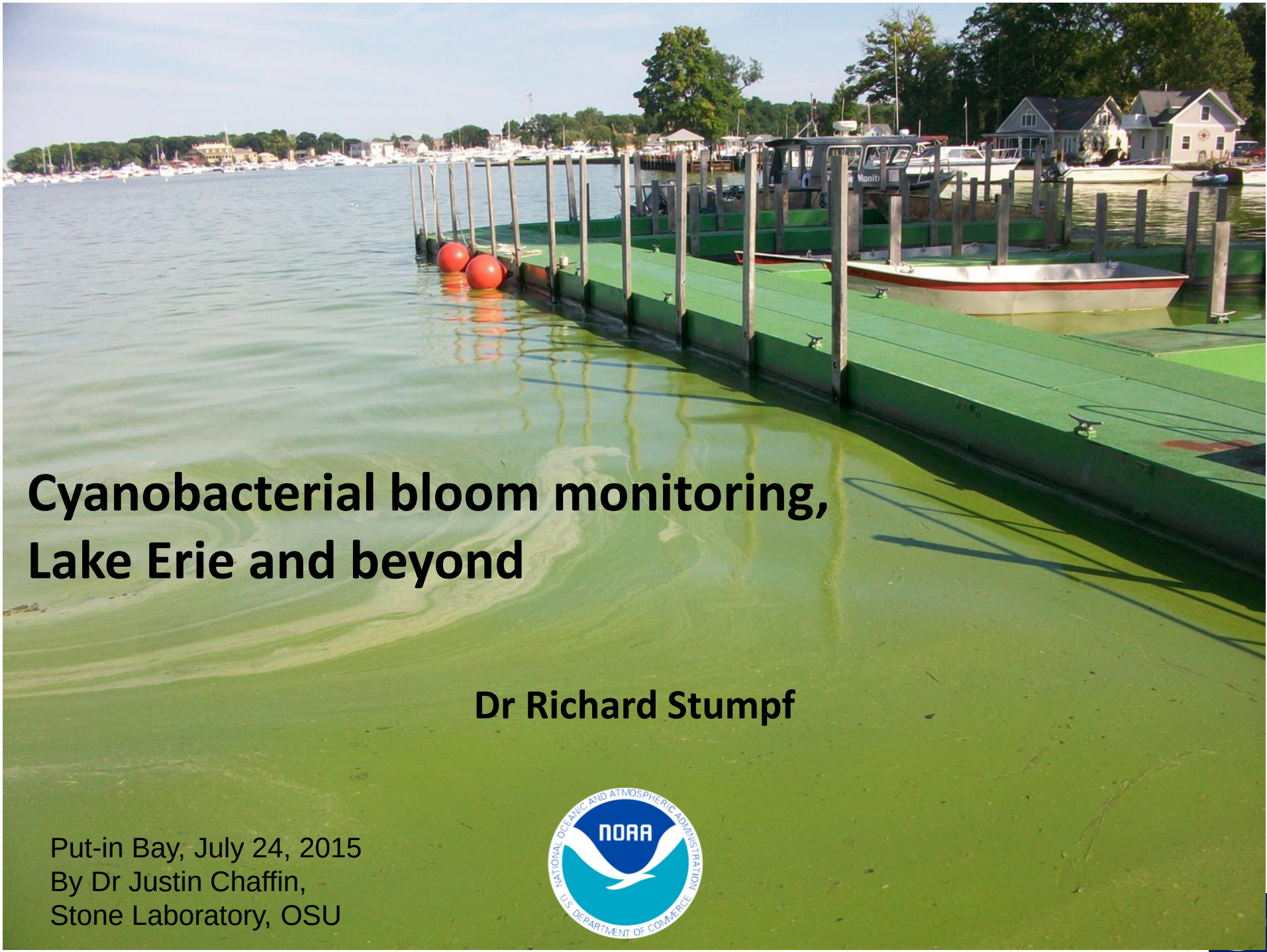
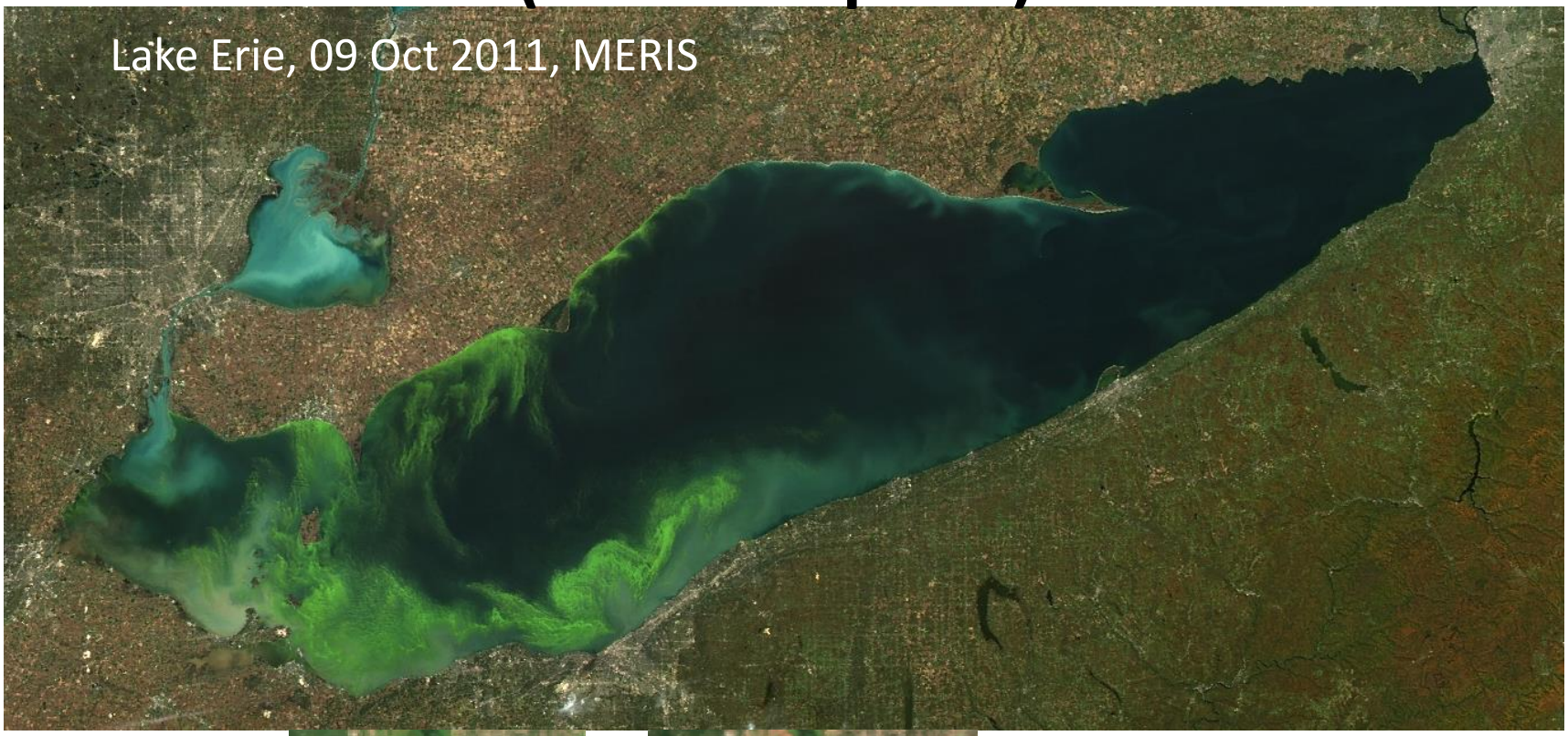


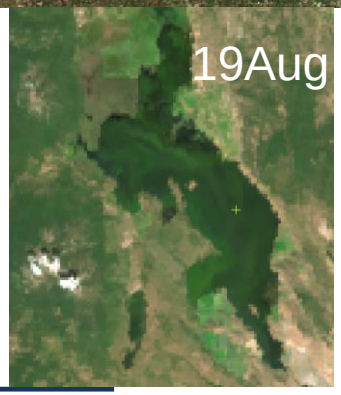
Cyanobacterial bloom monitoring, Lake Erie and beyond

Dr Richard Stumpf

Put-in Bay, July 24, 2015
By Dr Justin Chaffin,
Stone Laboratory, OSU

Emphasis on medium resolution (more frequent)





Upper Klamath Lake, Oregon
2011 MERIS

Cyanobacterial bloom problems that satellite monitoring might help

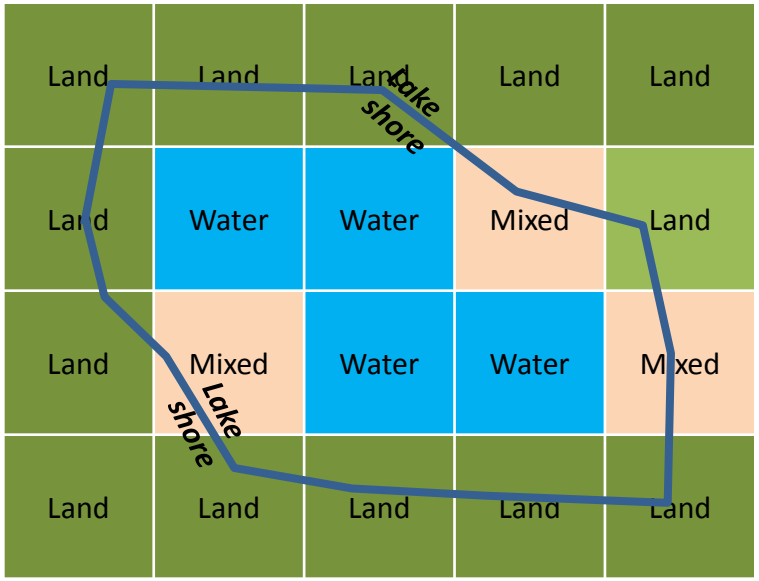
- Where are blooms now?
  - How bad are they (concentration)?
- Will it be worse tomorrow
  - For swimming or for water suppliers?
- Which lakes are typically bad
- Have lakes changed over the last decade?
- Can we explain what causes blooms
  - Predict how bad the bloom will be this summer
  - Inform management to reduce blooms by reducing nutrients

Satellite Comparison for cyano applications

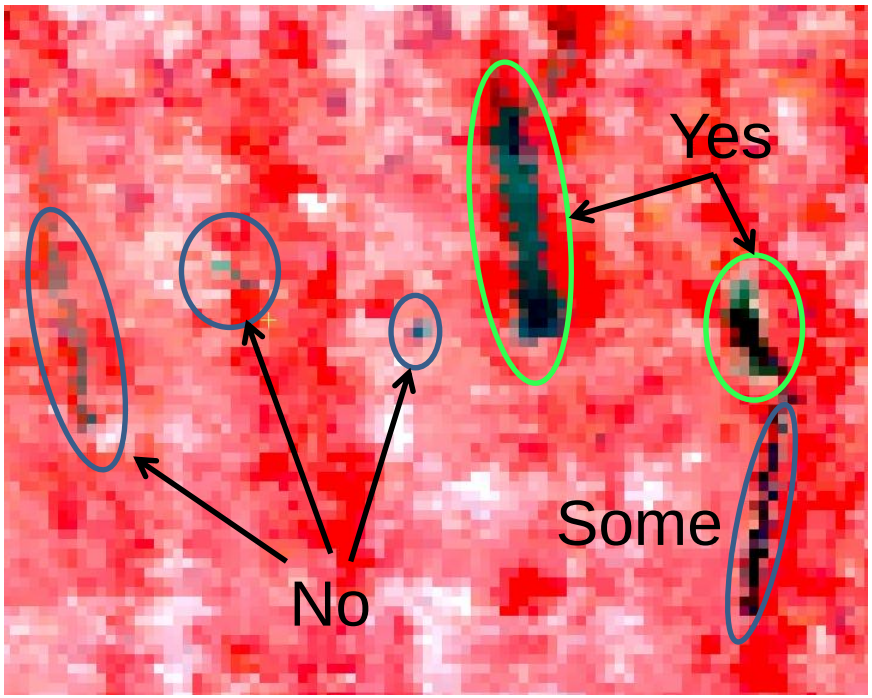
Satellite	Spatial	Temporal	Key Spectral
MERIS (2002-12) OLCI Sentinel-3 2015	300 m *OK*	2 day *good*	10 (5 on red edge) *good*
MODIS high res Terra 1999; Aqua 2002	250/500 m *OK*	1-2 day *good*	4 (1 red, 1 NIR) *marginal*
MODIS low res & SeaWiFS	1 km *poor*	1-2 day *good*	7-8 (2 in red edge) *OK*
Landsat	30 m *good*	8 or 16 day *poor*	4 (1 red, 1 NIR) *marginal*
Sentinel-2 (2015)	20 m *good*	10 day (5 day with 2nd satellite in 2017) *Potential with 2*	5 (1 red; 2 NIR, 1 in red edge) *potential*

Clouds take out 1/2 to 2/3 of imagery
Some sunglint is not a problem for our algorithms
Minimum resolution, 3 pixels across (2 mixed land/water)

Resolution and water bodies



Mixed pixels limit our ability to monitor small water bodies.

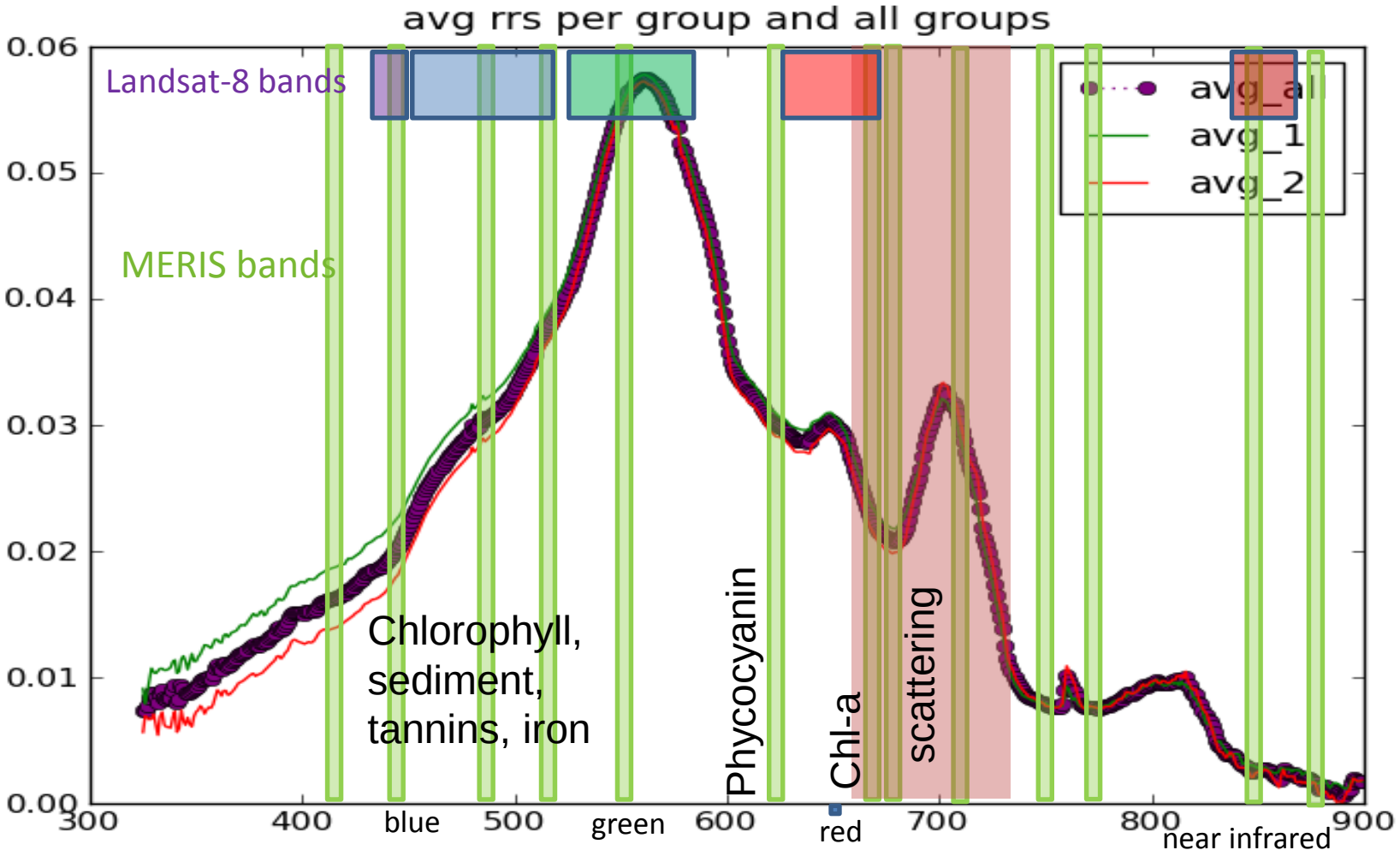


Note: false color sharpens distinction between land and water.
Reddish pixels at right include land.

Where are we with satellite

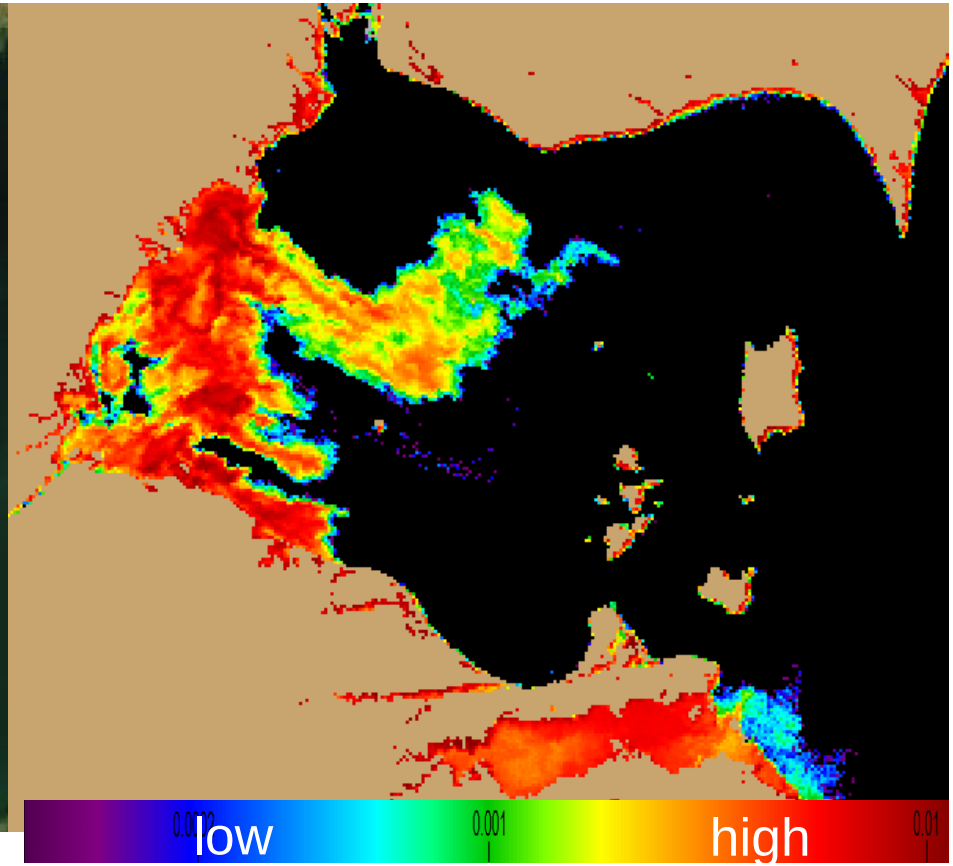
- All sensors can find scum
- All sensors can find turbid “eutrophic” water
  - Defining the right answer for mgmt is the problem
- We can find cyanobacteria blooms (with MERIS)
- All usable methods produce false positives
    - Some produce false negatives
- All sensors have limitations (time, space, spectra)
- MERIS was the best sensor for cyano detection,
  - Several bands in red and near-IR, 2-day repeat
  - 300 m and 1.2 km
- The future is OLCI on Sentinel-3 (Feb 2016 launch)
  - Replaces MERIS

MERIS (and Landsat) Bands on water spectra from *Microcystis*



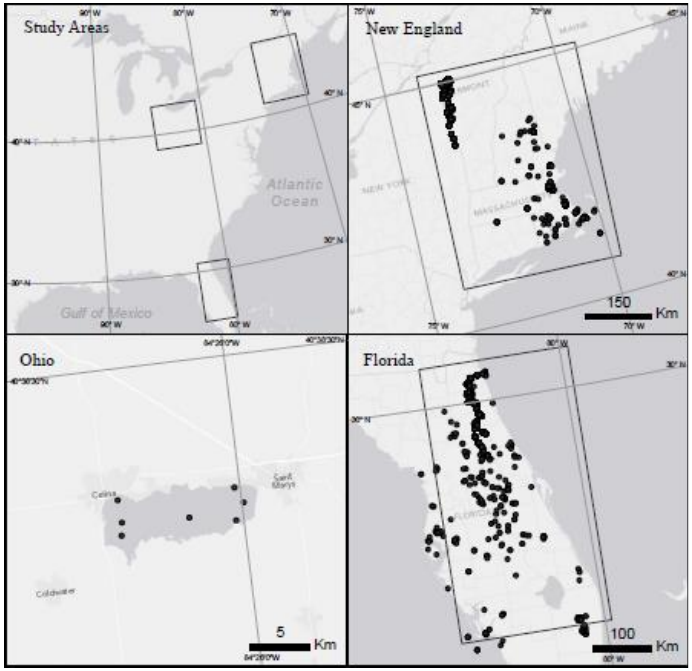
Also have to correct for atmosphere;
Landsat runs out of information content to discriminate everything

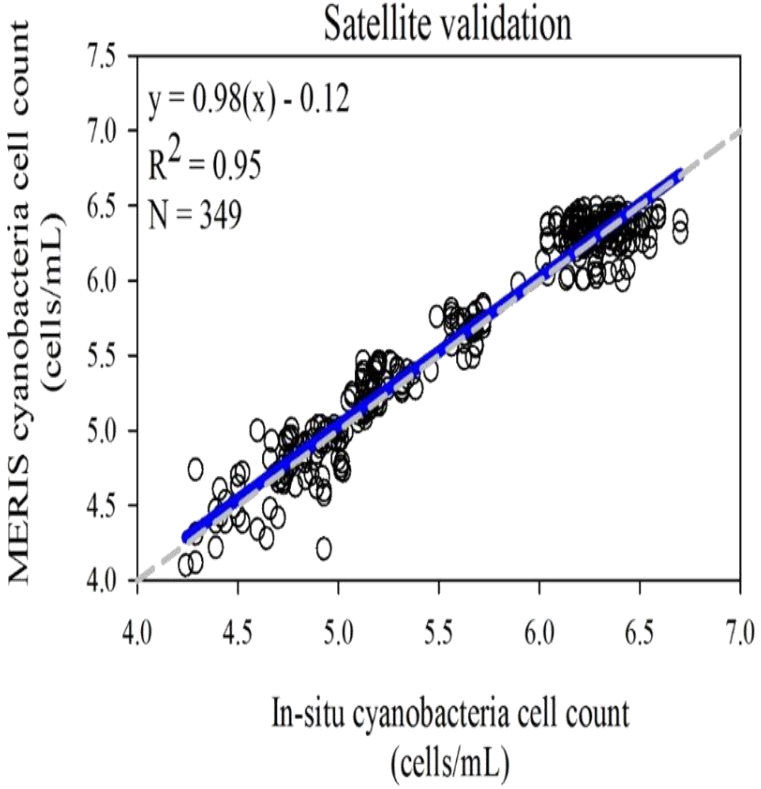
The extra wavelengths give a cyanobacteria index, “CI”, which equates to concentration

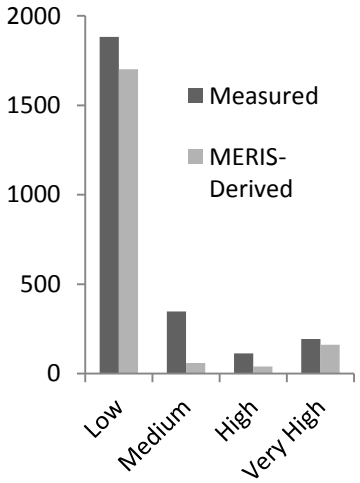


Validation of Lake Erie concentration algorithm for other areas

- **Remote Sensing**
  - *Uniform and systematic approach for identifying & quantifying cyanobacteria blooms.*
    - Second derivative spectral shape algorithms (SS; Wynne et al. 2008)



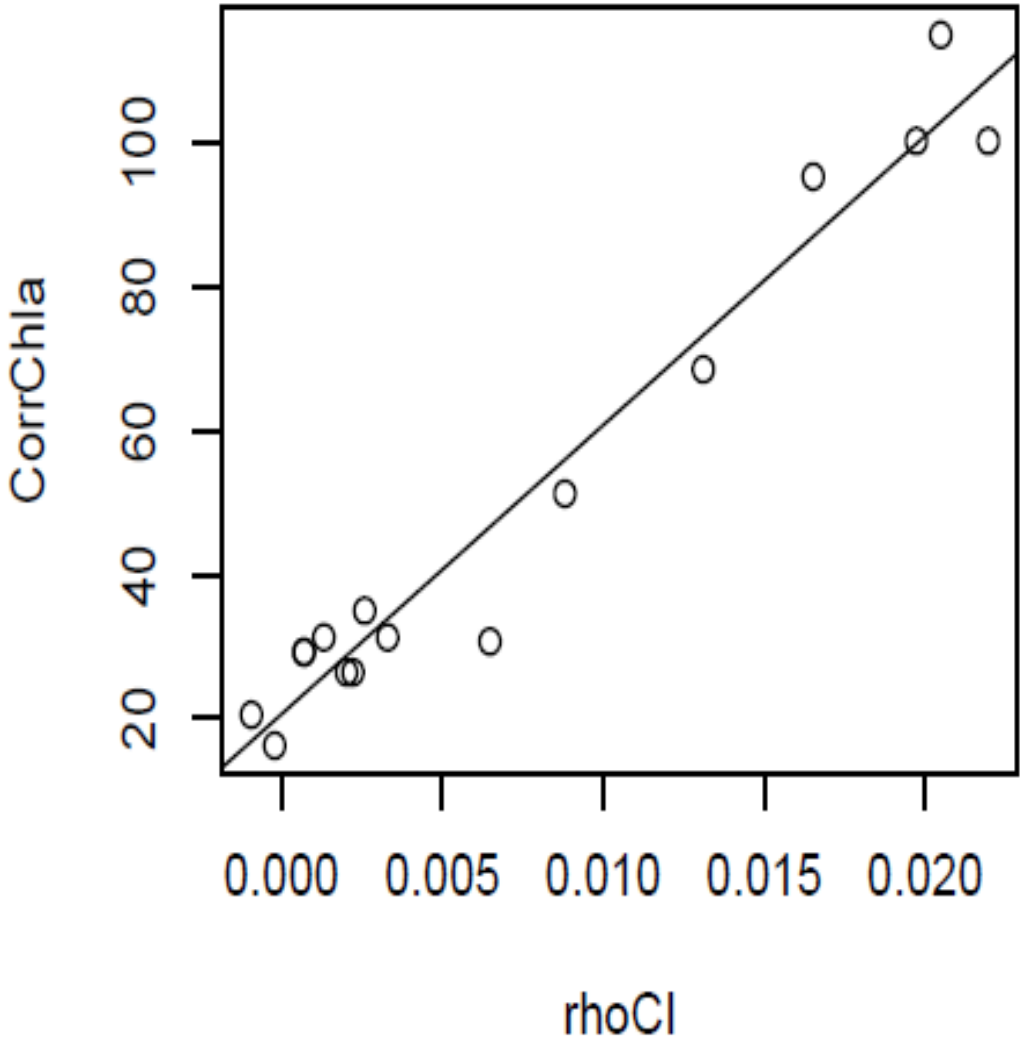




Lunetta, Schaeffer, Stumpf et al. Remote Sensing of Environment

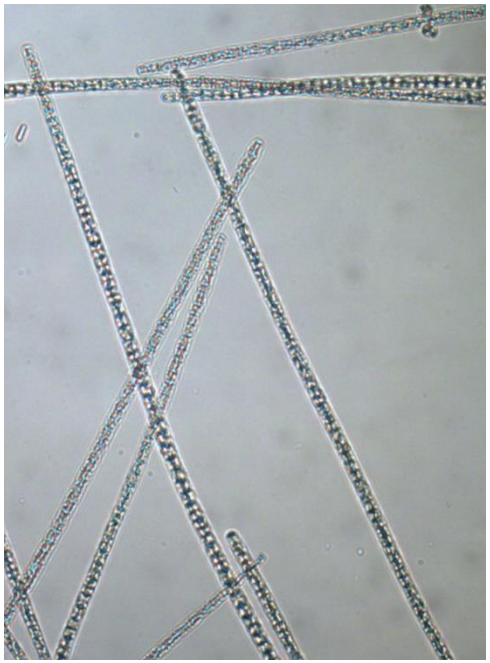
And Between Cl and chl-a from Florida (St Johns River WMD)

- r^2=0.96
- *Est chl* a =
- 4020*(*Cl*) + 20
- Detection of chlorophyll > 20 µg/L
  - (working on > 10 µg/L)



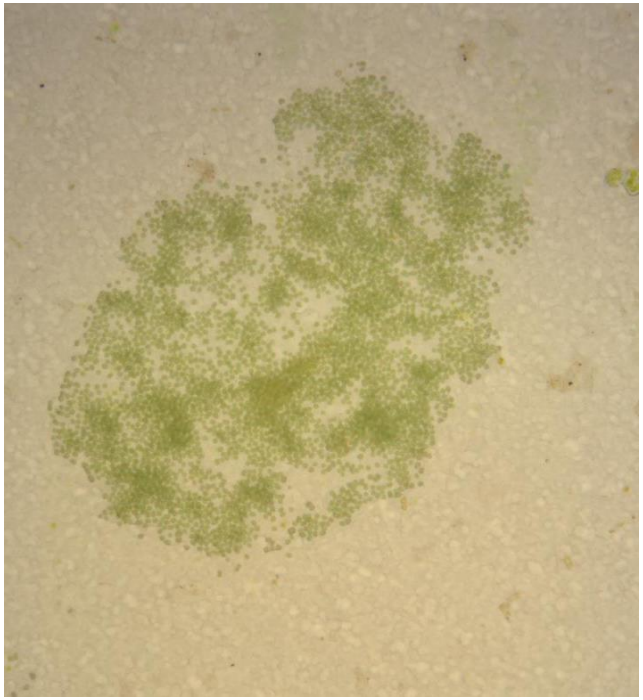
Planktothrix example

- Sandusky Bay, dispersed

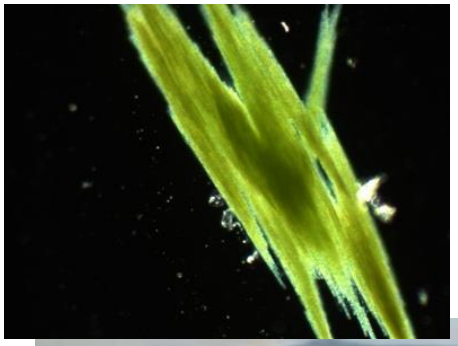


Microcystis example, it rises when it needs to make food

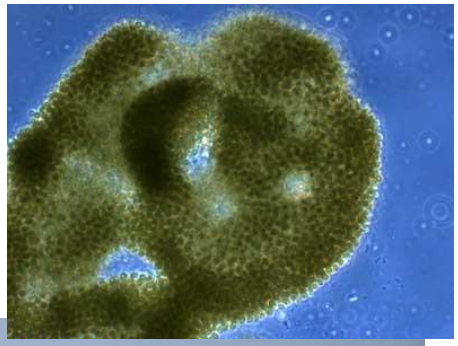
- Aug 2010, Lake Erie



Examples from California



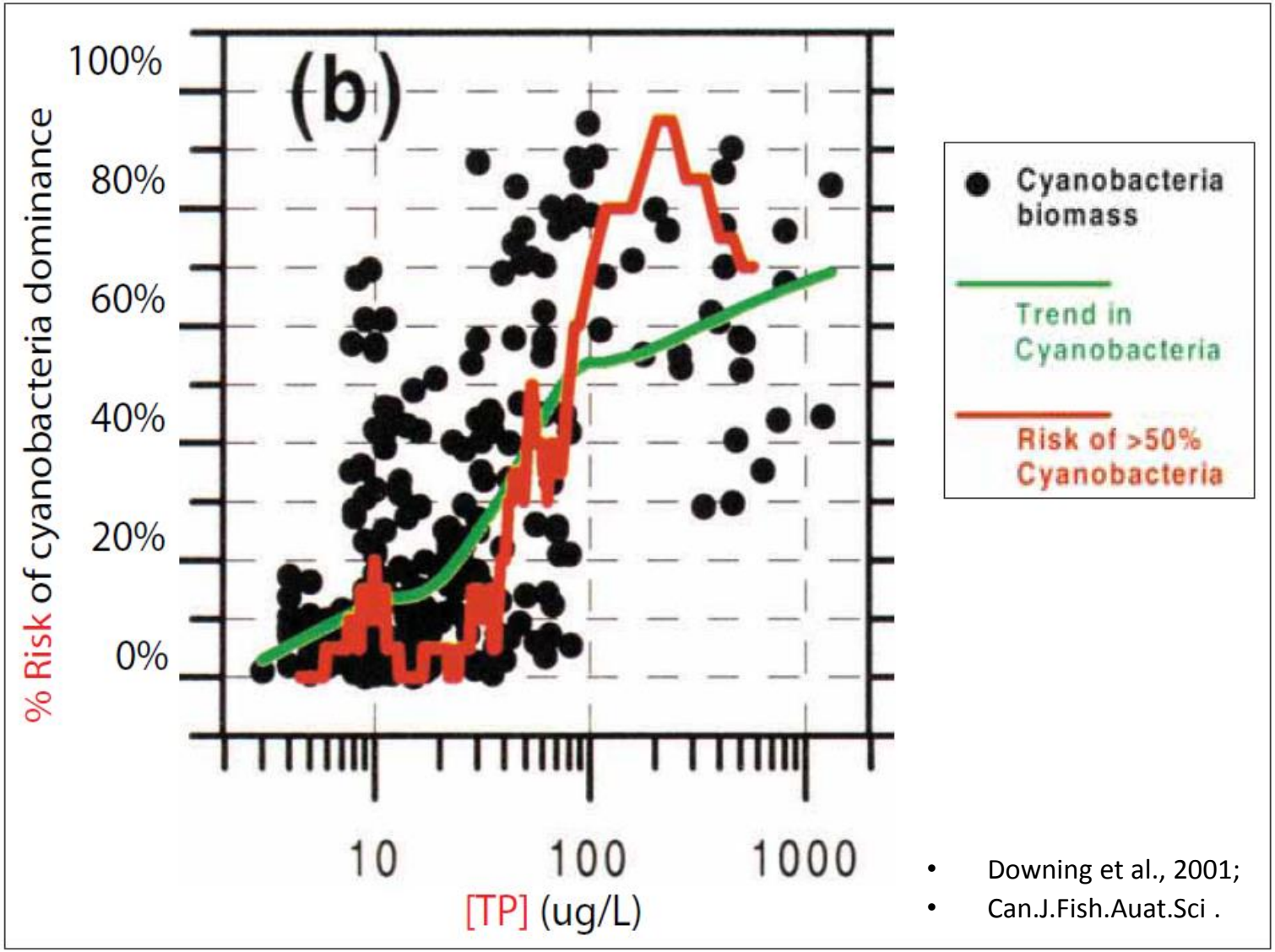
Photos from R. Kudela, UCSC



Aphanizomenon flos-aquae

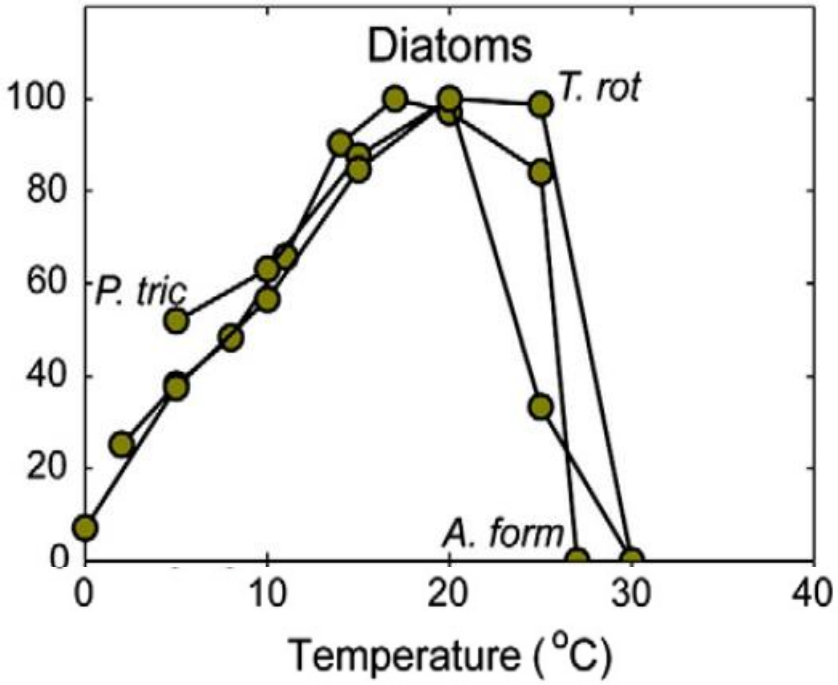
Microcystis spp.

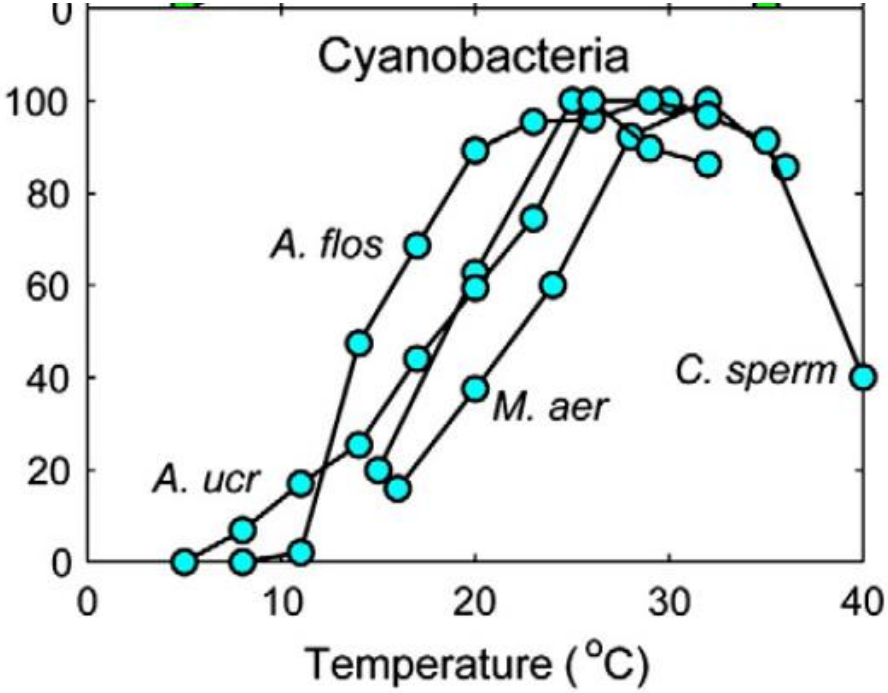
phosphorus useful for empirical models



- Downing et al., 2001;
- Can.J.Fish.Auat.Sci .

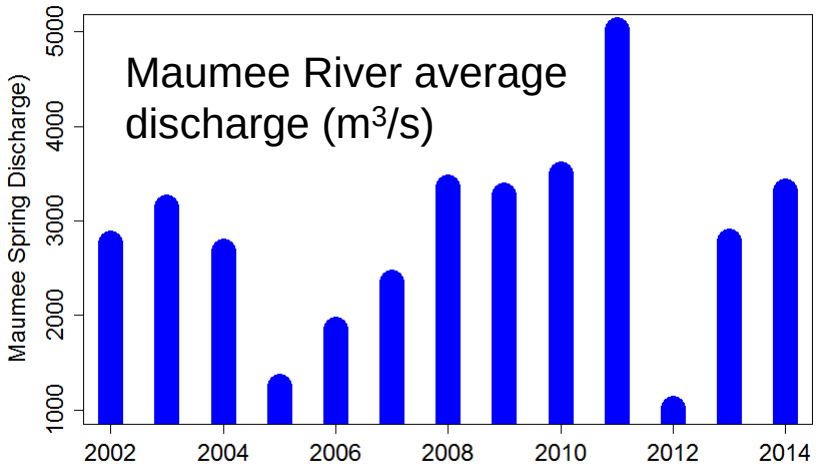
Cyanobacteria like warm water; strong growth > 20ºC; minimal growth < 15ºC Can help with ambiguities with Landsat, etc.

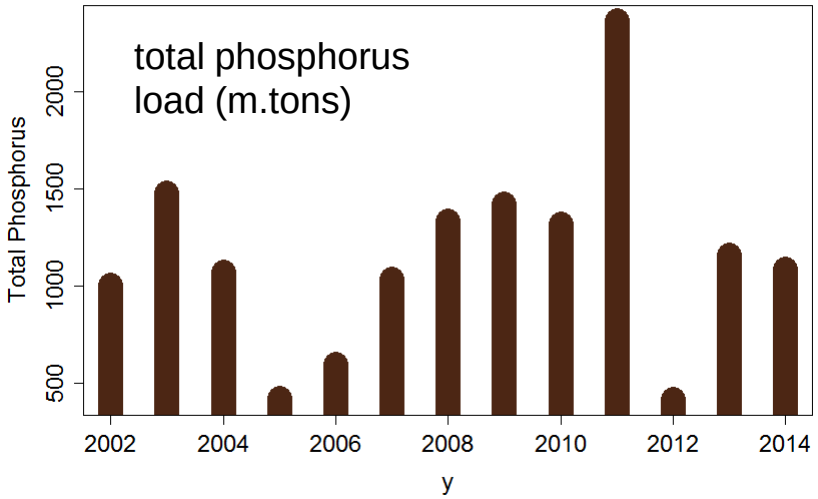


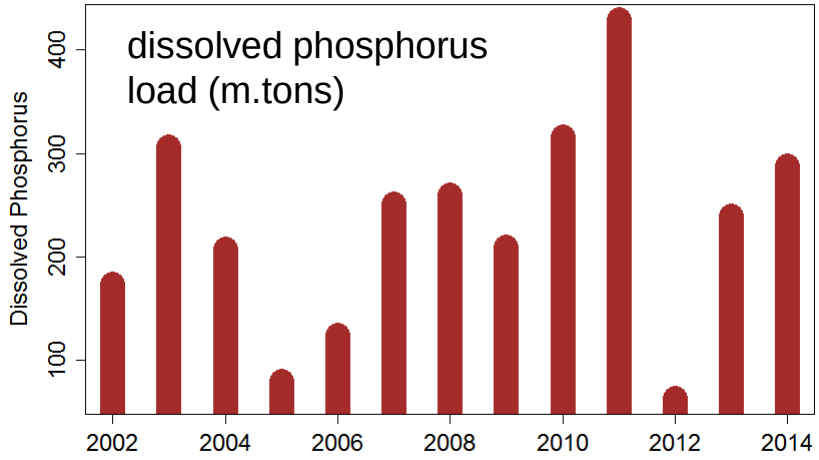


- Paerl et al., 2011 (Science of the Total Environment)

Spring loads from Maumee River into Lake Erie

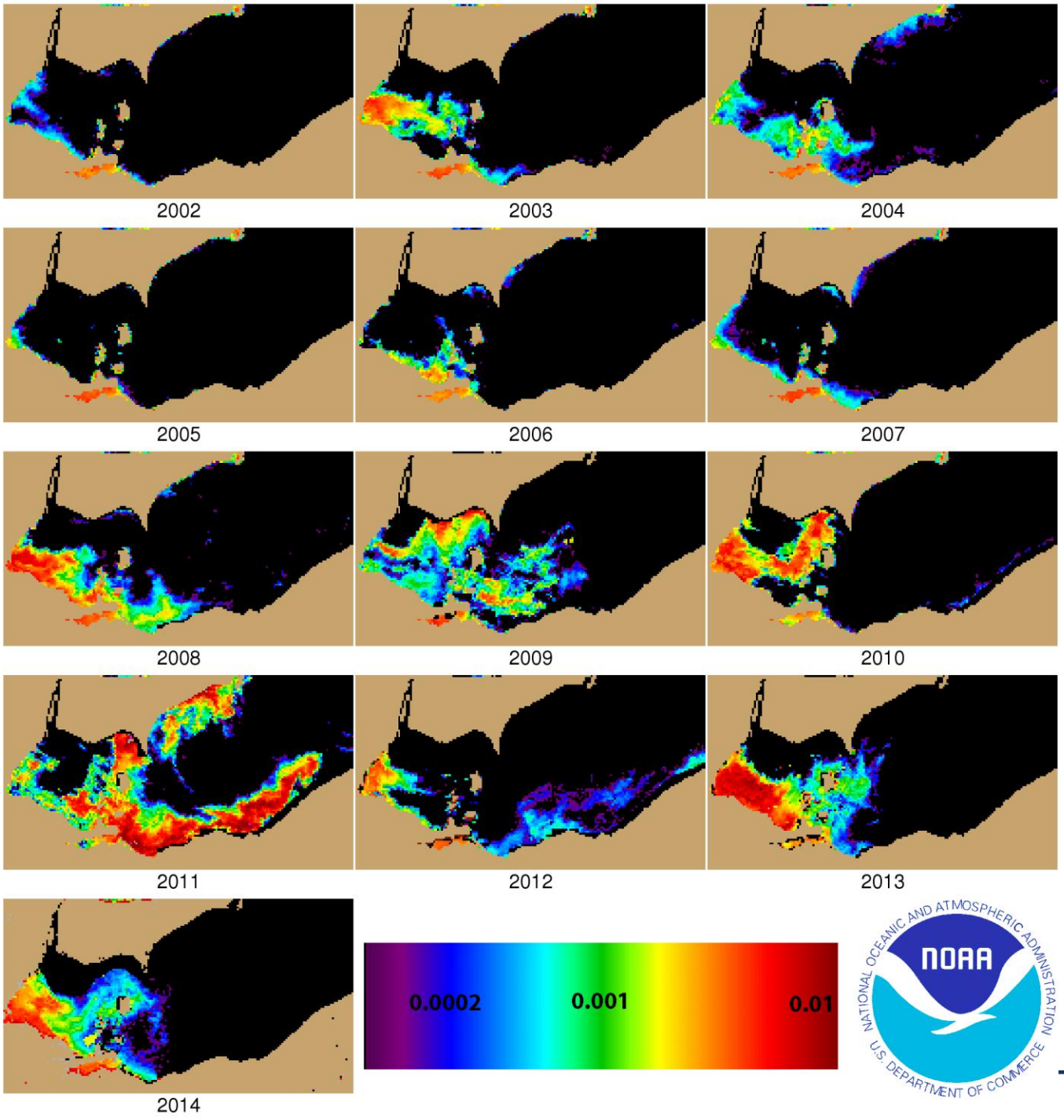






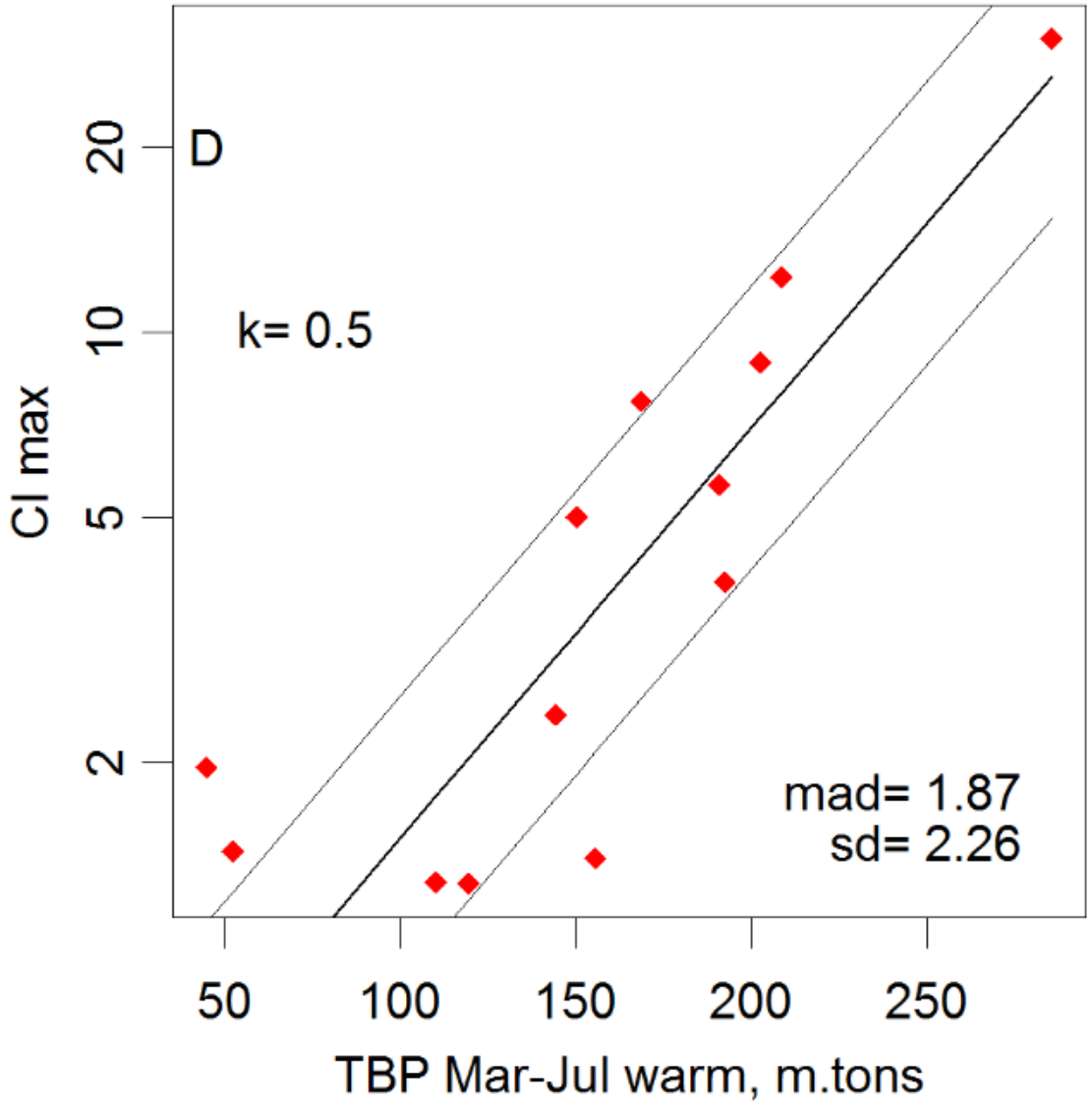
•Data from National Center for Water Quality Research

HEIDELBERG UNIVERSITY

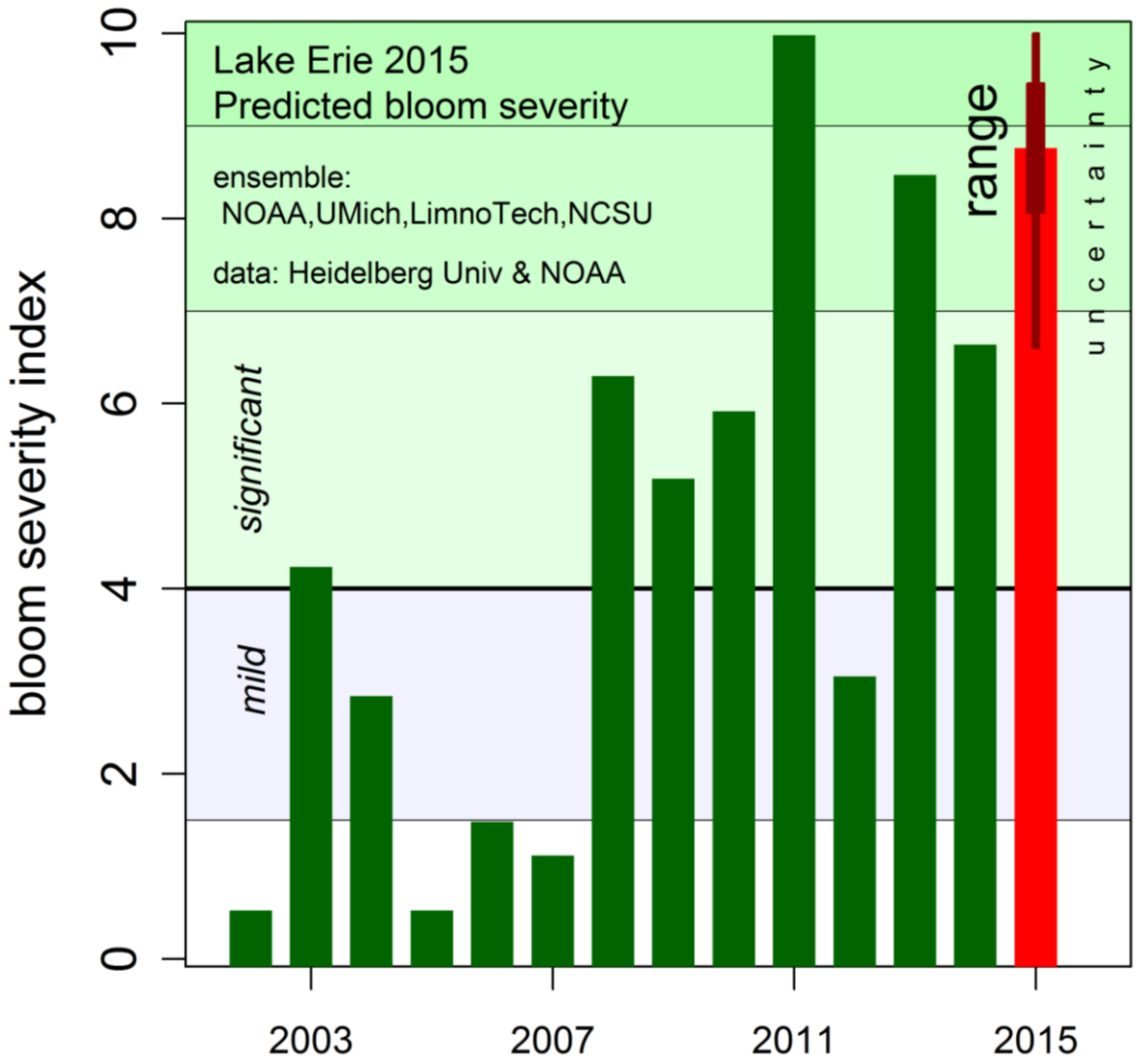


Lake Erie.
13 years of satellite data provide bloom extent

Cyanobacterial biomass related to total bio-available phosphorus (TBP) load from Maumee River, Lake Erie



2015 Forecast, depends on Heidelberg Univ monitoring program

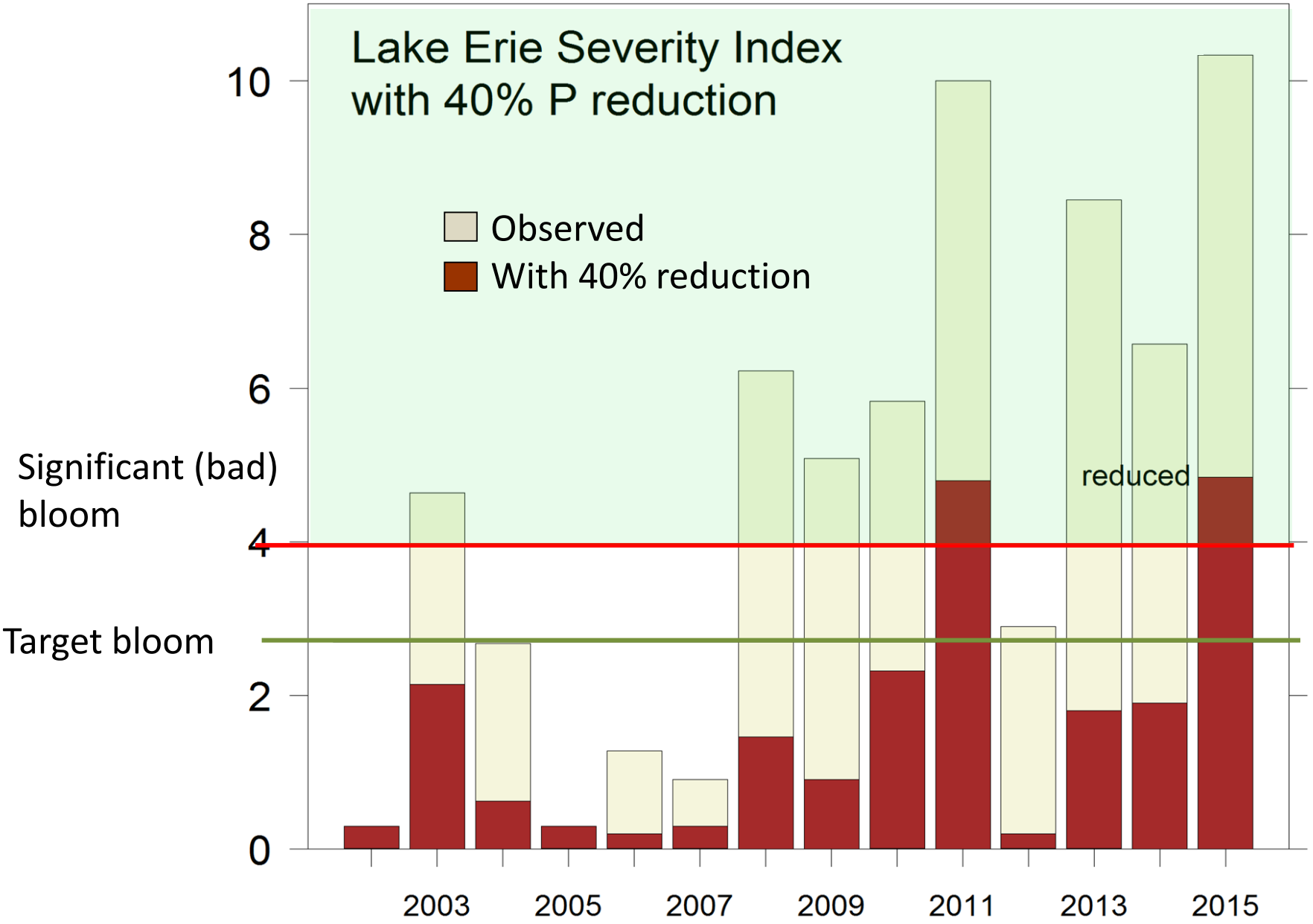


Similar to 2013, scale is worse than 2014.

What does this mean?

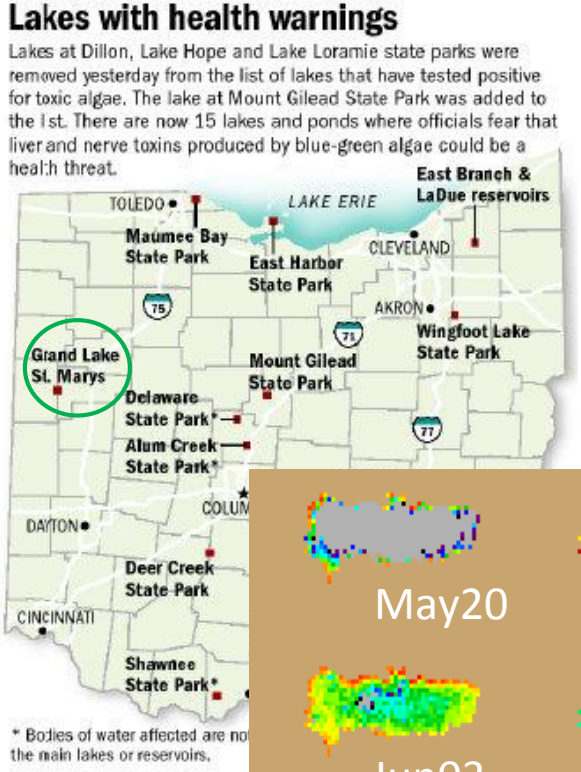
Advanced warning reduces risks. Monitor lake conditions.

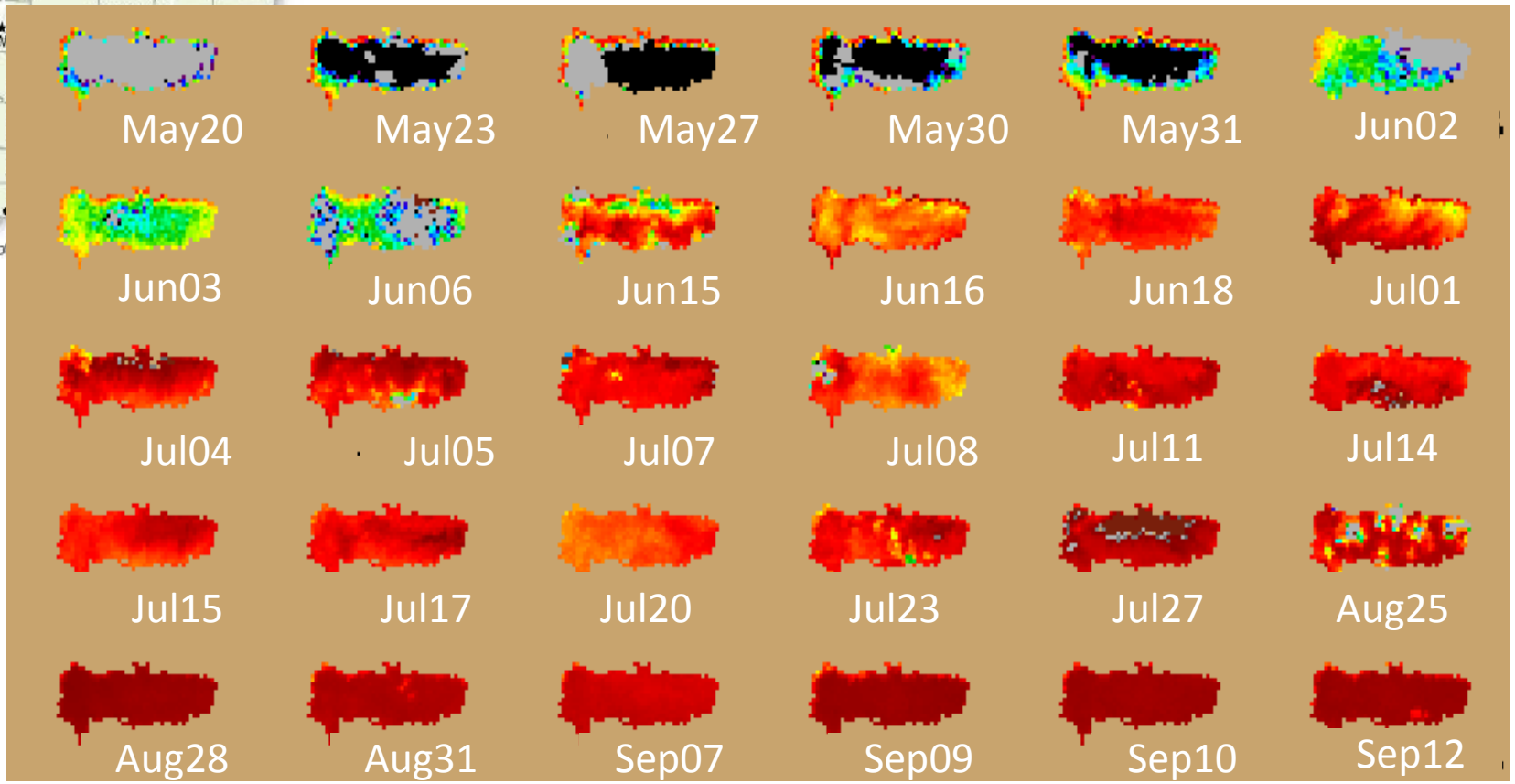
Proposed target reductions in phosphorus



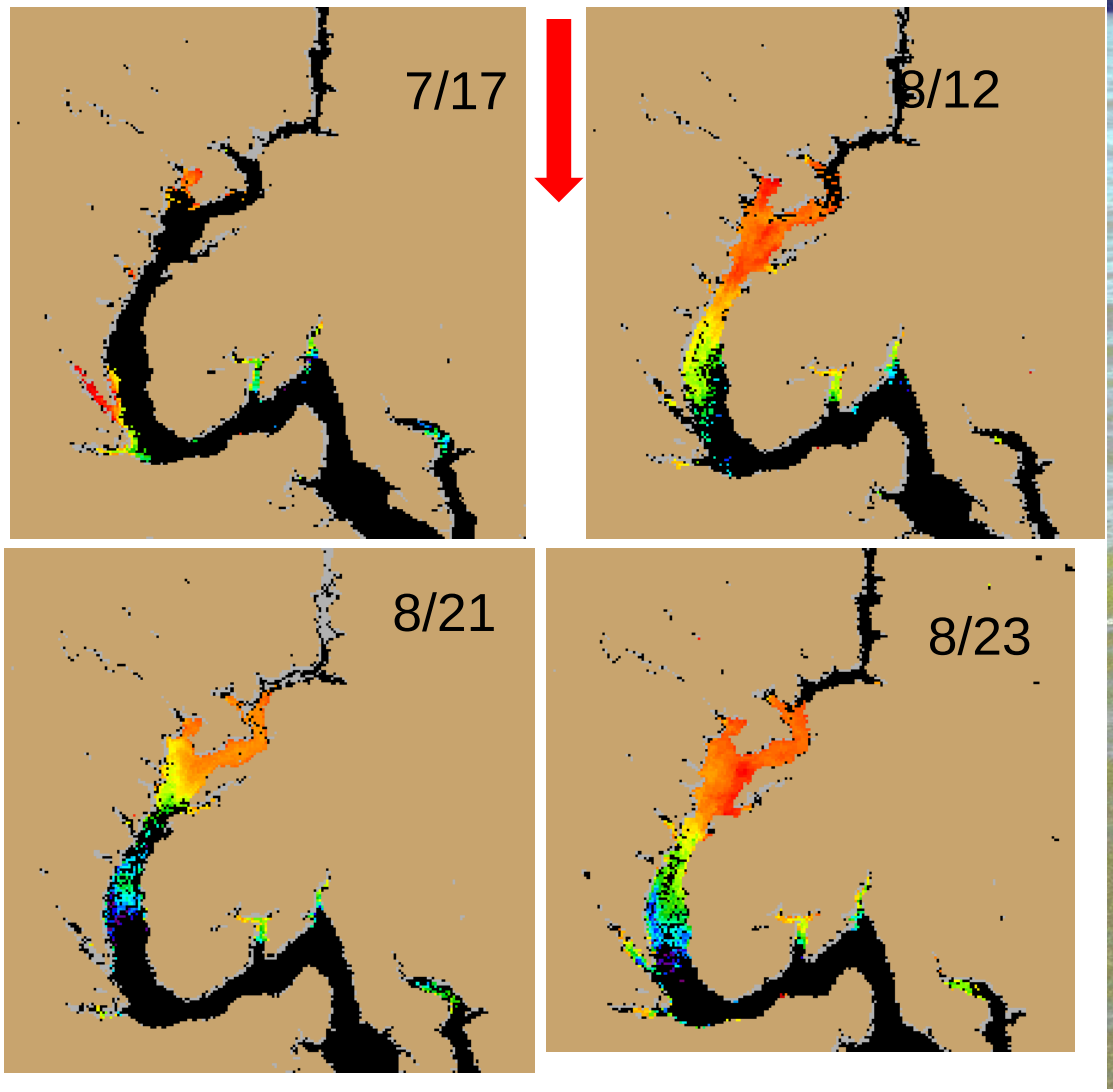
Temporal Patterns, when does bloom start? Grand Lake St Marys, Ohio

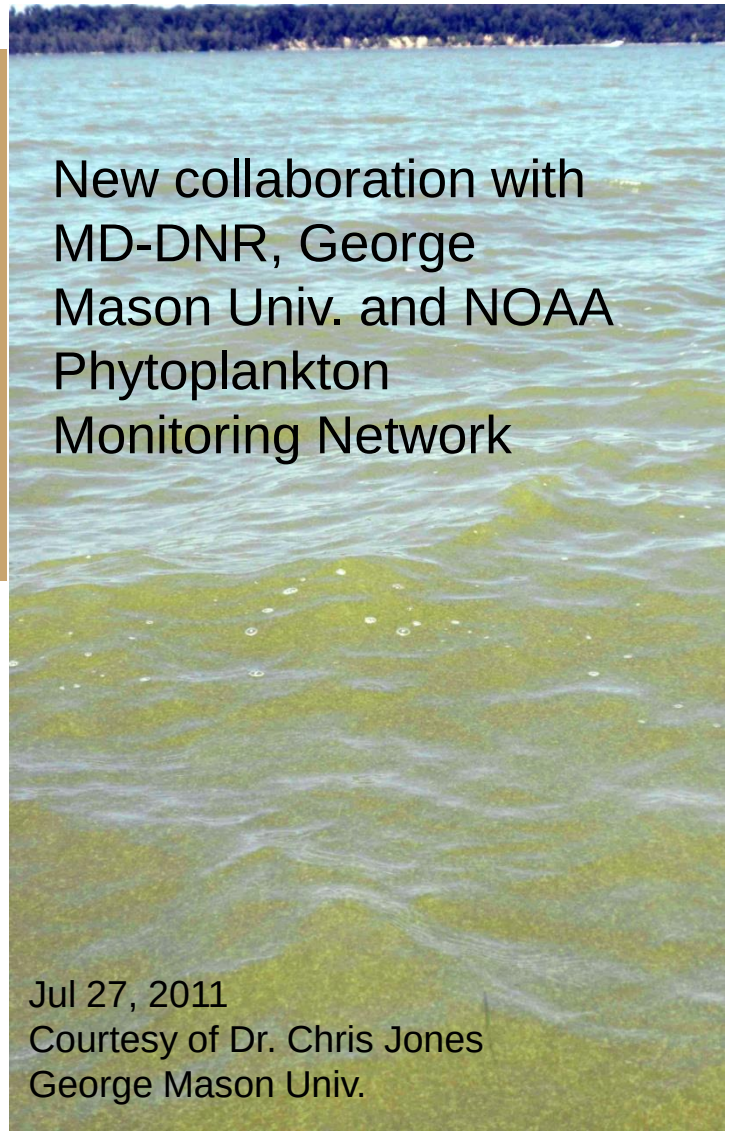
- Cyano index for 2010



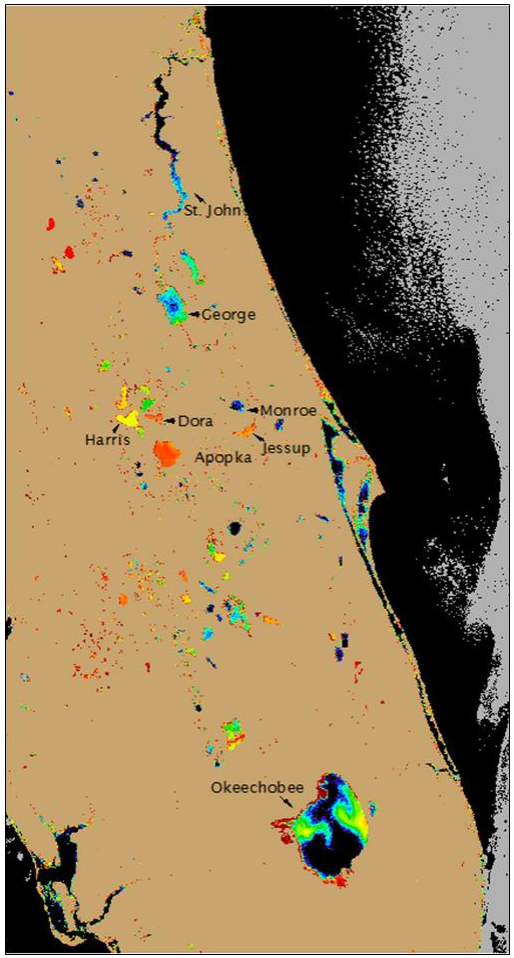


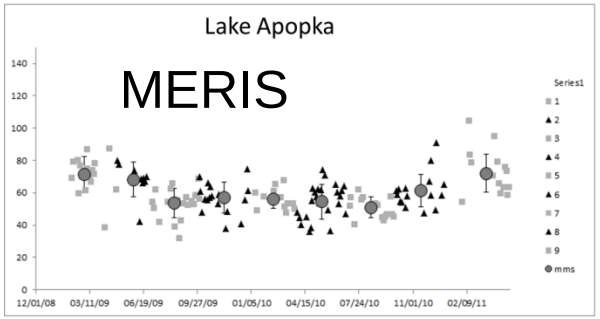
Potomac River *Microcystis* bloom

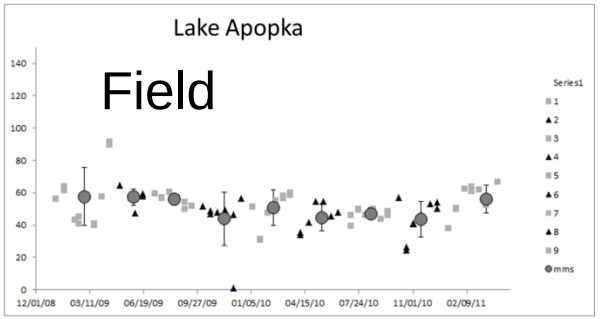


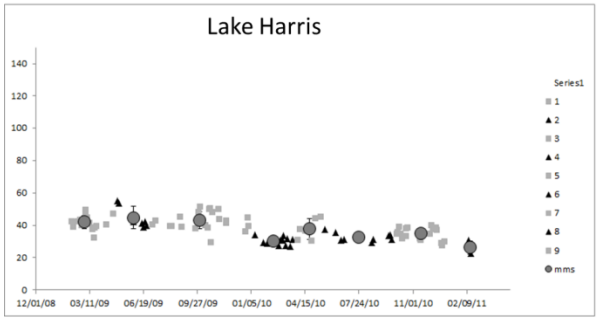


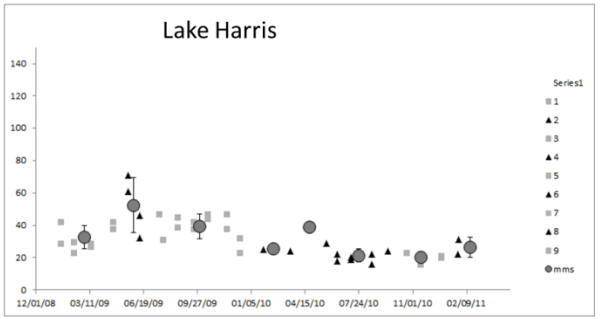
Compare chl-a in lakes over time (2 ½ years)

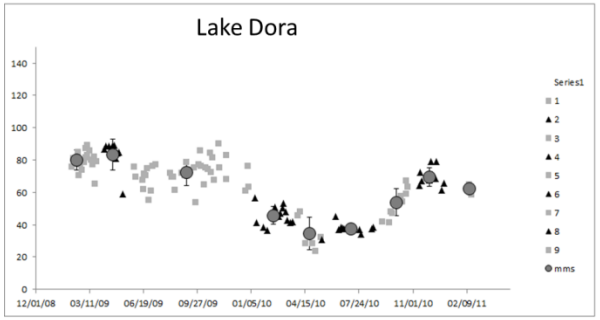


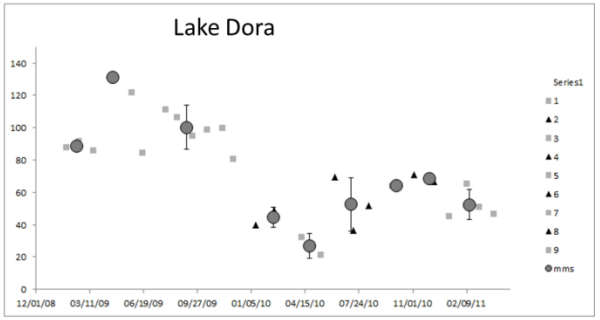


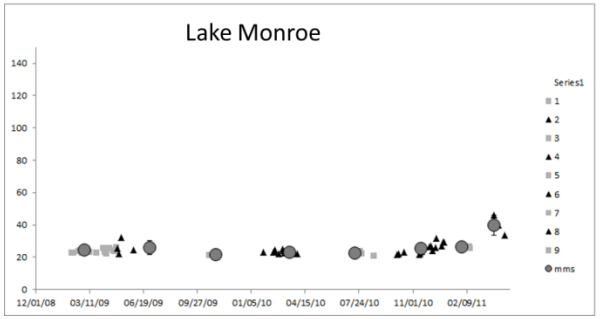


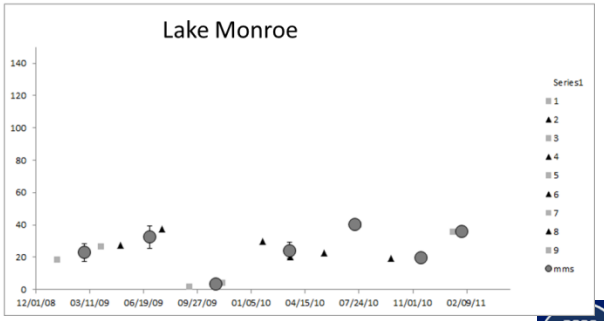






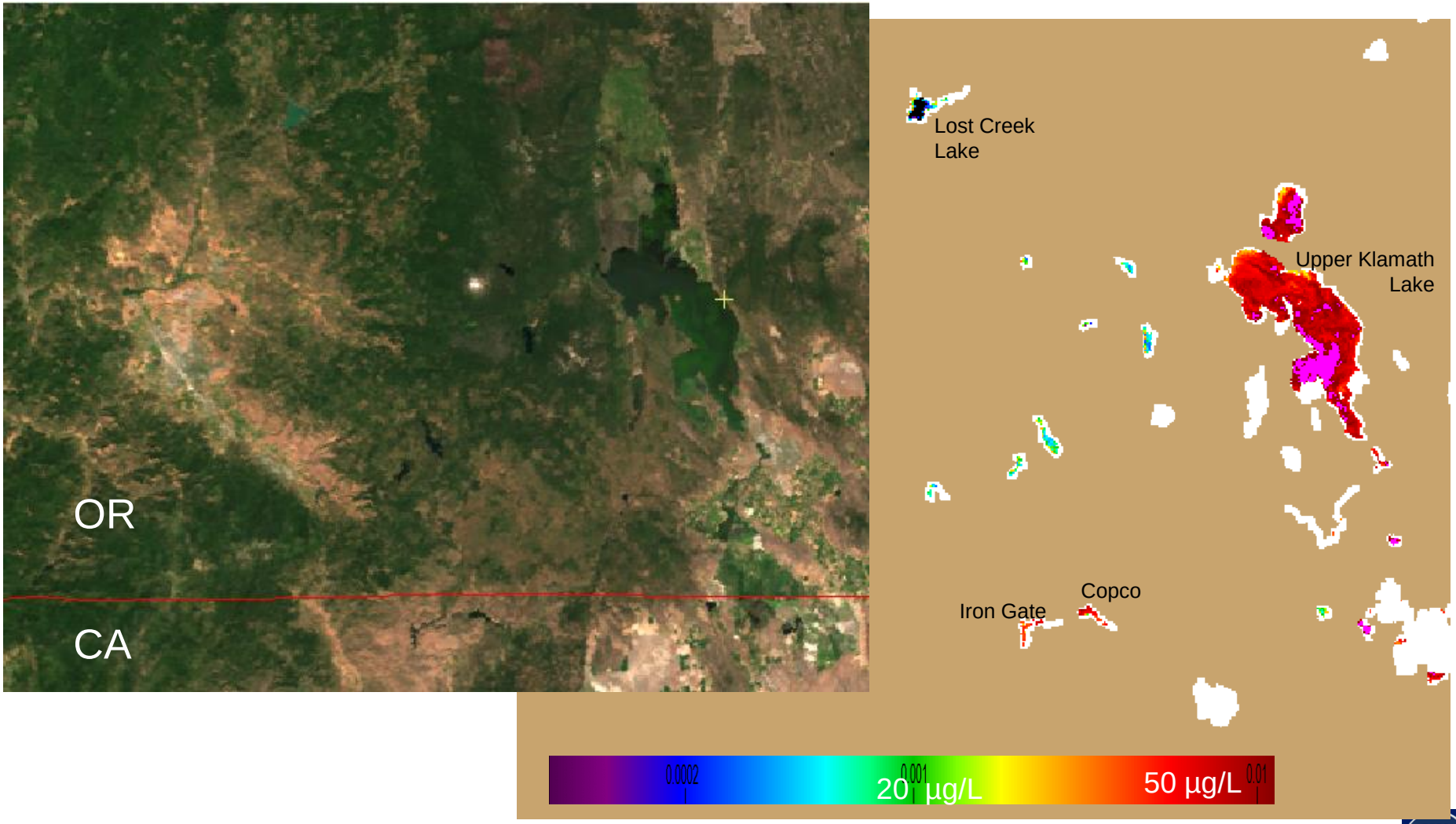




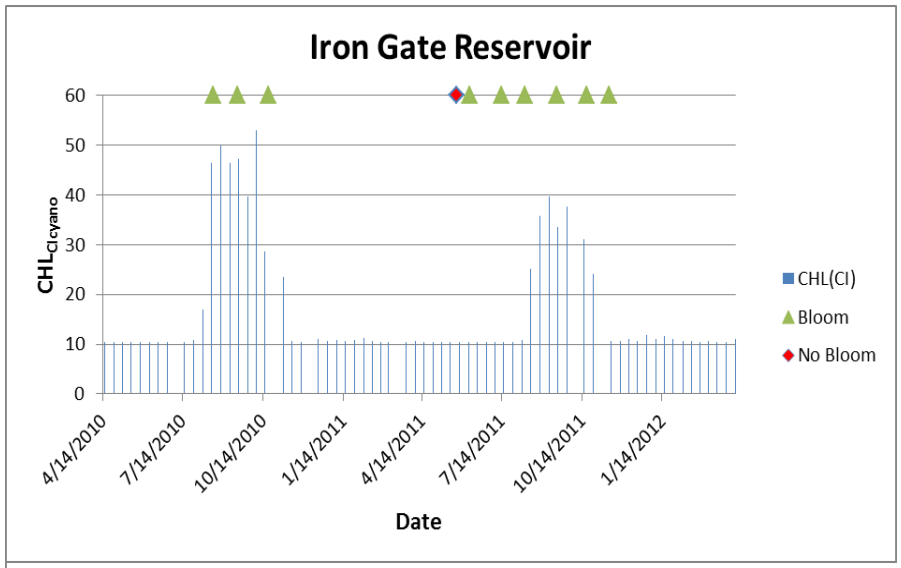


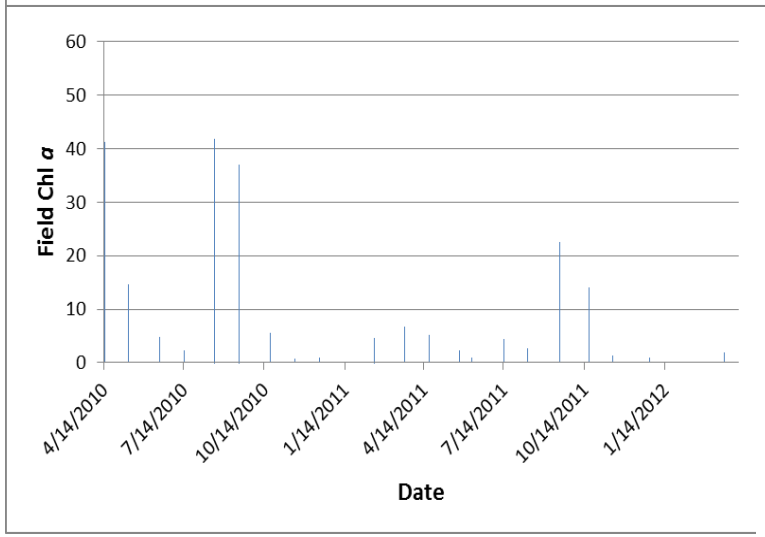
Klamath Lake Area, Oregon

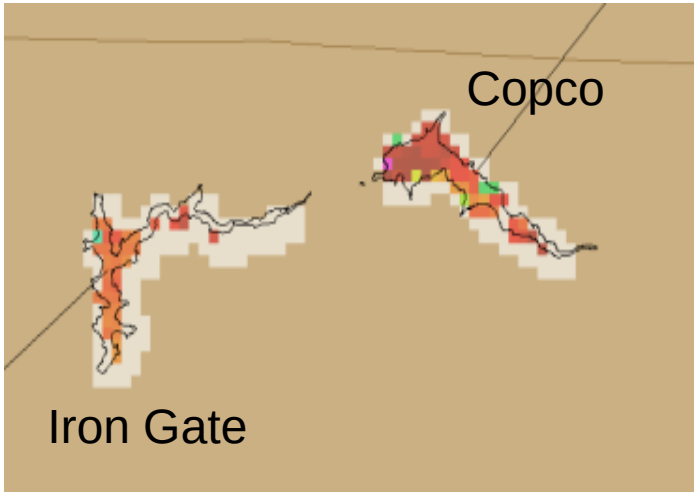
Aug 04 2010 MERIS



Klamath River (California) reservoirs.



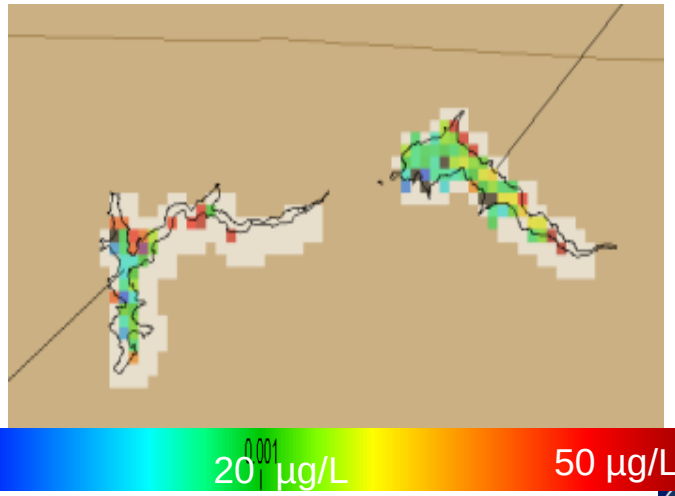




MERIS composites

Aug 11-20, 2010 top

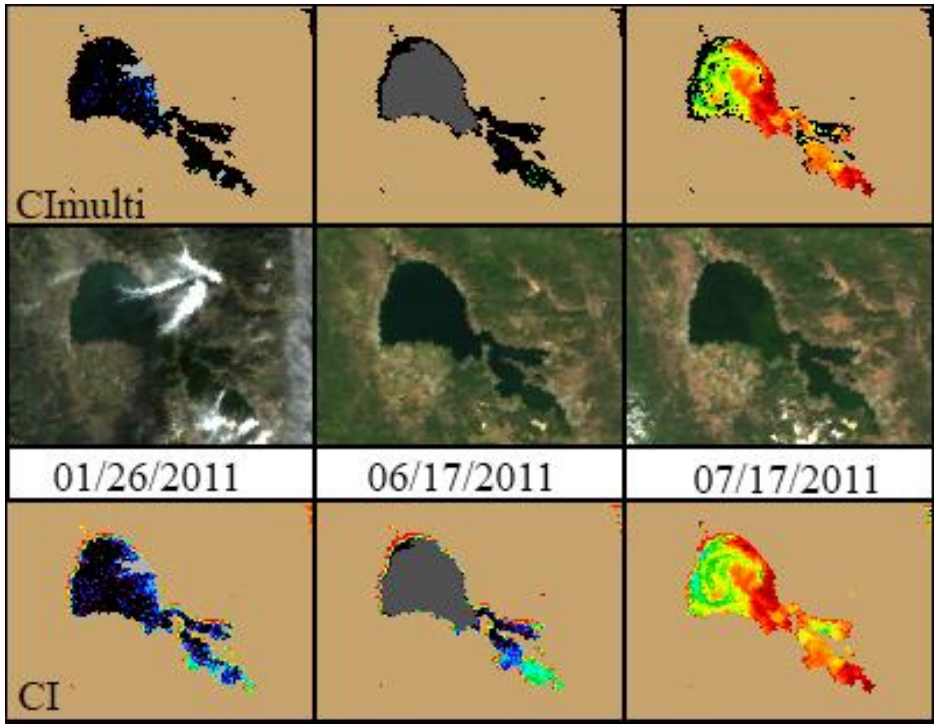
Feb 1-10, 2011 bottom



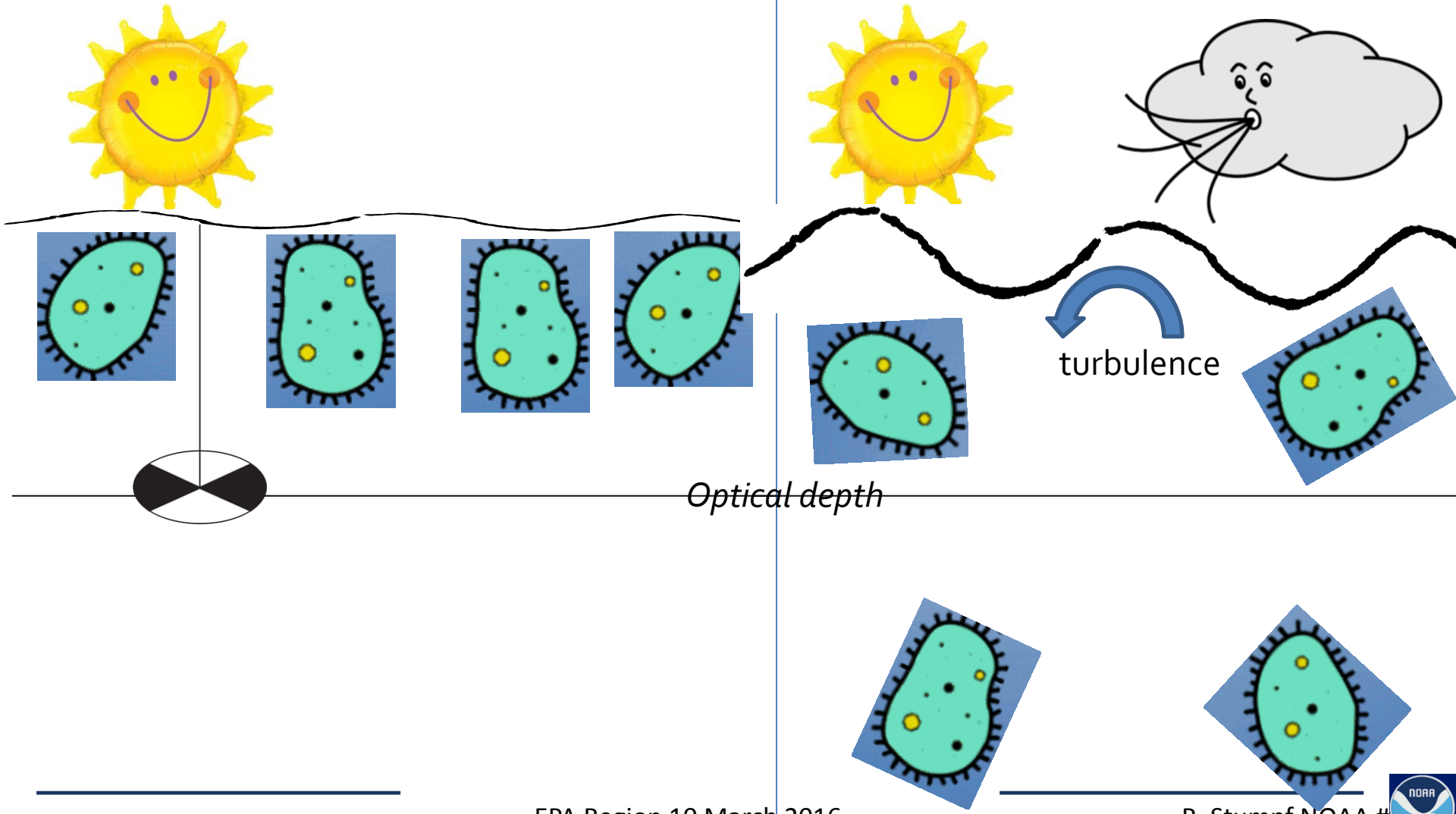
Proof-of-of Concept example Clear Lake, CA

(Imagery shows intensification of chlorophyll-a in June)

- In mid June chlorophyll increased dramatically Clear Lake Lower Arms on June 16th, 2011. Clear Lake subsequently suffered a devastating cyanobacteria bloom that continue through the summer. Early June chlorophyll ~3 ug/L in NW, 15 ug/L in Lower Arms.
- 60 and 130 ug/L in mid July.

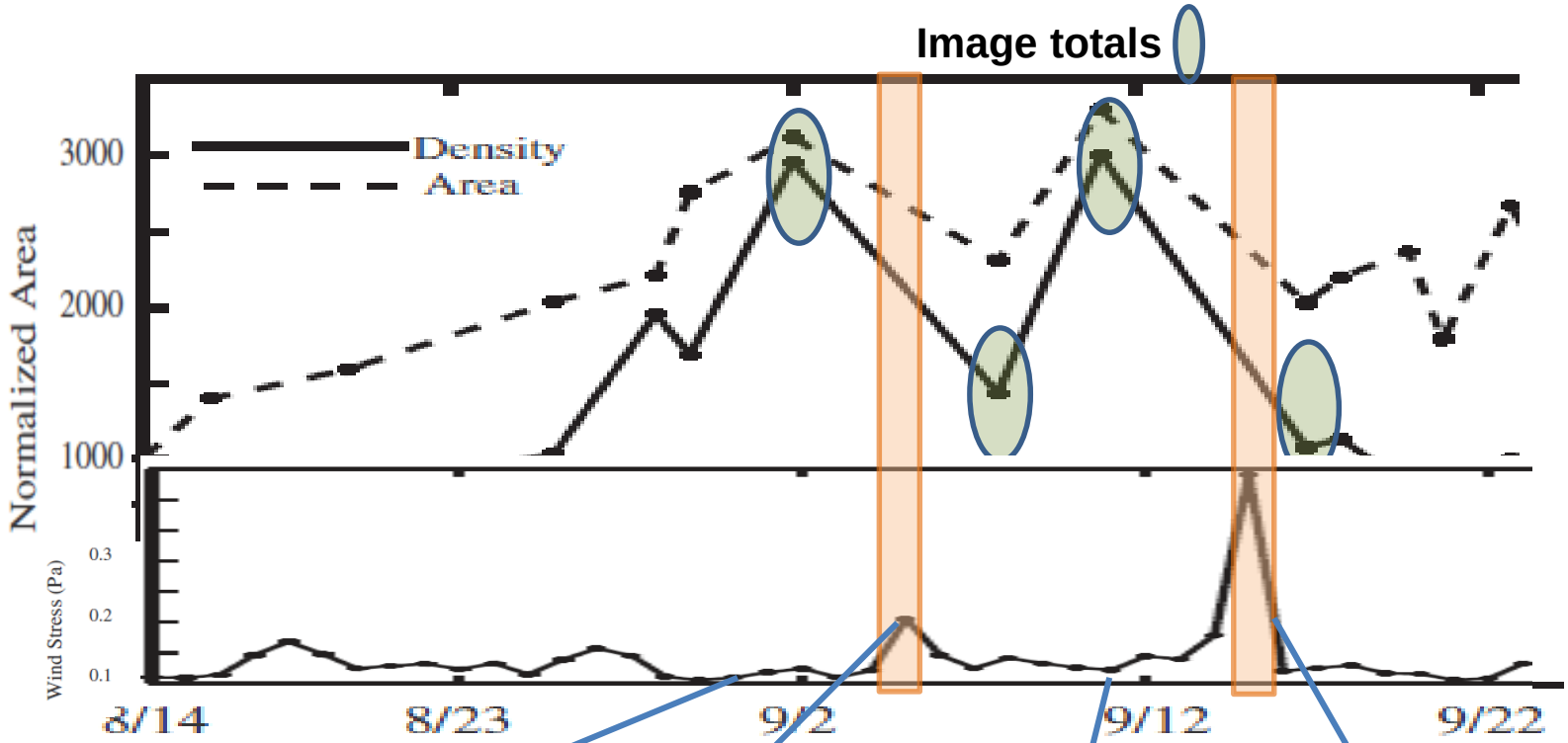


Satellite sees only surface concentration, so biomass requires additional work (just like using surface samples). Wind is a factor.



Satellite sees either surface scum or surface concentration. Avoid "averaging" buoyant blooms

Figure from Wynne et al., 2013)

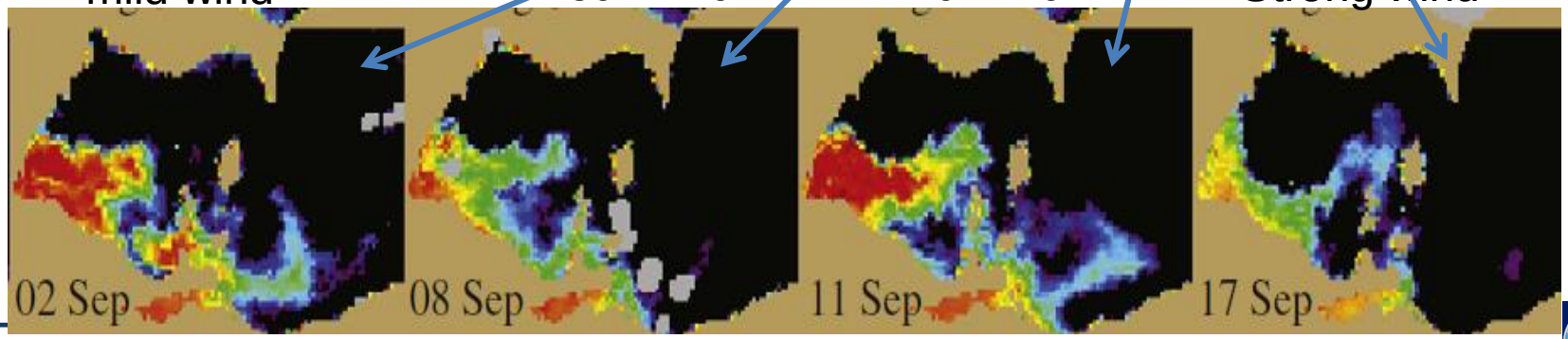


mild wind

Mod. wind

Mild wind

Strong wind



Satellite data

- Buoyant cyanos can cause a major problem with satellite statistics. (also with surface water samples)
- Calm day, high surface concentration
- Windy day, low surface concentration

Simple time-averaging will give inconsistent estimates of bloom severity with ALL algorithms. (worse with scum-specific algorithms, like floating algae index)

2015: 1500 subscribers + media reports

Experimental Lake Erie Harmful Algal Bloom Bulletin

National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory

The *Microcystis* cyanobacteria bloom continues across a large part of the western basin south of West Sister Island from Michigan to the islands. Dense scums have formed in highest concentration areas, with extensive scums occuring in the red to dark red areas in the western basin. The bloom is found east of the islands, including scum patches away from shore. Moderate concentrations extend as far as Rondeau on the Ontario coast. Microcystin is present in this bloom, and the toxin levels are extremely high in scums.

Light southerly to southwesterly winds will continue today and Tuesday, gradually increasing to Thursday. Least mixing and greatest scum formation earlier in the week, and greatest mixing with passage of a cold front late Wed and Thursday. These winds will cause continued movement of the eastern edge into the central basin and also eastward on the Ontario coast.

The persistent bloom in Sandusky Bay continues. No other blooms are evident in the central and eastern basins.

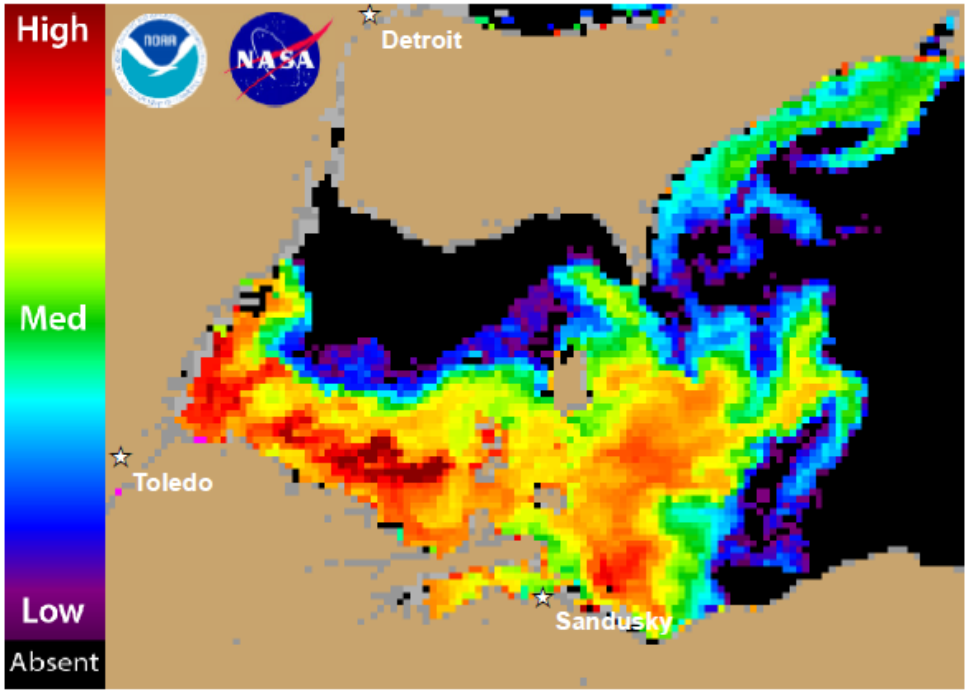


Figure 1. Cyanobacterial Index from NASA's MODIS-Terra data collected 16 August, 2015. Grey indicates clouds or missing data. Black represents

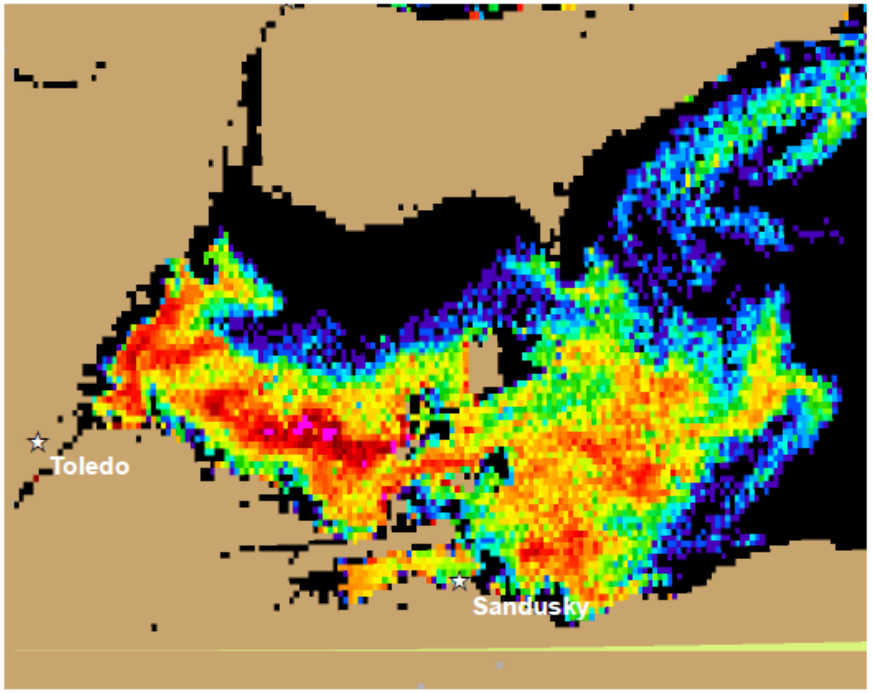


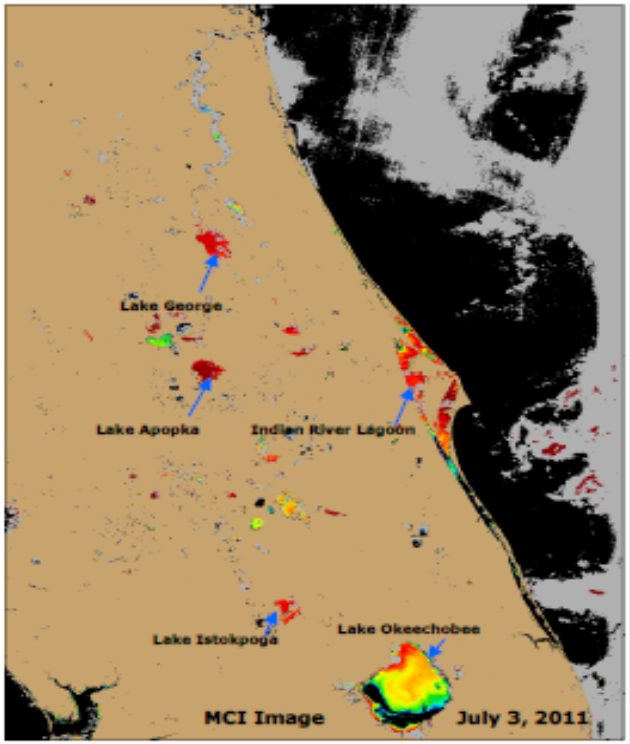
Figure 2. Nowcast position of bloom for 17 August, 2015 using GLCFS modeled currents to move the bloom from the 16 August,

Example: Satellite Health Bulletin

Experimental Cyanobacteria Bulletin: July 3, 2011

To report an illness related to a marine toxin or algal bloom please contact the FL Department of Health Aquatic Toxins Hotline at 1-888-232-8635.

For questions about the report: please contact Becky Lazensky, FL-DOH, at 352-955-1900. Images/data were obtained from Florida Water Management Districts, The National Oceanic and Atmospheric Administration (NOAA), NOAA National Climatic Data Centers and National Weather Centers. Support to produce this report was received through a NOAA/NASA Agreement (Number: NNH08ZDA001N)



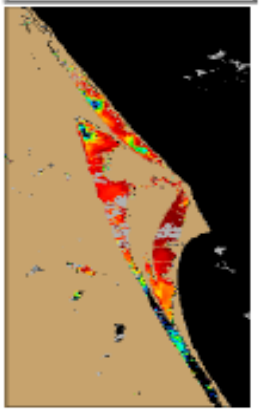
The MERIS Satellite Images above display a cyanobacteria index generated with a Medium Resolution Imaging Spectrometer (MERIS) satellite provided by the European Space Agency & NOAA.

- Very low likelihood of a bloom.
- May indicate clouds or missing data.
- Low cyanobacteria concentrations.
- Medium cyanobacteria concentrations.
- Probable bloom or higher cyanobacteria concentrations.

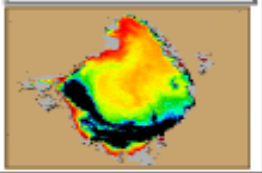
Conditions Report: July 3, 2011

- Cyanobacteria estimates were remarkably elevated in several lakes, including an ongoing detection in Lake George, Lake Apopka, Lake Istokpoga, and Lake Okeechobee.
- The Indian River Lagoon has recently begun showing an increase in estimated cyanobacteria concentrations.
- An ongoing bloom has been reported in the Caloosahatchee River (Lee County). Lake Okeechobee (photo on right) supplies water to the Caloosahatchee.

Indian River Lagoon



Lake Okeechobee



Recent Blooms

Caloosahatchee River
June 22
Photo by FL DEP

Coordinates: 26.7123, -81.6098
City: LaBelle
Confirmed Species: Anabaena flosaquae
Limnothrix, Pseudanabaena cf minima
Sample Collection Date: June 2, 2011
Bloom continuing as of June 22, 2011

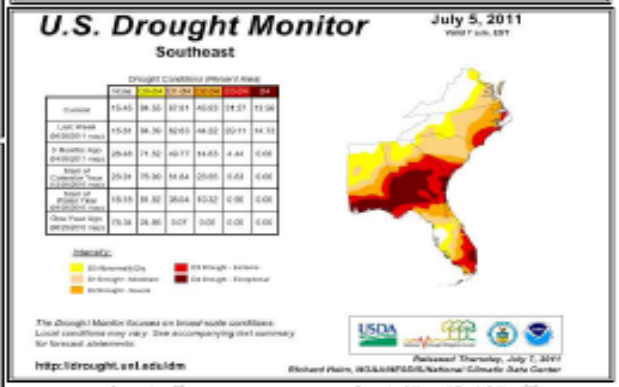
St Johns River Field Brief
By: Robert Burks, St Johns River Water Management District, June 20-23

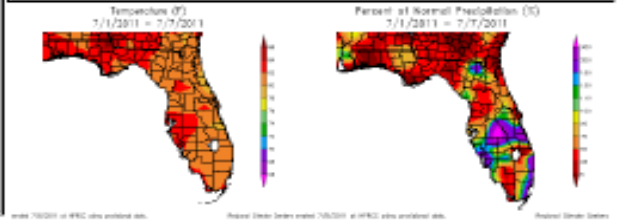
Surface Water quality: Lower Basin river continues to show high salinities through Hibernia Point (near Black Creek)

Weather/Rainfall: Hot and humid. Well above average day temps (+47F for week) and night (+ 16F for week). Rainfall at 1.21 inches on 6/17, and 1.78 inches for 6/23

Algal/HAB: No bloom or scum formations observed from Astor to Mayport, with the exception of some filamentous formations near shore at Black Creek on 6/22. HAB species were identified in samples from Doctors Lake, Mandarin Pt, & Plummers Cove

For a full report:
Email Robert Burks
rburks@sjrwmd.com





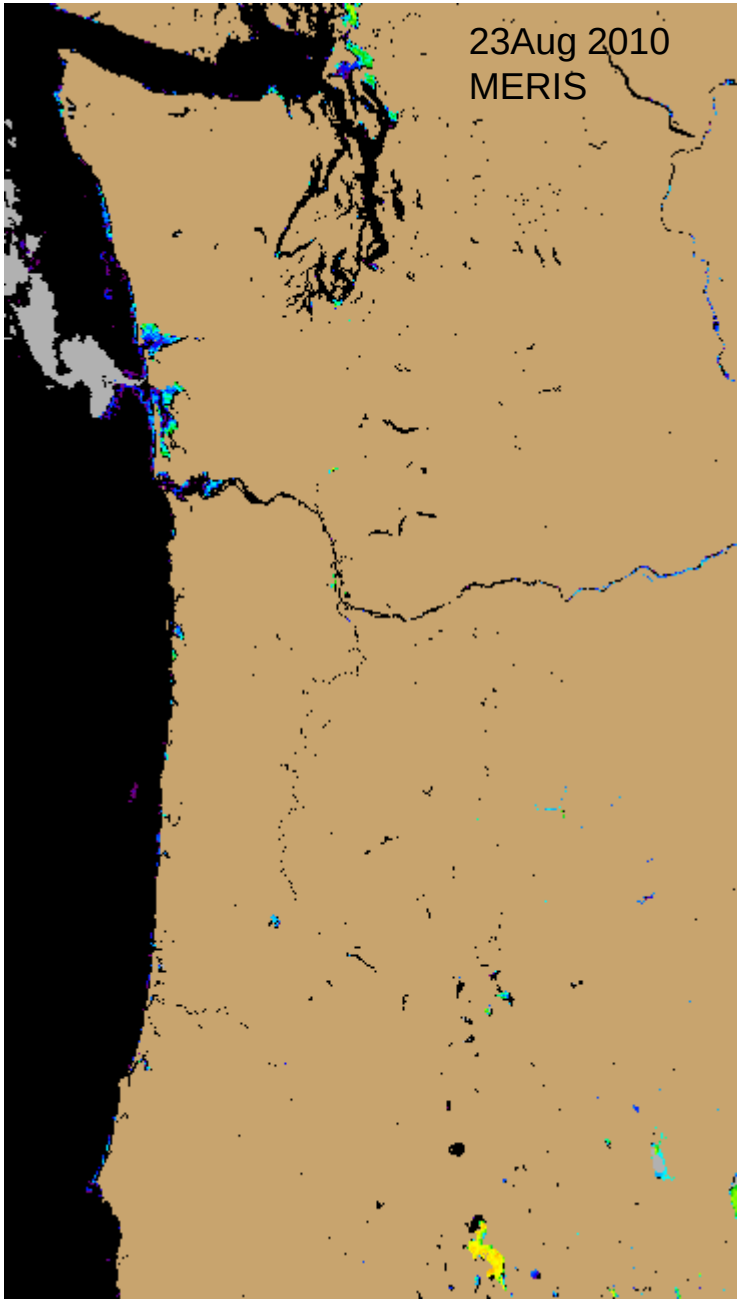
Where from here?

- CyAN project is testing MERIS data sets for several states.
  - (More in Blake Schaeffer's talk)

- OLCI (ocean land colour imager) launched February!
  - MERIS replacement
  - Monitoring with OLCI, retrospective with MERIS (2002-2012).

- Evaluating Landsat and Sentinel-2 (~30 m resolution).
  - Landsat may give eutrophic measure
    - working on cyano likelihood.
  - Less frequent, post season evaluation only (16-day Landsat, 10-day Sentinel-2 without clouds)
  - Sentinel-2 may give estimation of bloom concentration (but not spectral discrimination of cyanos)
  - Work in progress

Additional support from



NASA Ocean Biology and Biochemistry (NNH15AZ40I)

NASA Applied Science, Public Health (NNH10AO95I)

European Space Agency (C1P.9975)