US EPA ARCHIVE DOCUMENT

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Forecasting and remote sensing of harmful algal blooms on the other coasts

Rick Stumpf

National Ocean Service

National Centers for Coastal Ocean Science

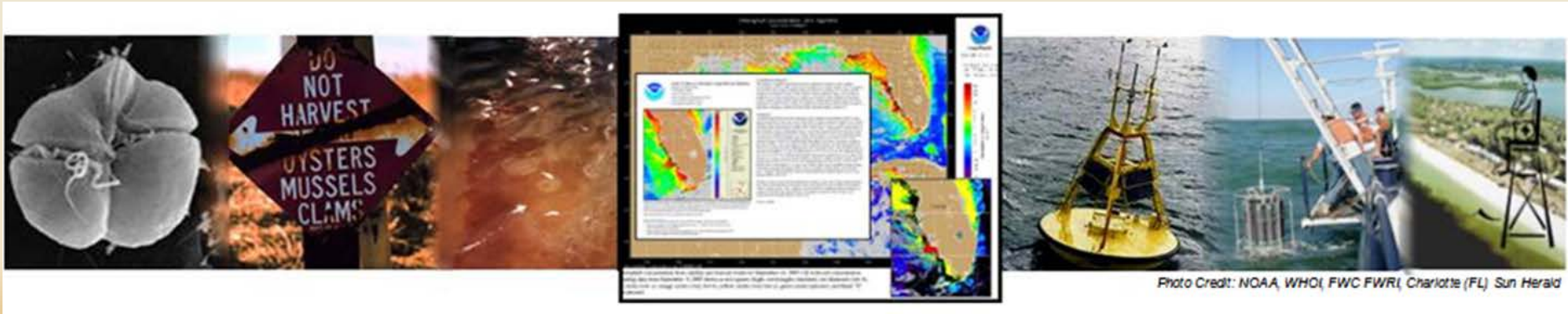
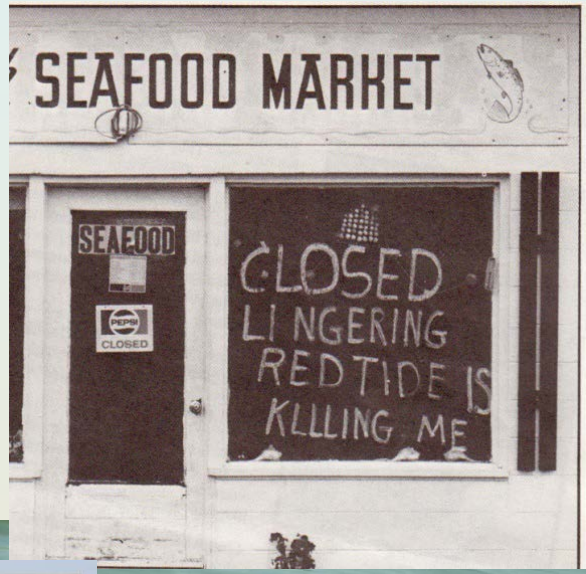


Photo Credit: NOAA, WHOI, FWC FWRI, Charlotte (FL) Sun Herald

Hazards of Harmful Algal Blooms (HABs)

- Shellfish poisoning
- Economic
- Fish kills
- Marine mammals and birds
- Freshwater swimming
- Drinking water
- Clogging desal plants



California sea lion undergoing stomach pumping after poisoning (photo courtesy Dr. Francis Gulland, Marine Mammal Center, Sausalito, CA)

URGENT NOTICE TO RESIDENTS

DO NOT DRINK THE WATER
DO NOT BOIL THE WATER

Why does HAB forecasting matter?

- Toledo, >$2 million economic loss from two-day bloom impact
  - Annually $11M for chemical treatment (nbcnews.com)
  - Methods will help with P reduction targets
- Florida tourism loss, $6M per month per county
  - Health, ER admissions 54% increase in respiratory, 40% increase in gastro-intestinal
- Gulf of Maine halo effect
  - 2005 $10's millions lost seafood

Thick, Putrid Algae Bloom Overwhelms Miles Of Florida Coastline

July 2, 2016 · 5:16 PM ET

Cyanobacterial (freshwater) HABs

Deaths at dialysis center in Brazil in 1996
Drinking water issue, cyano-toxins pose risk of liver & kidney damage

Toledo 2014

URGENT NOTICE TO RESIDENTS

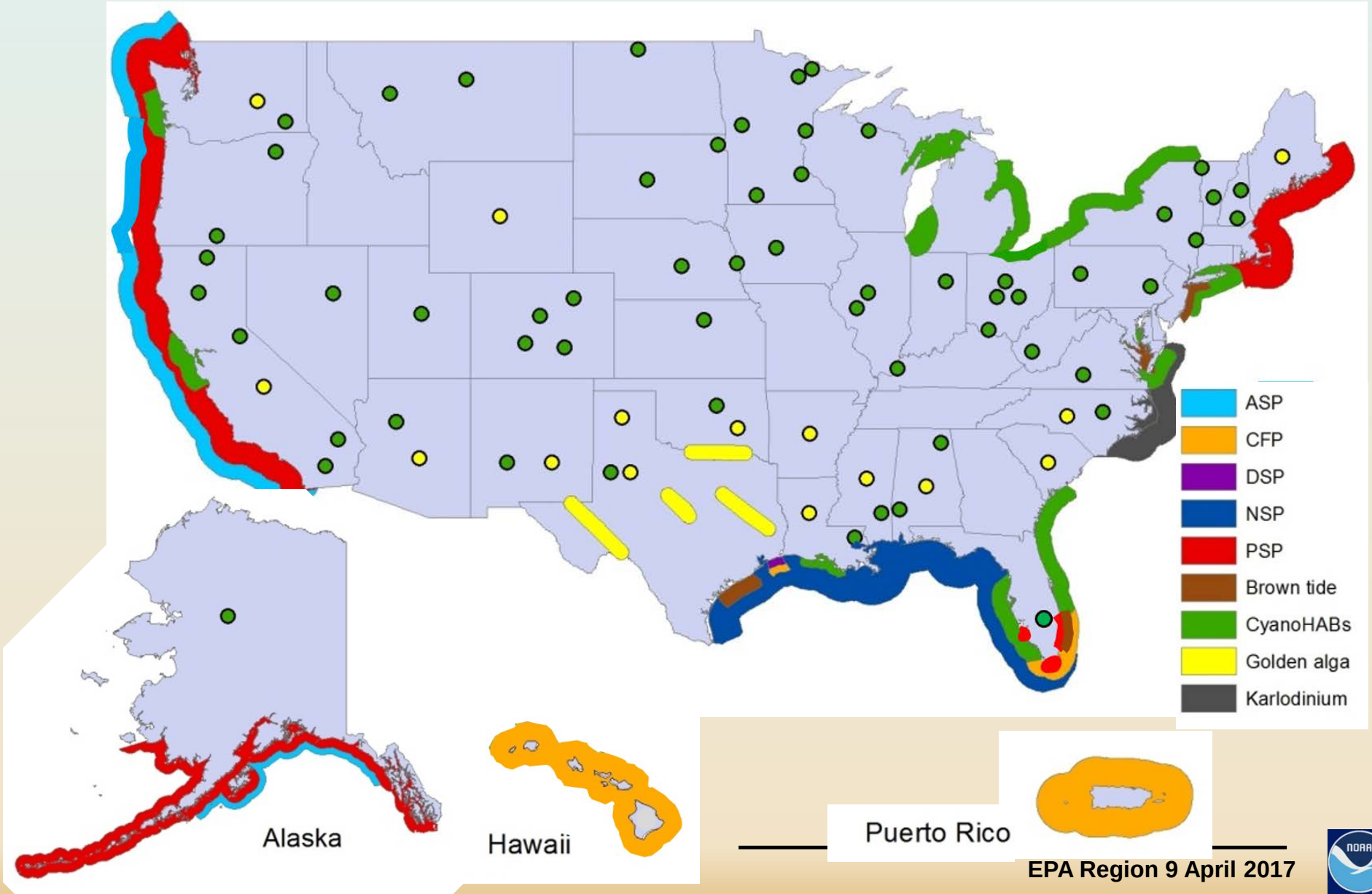
DO NOT DRINK THE WATER
DO NOT BOIL THE WATER

Toledo 2015, with no risk!

Tom Feran,
The Plain Dealer

Coastal HABS

Public Health Threats/Animal Mortality/Ecosystem Disruption



EPA Region 9 April 2017

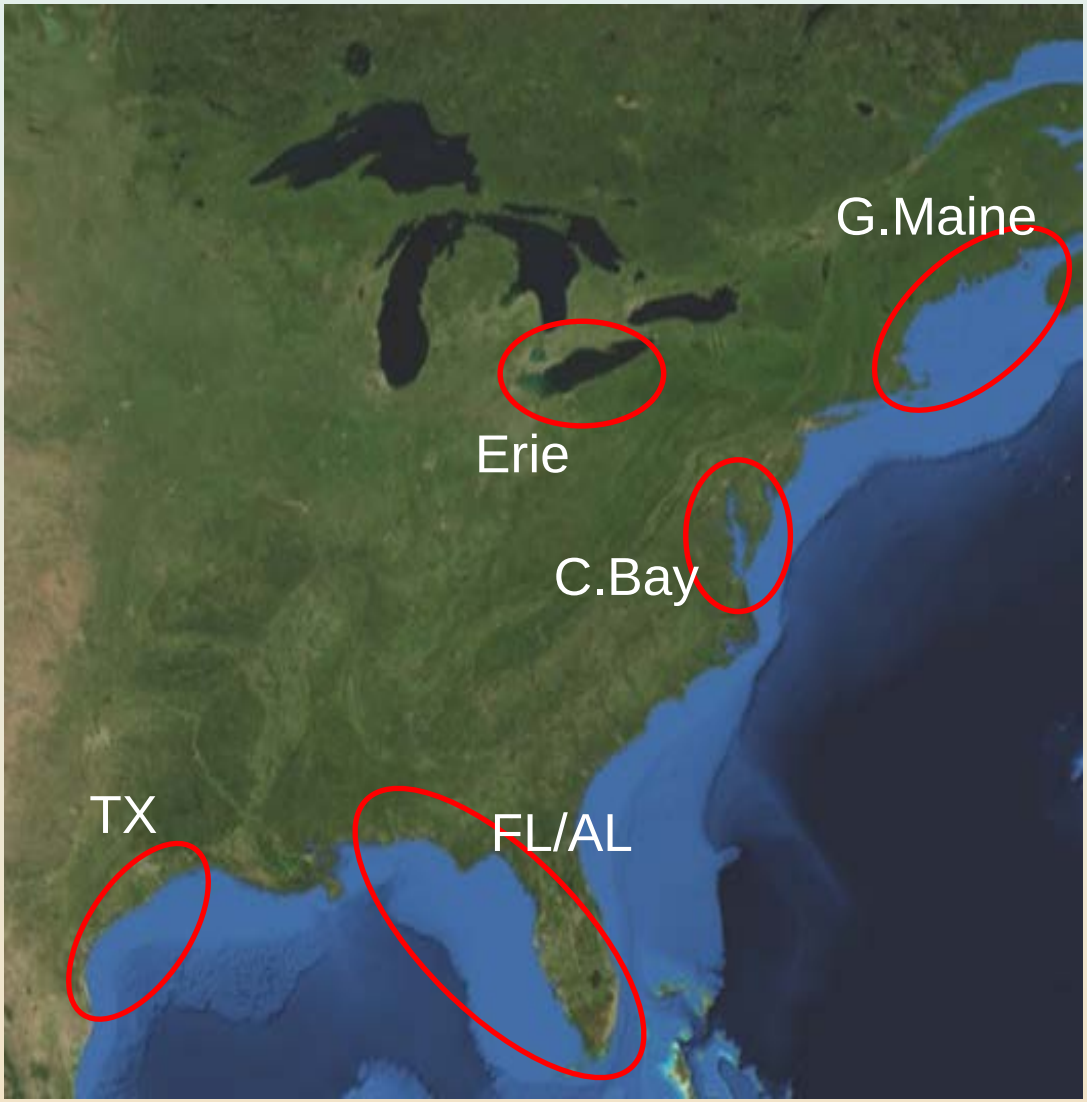
Impacts Coastal HABs

Name	Human & Animal* Poisoning	Fish Kills	Water Discoloration
Amnesic Shellfish Poisoning (ASP)	**Yes****	No	No
Ciguatera Fish Poisoning (CFP)	**Yes**	No	No
Diarrhetic Shellfish Poisoning (DSP)	**Yes**	No	No
Neurotoxic Shellfish Poisoning (NSP)	**Yes****	**Yes**	**Yes**
Paralytic Shellfish Poisoning (PSP)	**Yes****	**Yes**	**Yes**
Brown Tide	No	**Yes**	**Yes**
CyanoHABs	**Yes****	**Yes**	**Yes**
Golden Alga	No	**Yes**	**Yes**
Karlodinium	No	**Yes**	**Yes**

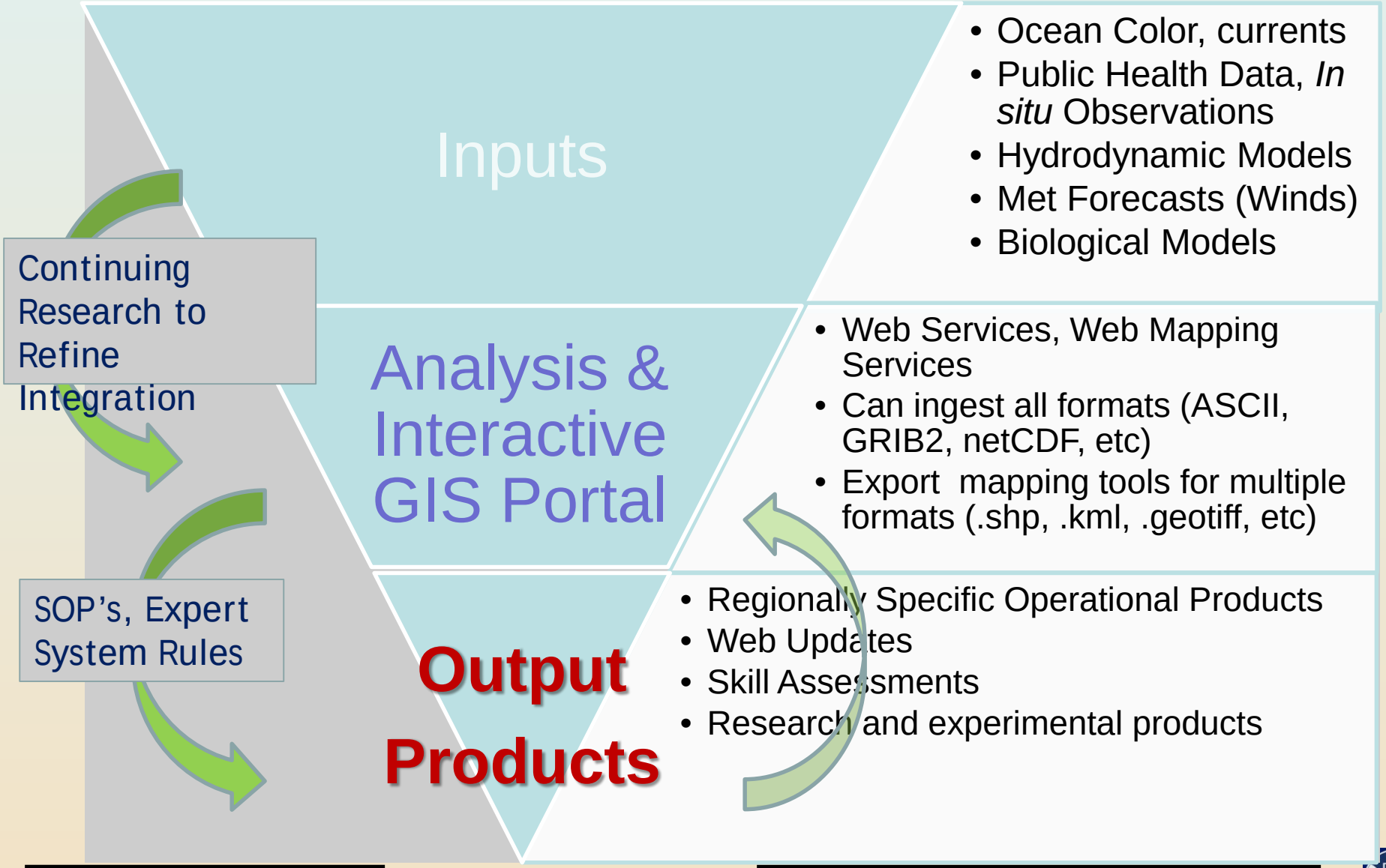
*Mammals, birds, turtles, often protected species

**Can cause human or animal deaths

Some regions with chronic severe HABs



HAB Operational Forecast System Concept: National Capability, Regional Implementation



Collaborative Forecasting

Observations (Local)

Automated observing and Operational Models/satellites (NOAA ESA)

Integration (NOAA)

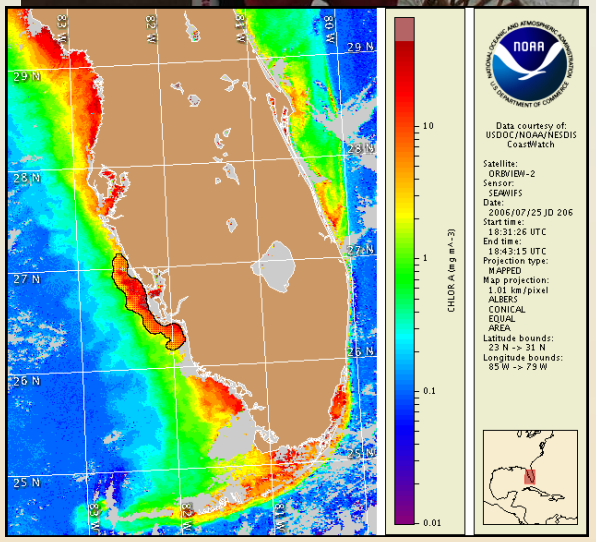
Local Analysts

Analysis system (NOAA)

Forecast with analyst interpretation:
"A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible … today through Thursday. "

HAB Operational Forecast System: Gulf of Mexico *Karenia brevis*

Padre Island National Seashore Closes Park to Dogs (December 9, 2009)

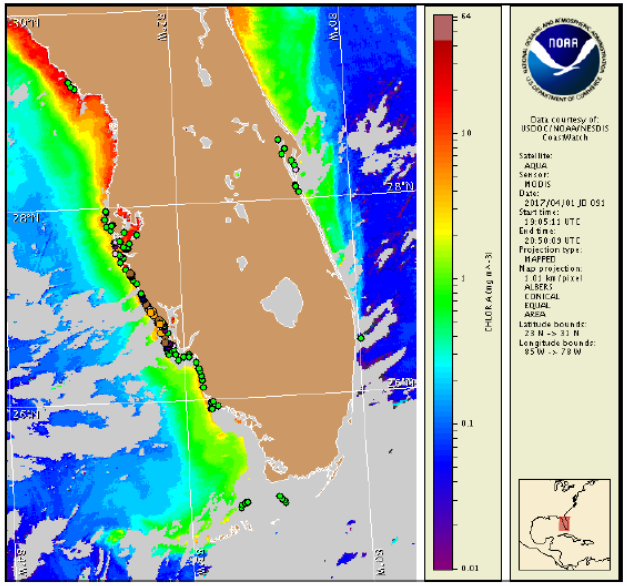


http://tidesandcurrents.noaa.gov/hab

Gulf of Mexico Harmful Algal Bloom Operational Forecast System

Gulf of Mexico Harmful Algal Bloom Bulletin

Region: Southwest Florida
Monday, 03 April 2017
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Thursday, March 30, 2017



Satellite chlorophyll image with possible *K. brevis* HAB areas shown by red polygon(s), when applicable. Points represent cell concentration sampling data from March 24 to 31: red (high), orange (medium), yello (low b), brown (low a), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute. For a list of sample providers and a key to the cell concentration categories, please see HAB-OFS bulletin guide:

http://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through FWC Fish and Wildlife Research Institute at:
http://myfwc.com/redtidestatus

To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit at: http://tidesandcurrents.noaa.gov/hab/bulletins.html

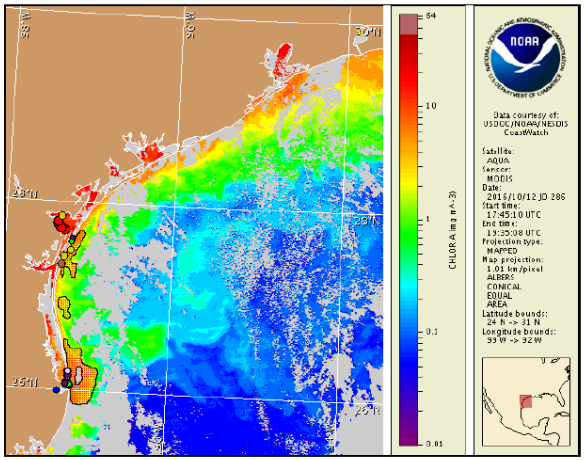
Conditions Report

Not present to medium concentrations of *Karenia brevis* (commonly known as Florida red tide) are present along- and offshore portions of southwest Florida and not present in the Florida Keys. *K. brevis* concentrations are patchy in nature and levels of respiratory irritation will vary locally based upon nearby bloom concentrations, ocean currents, and wind speed and direction. The highest level of potential respiratory irritation forecast for Monday, April 3 through Thursday, April 6 is listed below:

County Region: Forecast (Duration)
Southern Pinellas: Very Low (M-Th)
Southern Manatee: Very Low (M-Th)
Northern Sarasota: Low (M-Th)
Northern Sarasota, bay regions: Low (M-Th)
Southern Sarasota: Moderate (M-Th)
Southern Sarasota, bay regions: Low (M-Th)
Northern Charlotte: Moderate (M-Th)
Northern Charlotte, bay regions: Moderate (M-Th)

Gulf of Mexico Harmful Algal Bloom Bulletin

Region: Texas
Thursday, 13 October 2016
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Tuesday, October 11, 2016



Satellite chlorophyll image with possible *K. brevis* HAB areas shown by red polygon(s), when applicable. Points represent cell concentration sampling data from October 3 to 13: red (high), orange (medium), yellow (low b), brown (low a), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Texas Parks and Wildlife Department. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OFS bulletin guide:

http://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through the Texas Parks and Wildlife Department at:
http://www.tpwd.state.tx.us./landwater/water/environconcerns/hab/redtide/status.phtml

Conditions Report

Karenia brevis (commonly known as Texas red tide) ranges from not present to high concentrations along the Texas coast from the Corpus Christi Bay to Rio Grande regions. *K. brevis* concentrations are patchy in nature and levels of respiratory irritation will vary locally based upon nearby bloom concentrations, ocean currents, and wind speed and direction. The highest level of potential respiratory irritation forecast for Thursday, October 13 through Monday, October 17 is listed below:

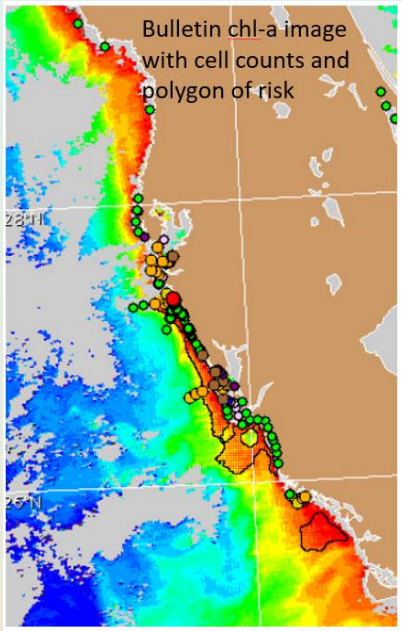
County Region: Forecast (Duration)
Bay region-Corpus Christi Bay: Moderate (Th-M)
Bay region-Upper Laguna Madre: Very Low (Th-M)
Aransas Pass to PINS: Moderate (Th-M)
Padre Island National Seashore region: Moderate (Th-M)
Mansfield Pass to Beach Access 6 region: Moderate (Th-Su), Low (M)
Beach Access 6 to Rio Grande region: Moderate (Th-Su), Low (M)
Bay region-Lower Laguna Madre to Laguna Vista: Low (Th-M)
All Other Texas Regions: None expected (Th-M)

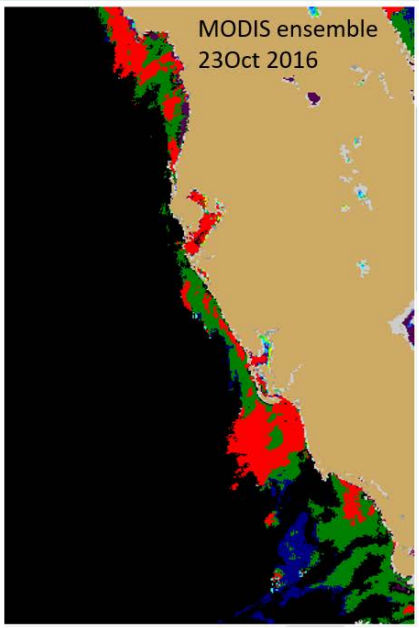
Check http://tidesandcurrents.noaa.gov/hab/beach_conditions.html for recent, local observations. Over the past few days, reports of respiratory irritation and discolored water have been received from the Corpus Christi Bay region.

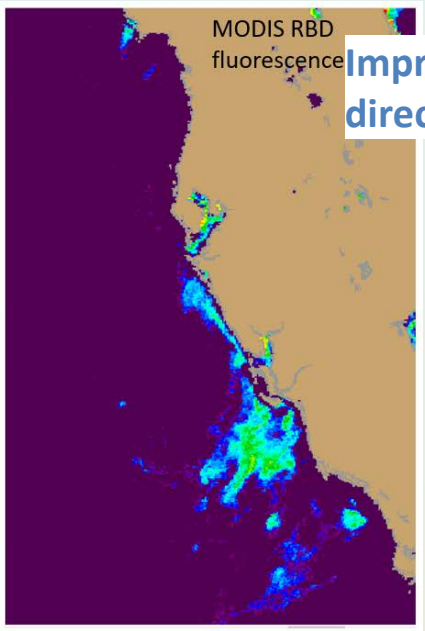
Analysis

Karenia brevis concentrations range between 'not present' and 'high' along the Texas coast from Aransas Pass to the Rio Grande (TPWD; 10/11-13). In the Corpus Christi Bay region, sampling this week continues to indicate up to 'high' *K. brevis* concentrations throughout the bay with corresponding reports of respiratory irritation and discolored water (TPWD; 10/11-12). Sampling from Texas A&M University's Imaging FlowCytobot, located on the Port Aransas ship channel, continues to indicate up to 'very low a' *K. brevis* concentrations (TAMU; 10/11-12). Sampling in the Upper Laguna Madre detected a 'very low a' *K. brevis* concentrations where previous sampling indicated *K. brevis* was not present (TPWD; 10/11). Recent sampling in the Padre Island National Seashore region continues to indicate up to 'low b' *K. brevis* concentrations (TPWD; 10/12). New sampling around the Lower Laguna Madre to Laguna Vista region continues to confirm *K. brevis* concentrations have decreased in the last week with only 'background' concentrations detected on 10/10 (Texas Red Tide Rangers). Detailed sample information and a summary of impacts can be obtained through Texas Parks and Wildlife Department at: http://www.tpwd.state.tx.us./landwater/water/environconcerns/hab/redtide/status.phtml. For information on area shellfish restrictions, contact the Texas Department of State Health Services.

Florida, developing improved respiratory forecast



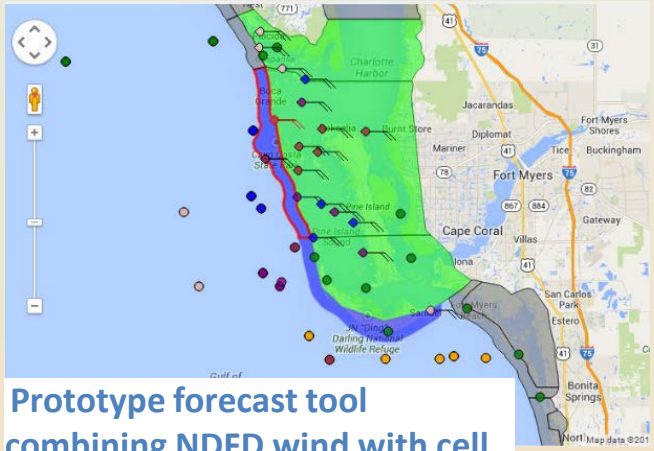




Improved satellite data to direct beach sampling

HABscope developed to bring in volunteer networks

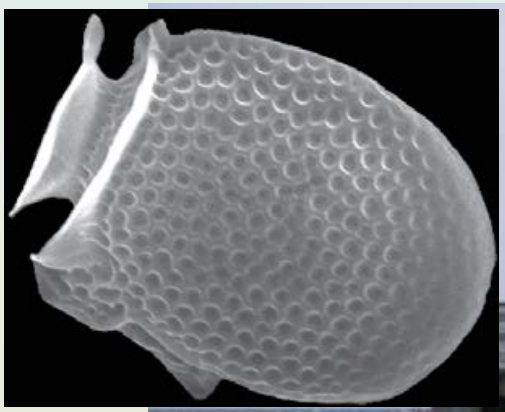
NOAA/NOS, GCOOS, Mote Marine Lab, NASA

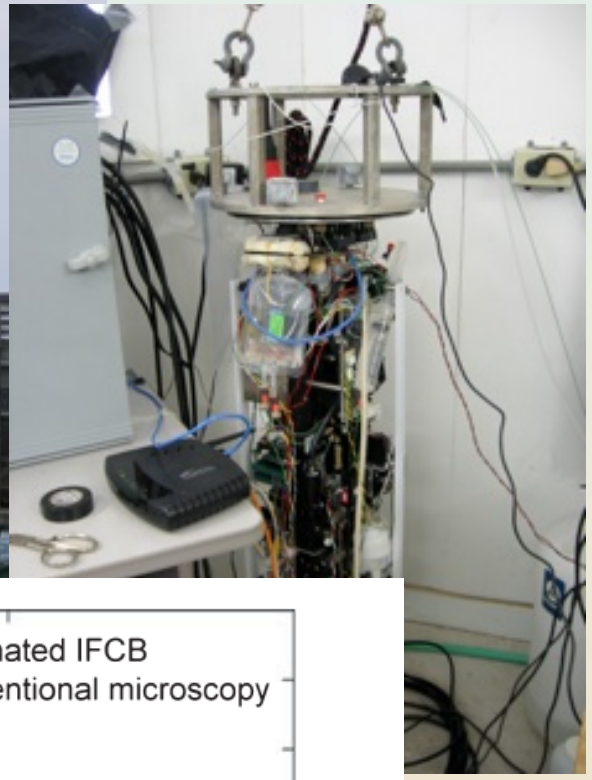


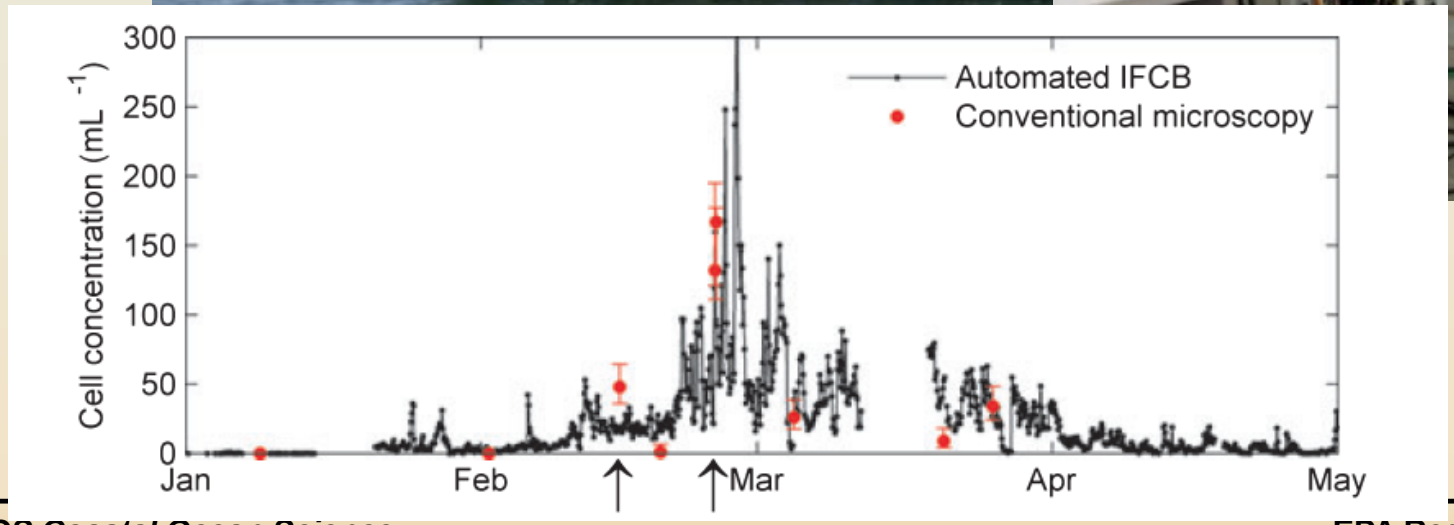
Prototype forecast tool combining NDFD wind with cell concentrations.

Video frame of *K. brevis* cells

Addition of Flow Cytobot in Texas
Dinophysis detected 2008, *Karenia* in recent years

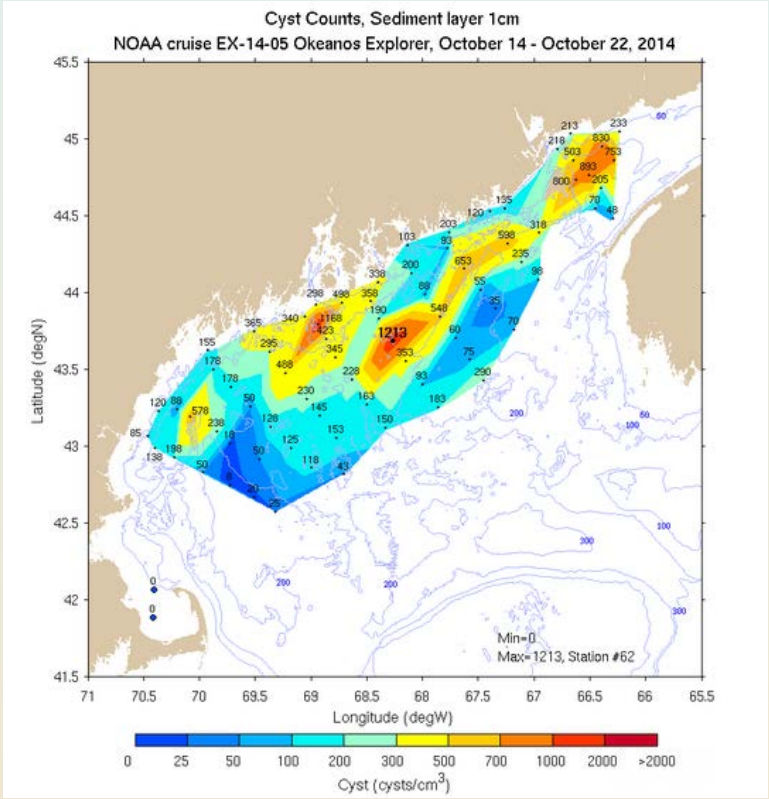






Gulf of Maine Transition

- 4nd year of cyst cruise led by NOAA, helped by WHOI
- *Alexandrium* biological model now in ROMS “trunk”, evaluations of biology happening on NCEP computers, hydro model integration across NOS
- Environmental Sample Processor (ESP) deployment - early warning to Maine
- Multi-partnered investment(> $20M) across NOAA, with EPA, FDA, NERACOOS, NSF, Canada DFO, Maine DMR



Gulf of Maine Seasonal forecast

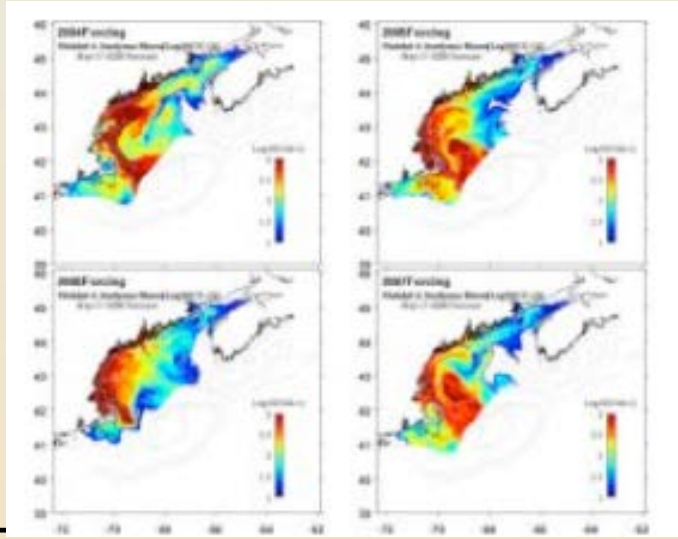
Gulf of Maine Red Tide Forecast Predicts Small Bloom for 2016

Posted on April 7th, 2016 (1 year ago) in Forecasting, Harmful Algal Blooms

This summer the Gulf of Maine red tide is predicted to be the smallest observed over the last eleven years, as forecast by researchers at Woods Hole Oceanographic Institution (WHOI) and North Carolina State University.

News Release : In Computer Models and Seafloor Observations, Researchers See Potential for Significant 2008 "Red Tide" Season

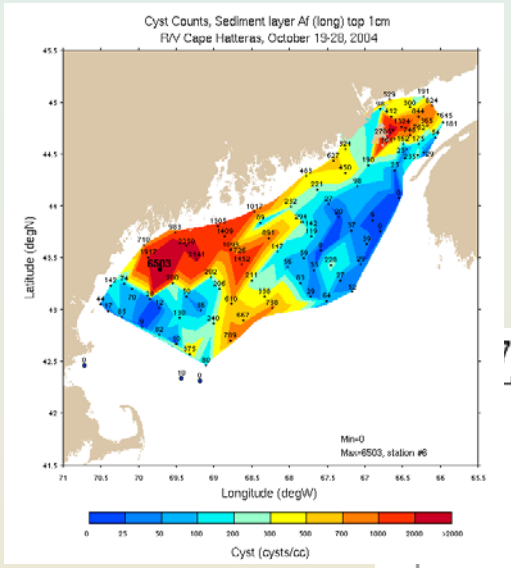
Conditions are ripe for another large bloom in New England waters; weather and ocean conditions will determine outcome



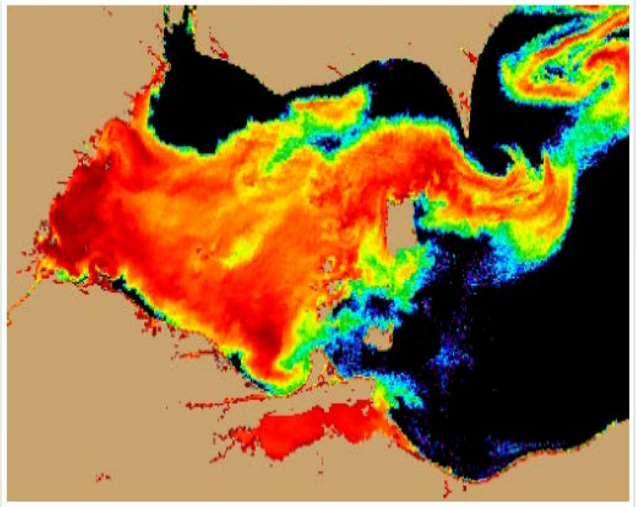
Courtesy:
Don Anderson, WHOI

Forecast Model types

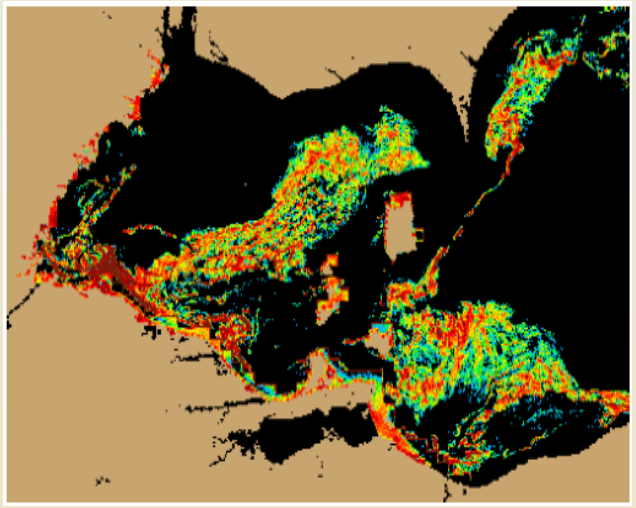
Gulf of Maine
Cyst Map



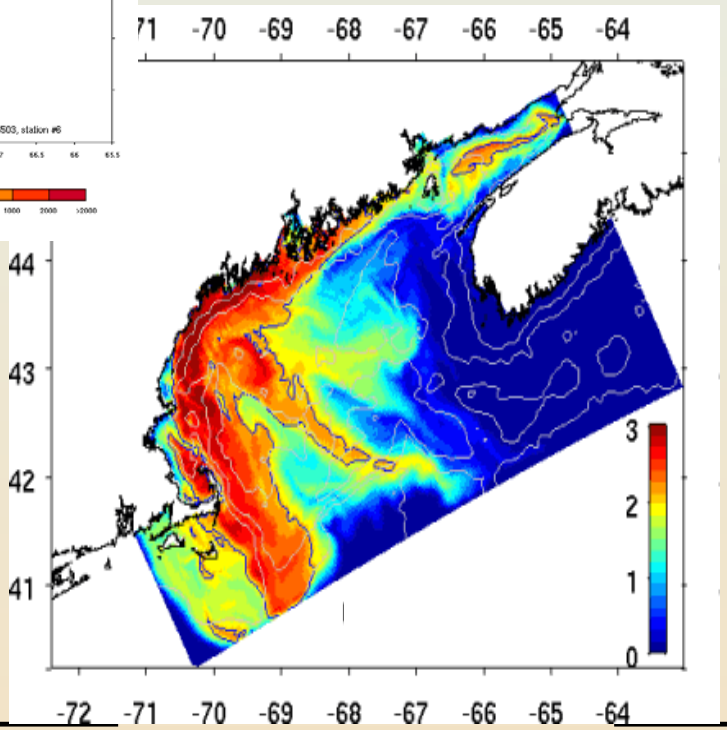
Lake Erie
Satellite
cyan index
Sep 2011



Lake Erie with POM model (3-D behavior in demonstration)



Gulf of Maine
Transport with ROMS 3-D model and biological response



Lake Erie Forecasts, run routinely since 2008

Experimental Lake Erie Harmful Algal Bloom Bulletin

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

27 July 2015, Bulletin 04

The Microcystis cyanobacteria bloom continues in the western basin. The bloom extends from west of West Sister Island, veering southward to the coast, then curving to the northeast through the islands toward the central basin and up to the Canadian coast

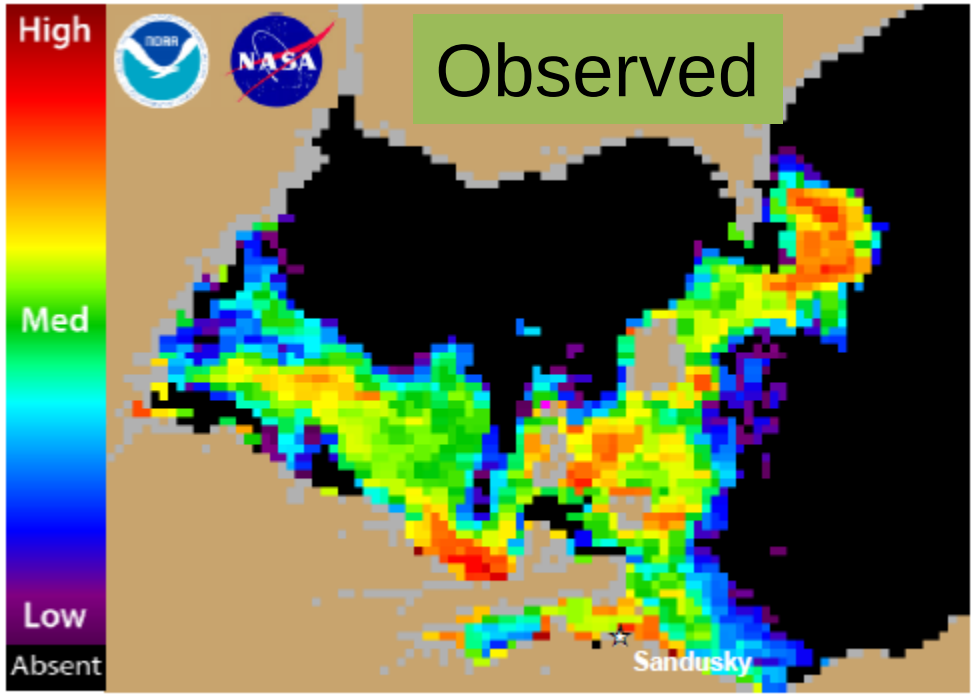


Figure 1. Cyanobacterial Index from NASA's MODIS-Terra data collected 24 July 2015 at 12:00 pm EDT. Grey indicates clouds or missing data. Black

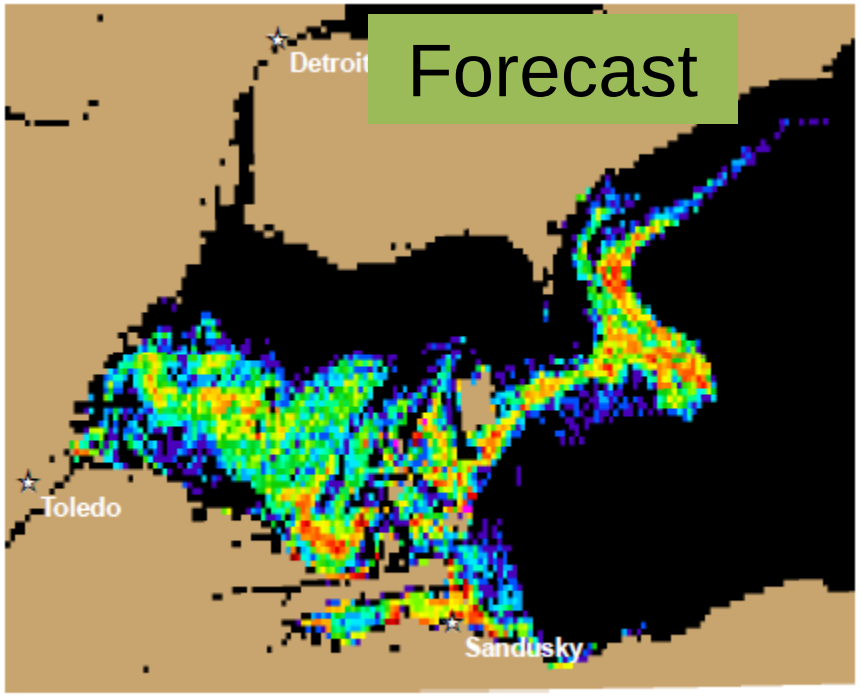
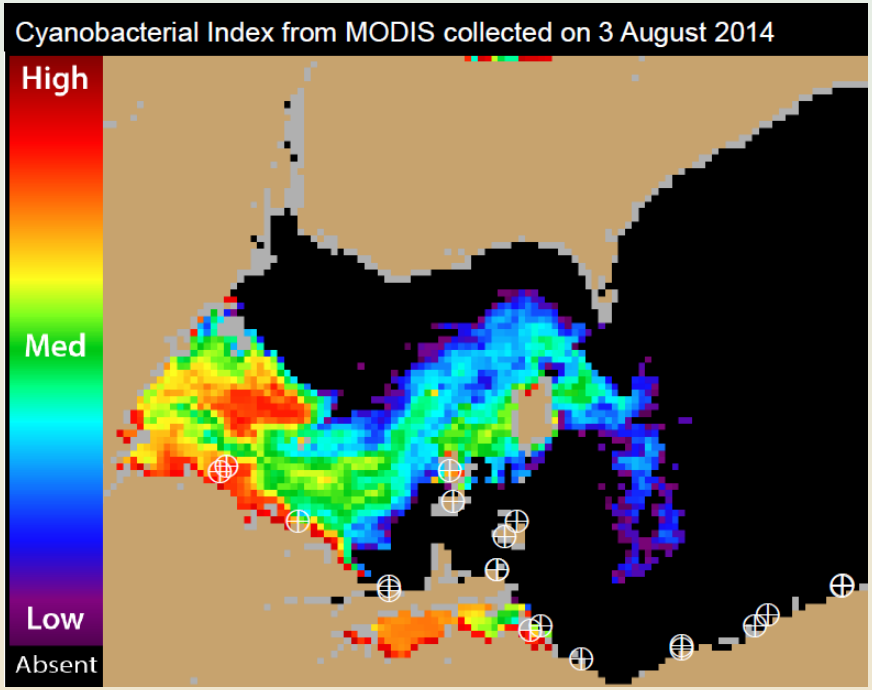


Figure 2. Nowcast position of bloom for 27 July 2015 using GLCFS modeled currents to move the bloom from the 24 July 2015 image.

Lake Erie Transition from NCcOS (Research) to CO-OPS (for operations)

- Toledo increased monitoring because of bloom increase identified in bulletin. Bulletin forecasts twice per week post-Toledo
- Improved integration of GLERL field data, and using operational high res (FVCOM) model for transport.

One product for Lake Erie, location relative to intakes

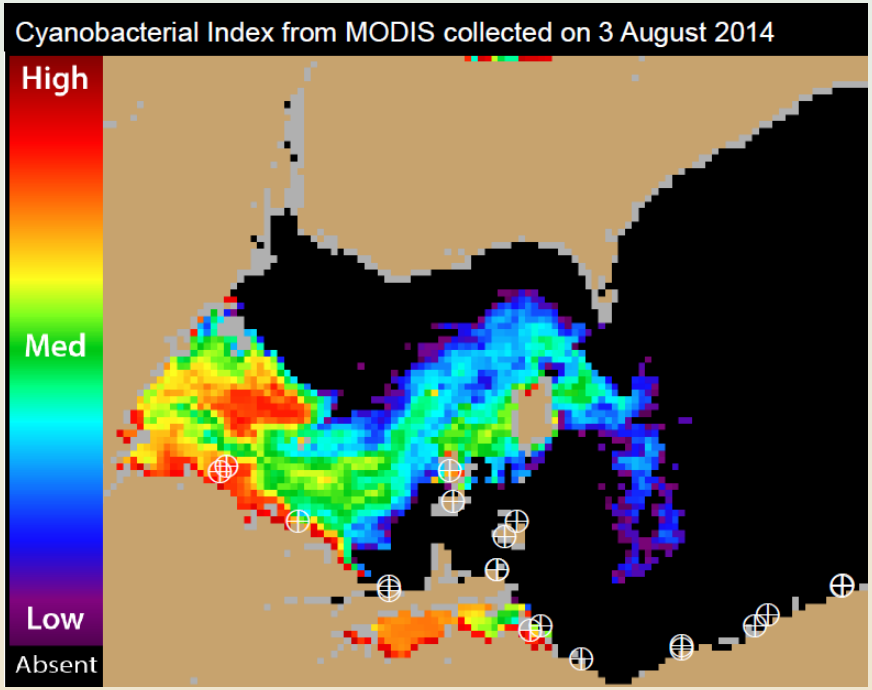


-- Bulletin Aug 1 a.m.
-- Toledo water ban late Aug 1 (Fri) --
Next bulletin issued Aug 4 (Mon) a.m.

Accomplishments:
Lake Erie ready for operations FY17

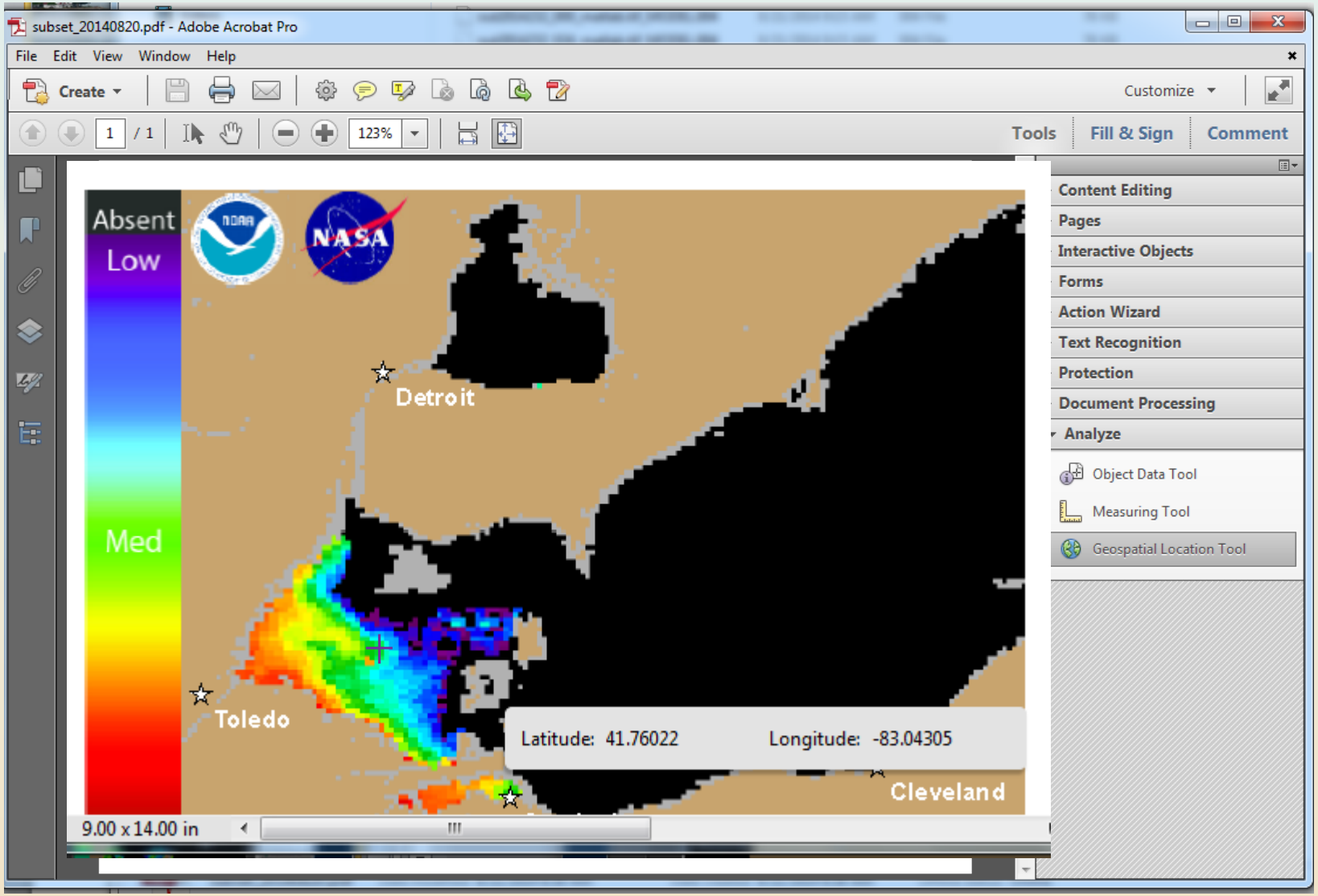
- 2016 was 8th season.
- 2000 subscribers + media distribution
- Stakeholder discussions
- Transition plan
- Research improvements now possible

One product for Lake Erie, location relative to intakes



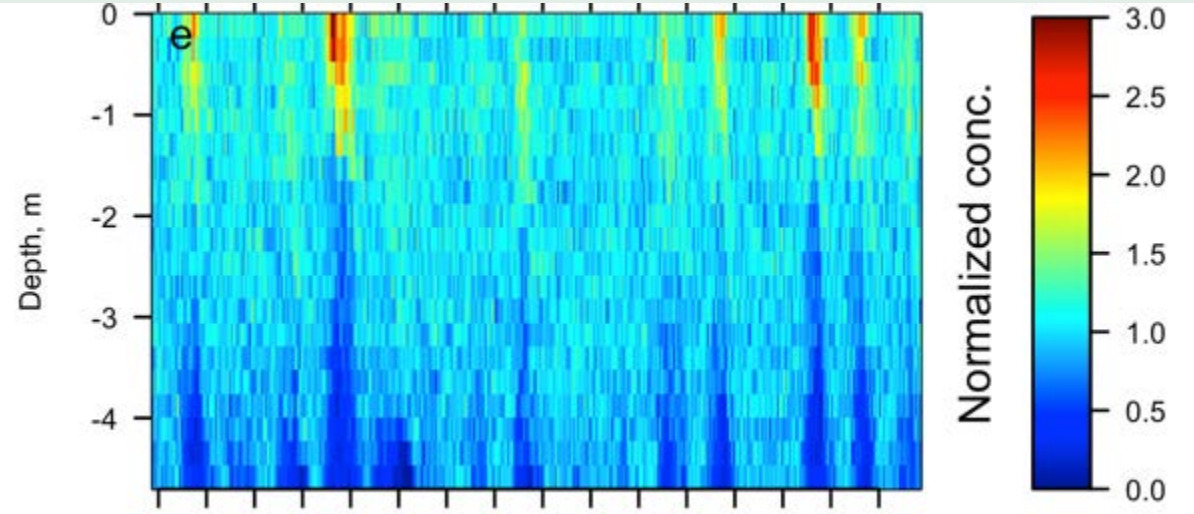
-- Bulletin Aug 1, 2014 a.m.
-- Toledo water ban late Aug 1 (Fri) --
Next bulletin issued Aug 4 (Mon) a.m.

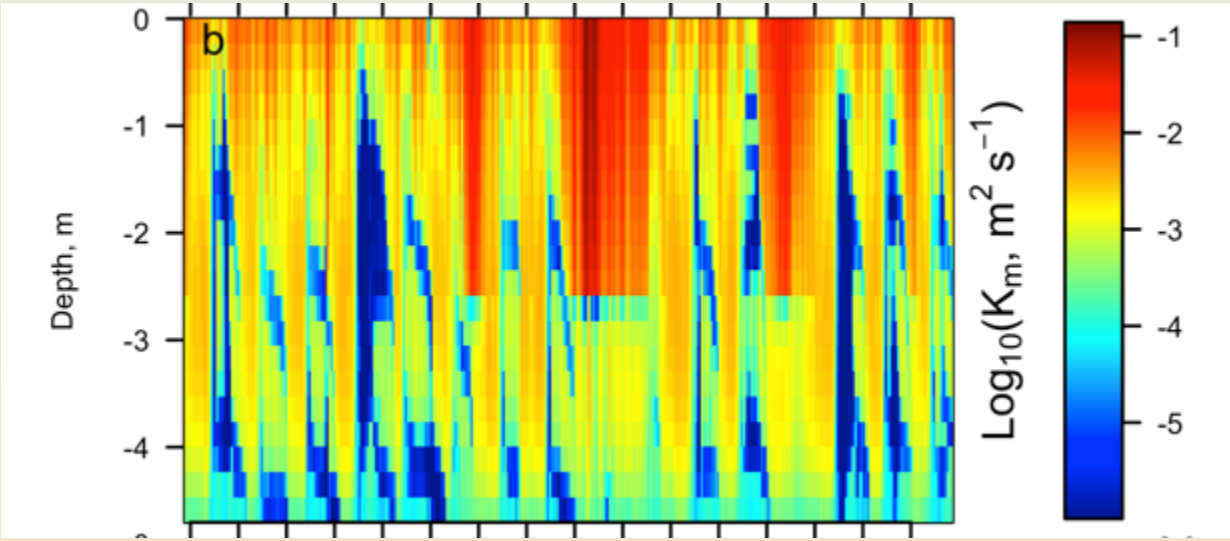
Bulletin PDF images are geoPDF, check locations



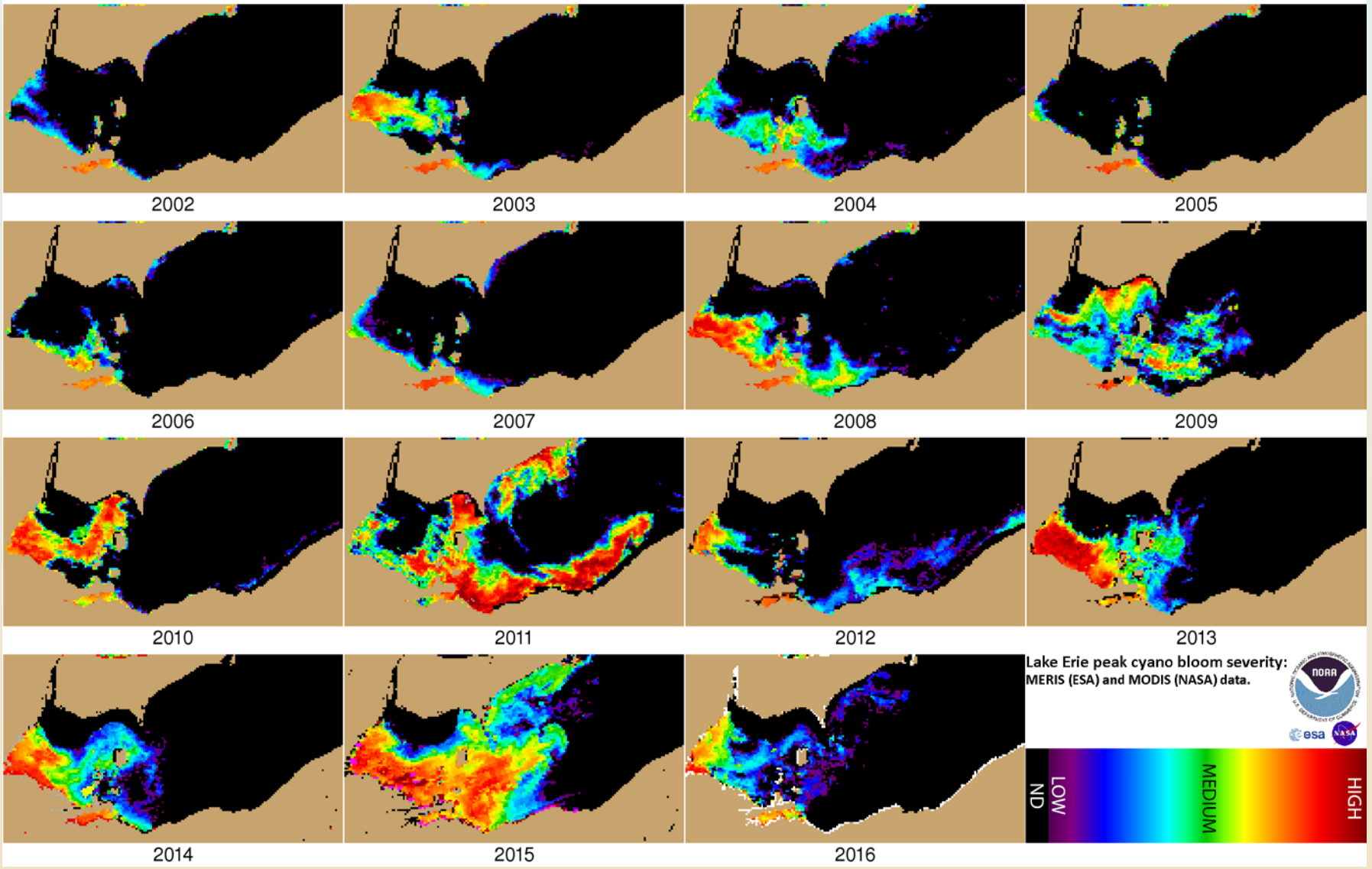
New models being developed

3-D model for Lake Erie to predict blooms subsurface or surface

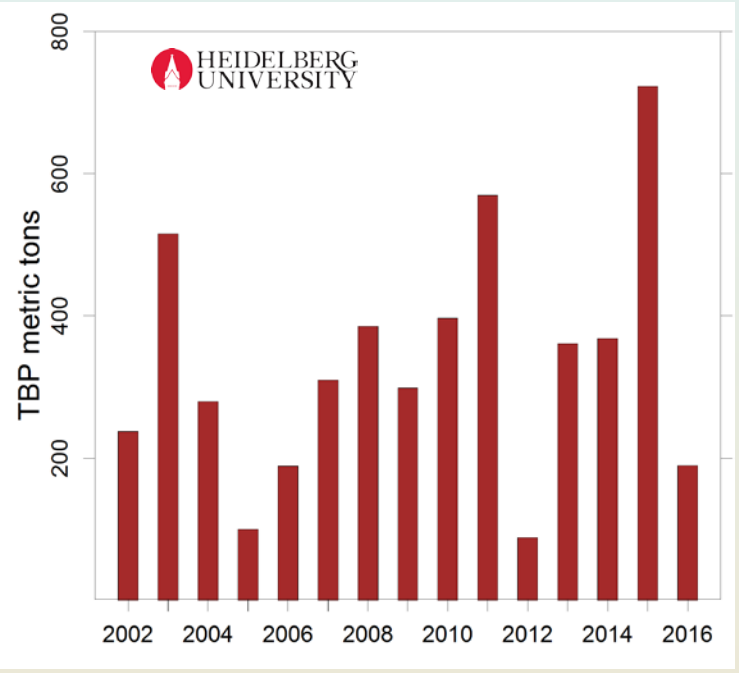




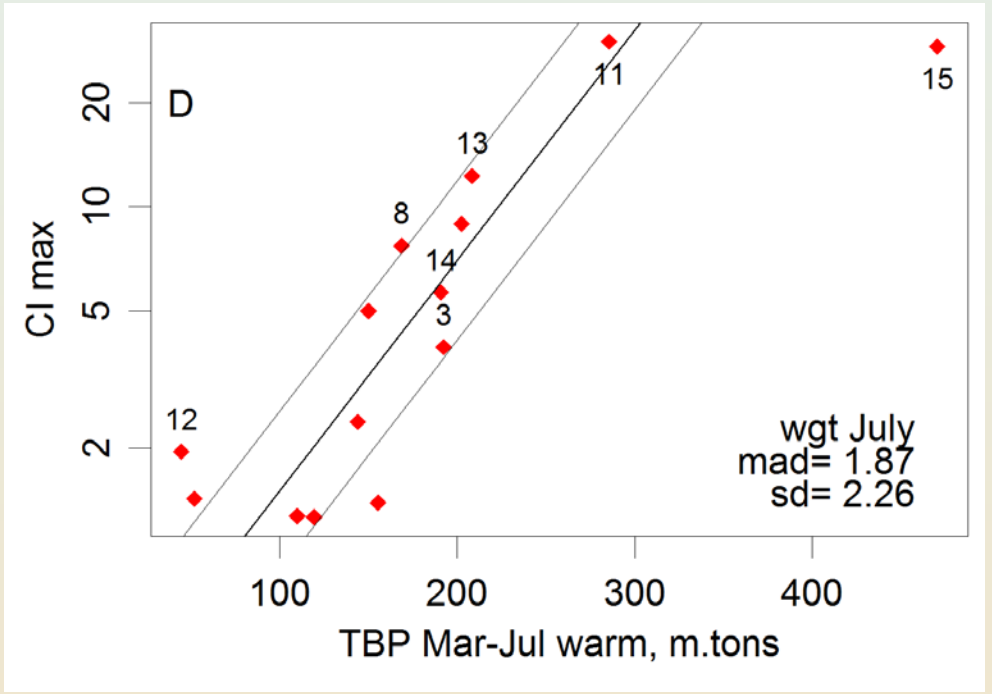
Annual assessment of blooms

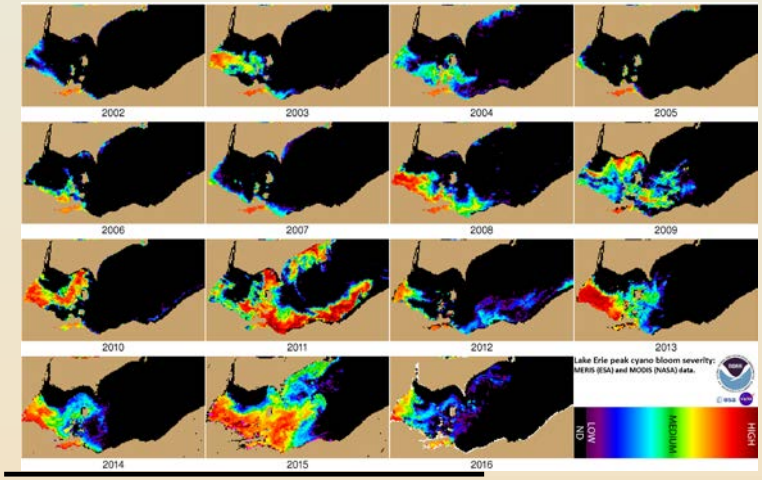


Comparison with Phosphorus Load



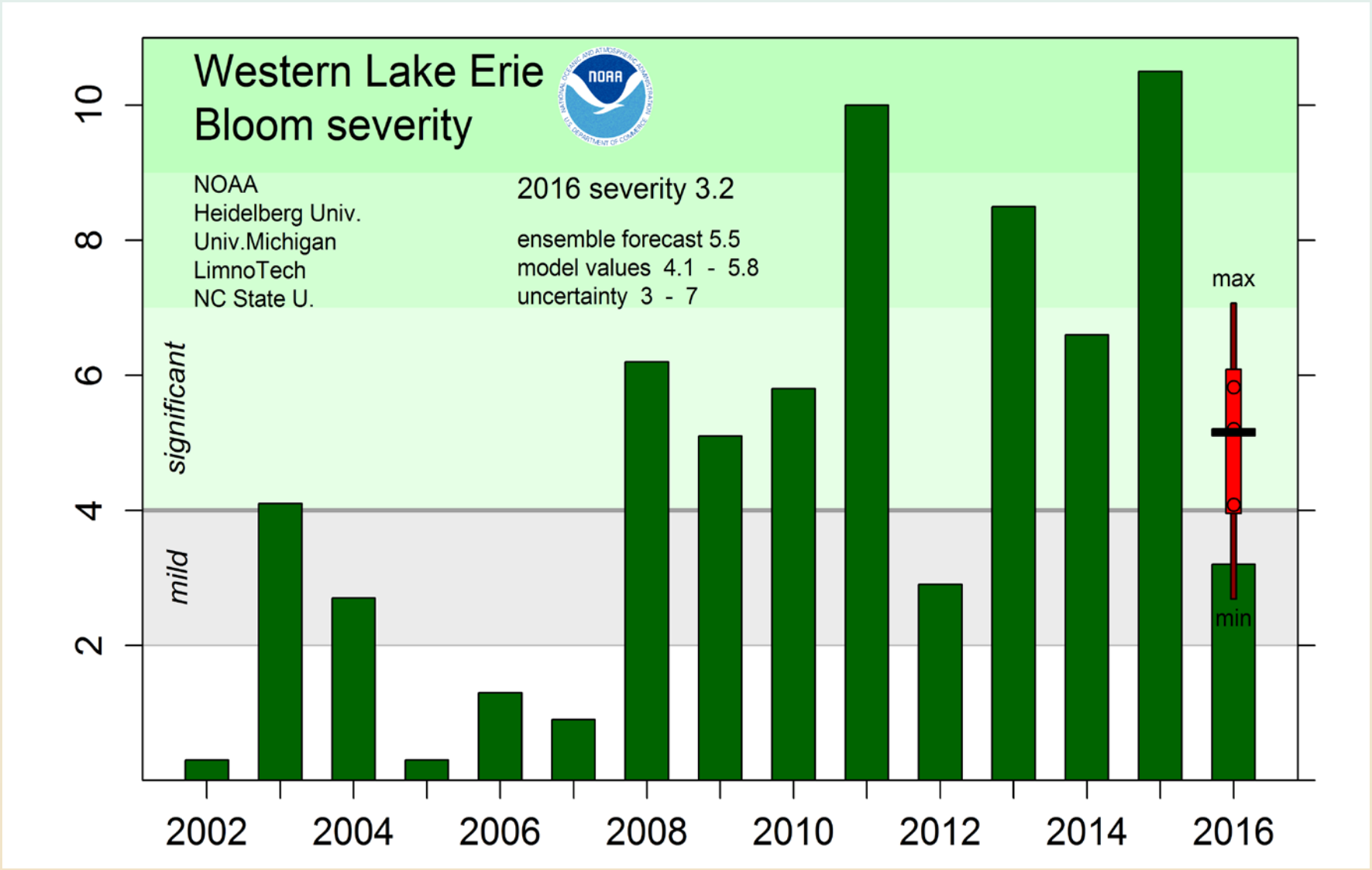
compare bloom biomass with total bioavailable phosphorus (TBP)





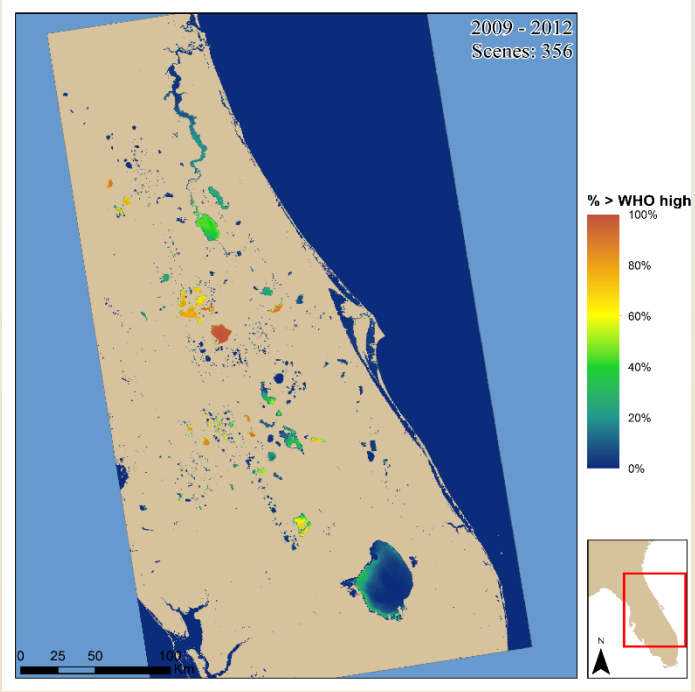
2016 Seasonal forecast milder than 2014 & 2015.

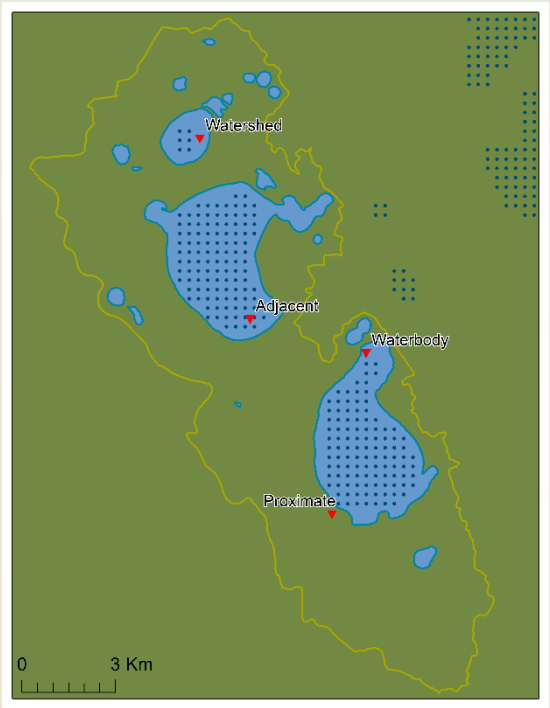
Correct, but several models overestimate internal loading from 2015

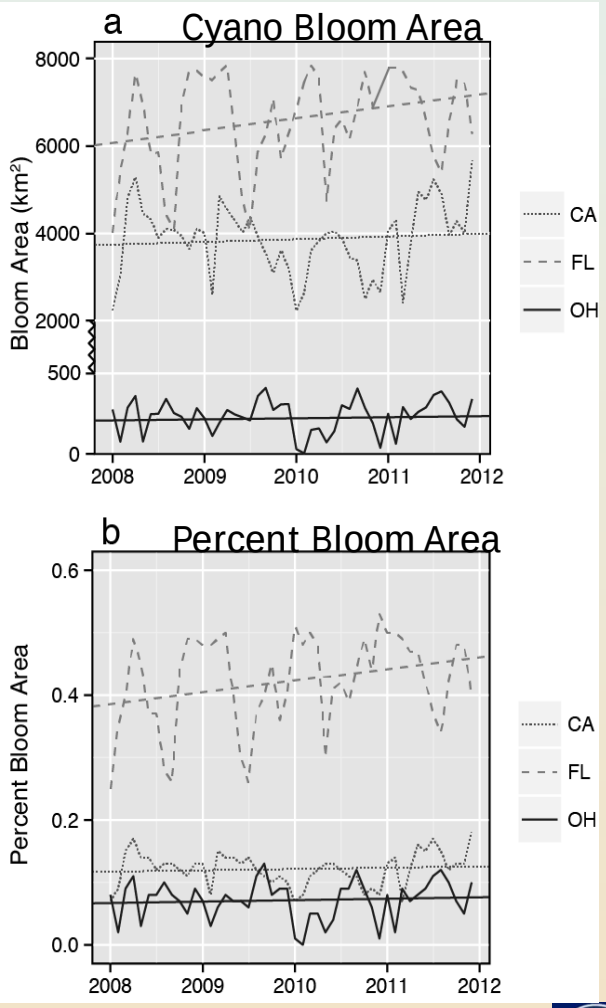


From Lake Erie to rest of country, CyAN, Collaboration with EPA, USGS, NASA

- Testing “bulk” methods with time series analysis of FL, OH, and CA (2008-2011)
- Frequency maps and surface drinking water intake monitoring methods



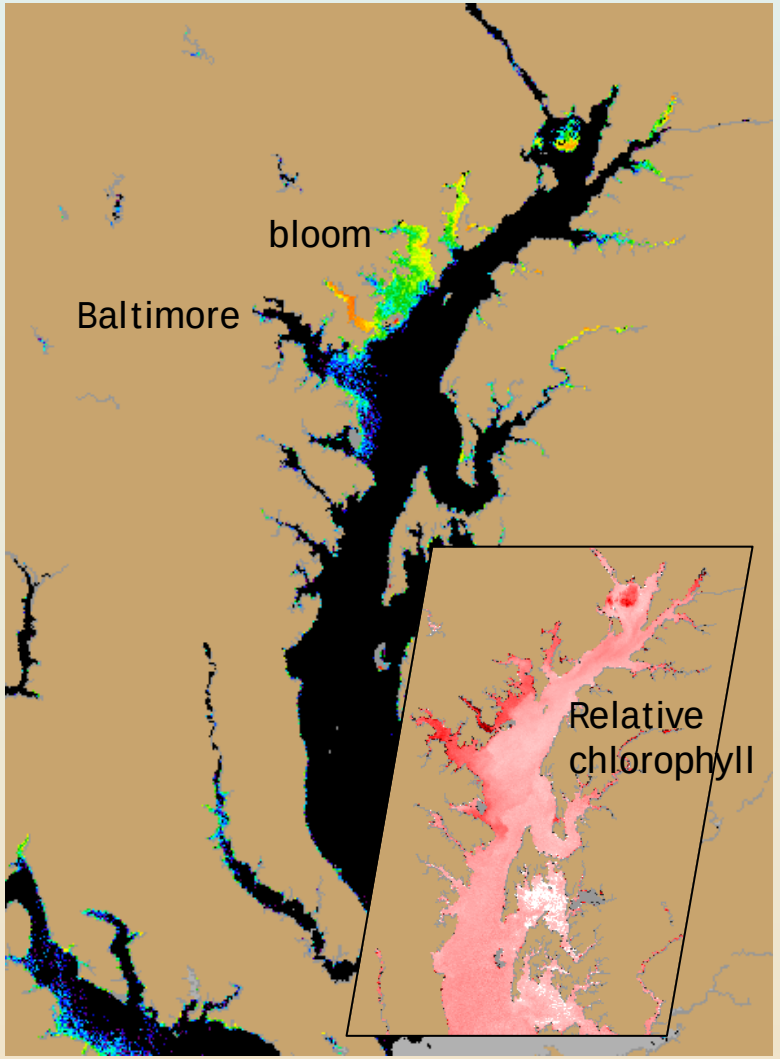




Evaluation of other products

Karlodinium veneficum bloom (not fluorescing) in Chesapeake Bay (12/19/2016)

Maryland Dept of the Environment. Fish kill Dec 19, 2016.
"*Karlodinium veneficum*, a toxin producing saltwater algae, pushed remarkably far into the freshwater end of the Chesapeake Bay estuary in 2016."



NOAA's Ecological Forecasting Roadmap

NOAA's Ecological Forecasting Roadmap will:

- Leverage NOAA-wide capability
- Establish priorities and collaborations
- Build-on existing infrastructure and partnerships
- Improve quality and delivery of products and services

To achieve:

- Operational forecasts based on strong science
- Delivery of more consistent, efficient, reliable, and national forecasts (tailored to region-specific needs)

NOAA initial focus areas: Harmful Algal Blooms, Hypoxia, Pathogens

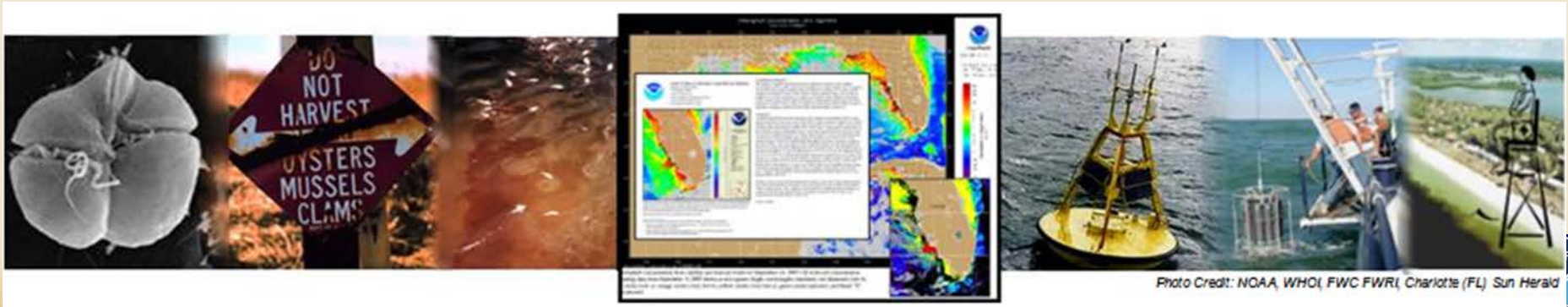


Photo Credit: NOAA, WHOI, FWC FWRI, Charlotte (FL) Sun Herald

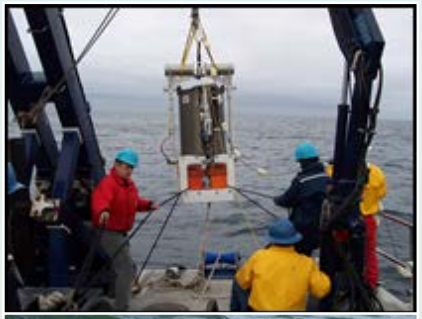
Biggest needs for modeling

Initializing operational models, we don’t have enough data on bloom location.

Scenario models, for most areas, insufficient data on initialization.

Validating operational model comparison (is one model “better”), we don’t have enough data on bloom location.

HAB Observing Networks: Development & Transition

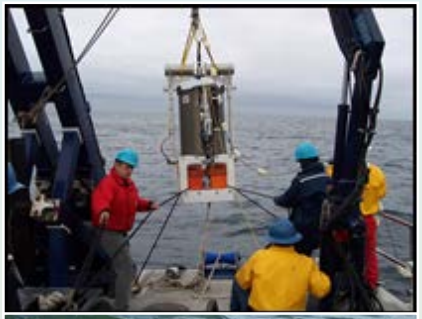


Objective: promote development & transition to operations of regional & national HAB observing networks

Rationale: observations & measurements of HAB species & toxins are important for:

- support of forecasting
  - validate satellite/airborne observations
  - data assimilation for model correction
- early warning of HAB events
- assessing bloom toxicity (potential impacts)
- identifying drivers of HAB growth & toxicity

HAB Observing Networks: Where are we going?

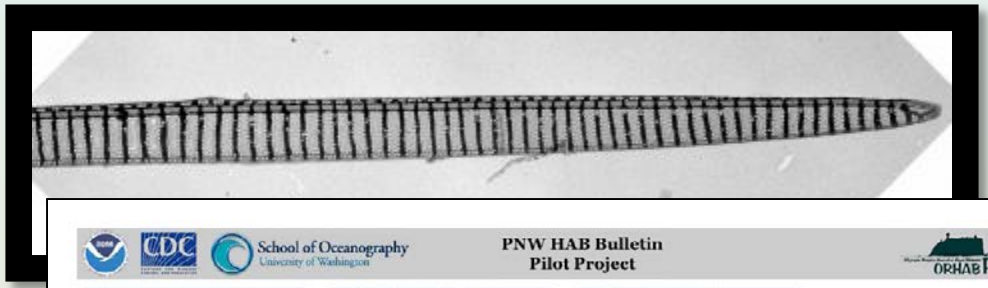


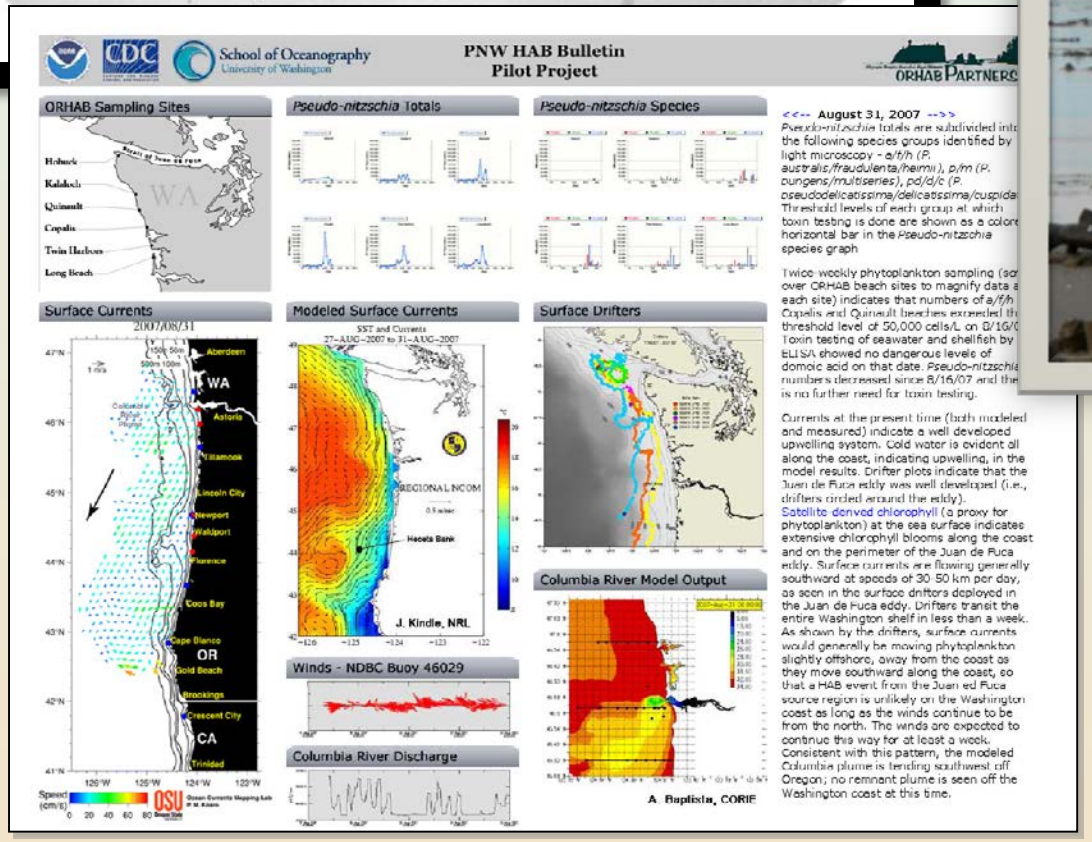
Overall Aim: observing networks will be fully integrated as components supporting a national HAB forecasting infrastructure

As we develop & deploy observing capabilities:

- identify & understand regional observing needs useful to managers & stakeholders
  - *focus on 'observations' not 'technologies'*
- leverage existing infrastructure to provide contextual data (IOOS RAs, NDBC, NWS, etc.)
- plan for data dissemination & assimilation

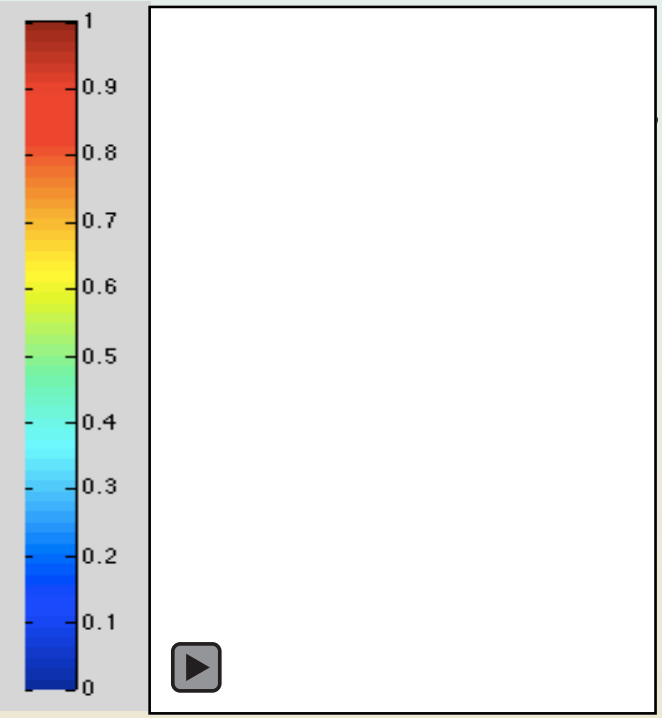
Health: *Pseudo-nitzschia* in Pacific NW, Amnesic Shellfish Poisoning



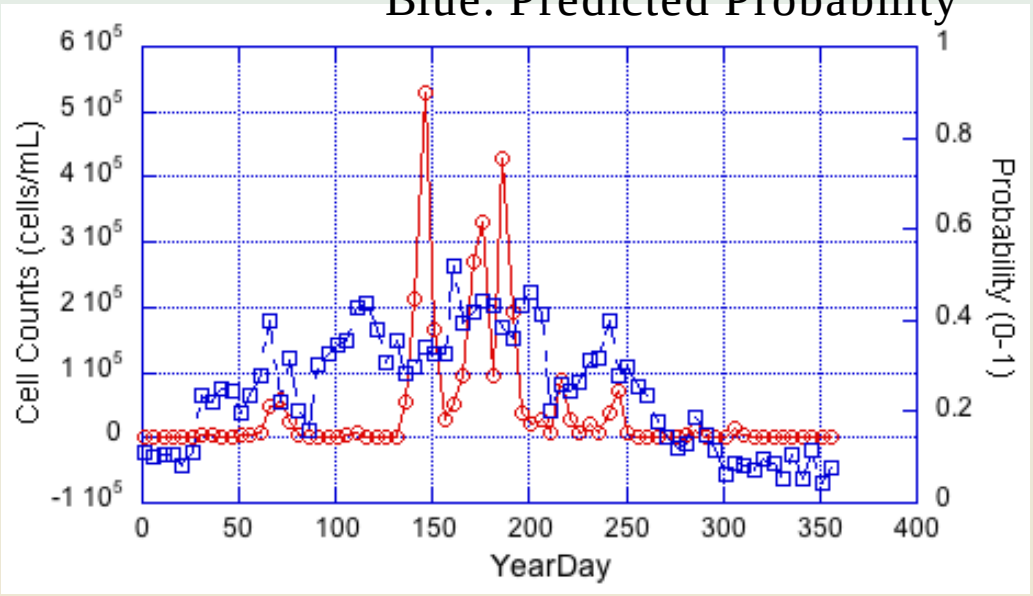


Slide courtesy of V. Trainer

California C-HARM
HINDCASTING *Pseudo-nitzschia*



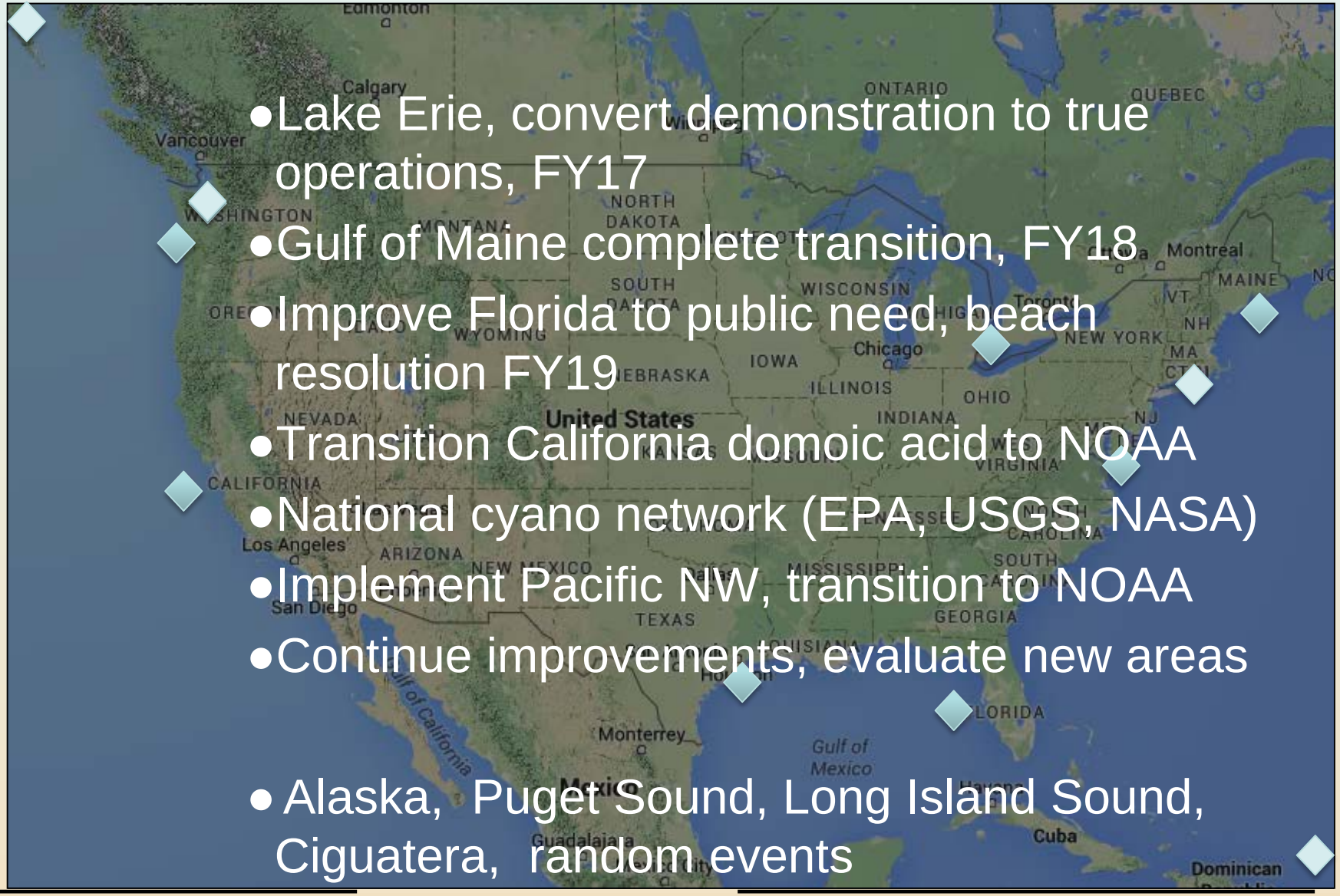
Red: Cell Counts
Blue: Predicted Probability



2009 Hindcast versus Cell Counts, Santa Barbara

- Focus on 2009 (*Anderson et al. 2011*)
- DINEOF reconstruction at 5-day intervals

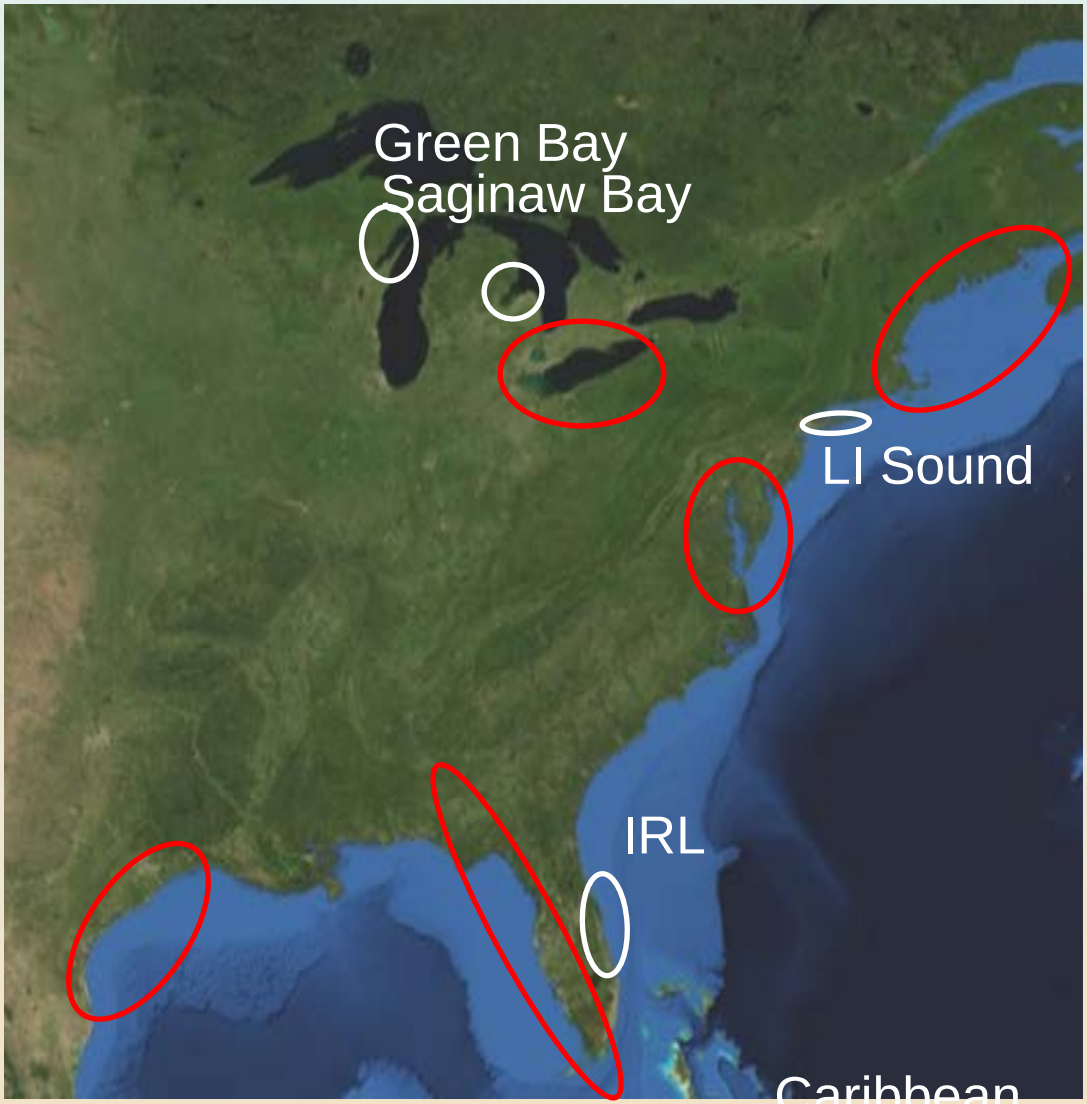
Five year vision



- Lake Erie, convert demonstration to true operations, FY17
- Gulf of Maine complete transition, FY18
- Improve Florida to public need, beach resolution FY19
- Transition California domoic acid to NOAA
- National cyano network (EPA, USGS, NASA)
- Implement Pacific NW, transition to NOAA
- Continue improvements, evaluate new areas

- Alaska, Puget Sound, Long Island Sound, Ciguatera, random events

“Emerging” problem areas



Detecting HABs in Freshwater Cyanobacteria Assessment Network

- Satellite **monitoring in larger lakes and reservoirs, OLCI and MERIS**
- **Estimate human exposure** to cyanotoxins
- **Disseminate info** → expedient public health advisories
- **Decrease costs** of monitoring
- **Reduce exposures**
- **Create a standard** approach for early HAB detection based on new satellite data (OLCI)
- Retrospective with MERIS
- Evaluate Landsat

EPA, NASA, NOAA, and USGS

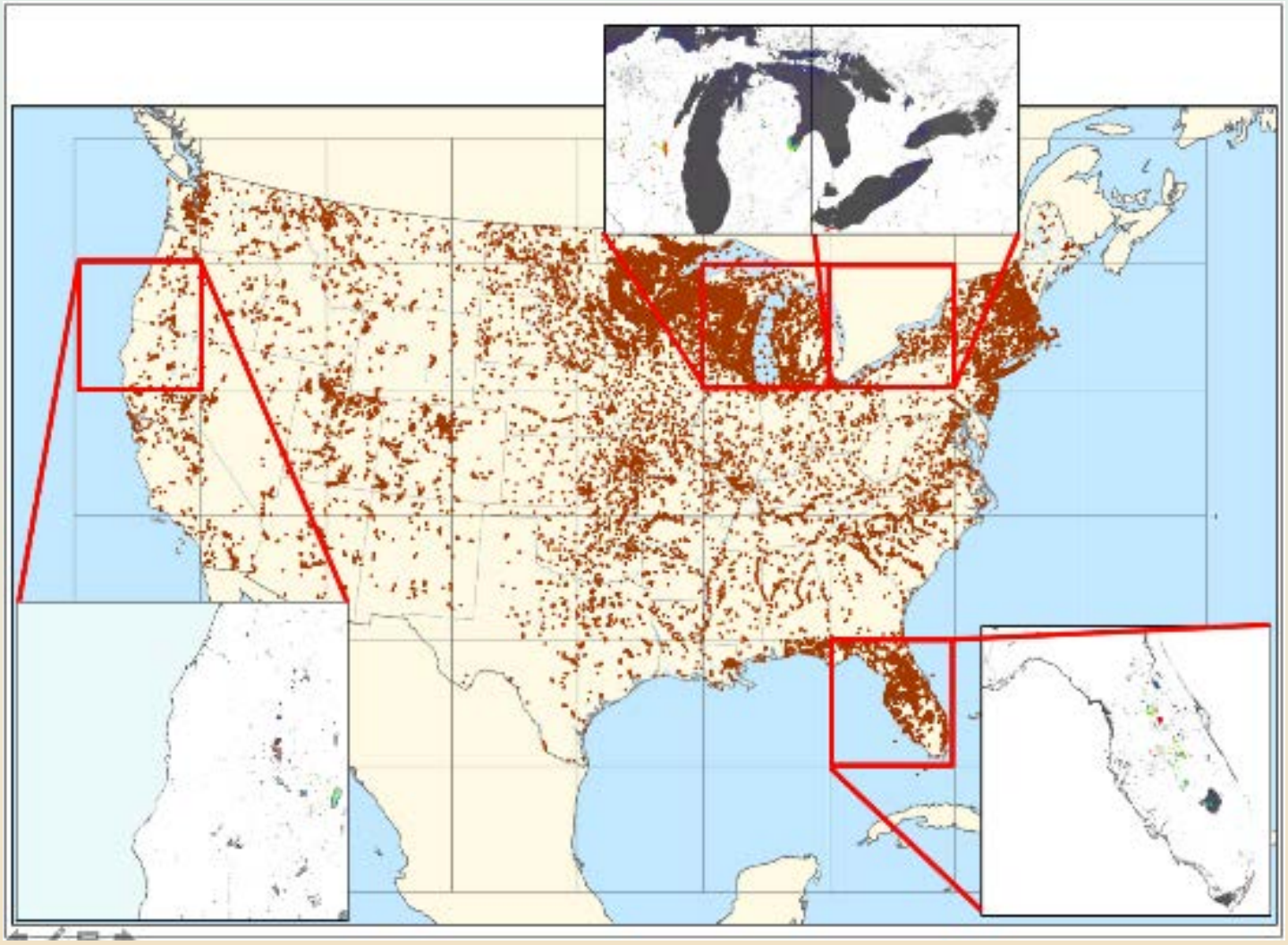
Sentinel-3 satellite
Launched February 2016

CyAN. National scope

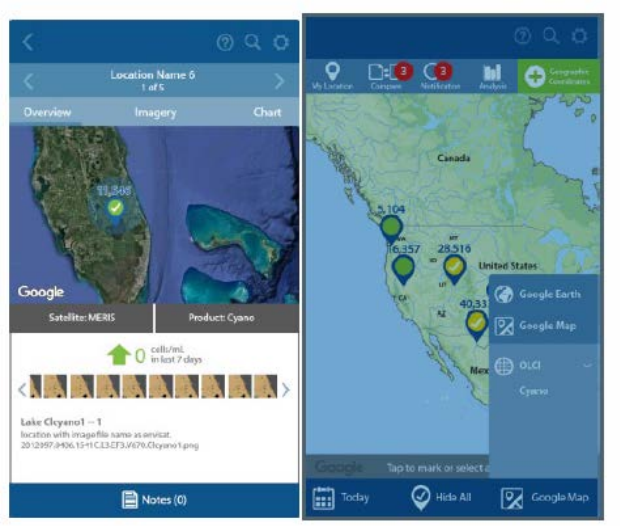
Red points are locations of water quality data.

MERIS tiles outlines in gray.

Insets are test MERIS files



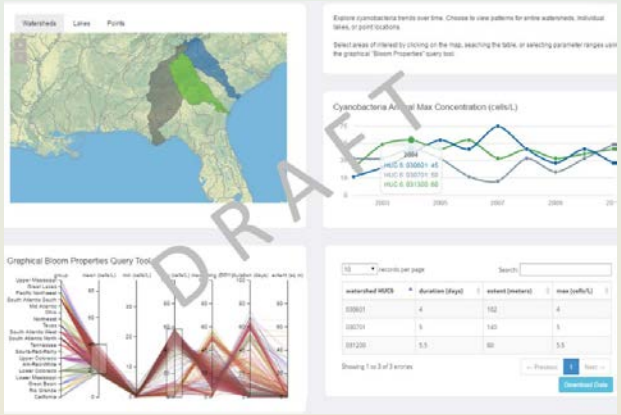
CyAN objective of providing data, tools, and "bulk" analysis



Android mobile apps

EPA EnviroAtlas

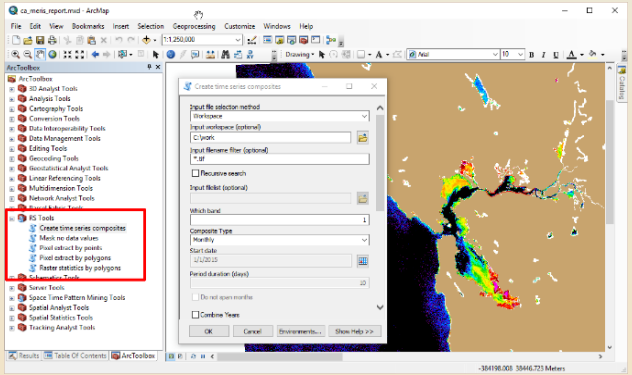
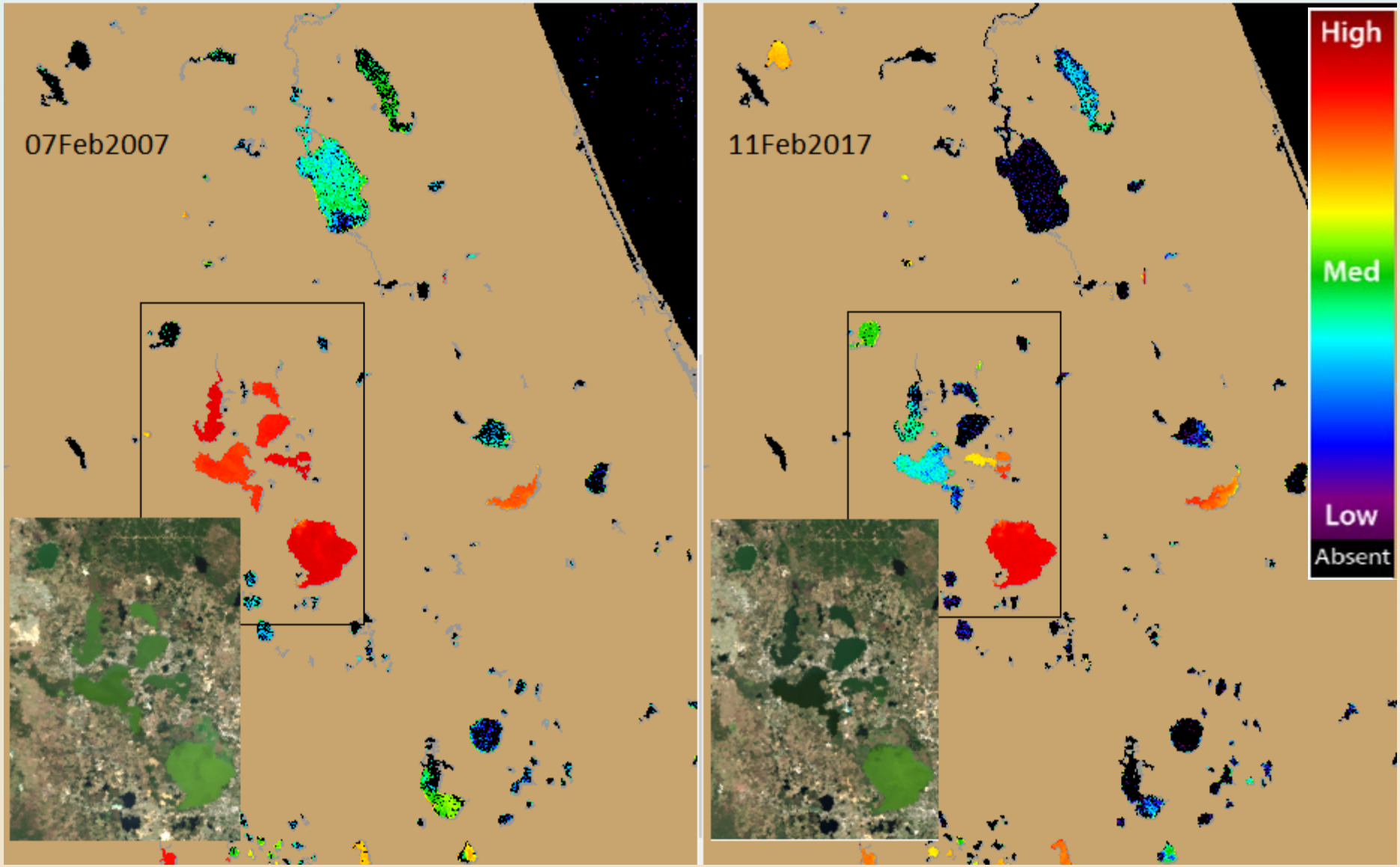
(Data dashboard)



RSTools (ArcGIS)

support for CyAN data

(developed for CA WaterBoard)



Northern Florida clear Scenes, MERIS to OLCI comparison