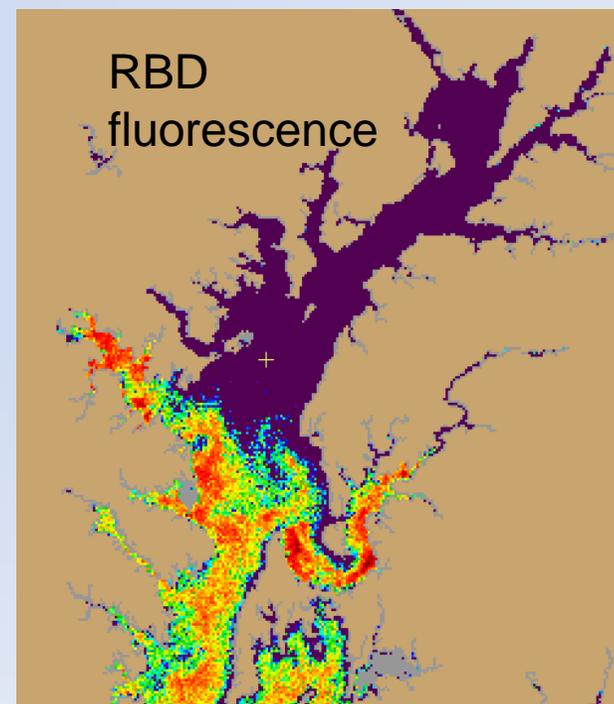
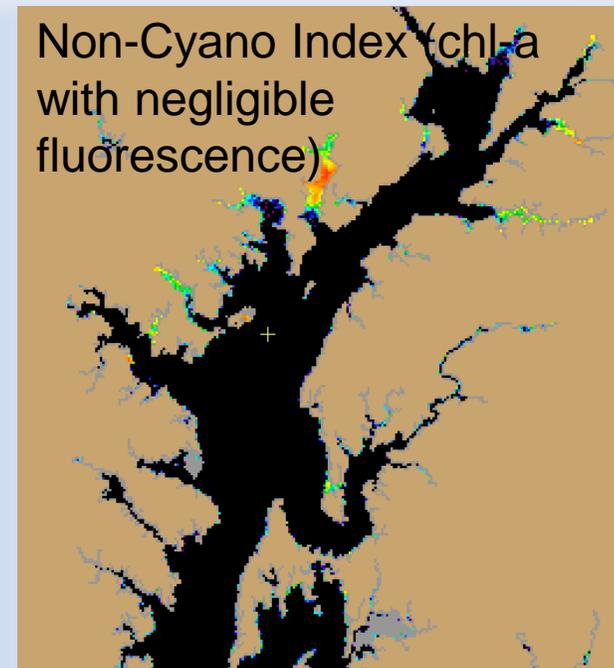
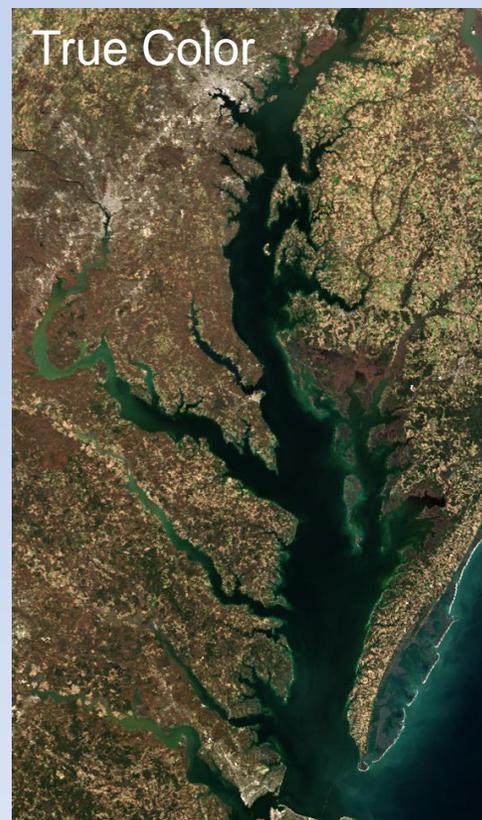
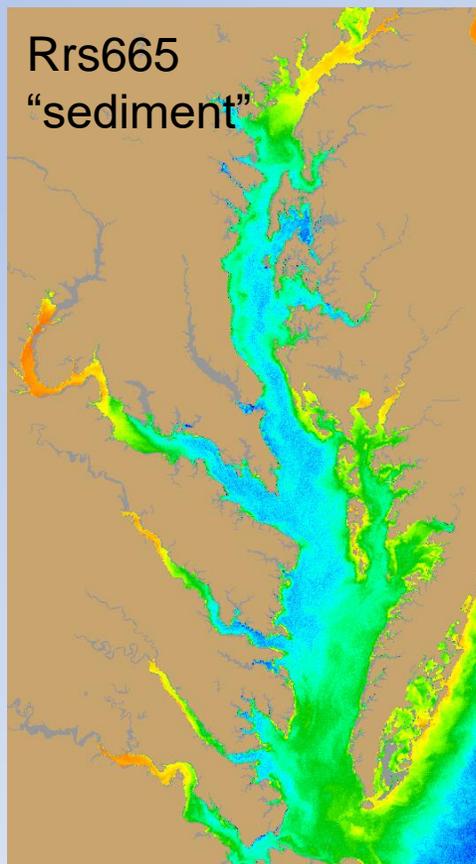
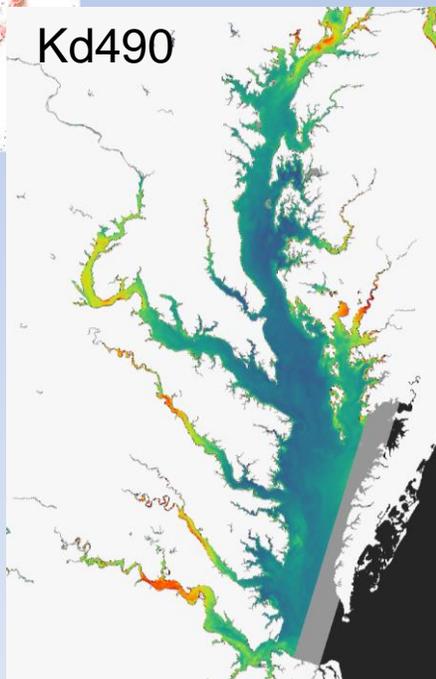
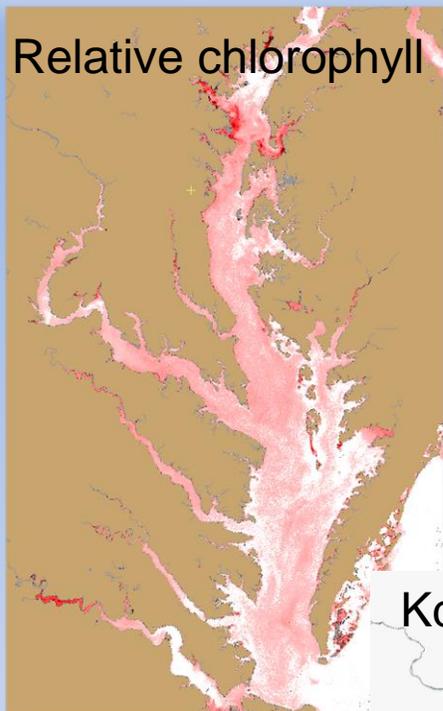
High chlorophyll detection

Sep 09 Florida high chla algorithm
using red/red edge NIR

std ocean chla, blue and green: good offshore,
severe over-estimation and false positives nearshore

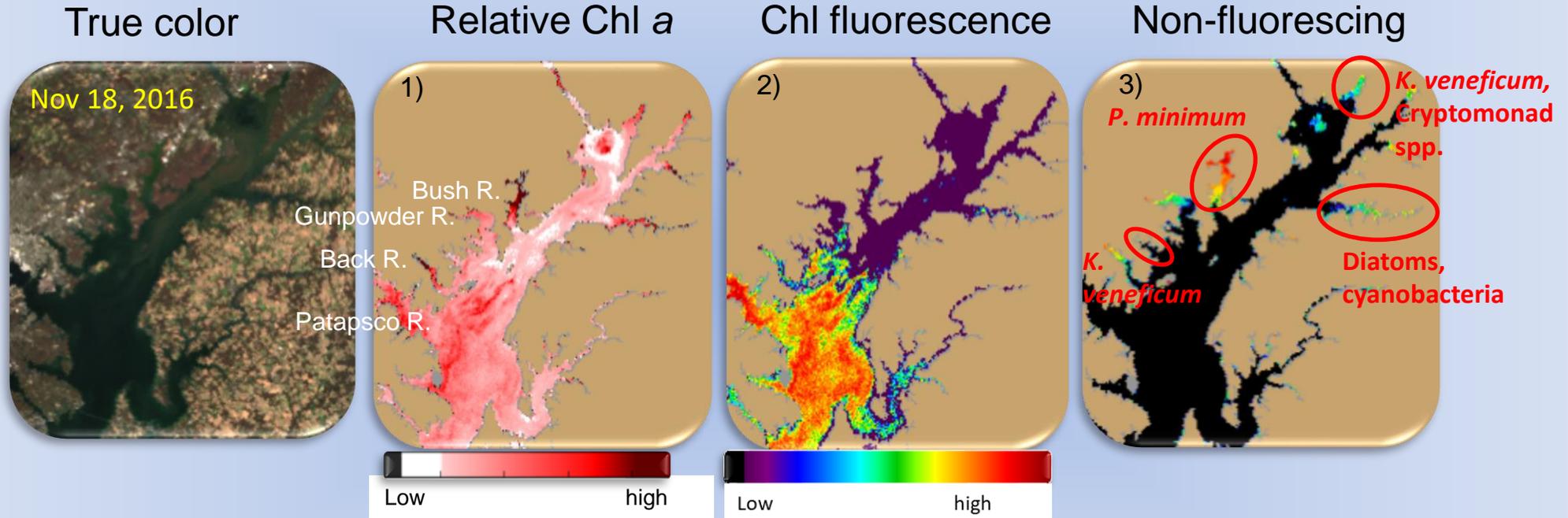


A variety of satellite products Chesapeake Bay



*Note: Imagery derived from Copernicus Sentinel data from EUMETSAT

OLCI satellite algorithms for high biomass blooms



(1) Red Band Difference (RBD) (Amin et al., 2009)

(2) Red-edge (Gilerson, 2010)

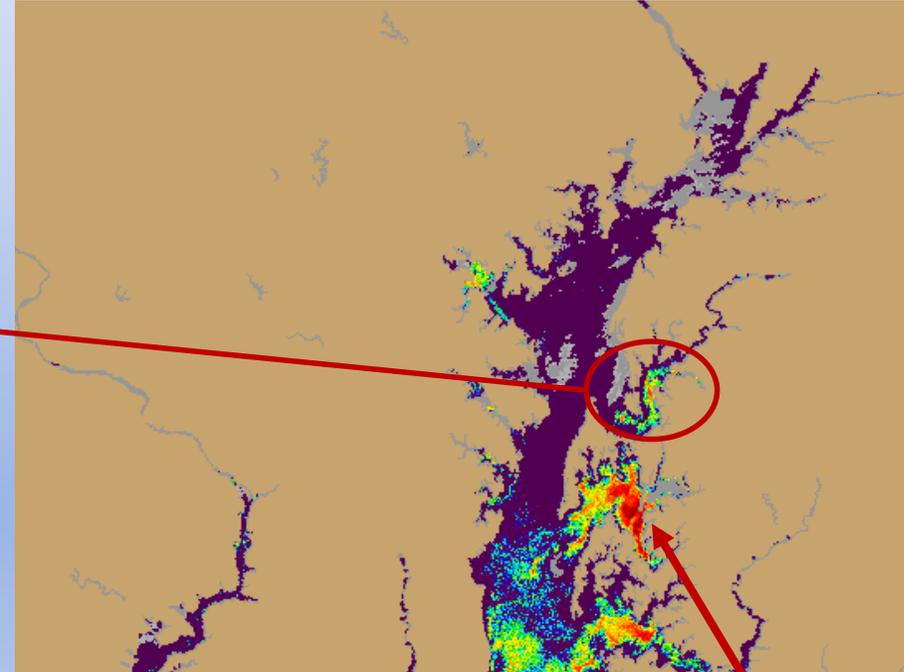
(3) Cyanobacteria Index (Wynne et al., 2008) modified by a negative shape at 665 nm

Bloom of *Gymnodinium instriatum* in the Chester River on October 2-4, 2018

Photo courtesy of
Tim Trumbauer, Chester River Keeper
Oct 4, 2018

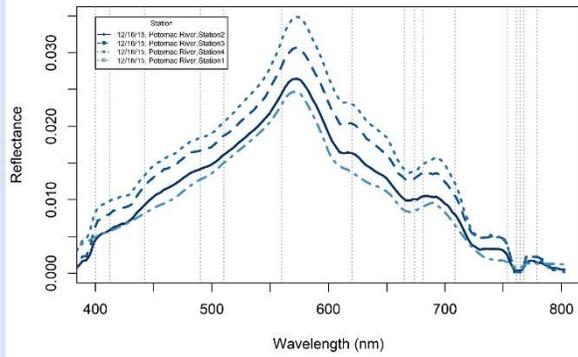


G. instriatum

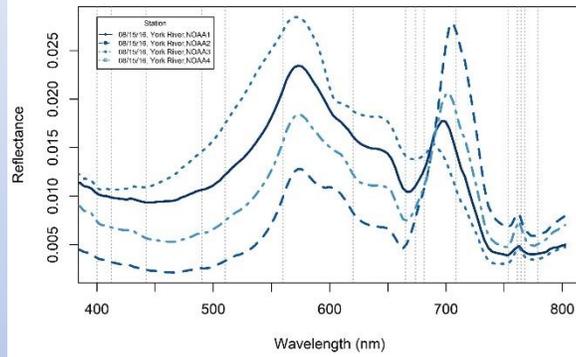


Prorocentrum and
Heterocapsa in Eastern Bay

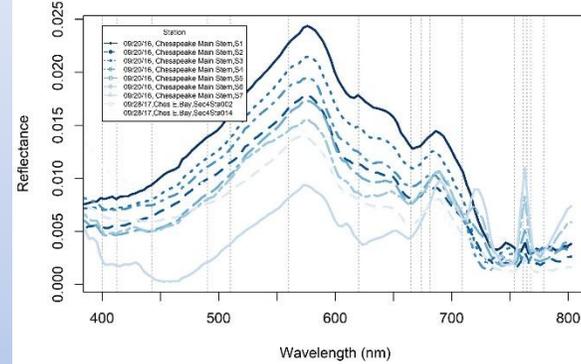
Mixed Prorocentrum minimum & Karlodinium veneficum



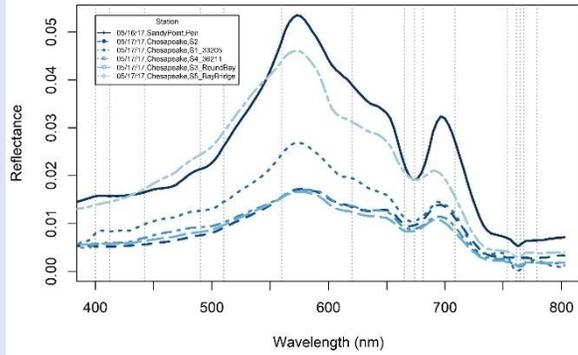
Margelefidinium polykrikoides



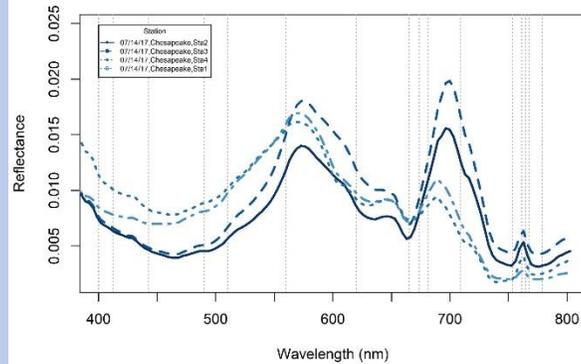
Leptocylindrus minimus



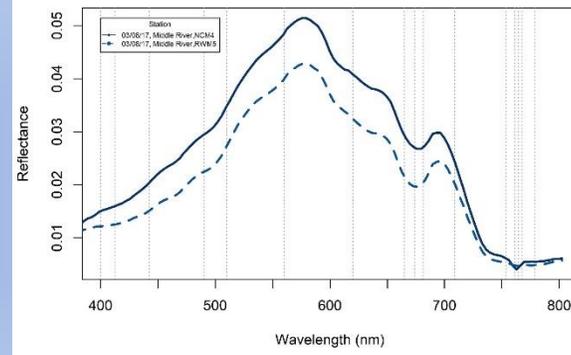
Prorocentrum minimum



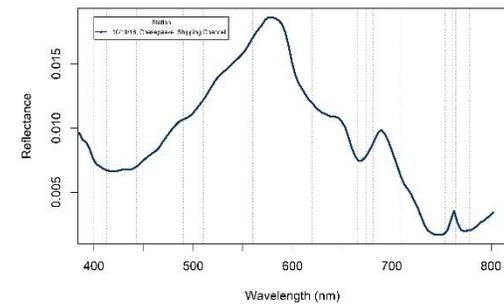
Heterocapsa lanceolata



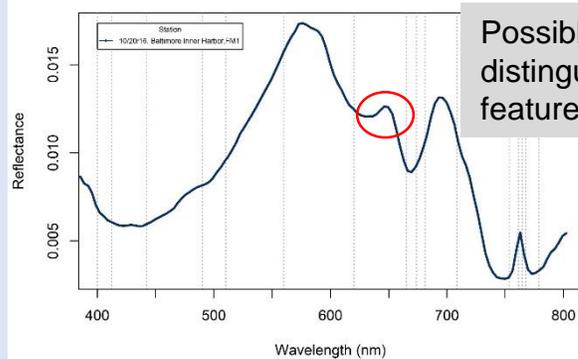
Cryptomonad flagellates



Diatoms

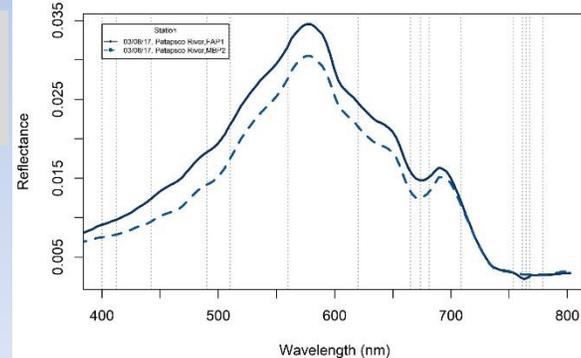


Akashiwo sanguinea

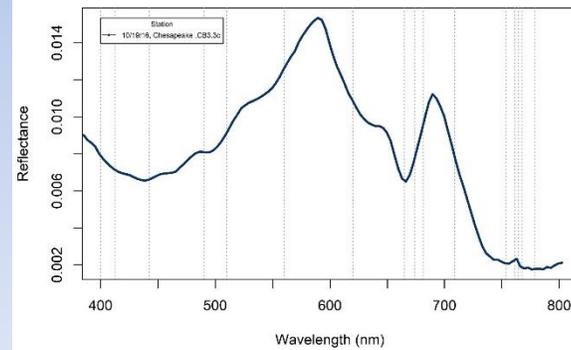


Possible distinguishing feature?

Heterocapsa spp.

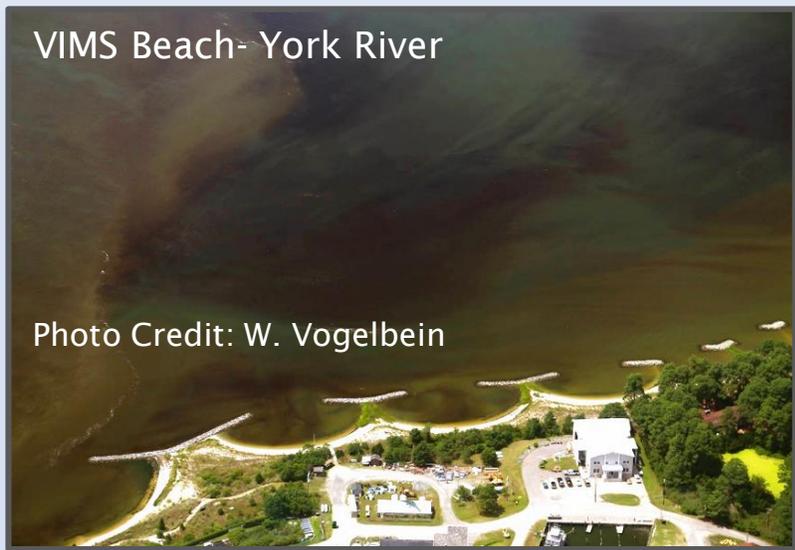


Mixed Heterosigma akashiwo and Mesodinium rubrum



Radiometry collected in collaboration with DNR, MDE

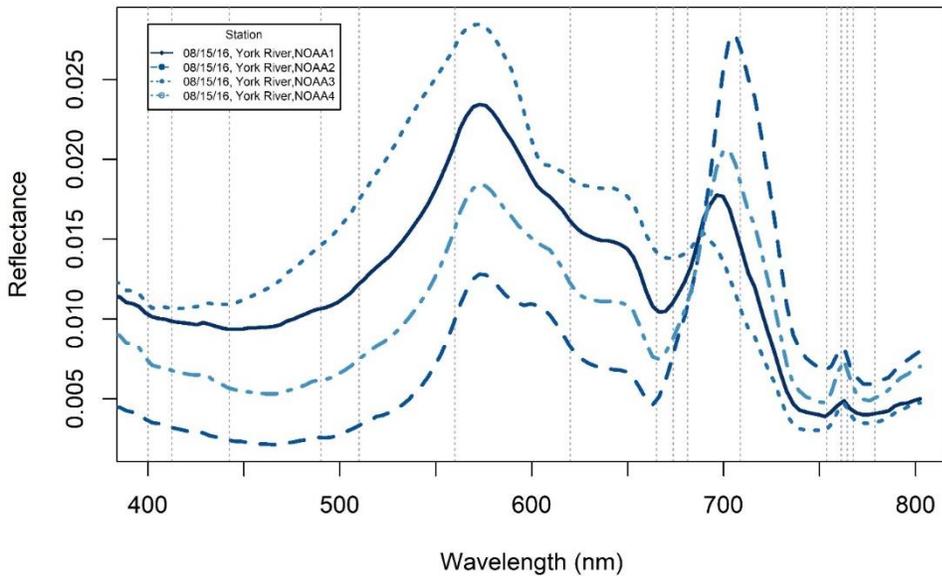
Validation provided by J. Wolny, Maryland DNR



High biomass surface
dinoflagellate blooms

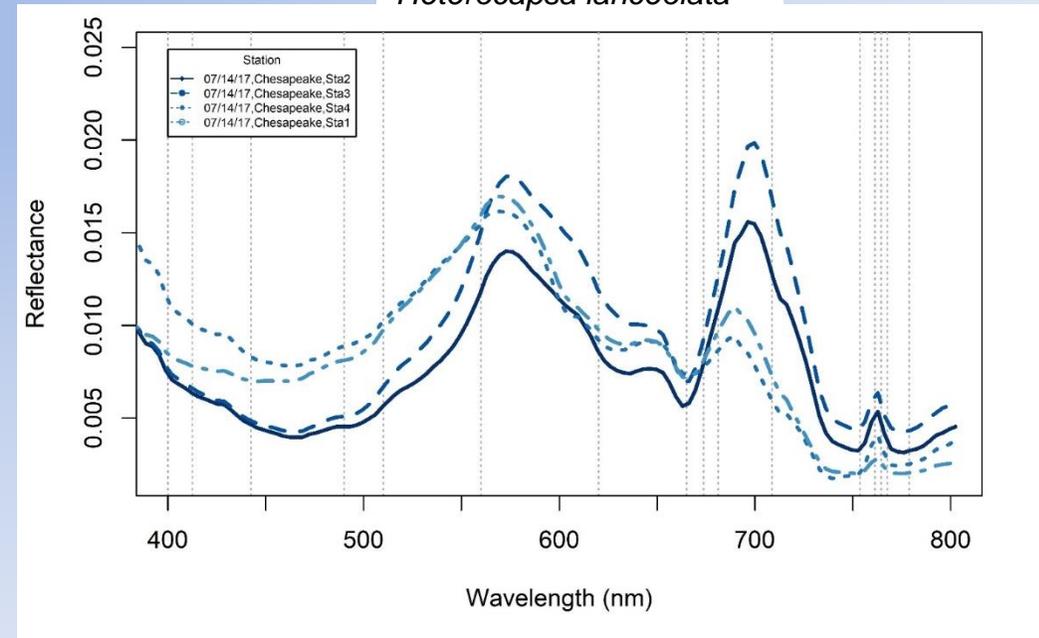


Margelefidinium polykrikoides

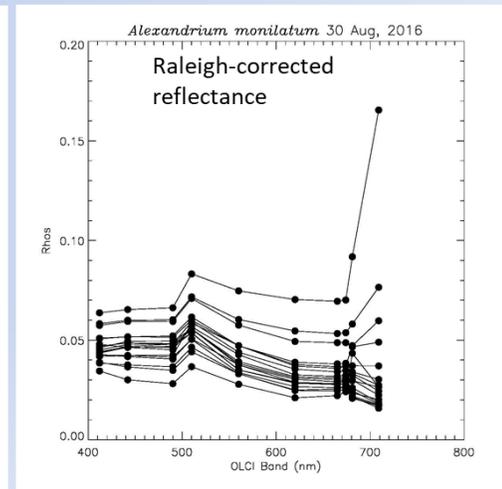
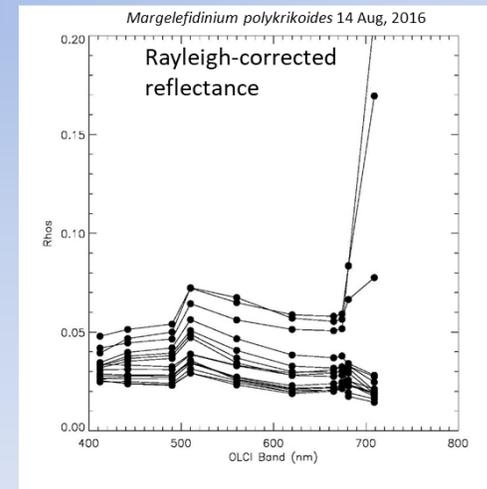
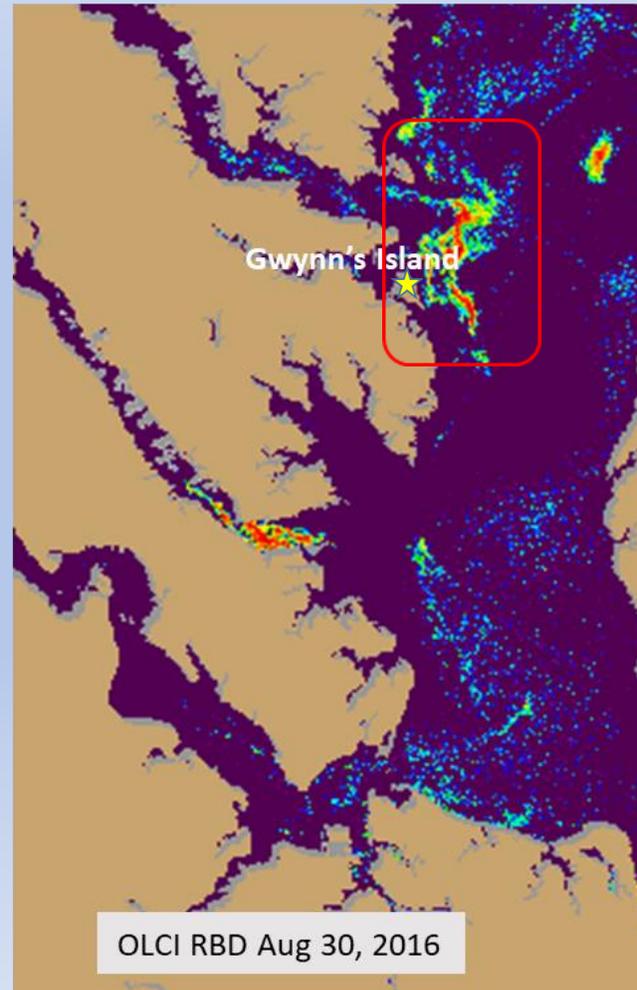
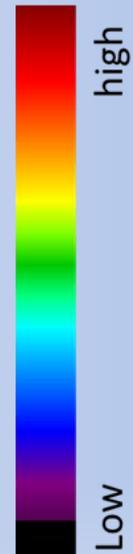
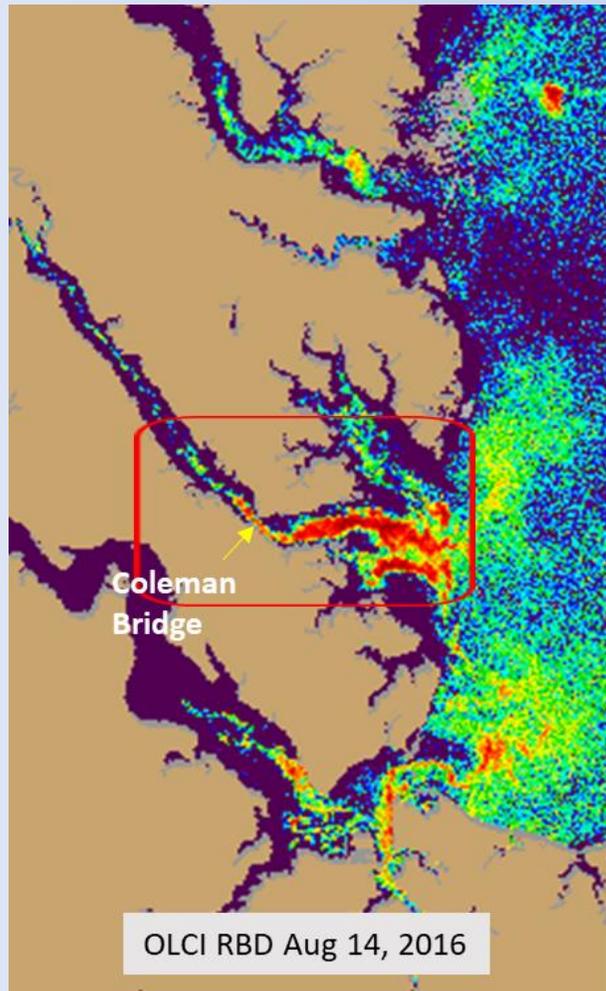


While magnitude
of peaks may
change with
concentration,
overall shape is
the same

Heterocapsa lanceolata



Satellite (or optical) spectra alone cannot separate blooms



Ecological approaches, temporal anomaly method

Anomaly finds *New Blooms*

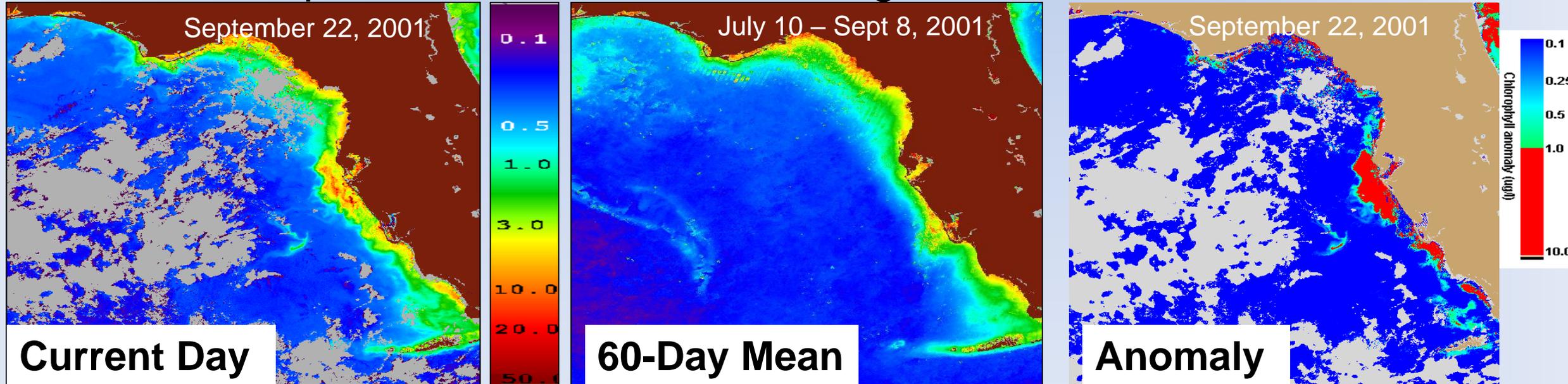
Demonstrated as effective for *Karenia brevis*

K. brevis dominates biomass in late summer

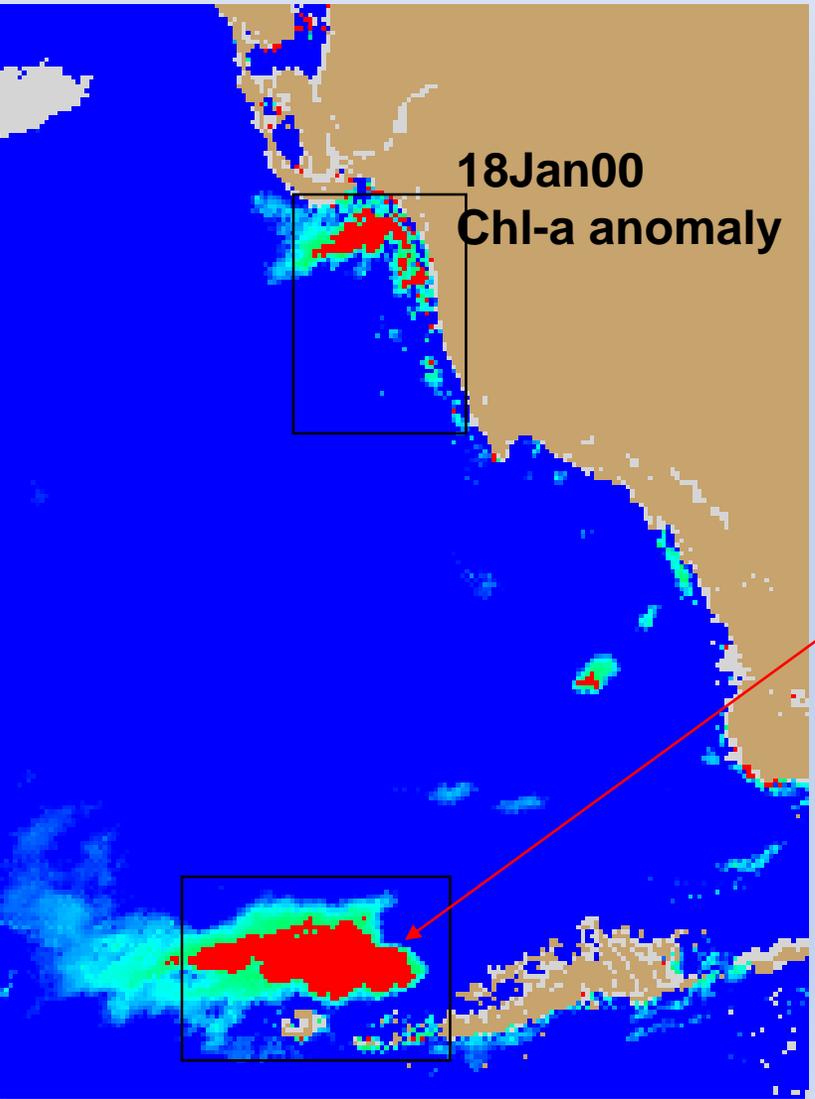
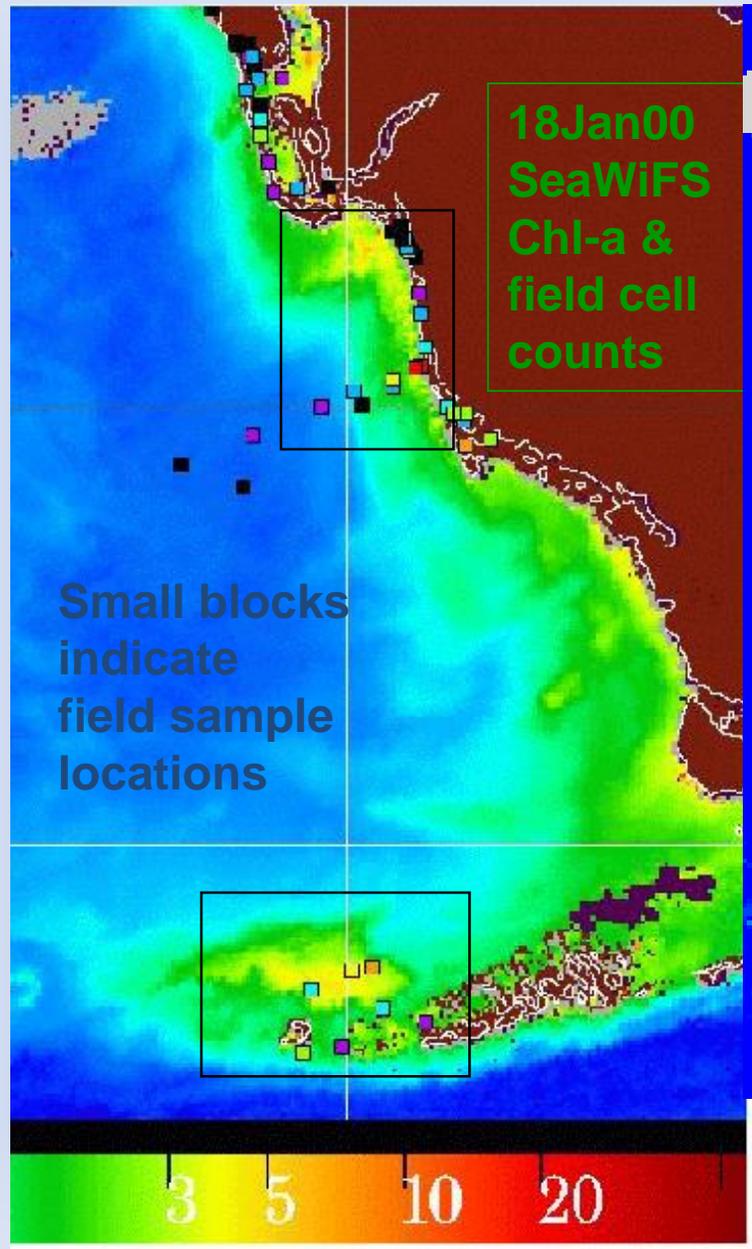
Better in case 2 water (with turbidity) than optical algorithms

Accuracy > 80% during summer and fall

False positives common, False negatives rare. **New Blooms**



HAB Detection from SeaWiFS



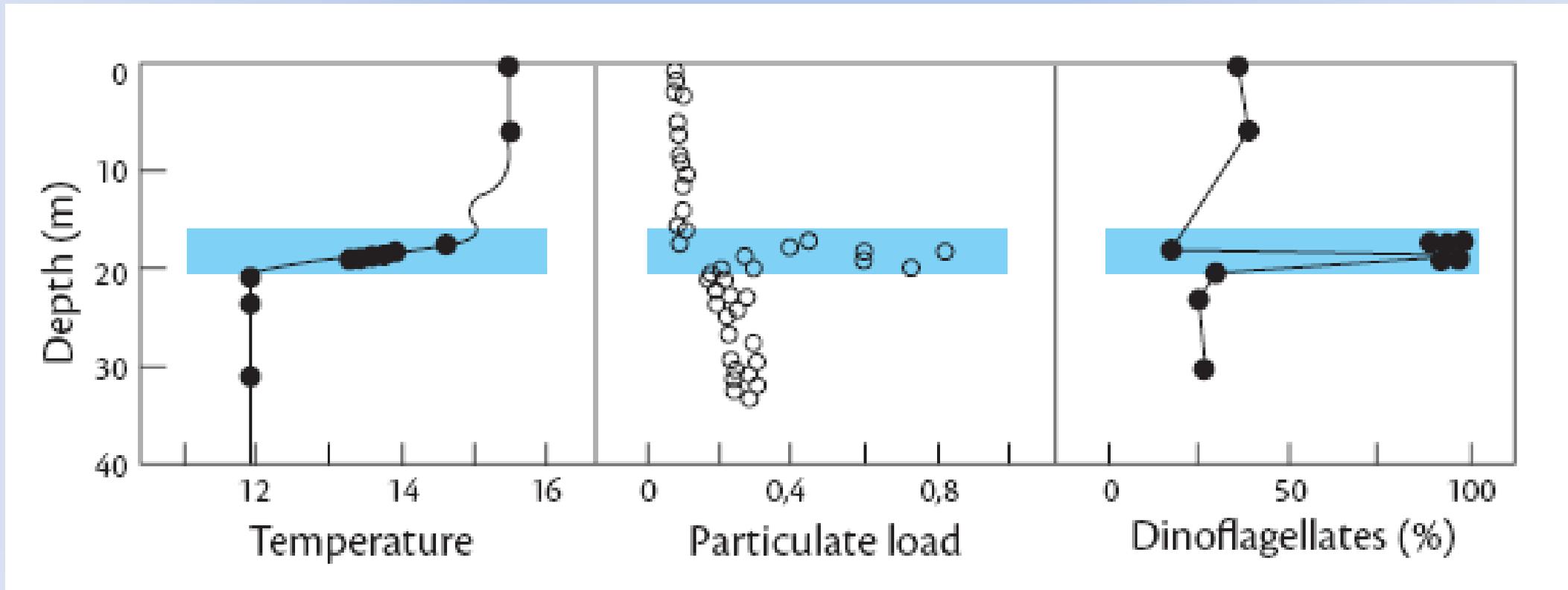
First HAB
detected
from
satellite
prior to field

- Bloom extent not identified by field sampling, but satellite provides full size

Dinoflagellates swim and so collect at fronts.

Hydrography meets biology

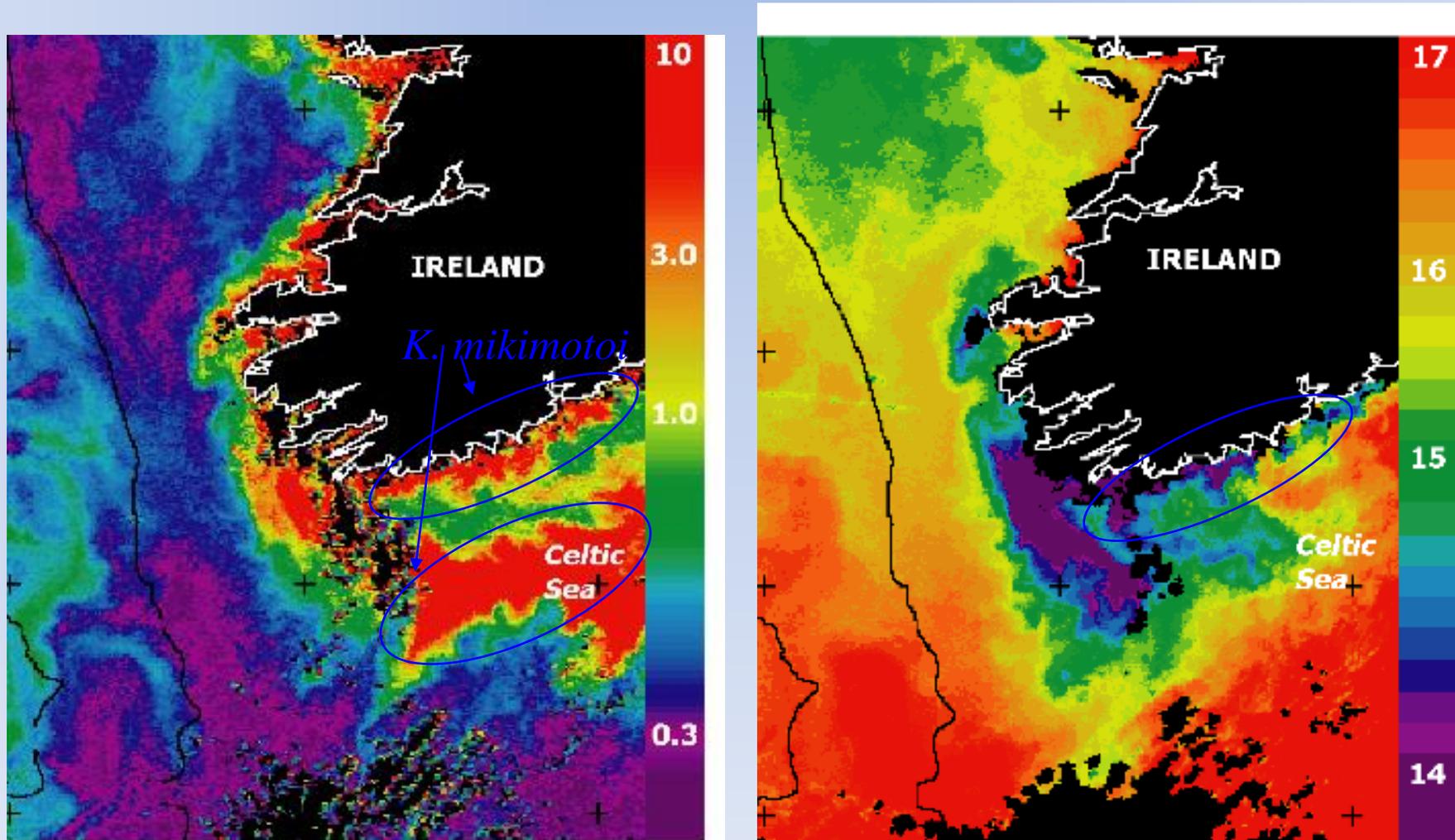
- Example with *Dinophysis acumenata*



Gentien et al., 2005

Combining satellite data sets help.

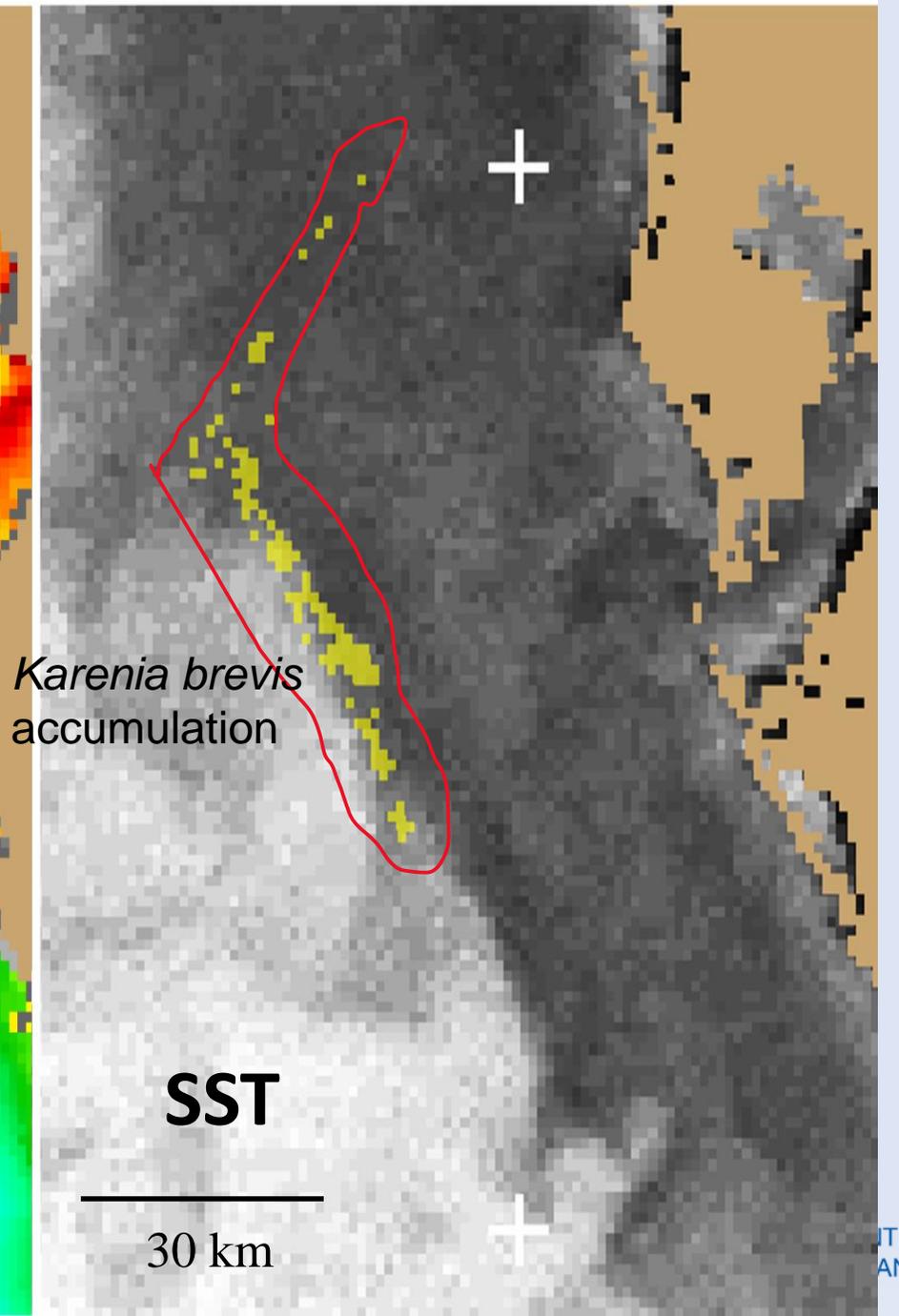
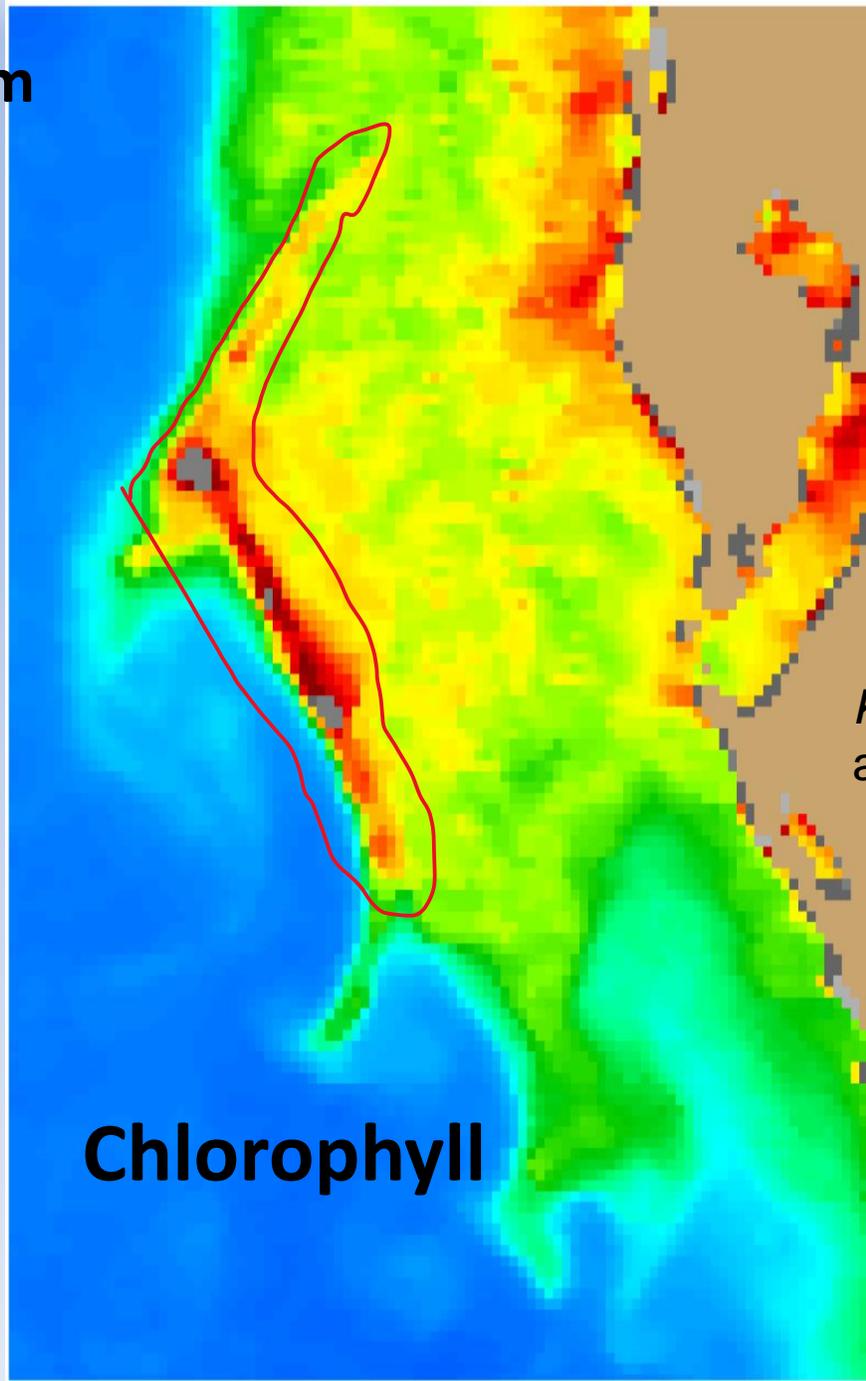
K. mikimotoi starts at pycnocline, appears at the coast in upwelled cold water (Raine et al., 2001)



Nov 7, 2018

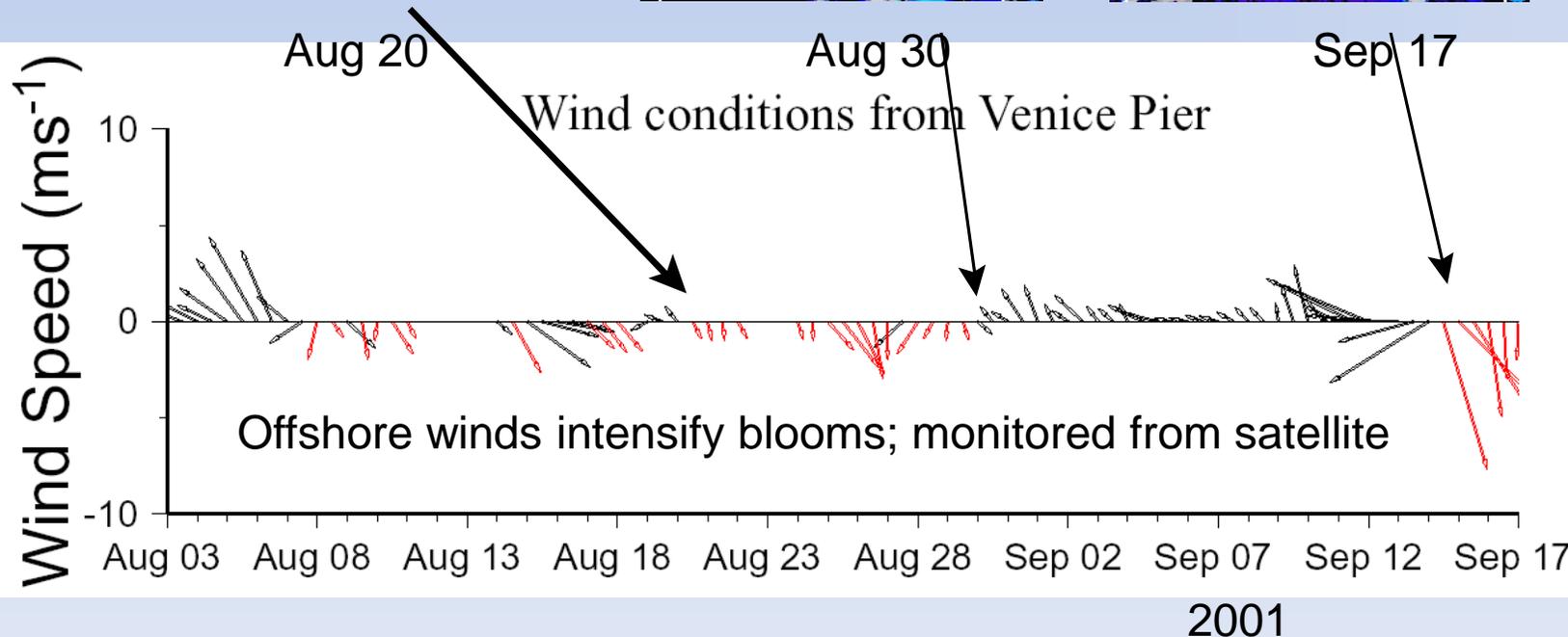
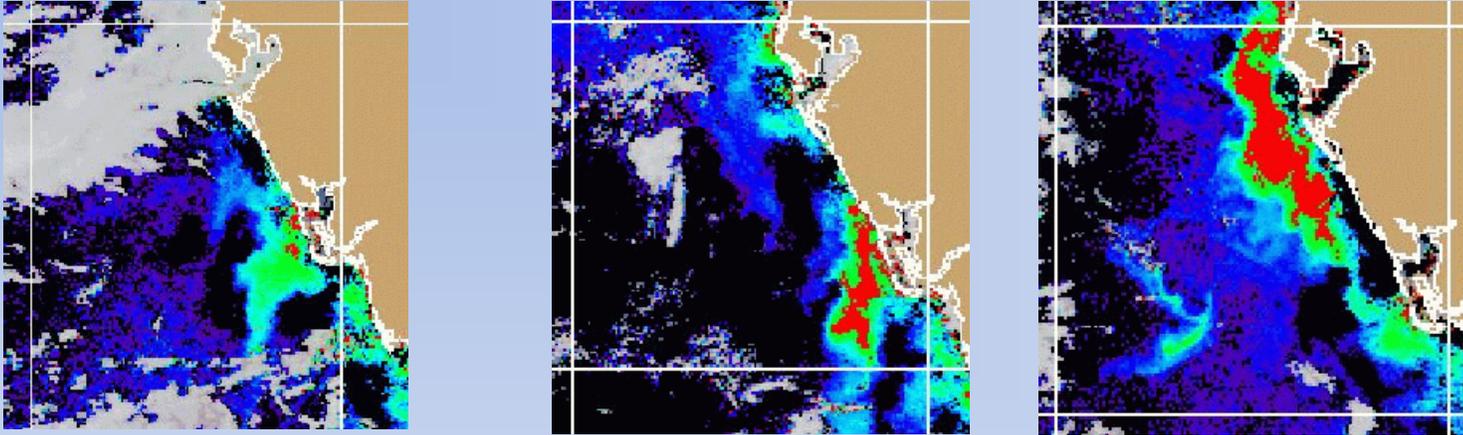
AWRA Annual Conference

Karenia brevis bloom
accumulates at
temperature front



New Bloom after late fall upwelling more likely to be *K. brevis*

HAB-flag (Red is HAB, green is weaker HAB)



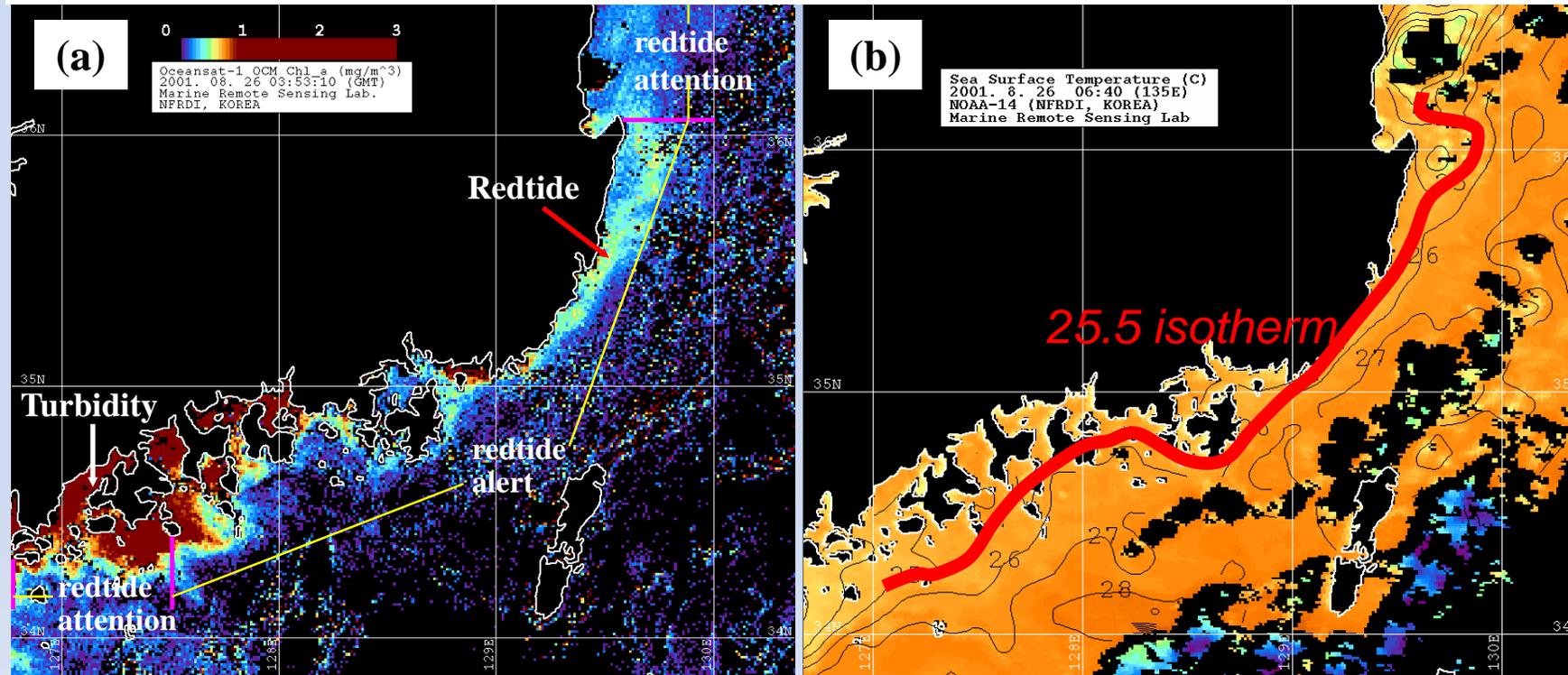
Accumulation
involves
two-layer flow
(physical)

And swimming
(biology)

Korea HAB linkage to 25-26 °C line

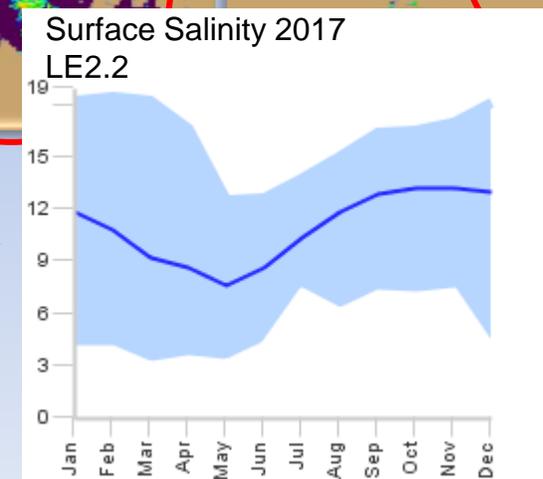
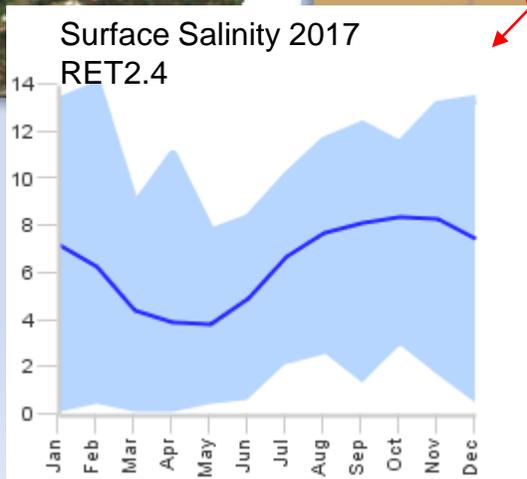
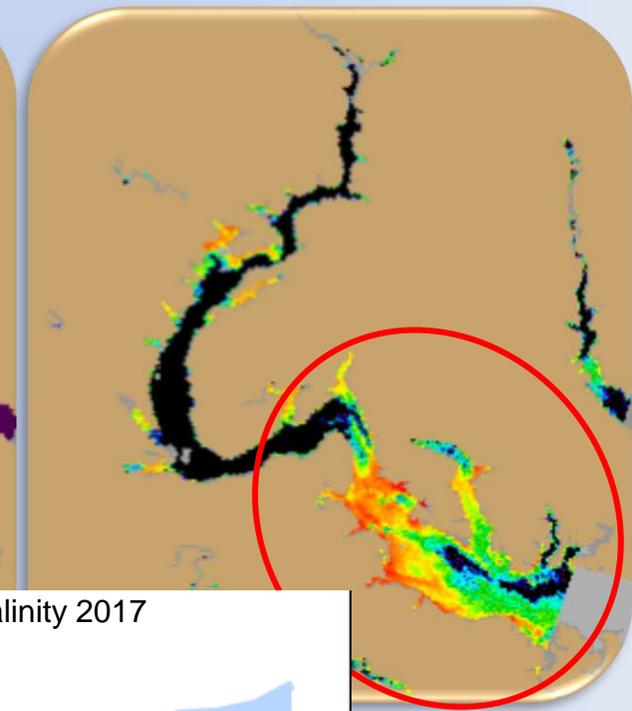
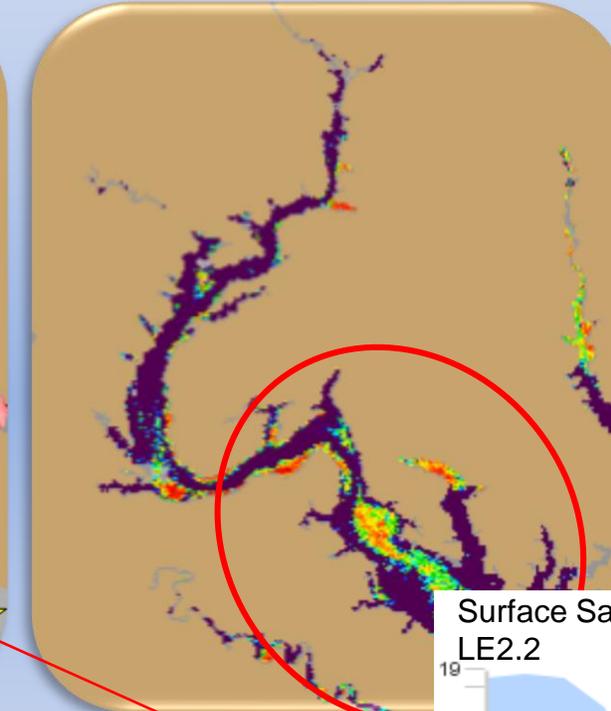
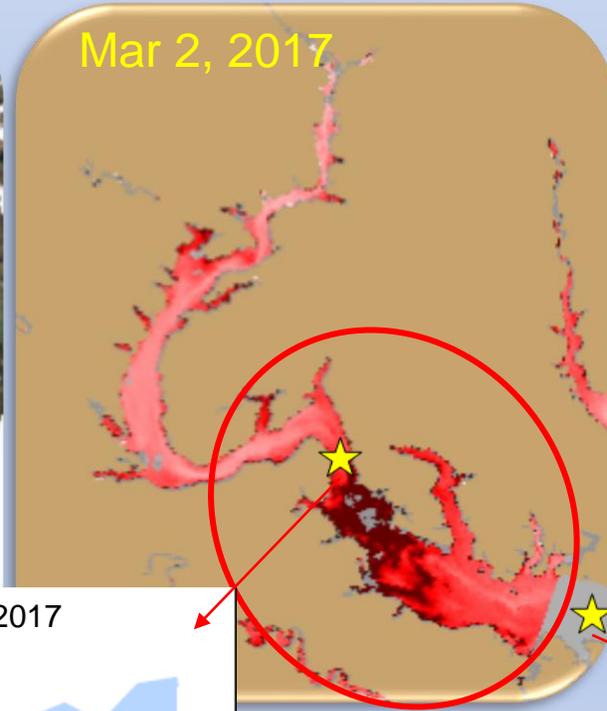
Chlorophyll

SST



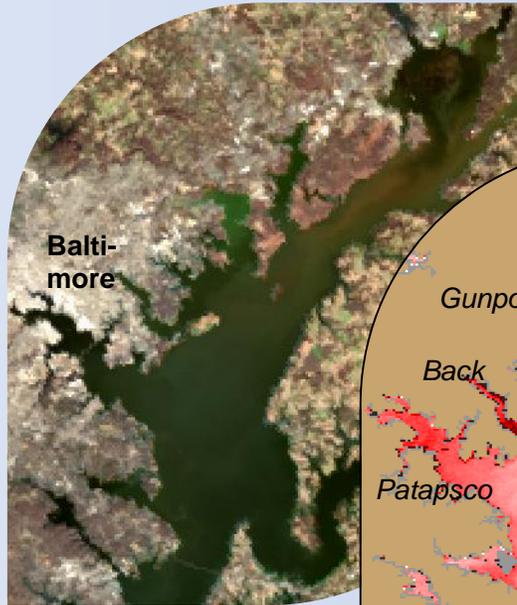
Heterocapsa triquetra associated along salinity fronts

March 6, MD DNR monitoring confirmed salinity change

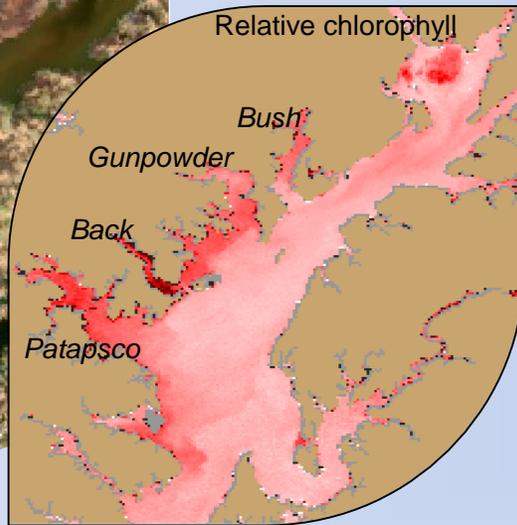




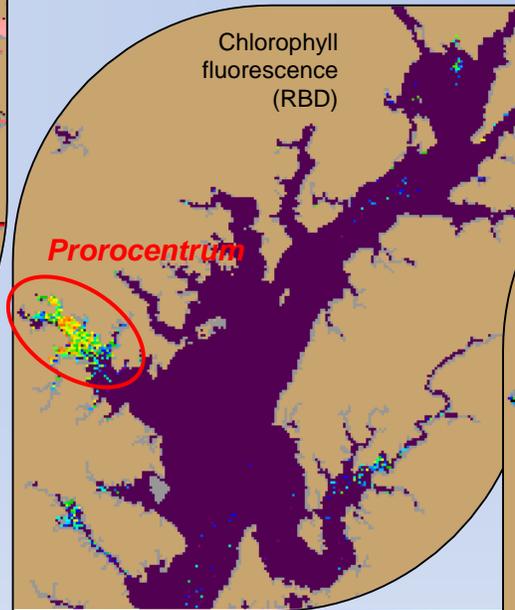
Chesapeake Bay Blooms. Fish kills in tributaries, Dec 20, 2016. *Karlodinium* present (fish killing). No kills in Patapsco, Bush (*Prorocentrum*, *Heterocapsa*)



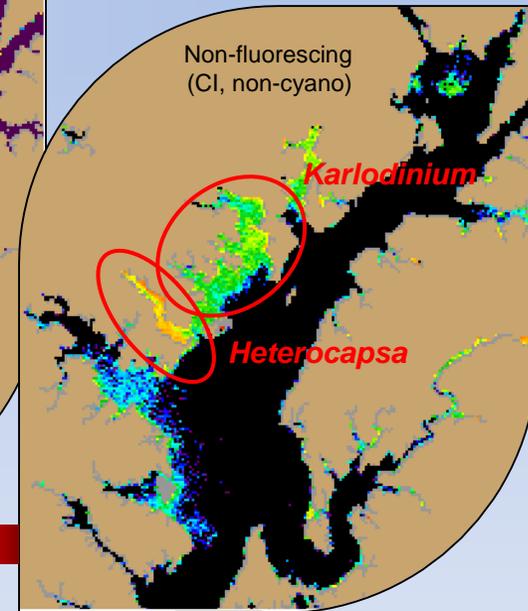
OLCI "true color"



low high



Low high



R. Stumpf
M. Tomlinson



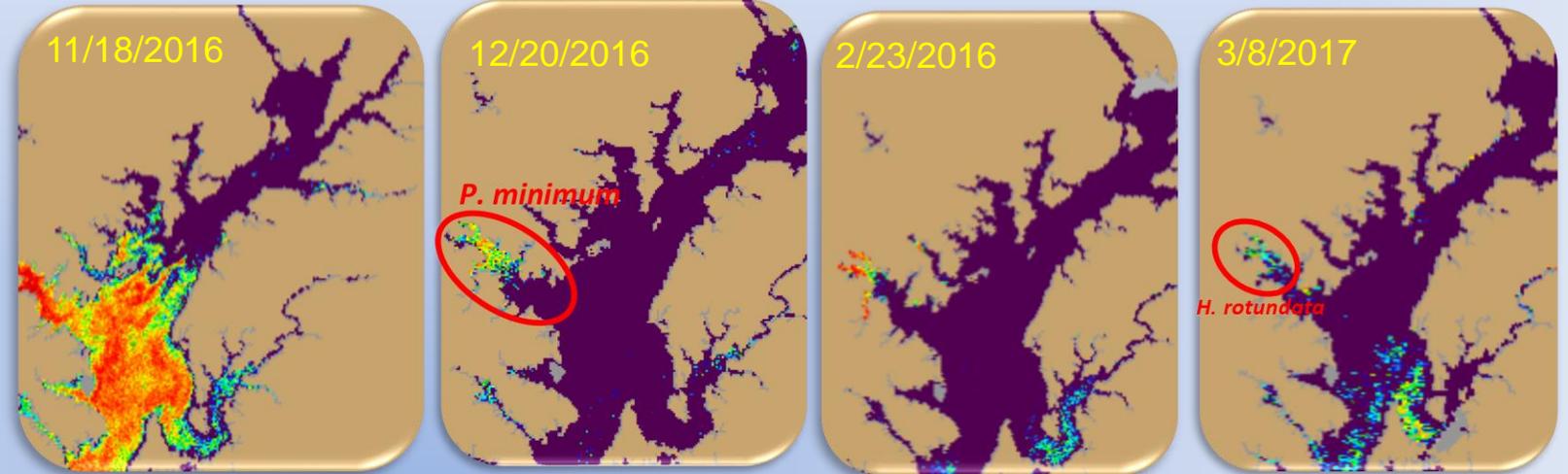
J. Wolny
Maryland
DNR



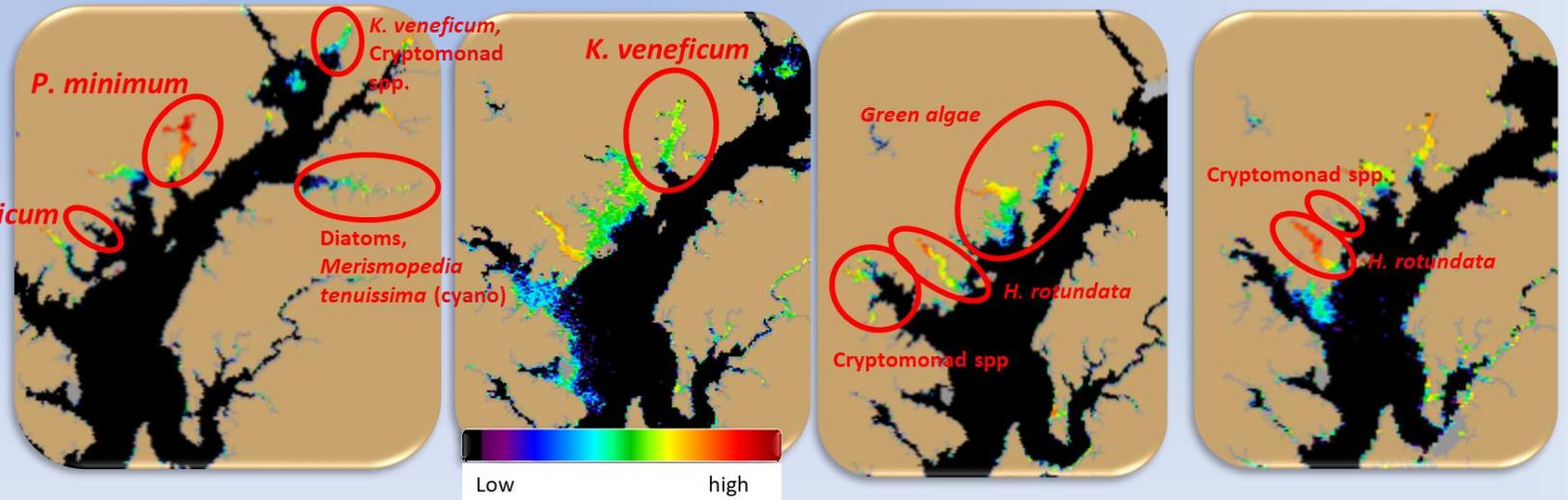
Factors influencing non-fluorescing, high biomass blooms

Chl fluorescence

- Low light
 - Increased turbidity
 - Time of year (Late Fall/Early Spring)
- Mixotrophy
 - Several species such as *K. veneficum*, *H. rotundata* and *P. minimum* are mixotrophic



Non-fluorescing,
High biomass blooms



Satellites can find blooms, but need more information to identify what they are

time

temperature

salinity

Physics:

circulation, fronts, upwelling, downwelling

light availability,

time of year