



# Forecasting cyanobacterial blooms in Lake Erie

Richard P. Stumpf  
NOAA National Ocean Service

Credit: Tom Archer



# Lake Erie had a cyanobacteria problem in 1960s-1970s

- Clean Water Act
- IJC, GLWQA

Phosphorus reduction  
from point sources





In 2003 strong bloom  
appeared, first in  
years

Landsat Aug 18, 2003

In 2005, the 2003 bloom was  
described as “perhaps the  
most severe in Lake Erie’s  
recent history” (EPA)





# 2008-2010 more blooms



Credit: Thomas Archer (left)



Diane Straw (right)



Then 2011

May was wet.



## Flooding closes roads, some Metroparks



BLADE STAFF  
The Blade

MAY 27, 2011

2:52 PM

# Lake Erie July

- 22 July 2011





# 2011 largest known bloom

Nearly all western basin in Aug



Terra satellite Aug 19, 2011

and all Ohio and some of Canada in Oct



Envisat satellite Oct 08, 2011

Need to do  
something



Department of Agriculture  
Department of Natural Resources  
Environmental Protection Agency  
Lake Erie Commission

## Ohio Lake Erie Phosphorus Task Force II Final Report

What is driving the blooms?

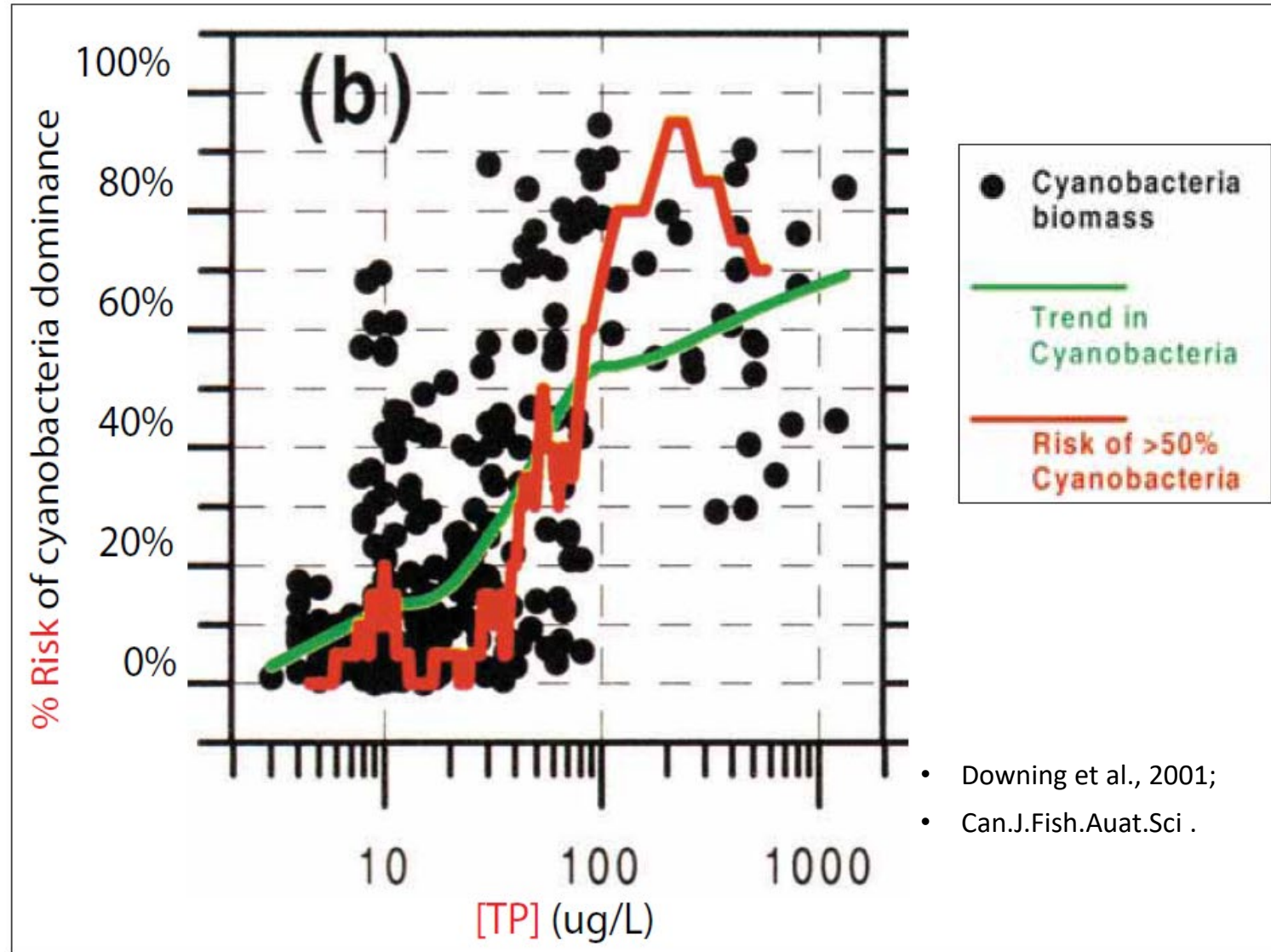
Nutrients, Phosphorus, but when and how?

Need amount of cyanobacteria (biomass)

And need nutrients



# Excessive phosphorus promotes cyano blooms in many lakes

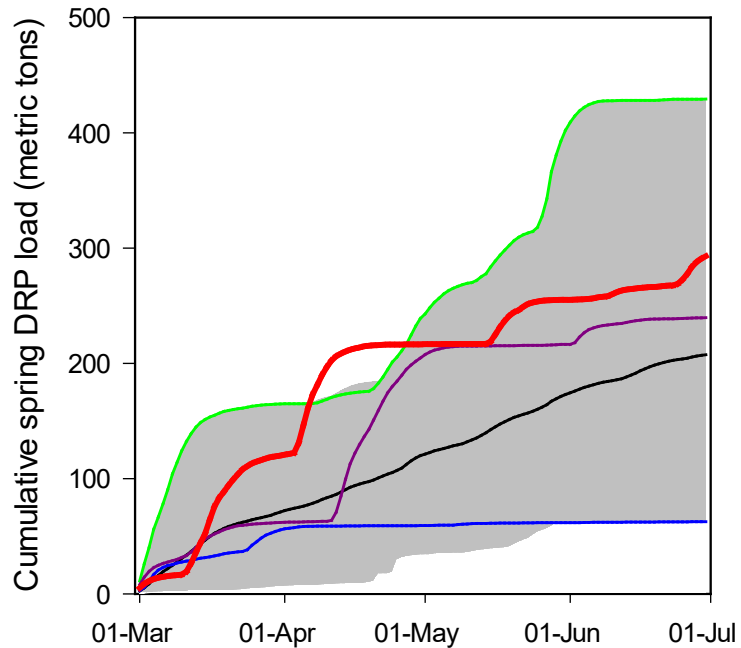


# Heidelberg University

National Center for Water Quality  
Research

Data on Maumee River since 1970s

This is 50<sup>th</sup> anniversary of the  
Center!

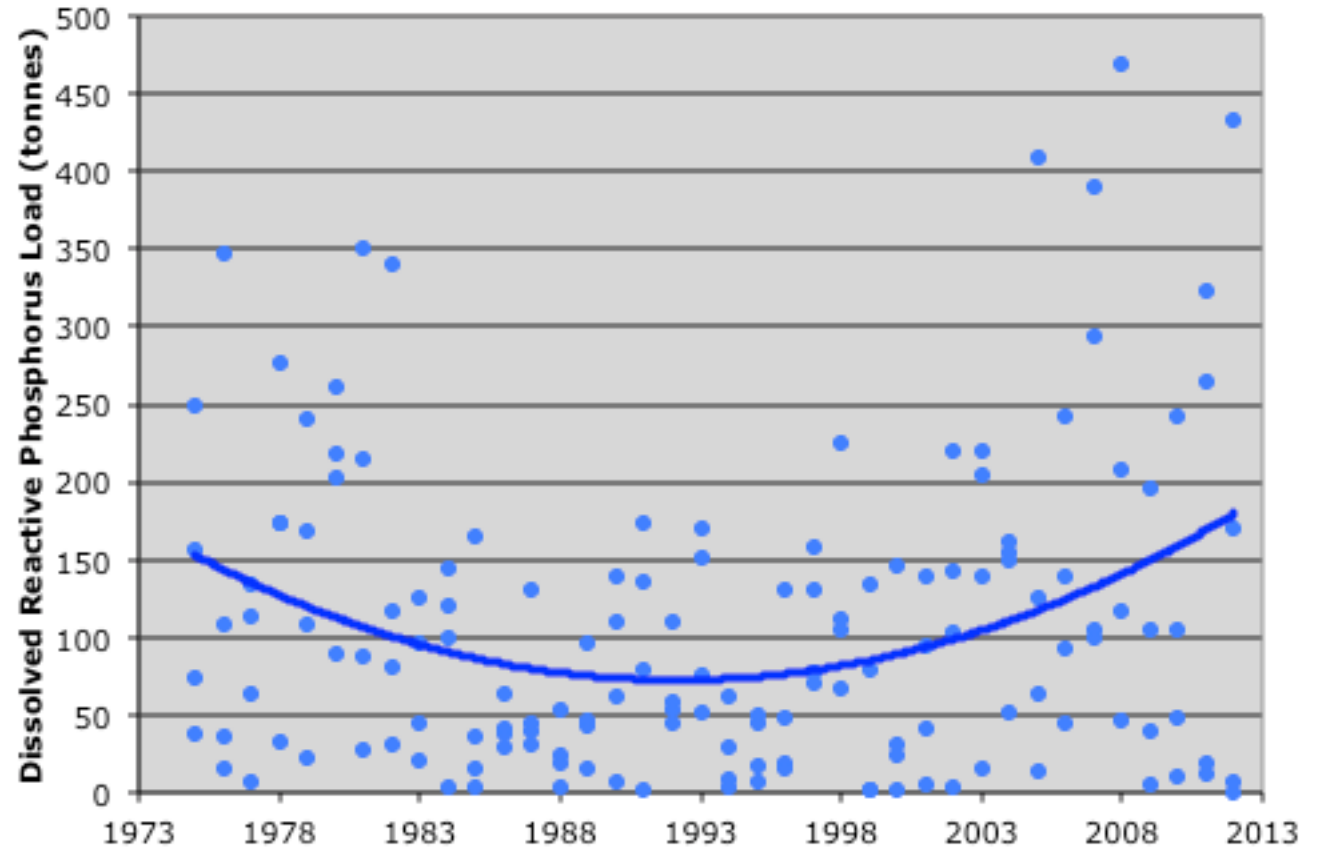


For more information visit:

<http://www.heidelberg.edu/NCWQR>

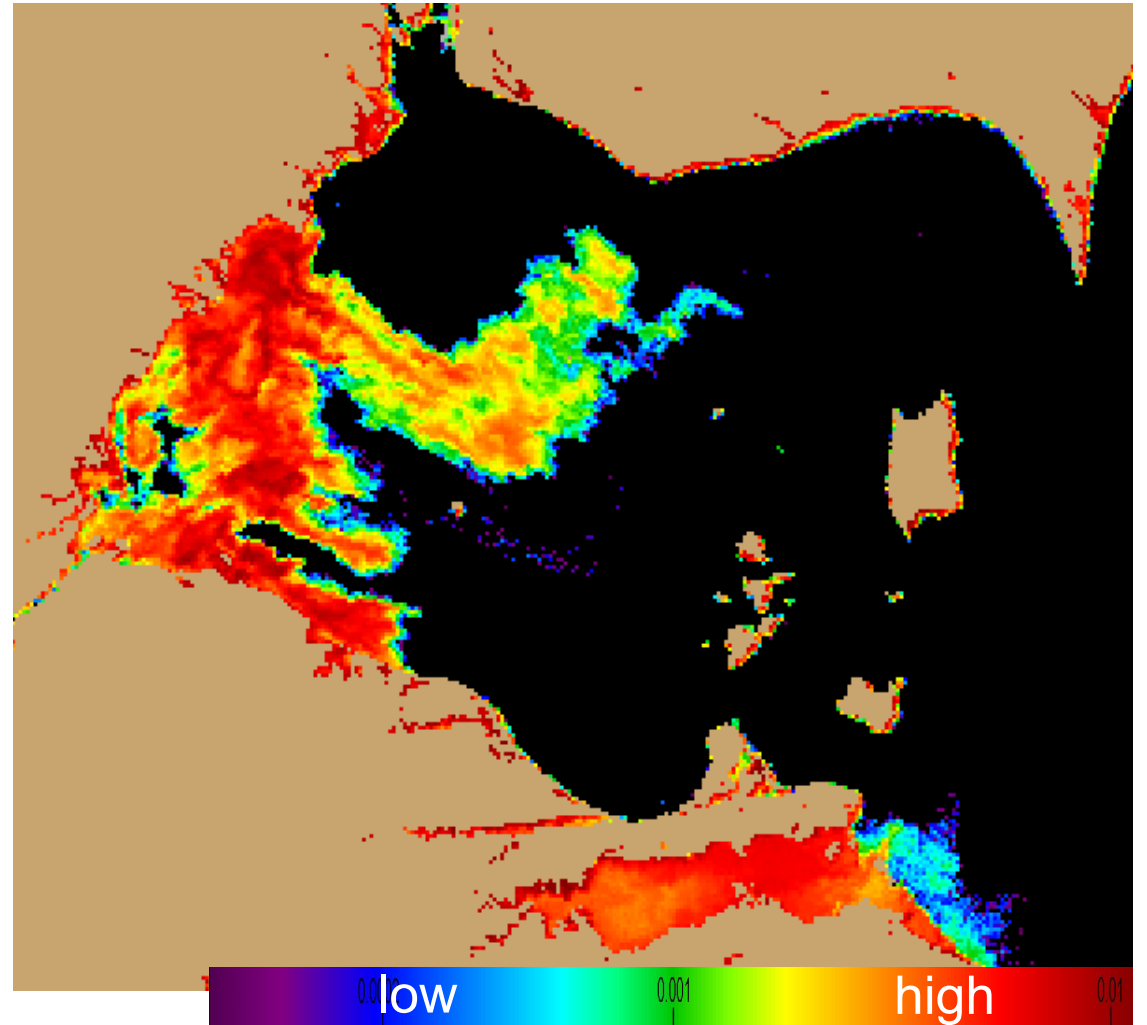
HEIDELBERG UNIVERSITY

Maumee River 1975-2012

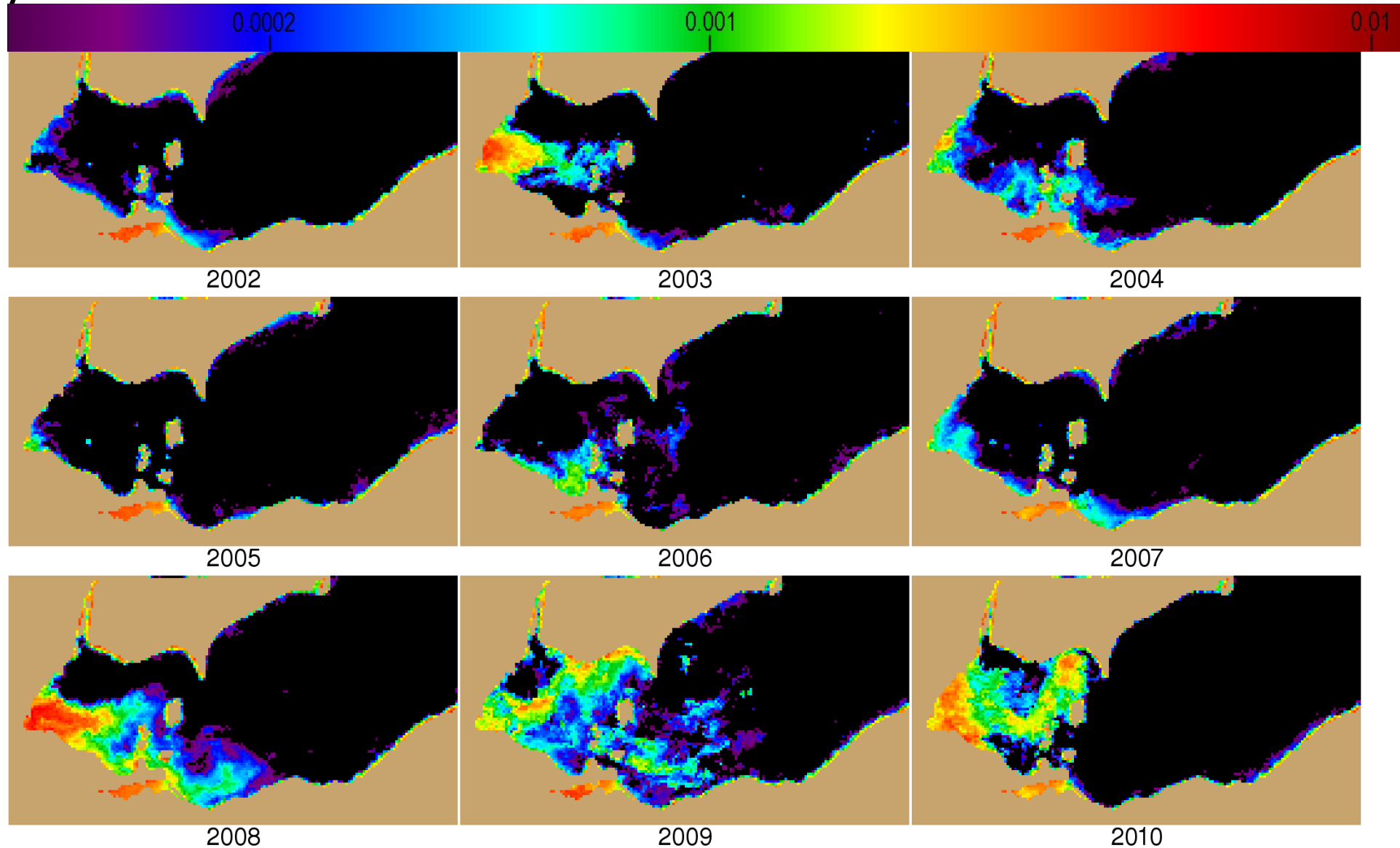




Satellite can do more than pretty pictures  
Using light spectrum can quantify amount of bloom



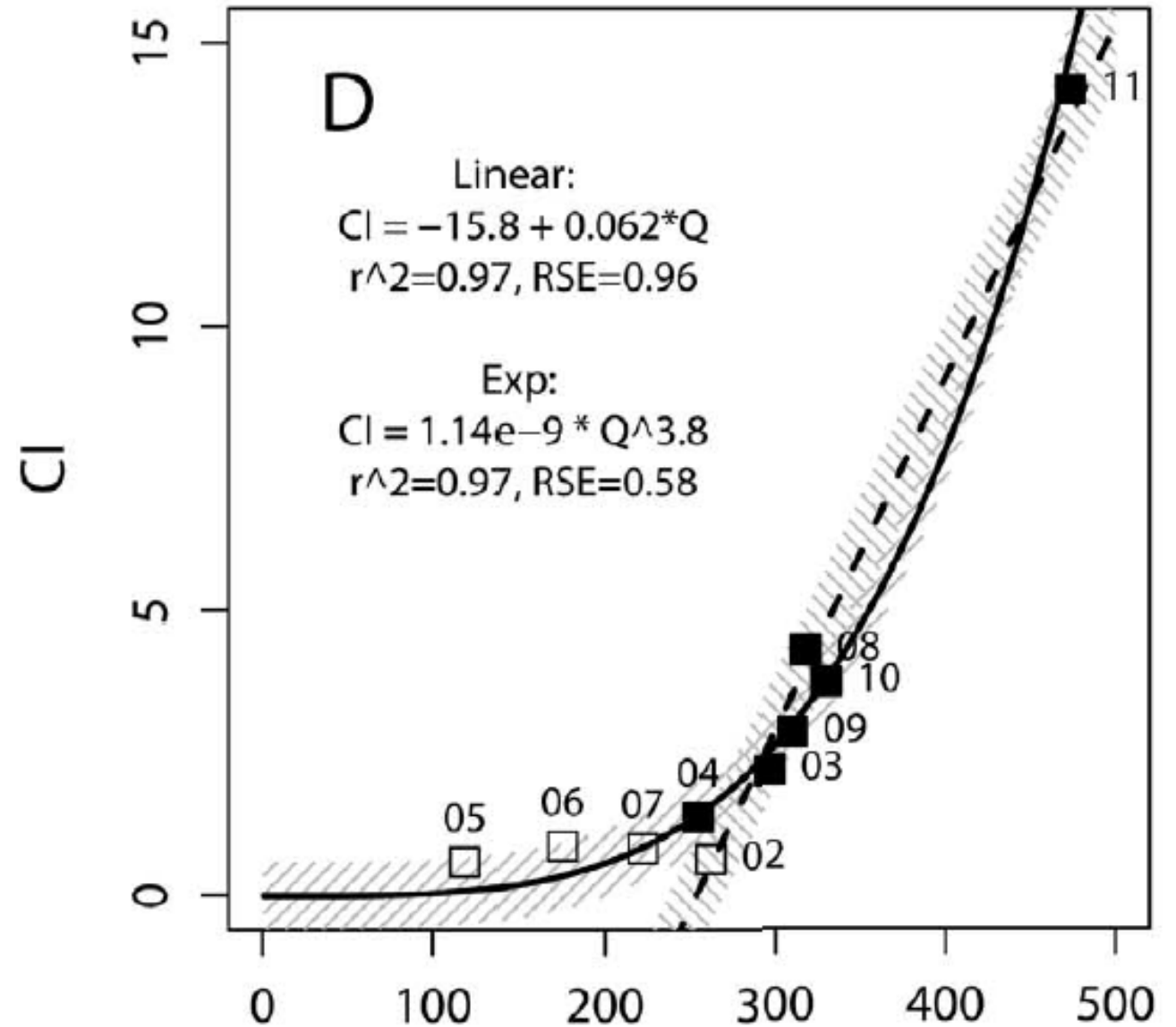
# 10 years of MERIS data, mapped peak of bloom each year



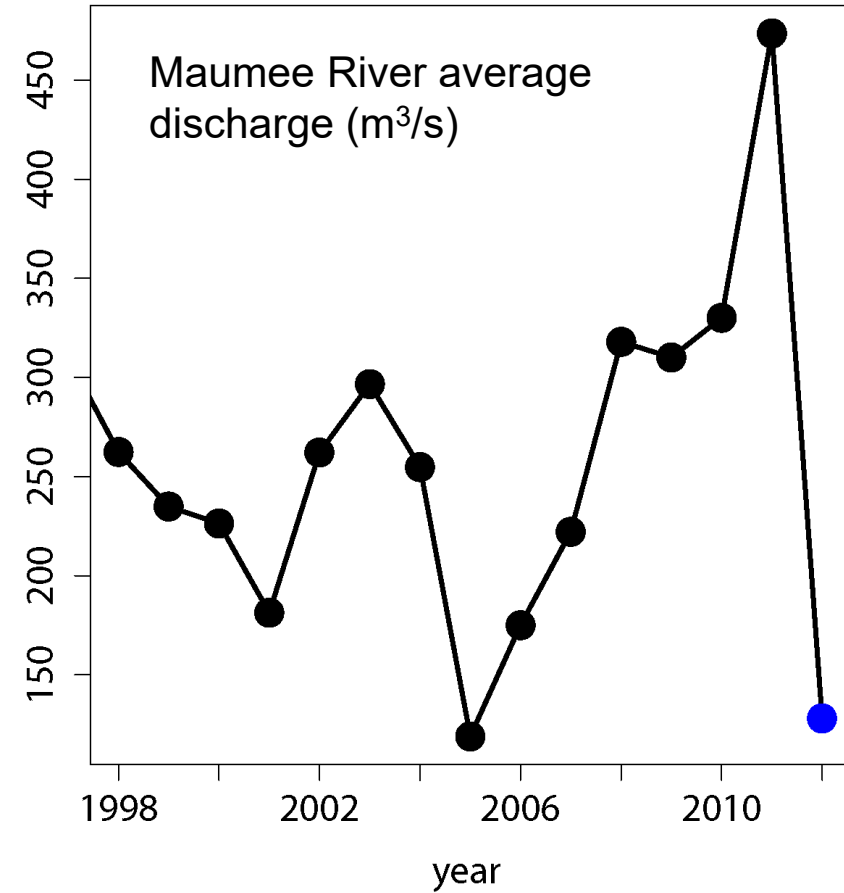
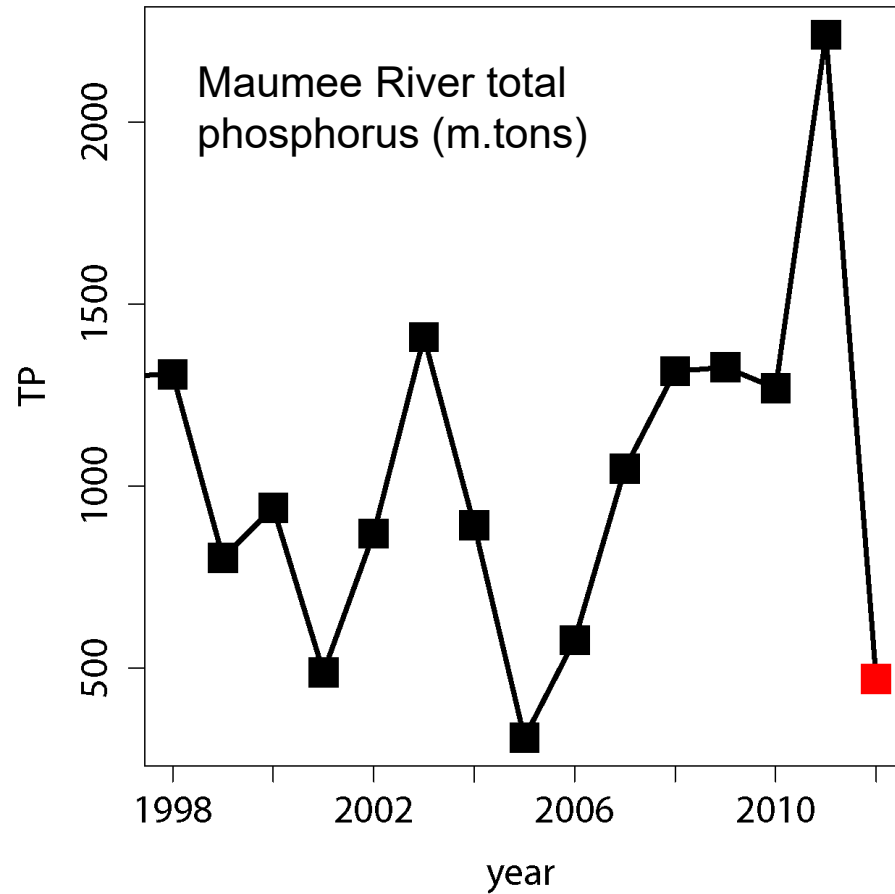


Annual load, spring  
load?

Spring Mar-June  
determines bloom



# 2012: dry spring and low loads





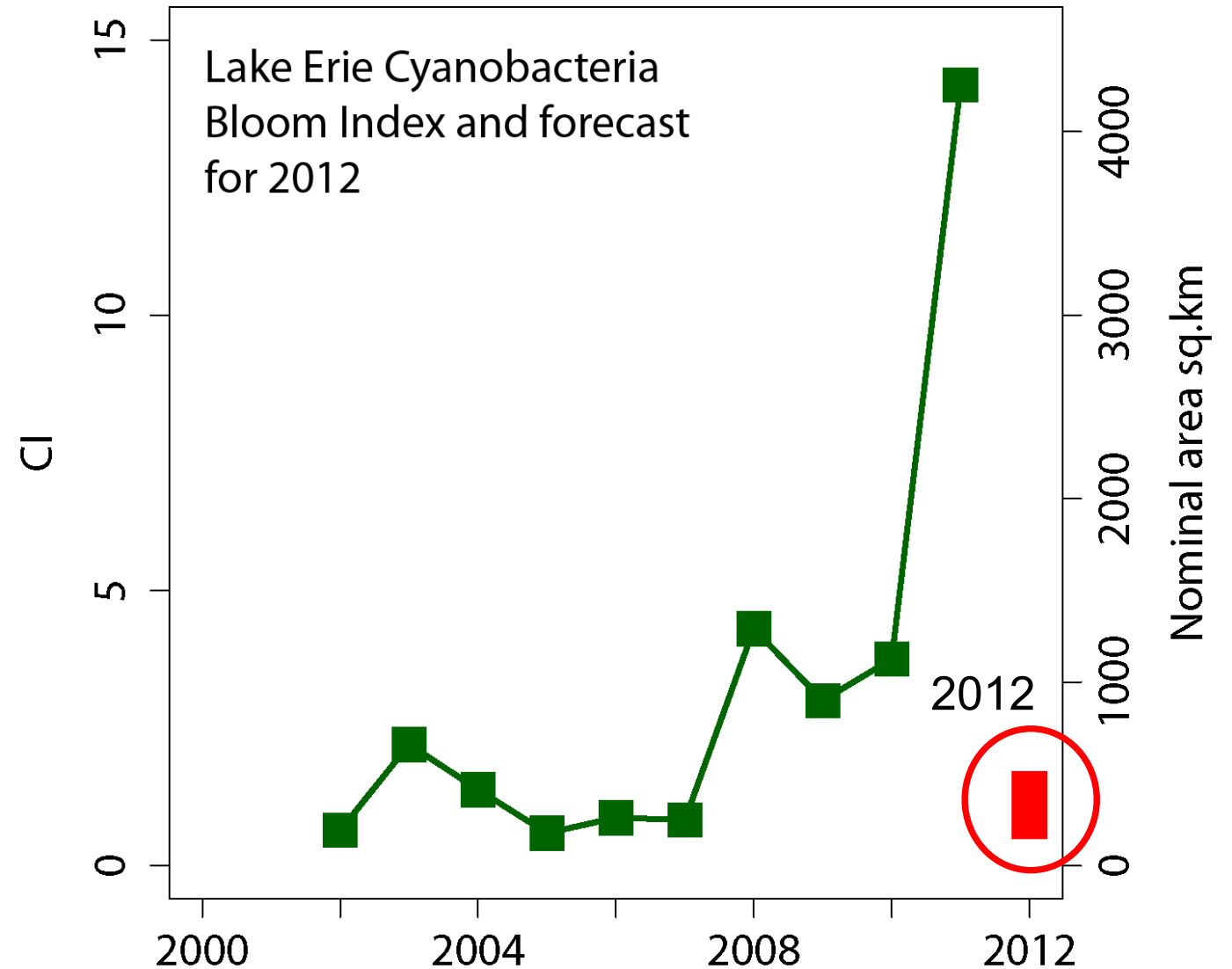
If we understand it,  
we can forecast it

July 5, 2012 First Forecast at Stone  
Lab

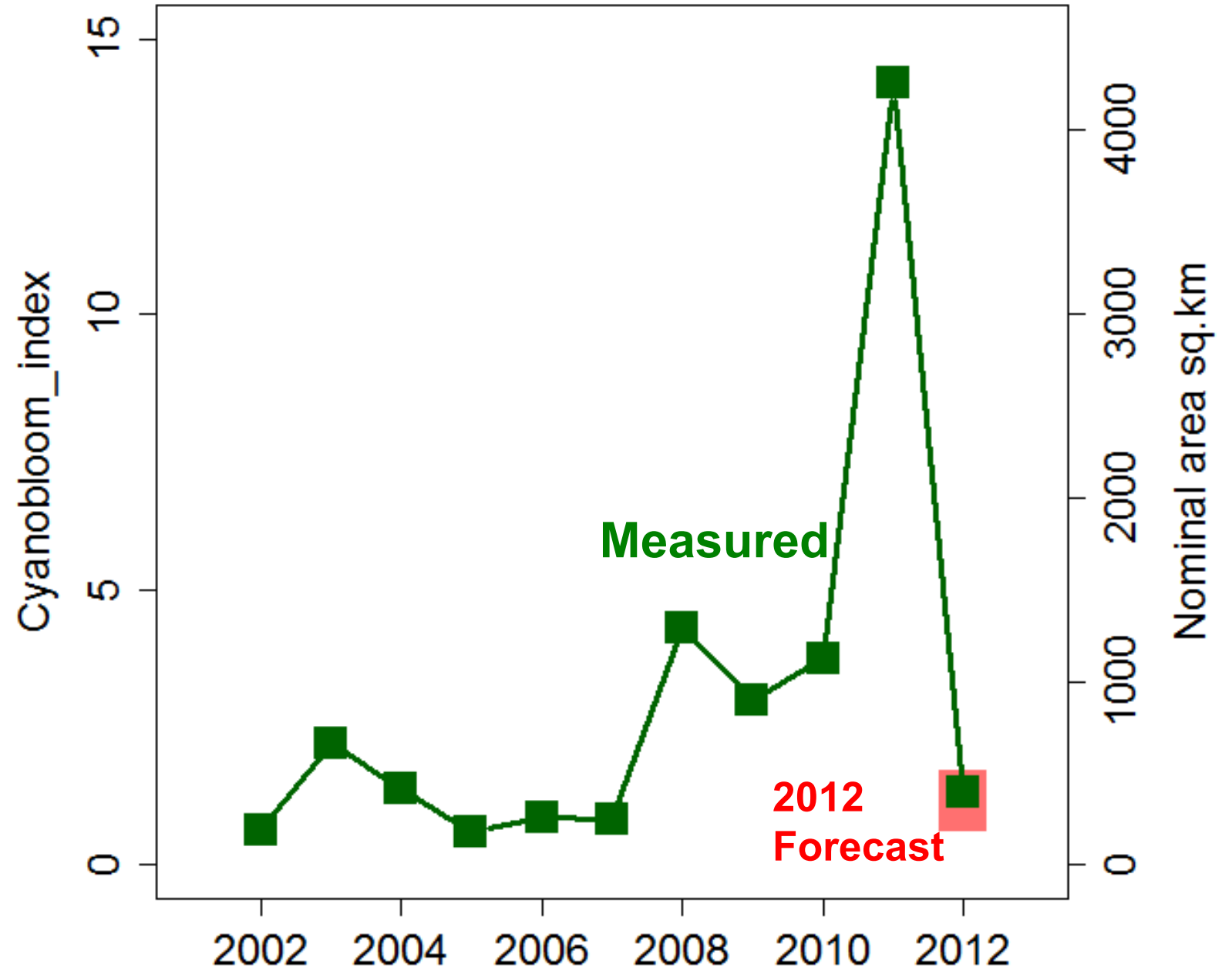
**“2012 bloom in western Lake Erie  
will be mild. ”**

**2012 is excellent test year**  
**Wet winter, dry spring.**

(No severity metric in 2012)



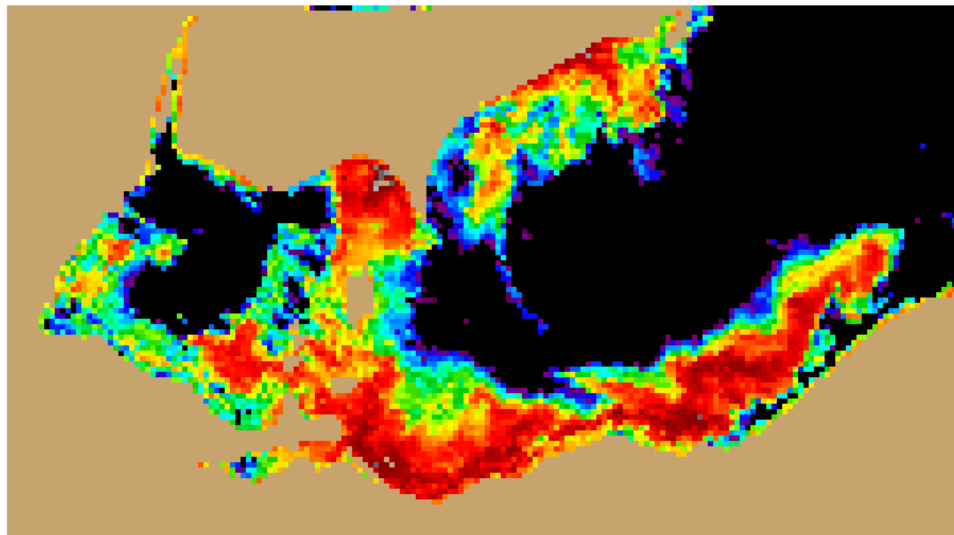
We were right!  
2012 mild bloom





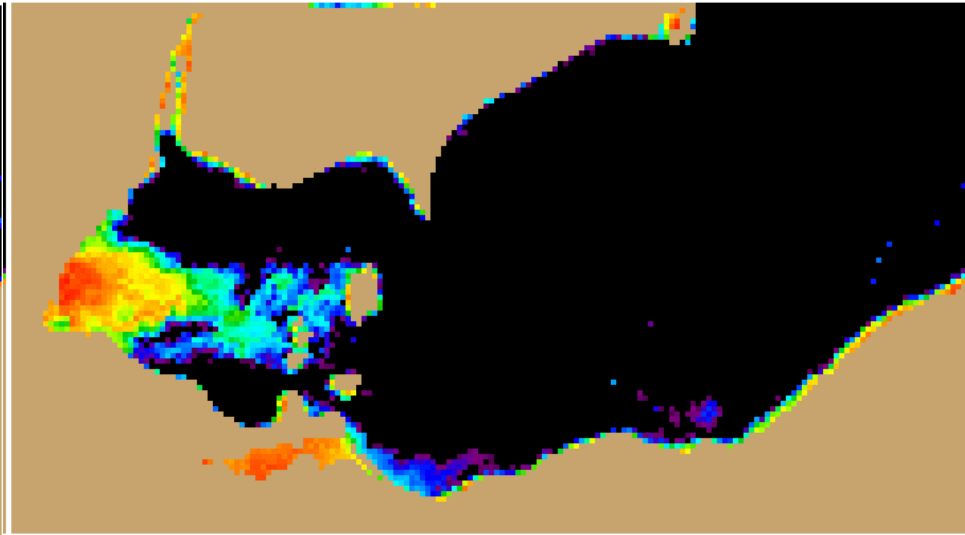
# 2013 prediction for western Lake Erie similar to 2003, <1/5 of 2011

2011 for comparison



2011

2013 may resemble 2003



2003



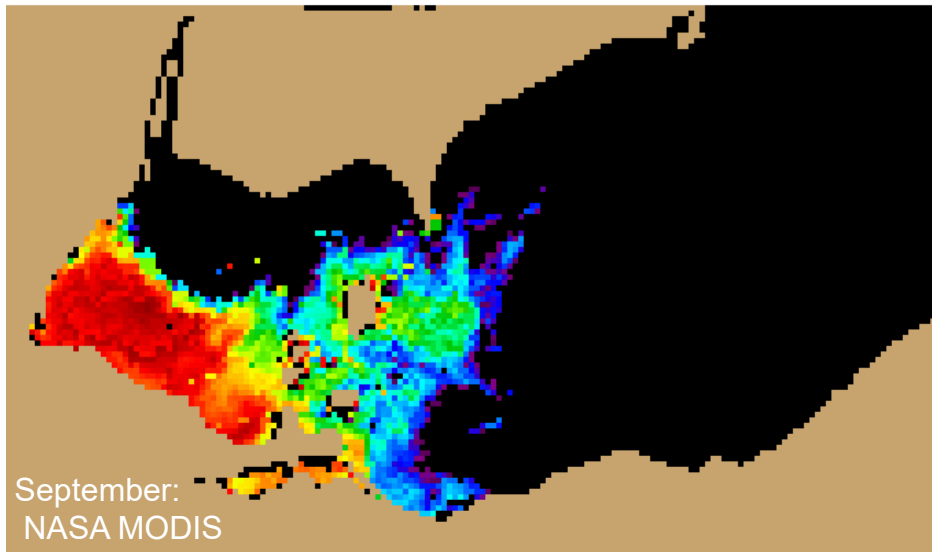
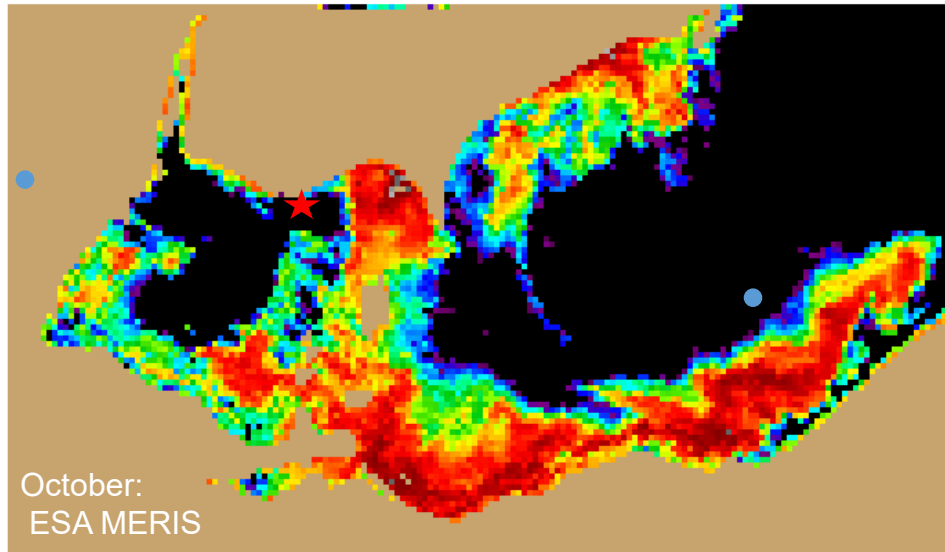
concentration

**It is difficult to predict, especially the future**

Danish Proverb (attributed to many people).

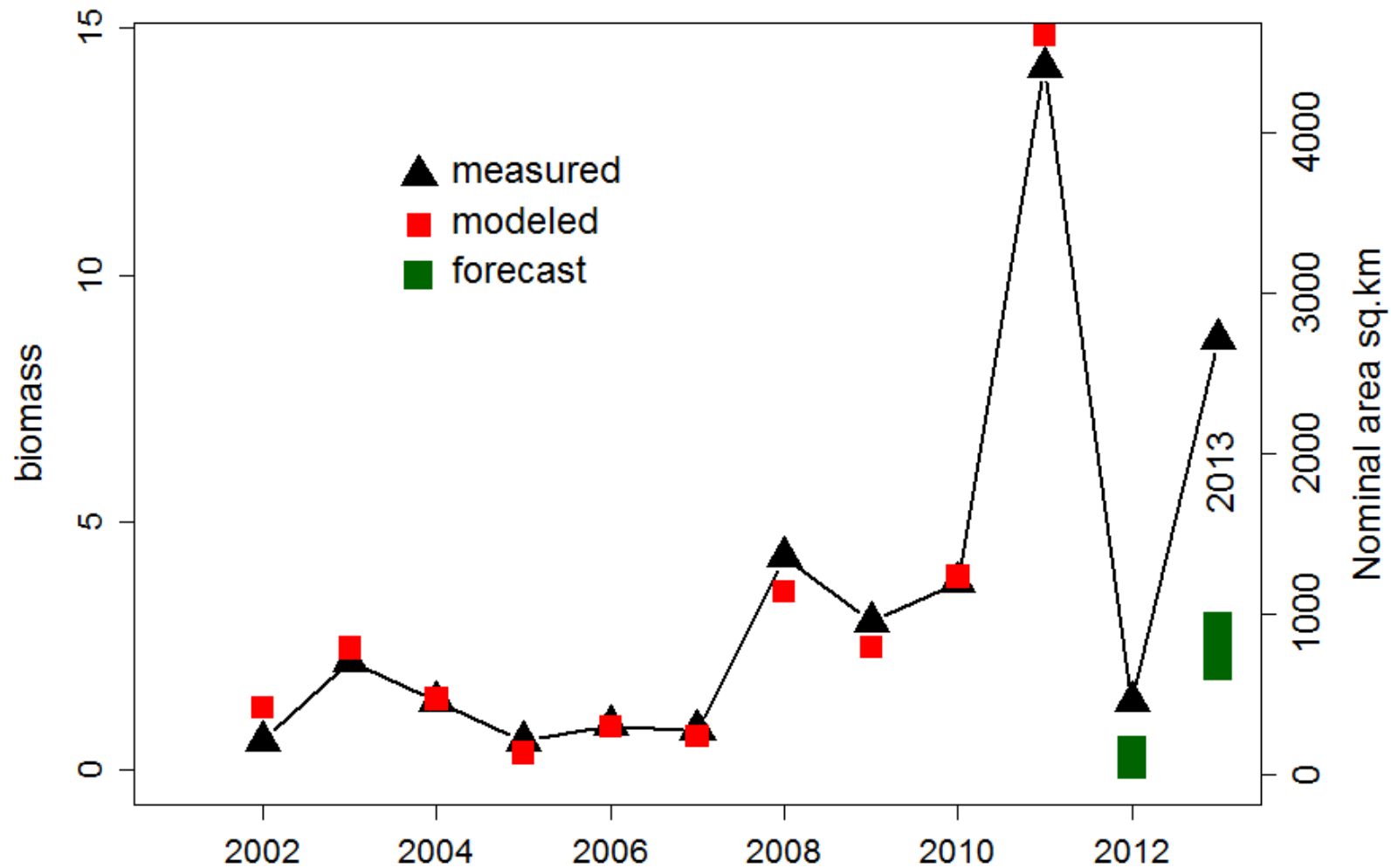


2013 was 2<sup>nd</sup> most intense after 2011  
& concentrated in western basin



# Two years of forecasts.

2012 Forecast mild bloom. 2013 Forecast “significant bloom”,  
but 2013 severity in western basin was worse than expected.





All models are wrong but some are useful.

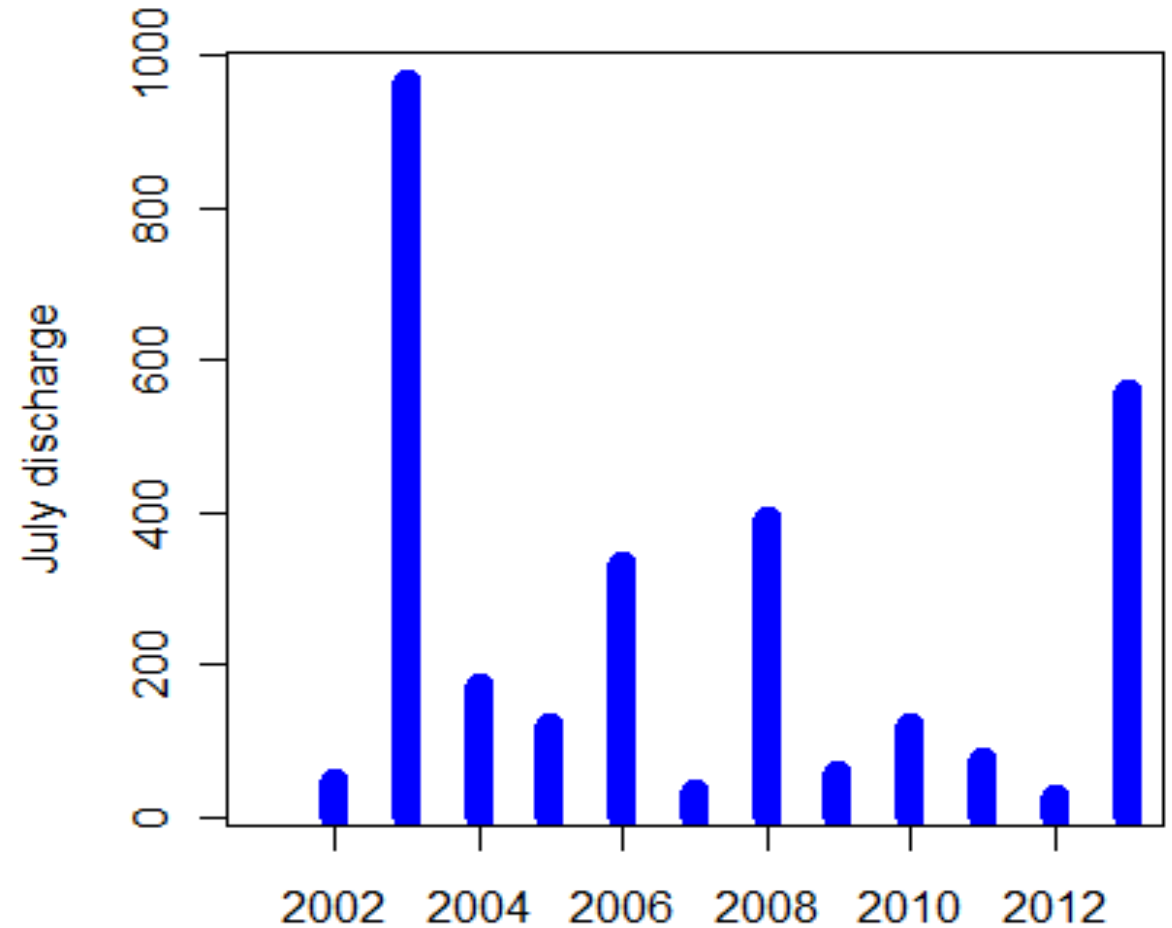
How wrong do they need to be before they are not useful?

George E.P. Box

2013 was useful.

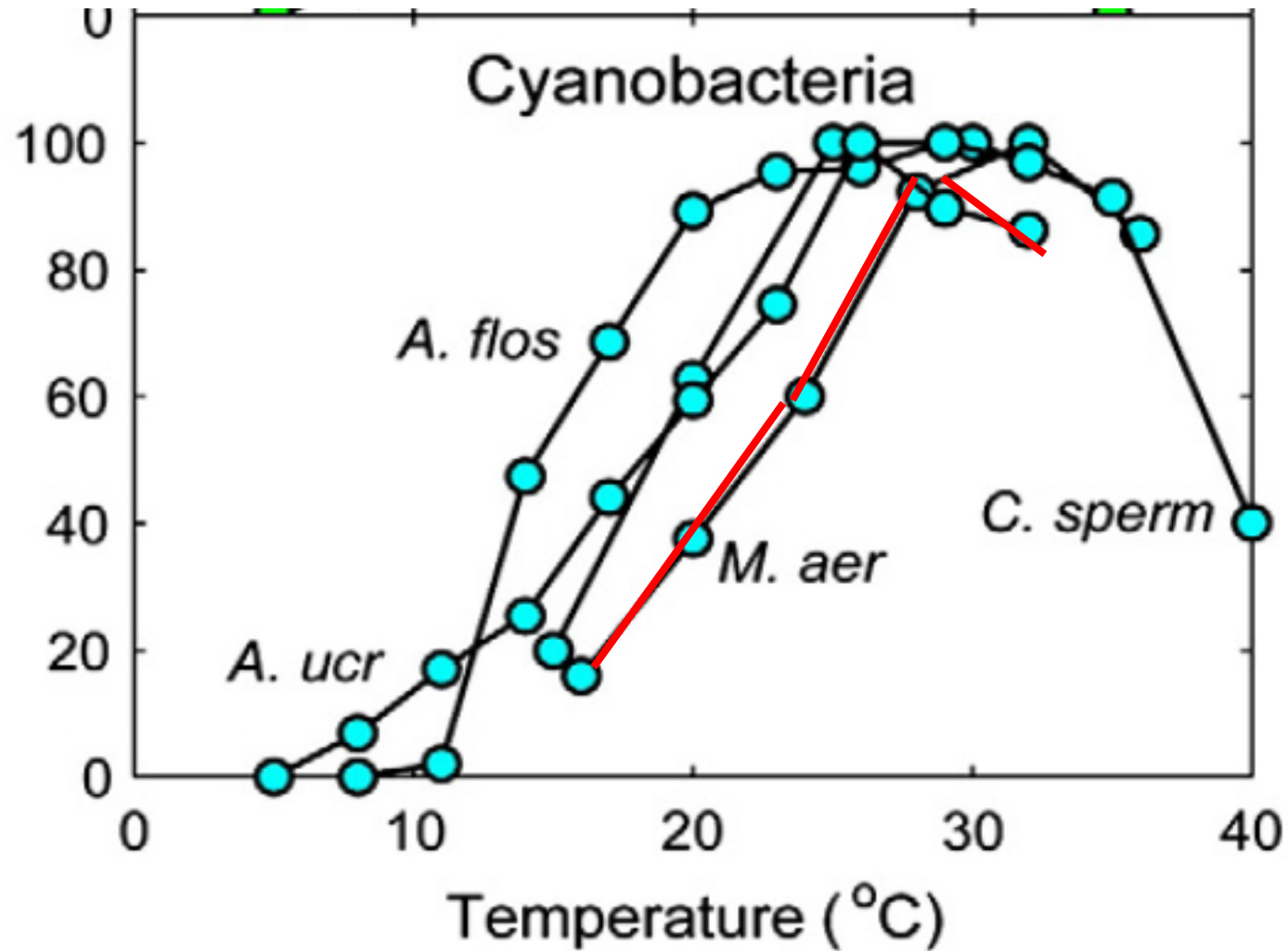
# What was different in 2013?

- Model used loads from Mar to June.
- 2013 had wet July and long calm autumn (Sep-Oct)
- But what about 2003 and 2008?



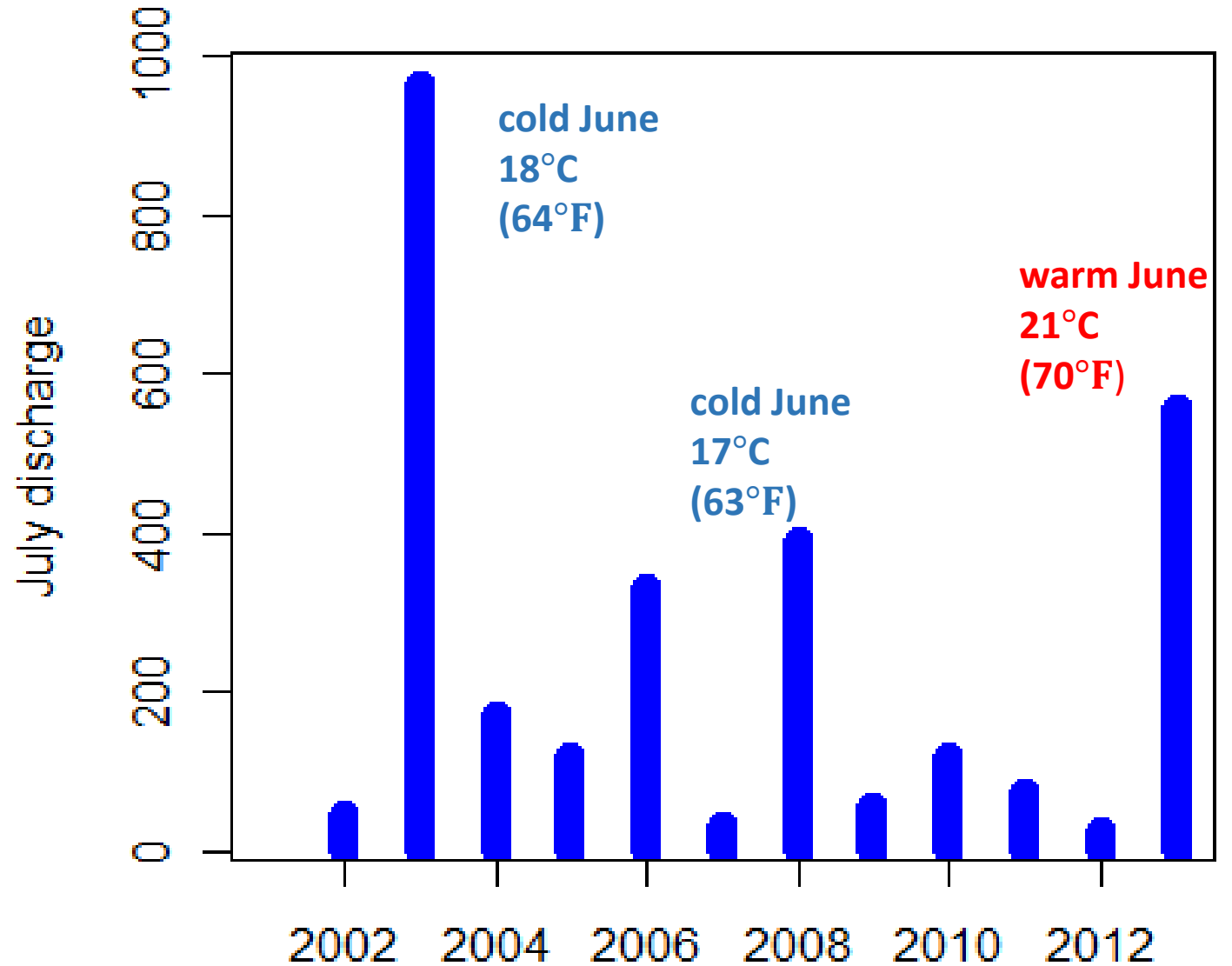


*Microcystis aeruginosa* likes it hot



# What was different in 2013?

- July appears to matter when June is warm.
- Cyanos can start growing in warm June and grab nutrients in July.
- Warm June water will probably will be routine in future.



# Now we add July (probably)

When June is warm.

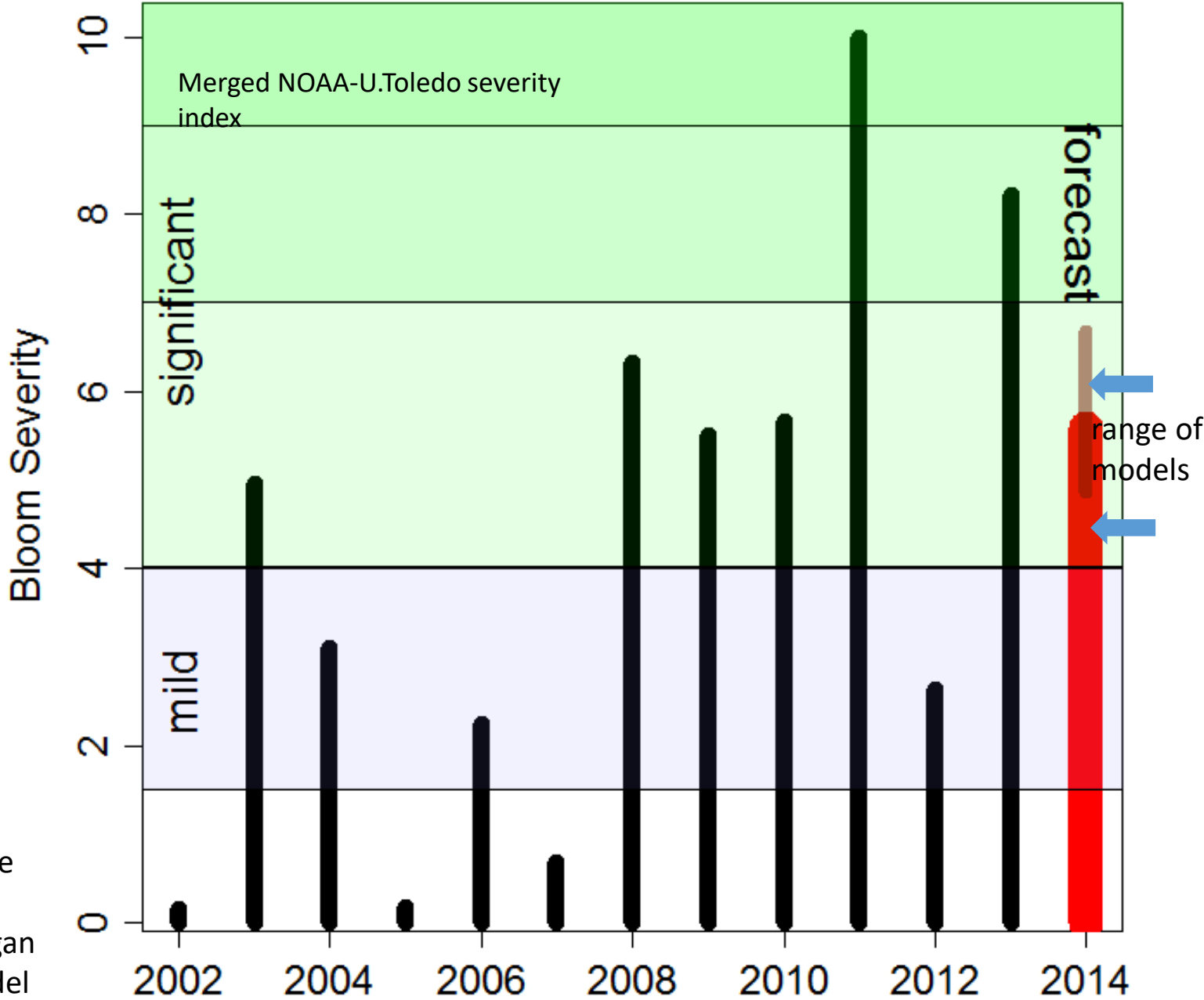
Climatologically July is normally a dry month.



# 2014 Forecast

2013 also taught us that we need a numeric severity this is biomass over peak three 10-day periods (30 days)

2014 Ensemble Includes U.Michigan trial model



# A problem in 2014

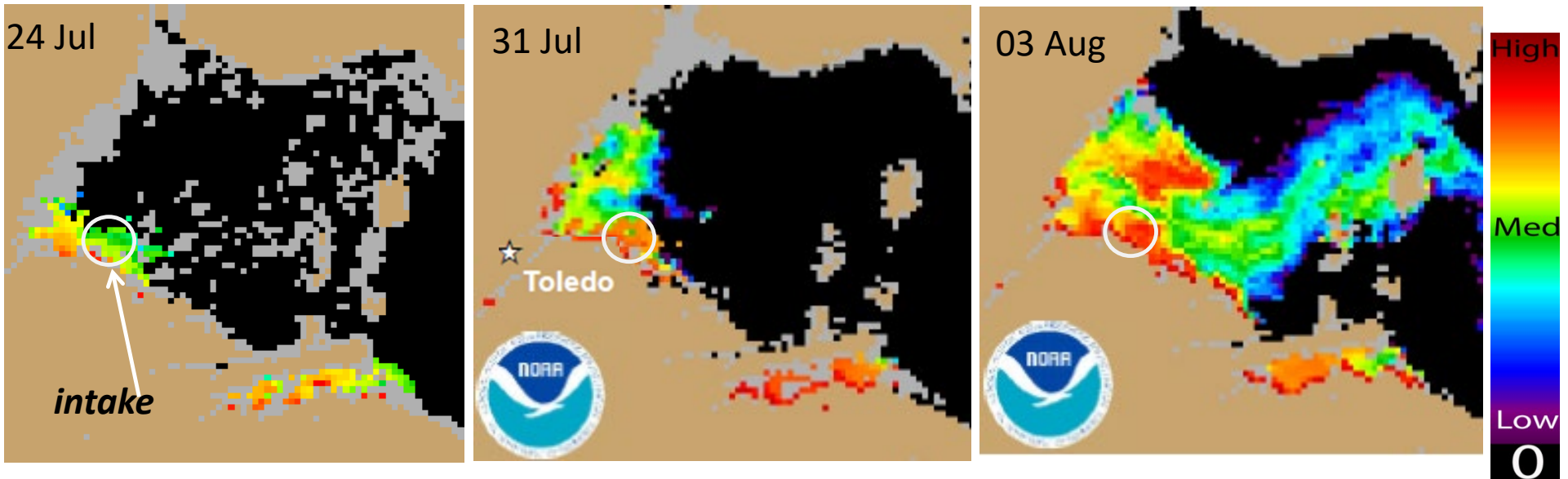
URGENT NOTICE TO RESIDENTS OF TOLEDO & LUCAS COUNTY WHO RECEIVE WATER FROM THE CITY OF TOLEDO

DO NOT DRINK THE WATER  
DO NOT BOIL THE WATER

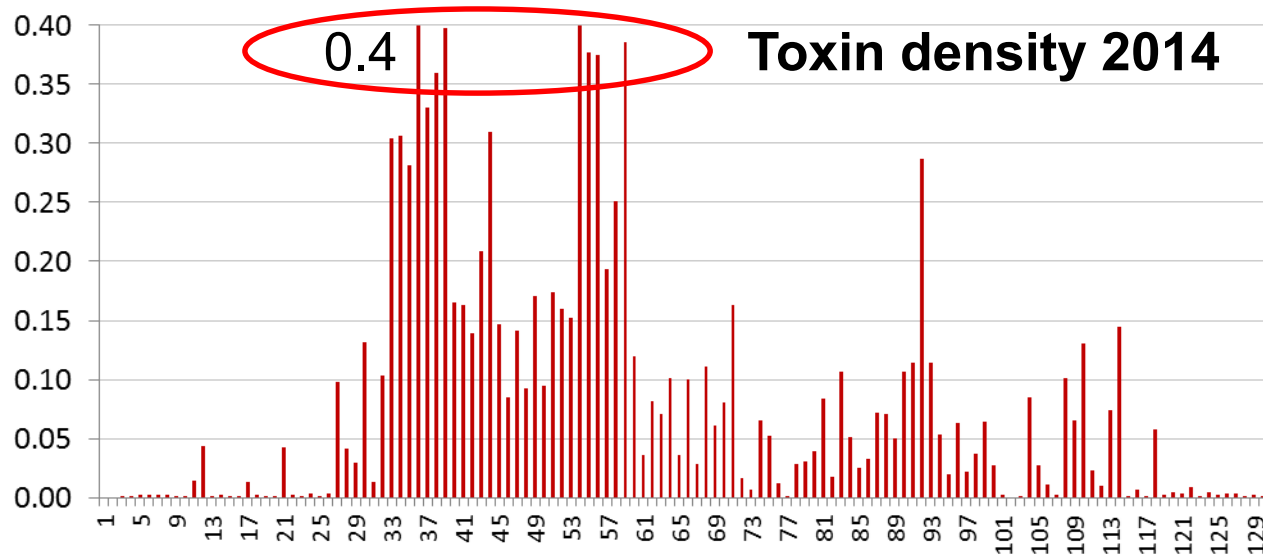
Aug 2-3, 2014

Chemists testing water at Toledo's Collins Park Water Treatment Plant had two sample readings for microcystin in excess of the recommended "DO NOT DRINK" 1 microgram per liter standard. This notice applies to ALL customers of Toledo water.

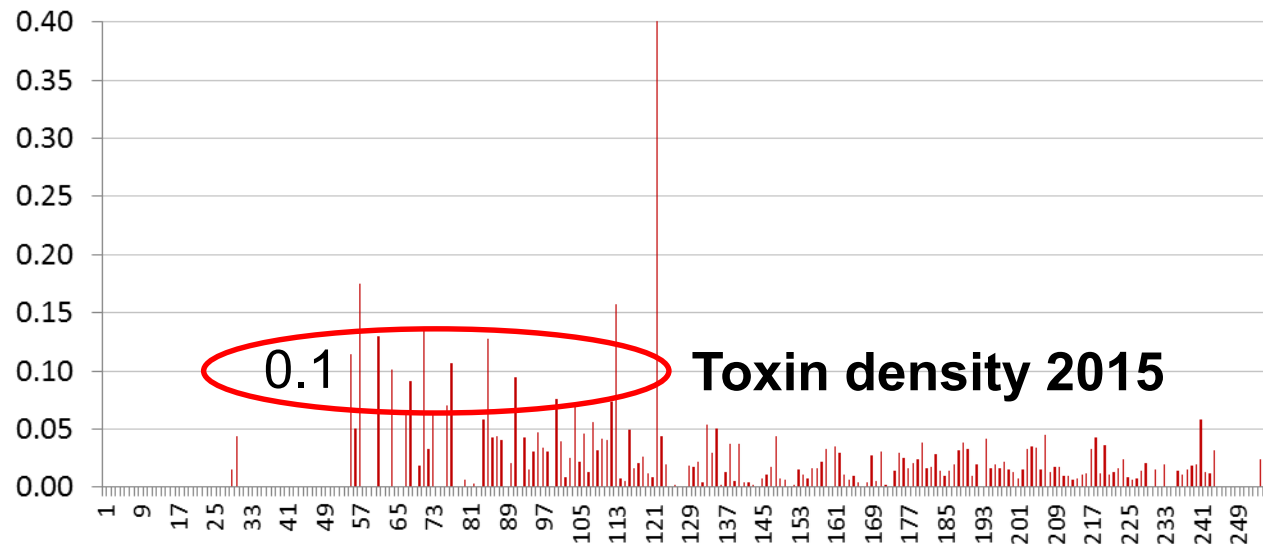
*Rapid increase in bloom at end of July, concentrated near Toledo.  
We cannot predict timing of bloom yet..*



# We can't yet model toxicity



2014 beginning, each cell was churning out toxin. Highest production observed in five years



Blooms always make toxin, but make less later.

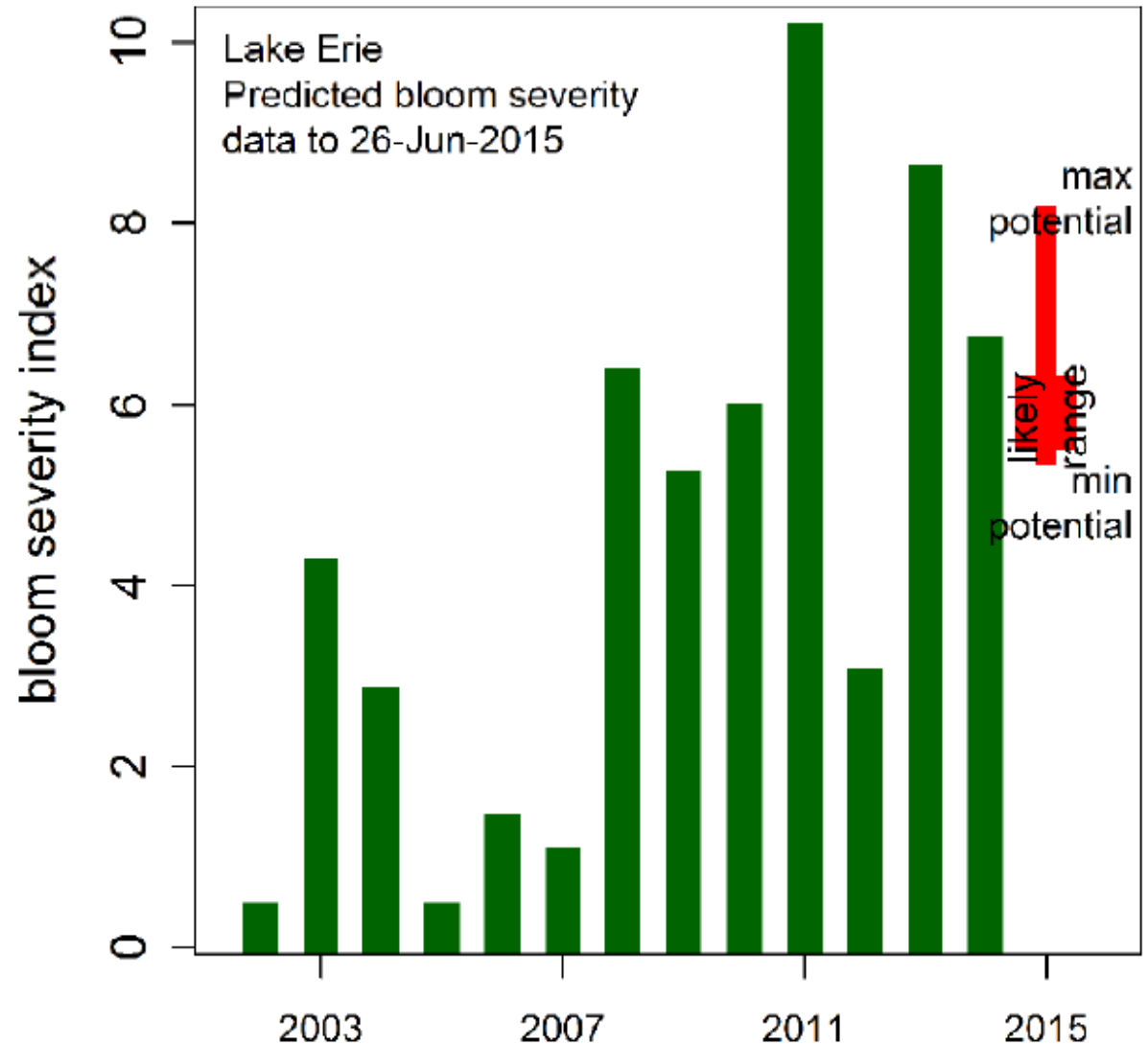
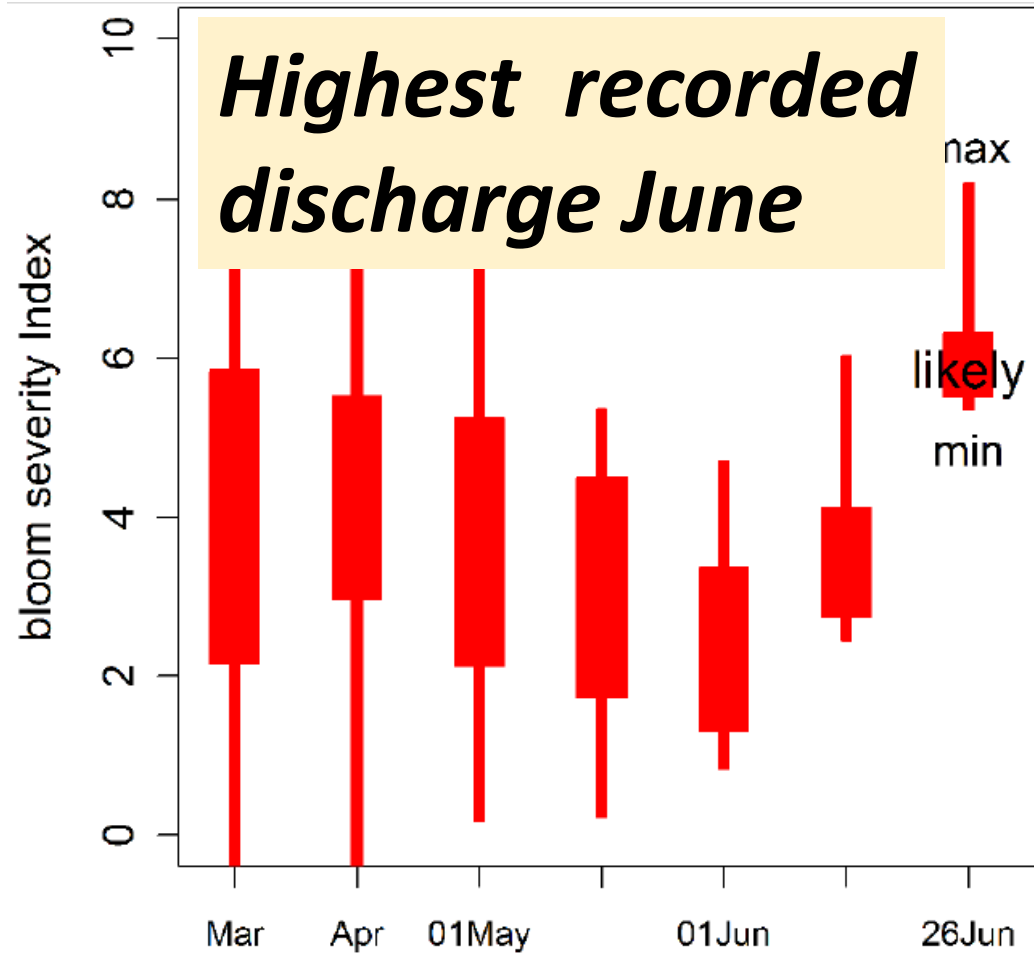
Justin Chaffin and co. are working on toxin model

Also, a lot of other things going on in 2014

Steffan et al., 2017  
ES&T



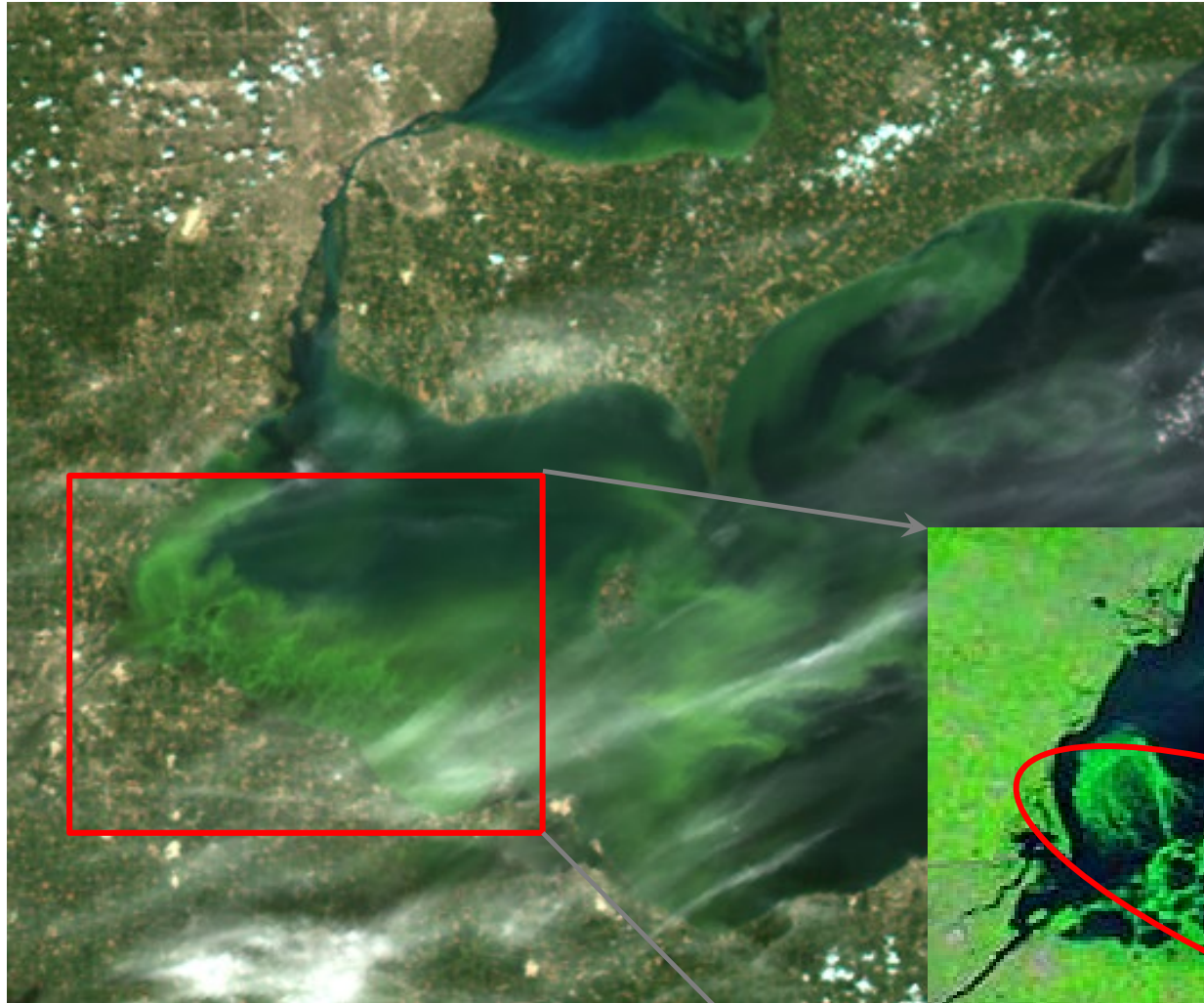
2015. Started early season projection.  
Used climatology. What's wrong with that?



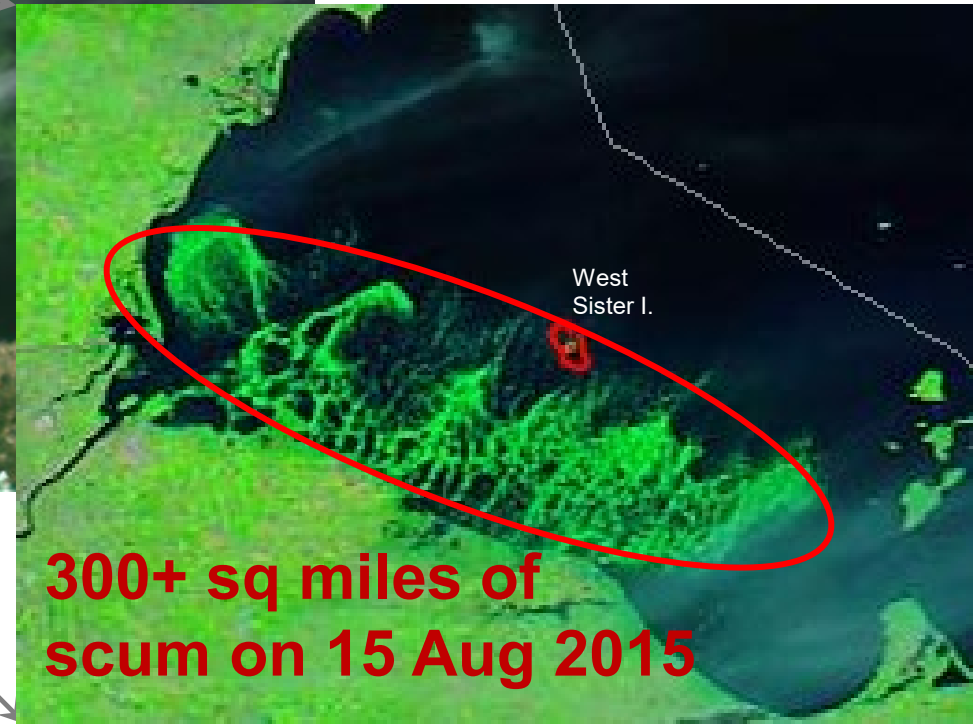
# What happened in June 2015 (keep in mind against 2019)

- Rain!
  - Wettest month ever at Ft Wayne (11.98")
  - 4<sup>th</sup> wettest June at Toledo, 7.2" of rain;
  - Among top 20 wettest months since 1880's.
- Floods
  - Maumee River record discharge for June and July
  - Estimated 3<sup>rd</sup> highest discharge month ever (starting 1930)
- Nutrients
  - Largest June total phosphorus load since 1981
  - Largest June dissolved phosphorus load recorded (since 1975)

# 2015 intensified early, in July and August



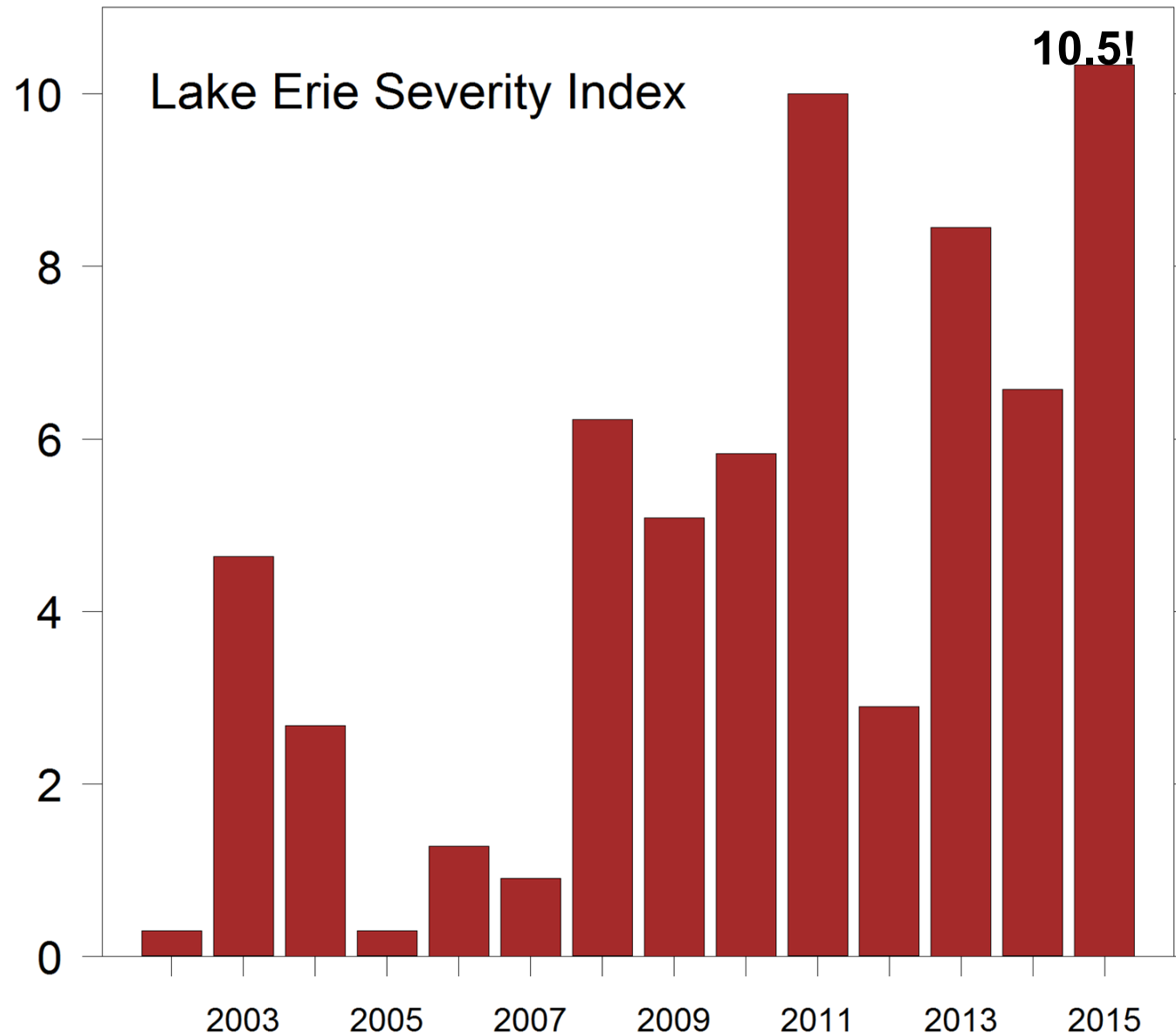
For 40+ days (7/21 to 8/30)  
2015 scum amount was  
matched only by one week  
(early Oct) in 2011.



**300+ sq miles of  
scum on 15 Aug 2015**



# 2015: Lake Erie's most intense bloom



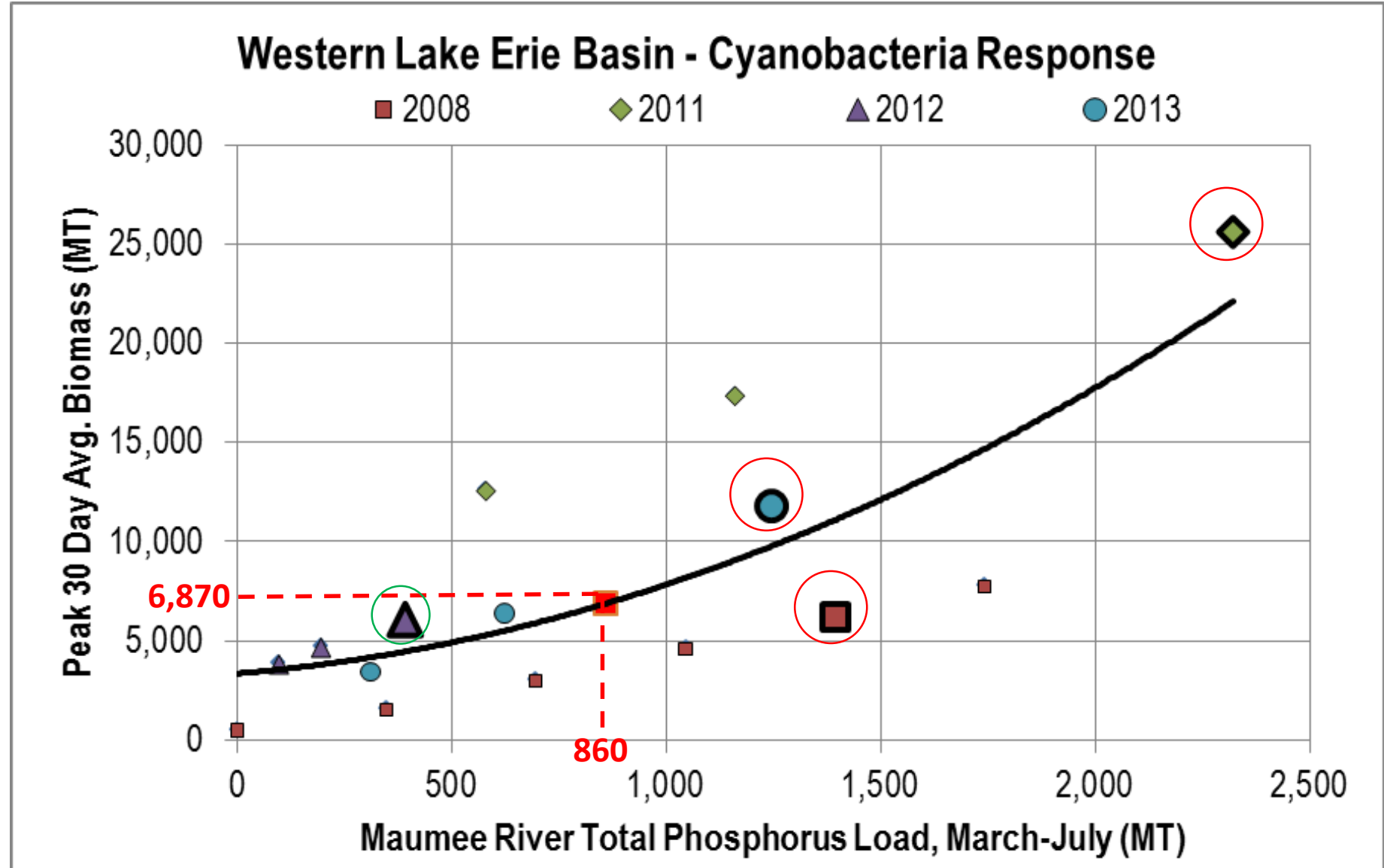
Ensemble of models  
all forecast a big  
bloom.

Very different models  
(numerical WLEEM  
Limnotech,  
statistical/heuristic,  
Bayesian. Different  
assumptions

# Ensemble of models used for GLWQA P target estimation

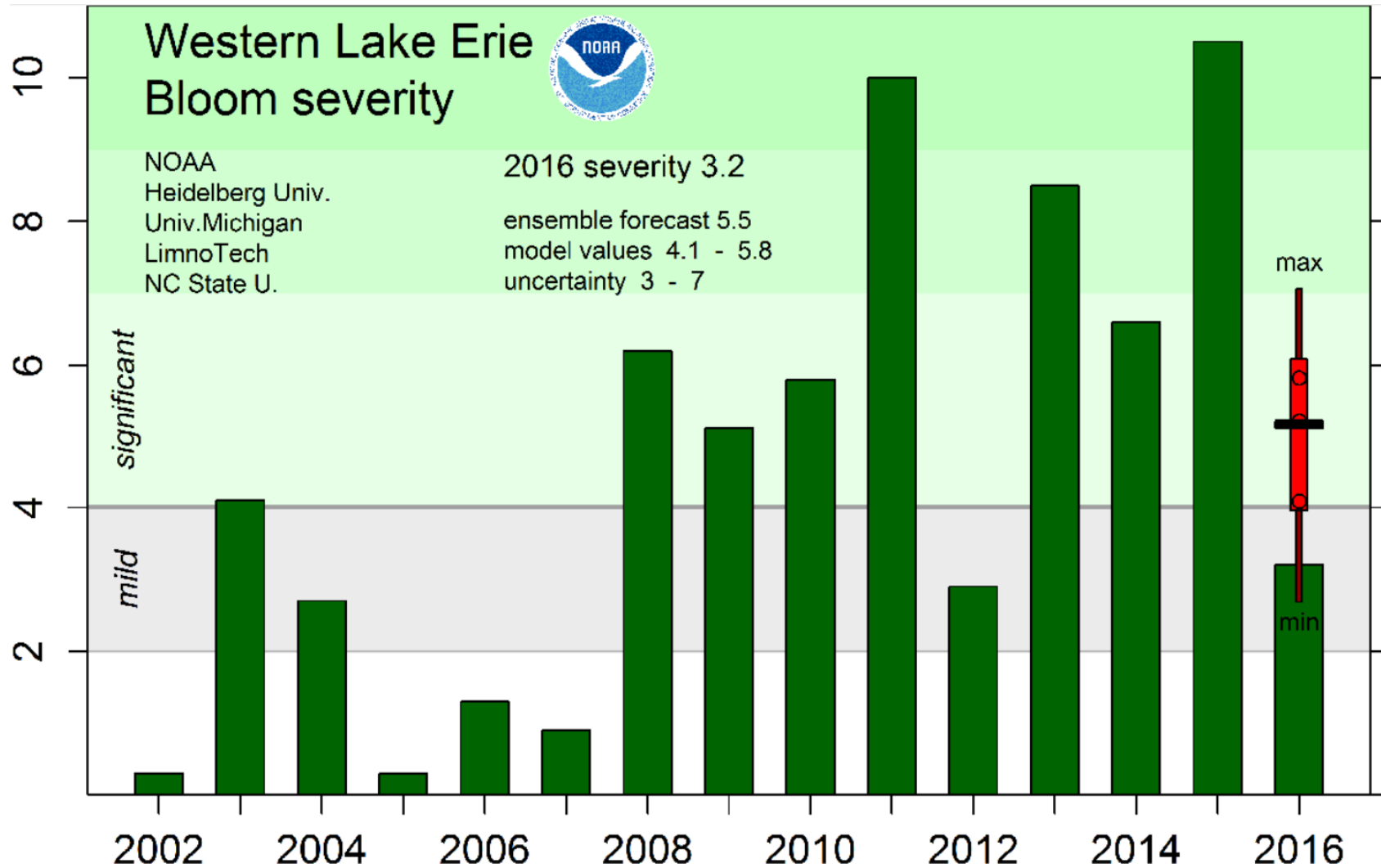
Reduction based  
on very different  
models

That come up with  
the same answer



# 2016 Bloom

much smaller than 2015 and smaller than forecast





## 2016 Models overestimated bloom size Why?

- Nearly all models included “internal load” of phosphorus (P), more than occurred.

(Internal load is P released from ‘storage’ in lake sediments; external load flows into lake (Maumee R. etc.)

NOAA models “internal load” was excess P “carryover” from record 2015. The estimate was too large.

- While growth started early (LimnoTech WLEEM model predicted this), growth stalled when P was used up.

- Reinforces the message, load from the tributaries!

Reduce the P load from the Maumee (and other tribs), decrease the blooms.

2018, “Déjà vu all over again”

2016 problem repeated with “legacy” (also use of TP in one model

- Several models included “internal load” of phosphorus (P), more than occurred.
- While growth started early, growth stalled when P was used up.
- Reinforces the message, load from the tributaries!  
Reduce the P load from the Maumee (and other tribs), decrease the blooms.

# 2018, Unusual, climate or weather change

- Earliest start to bloom (late June)
- Earliest ending of a bloom (high winds in September)
- (most years the bloom peaks in September)

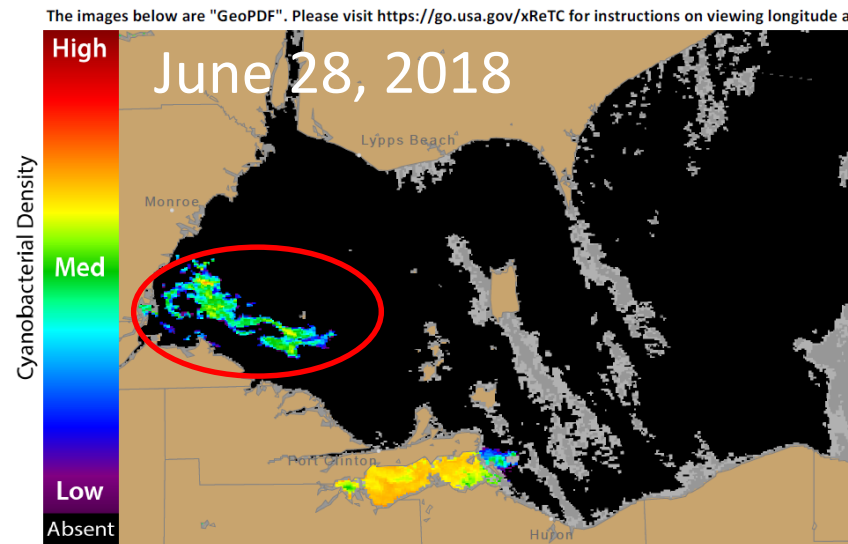
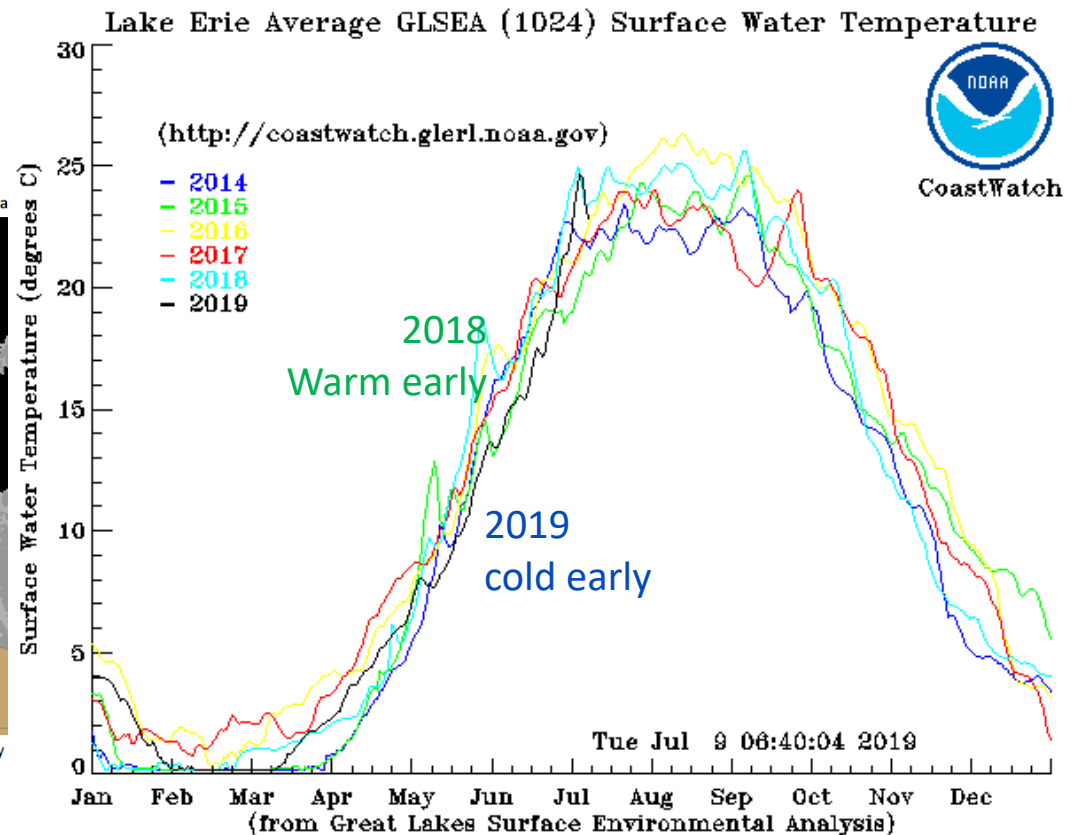


Figure 1. Cyanobacterial Index from modified Copernicus Sentinel 3 data collected 28 June, 2018 at 11:23 EST. Grey The estimated threshold for cyanobacteria detection is 20,000 cells/ml

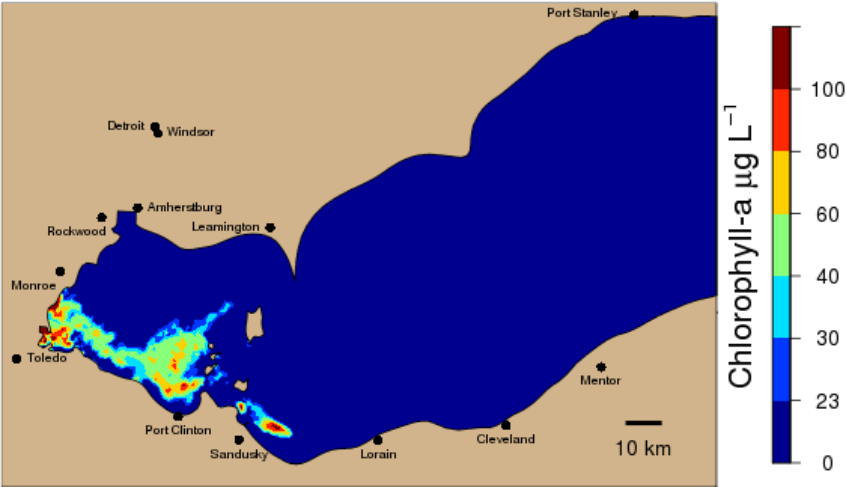


# Other Forecasts, short-term (days) transport

2017-09-13 12:00 EDT



2017-09-15 18:00 EDT



Experimental  
Lake Erie Harmful Algal Bloom Bulletin  
2011-008  
08 September 2011  
National Ocean Service  
Great Lakes Environmental Research Laboratory  
Last bulletin: 22 July 2011

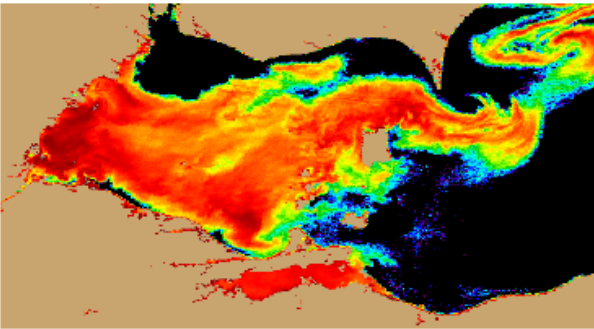


Figure 1. MERIS image from the European Space Agency. Imagery shows the spectral shape at 681 nm from September 03, where colored pixels indicate the likelihood of the last known position of the *Microcystis* spp. bloom (with red being the highest concentration). *Microcystis* spp. abundance data from shown as white squares (very high), circles (high), diamonds (medium), triangles (low), + (very low) and X (not present).

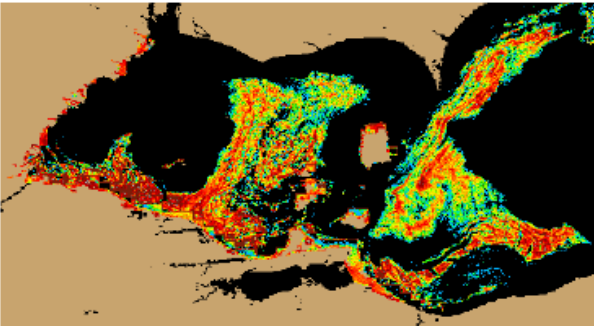


Figure 2. Nowcast position of *Microcystis* spp. bloom for September 08 using GLCFS modeled currents to move the bloom from the September 03 image.





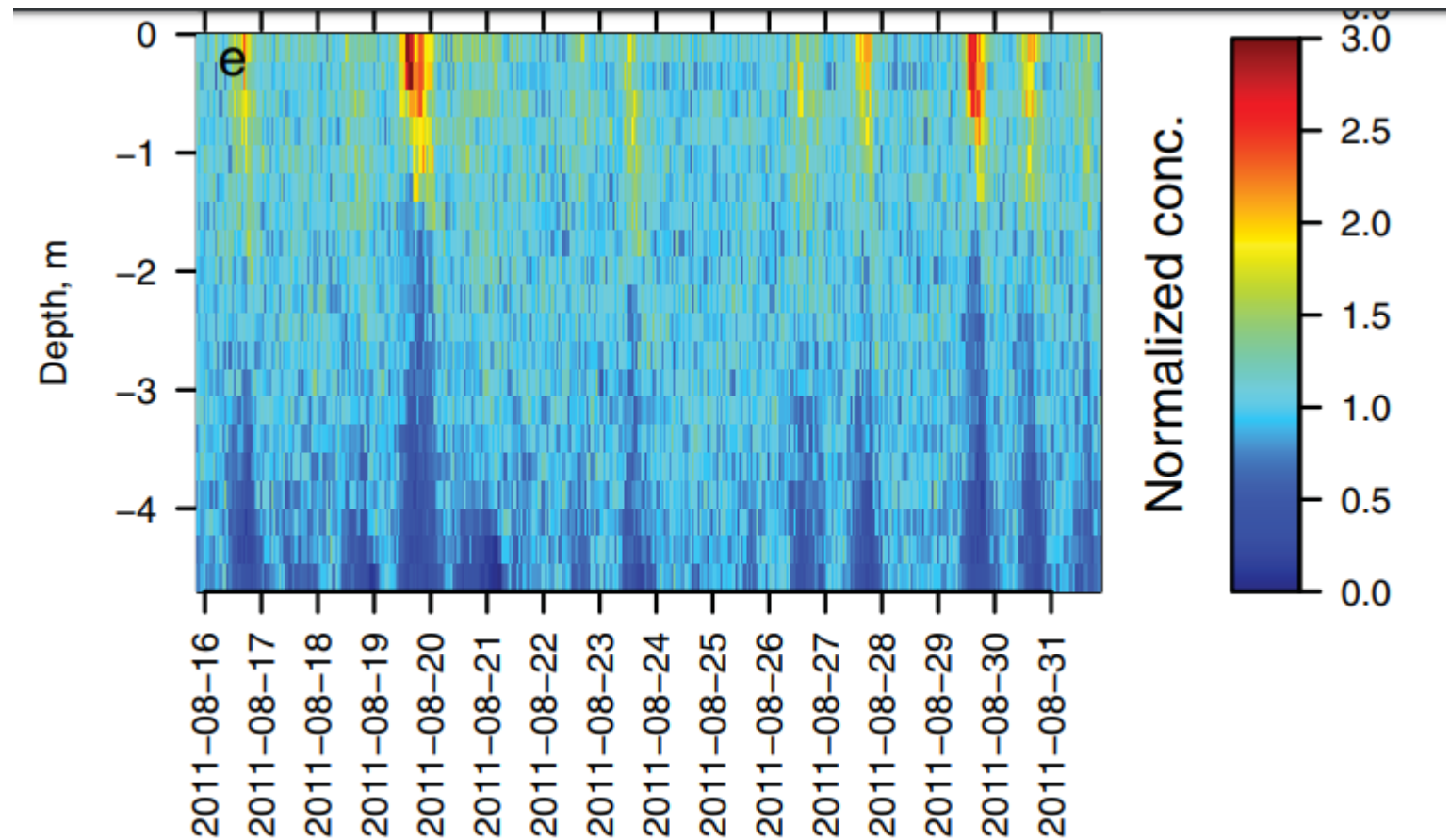
Microcystis moves up and down in water, if there is light wind. Mixing forecasts are useful

Mixed is a problem for intakes  
Surface is a problem for recreation

< 5 knot winds, definite scum  
>10 knot, rare scum.

Model does more and can be applied by the hour.

With Mark Rowe at  
CILER/GLERL

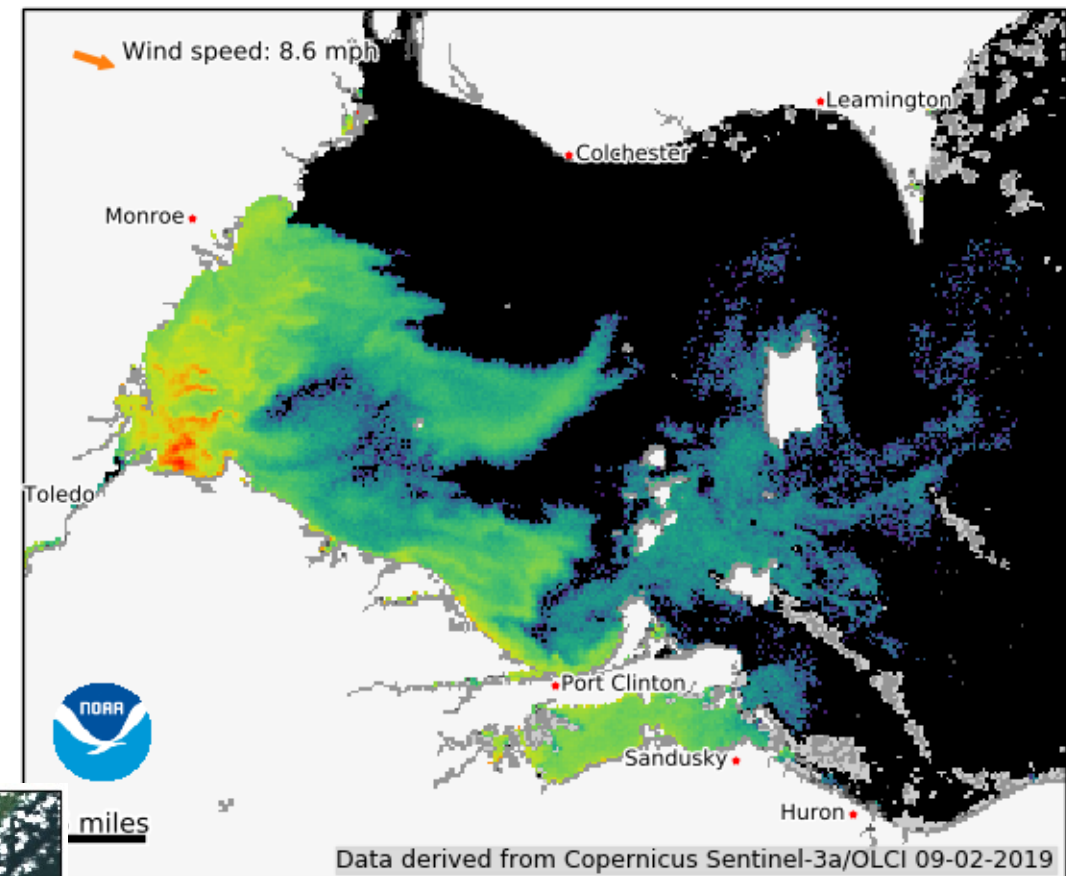
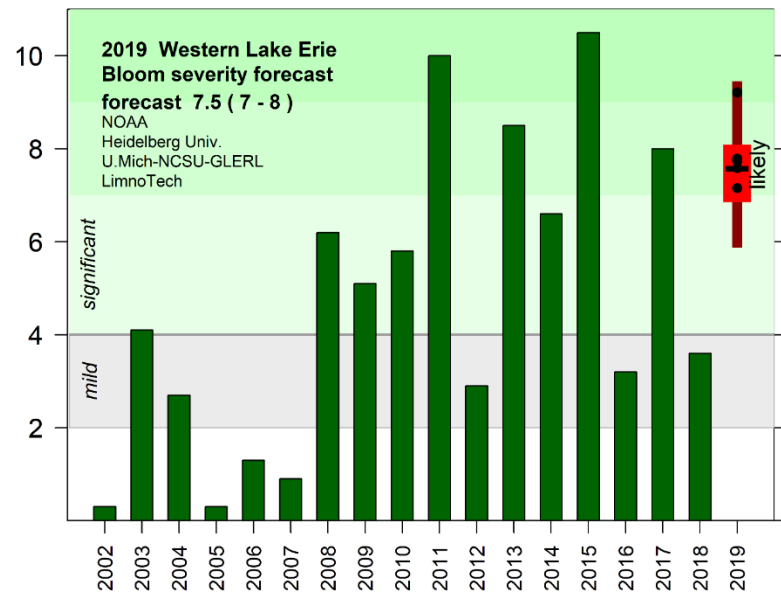


# How is 2019 forecast doing?

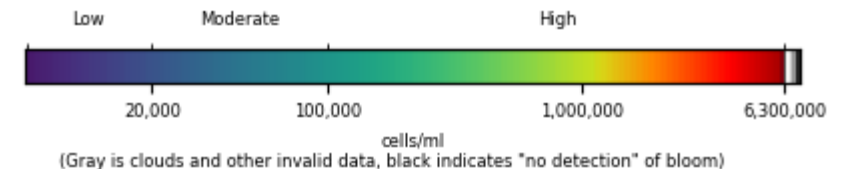
About 600-700 square miles in late Aug-early Sep.

2017 reached 800 sq. miles.

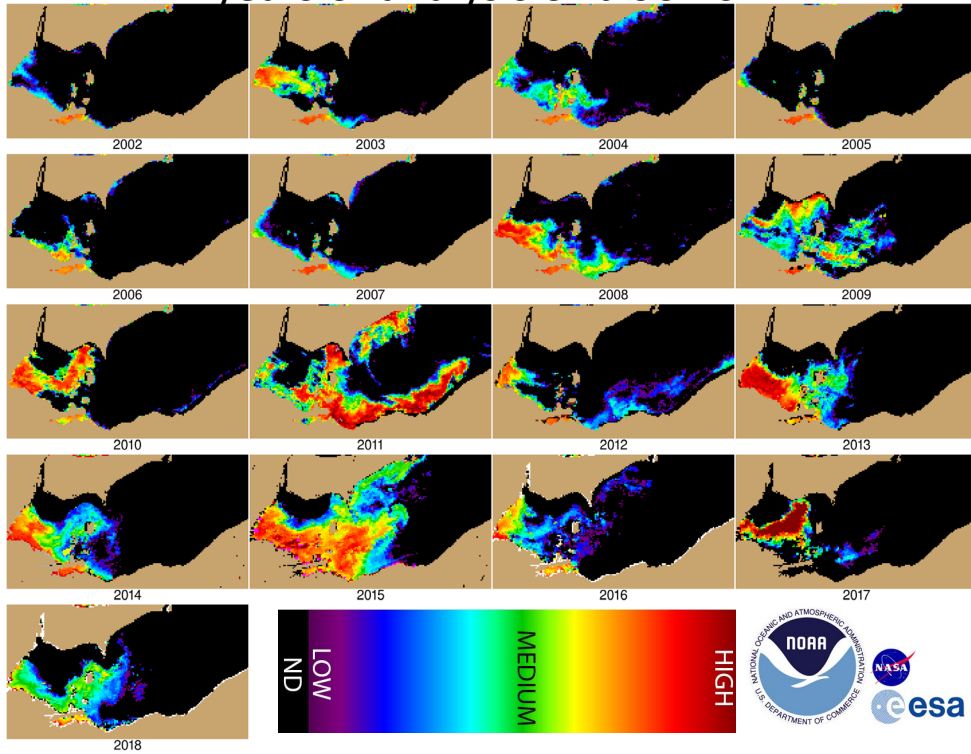
Windy September so far, several weeks to go.



Chlorophyll a (CI) for Western Lake Erie basin. Algal bloom covers about 650 square miles. Winds above 4.0 mph may mix the bloom and clouds may obscure it, leading to an underestimate of the area. Moderate and low concentrations may not be obvious to the eye. Winds from NOAA station THLO1.



## 17 years of analysis of blooms



[www.glerl.noaa.gov/res/HABs\\_and\\_Hypoxia/](http://www.glerl.noaa.gov/res/HABs_and_Hypoxia/)



## Great Lakes Harmful Algal Blooms (HABs) and Hypoxia

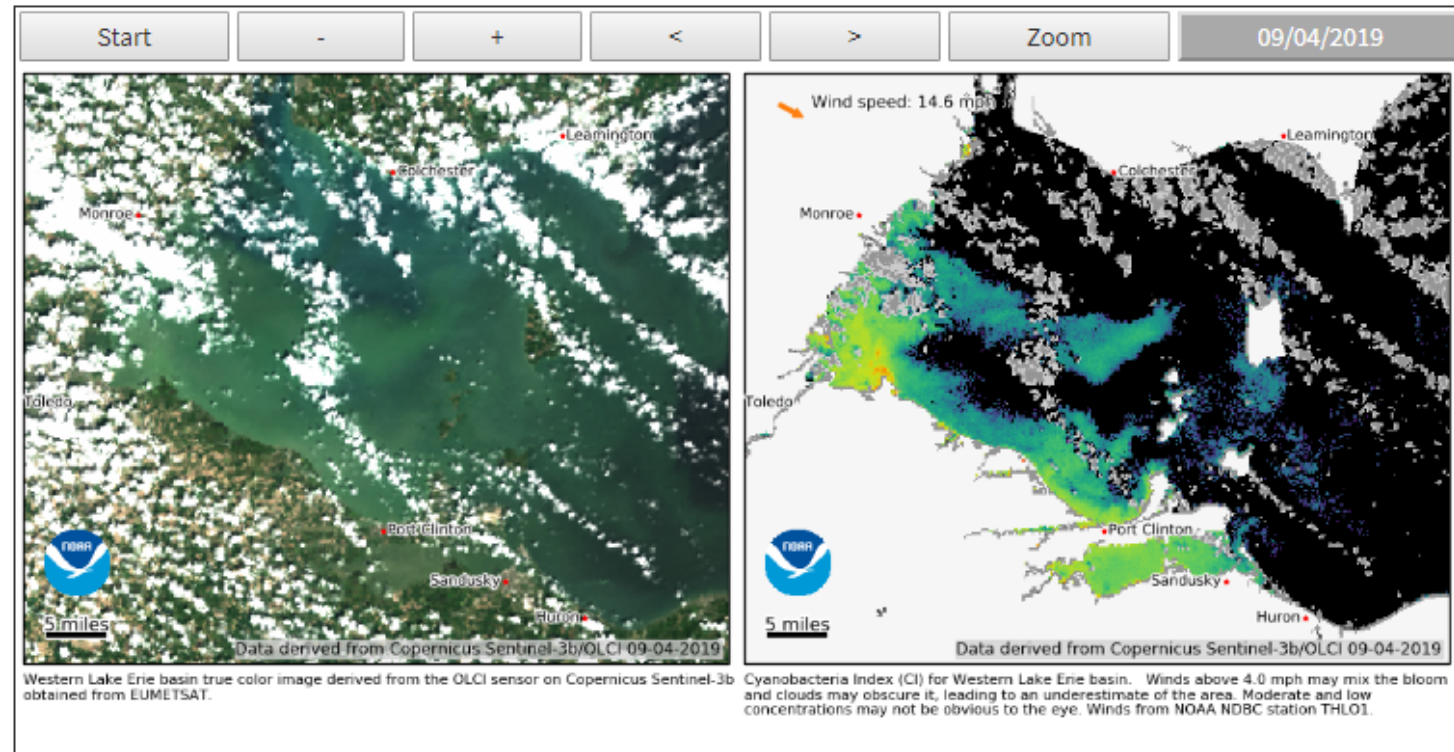


# Monitoring & evaluation continue

## Daily satellite updates

[coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-monitoring-system/](http://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-monitoring-system/)

*Click the next and previous arrows to view the most recent 17 usable images from the last 14 days.  
(You may need to refresh your browser or clear your browsing data to see the latest forecast.)*





# What have we learned (so far) in forecasting?

Numeric scores are better than adjectives

TBP (total bioavailable phosphorus)

Spring load matters, not winter or annual

(e.g., 2005, 2007 and 2012 major winter run off)

July appears to matter (2013, 2015, 2017)

Previous years have small (if any) impact

low spring load years have small blooms

All models are wrong, and some are useful.

And some are close to being right most of the time.





# What do we need to work on for forecasts?

Toxicity. Where and how much

in September, non-scum toxin levels are relatively low

Timing. Last several blooms have increased rapidly in late July.

Not as simple as temperature. Maybe spring bloom, wind,

Double bloom. Appears to have a second peak

Distribution. Winds.

North wind blows ill for Ohio, south wind for Ontario.

Wind models are not useful more than a few days out.



Context: Even in a bad year like 2013, The worse did not reach islands, and did not include all the lake.



Photo: Jeff Reutter

No problem for Perry Bicentennial!

