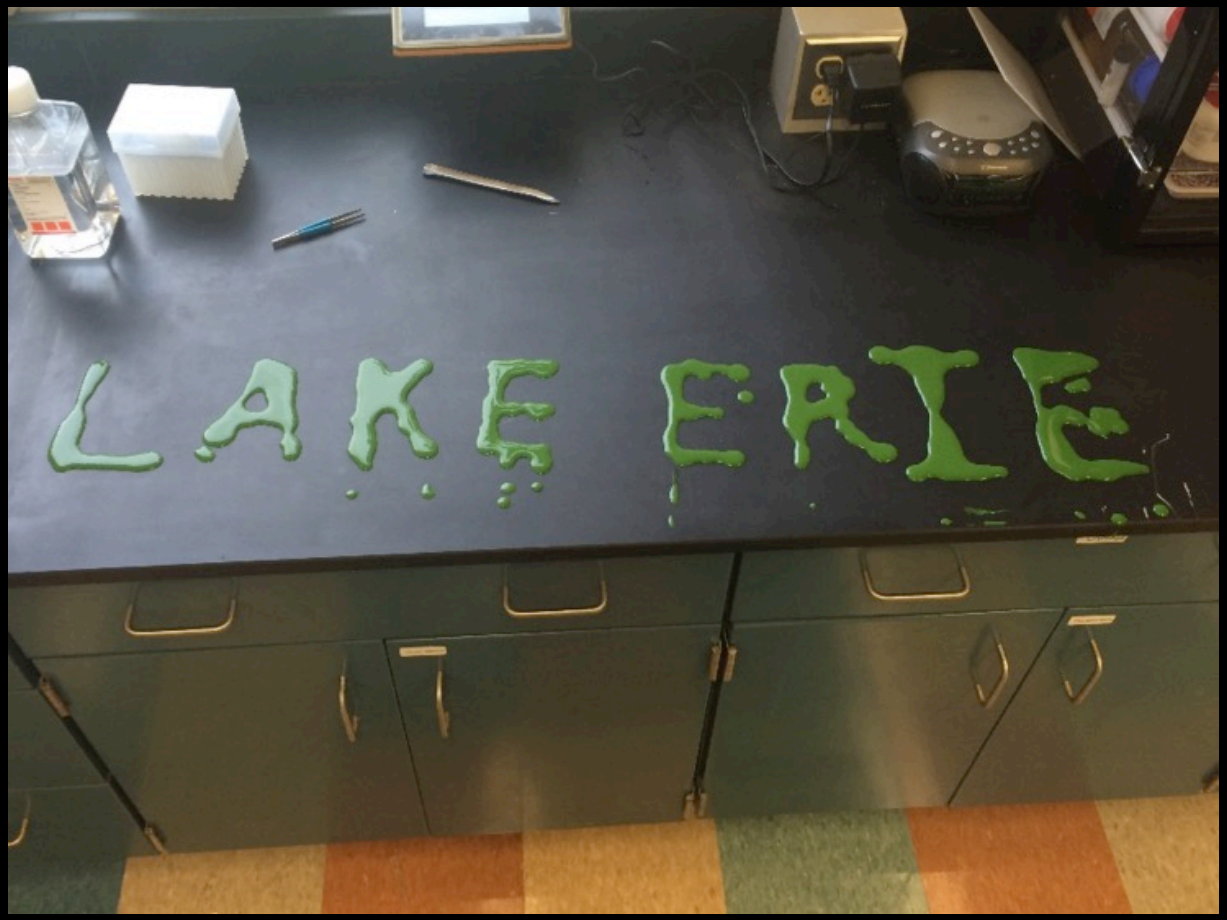
Integrating HAB detection technologies with a regional observing system in the Great Lakes

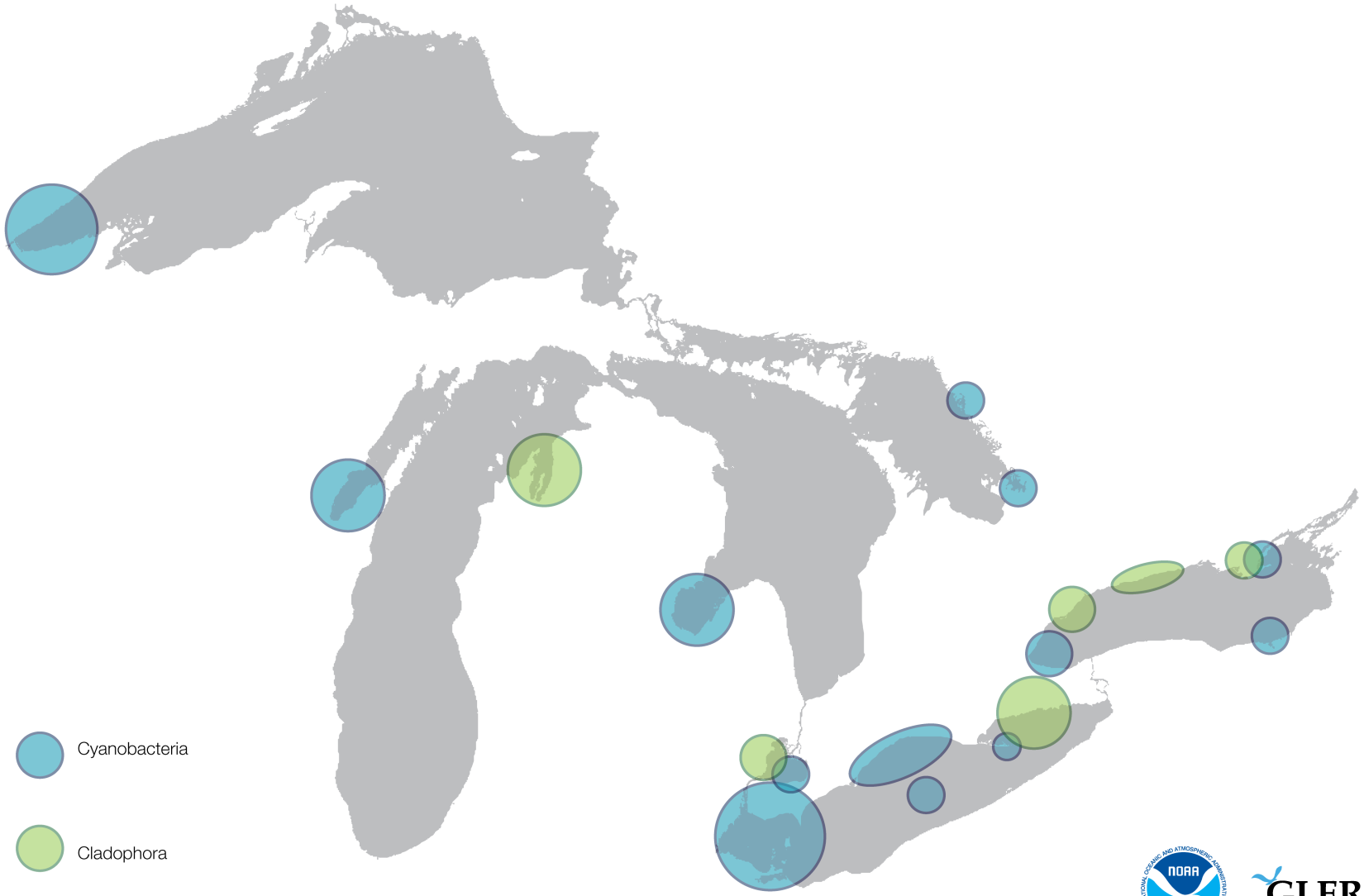


CILER
Cooperative Institute for Limnology and Ecosystems Research

GLERL
Great Lakes Environmental Research Laboratory

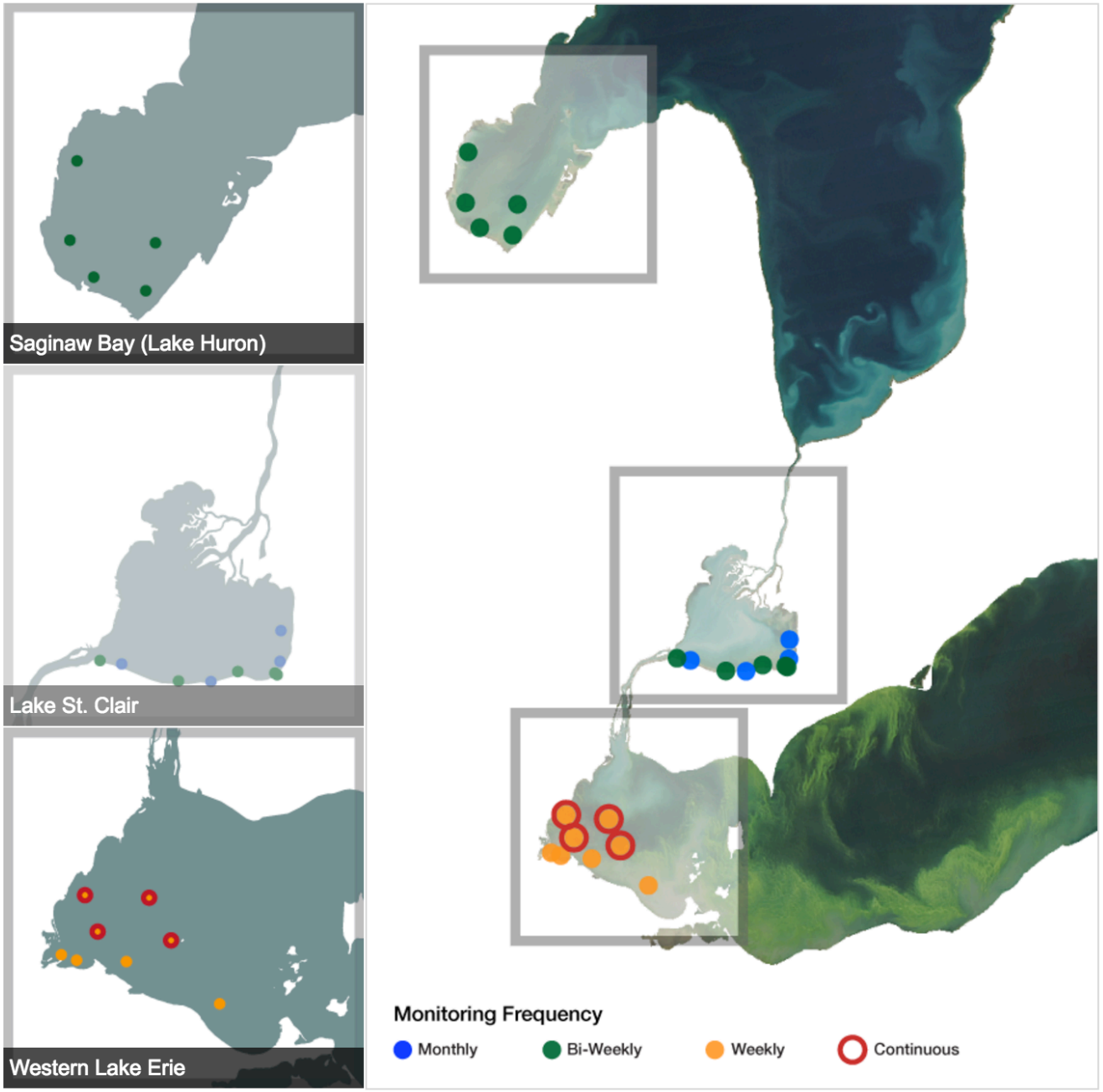
NCCOS

HABs occur throughout the Great Lakes basin

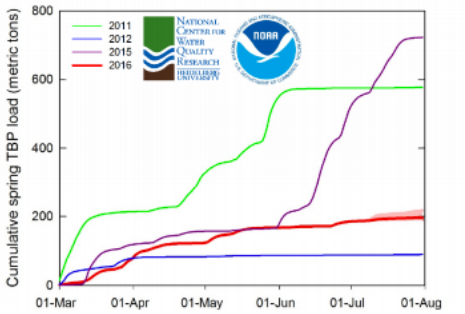


GLERL
Great Lakes Environmental Research Laboratory

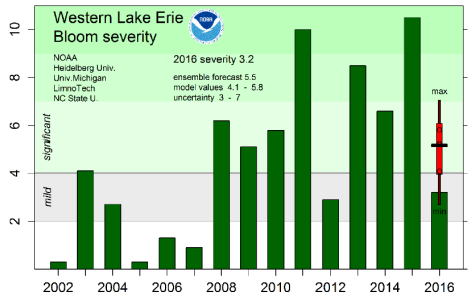
NOAA studies HABs throughout the Great Lakes



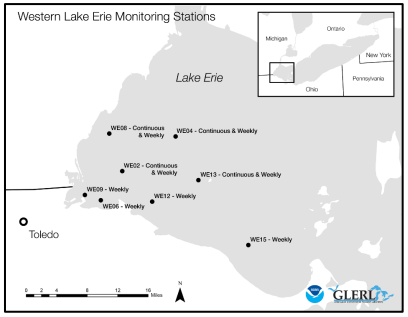
Bloom projection to data dissemination requires a multifaceted effort



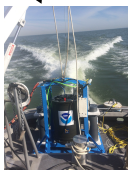
1) Project

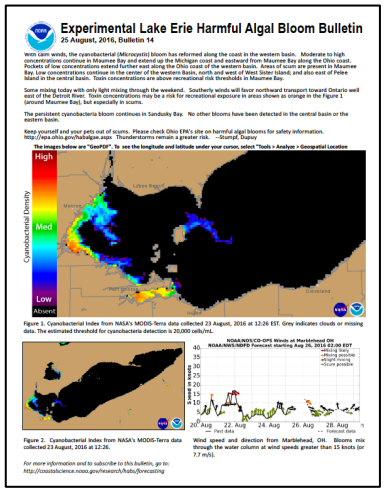


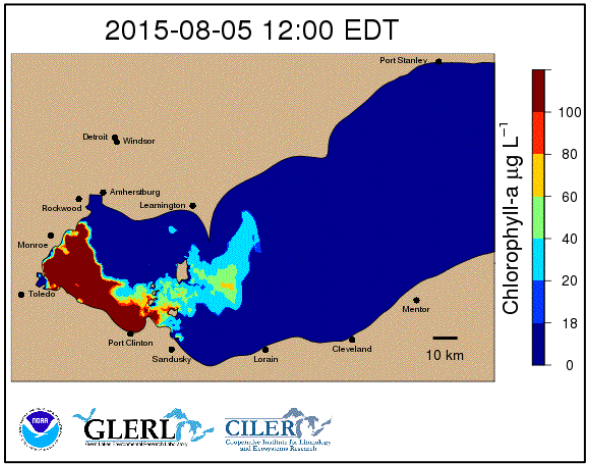
2) Predict



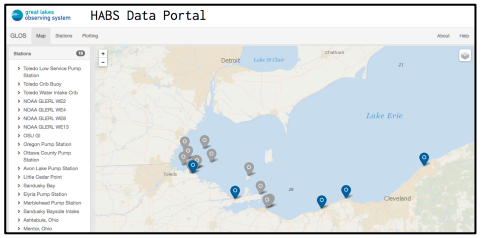
3) Monitor







4) Forecast



5) Disseminate Monitoring Data

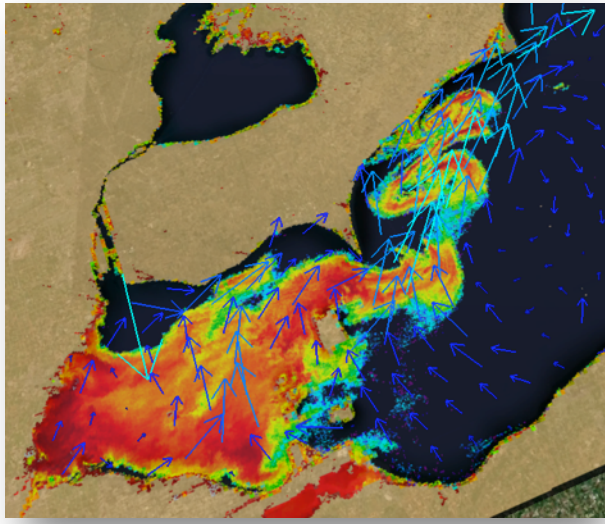
NOAA's cross-line office CHAB team

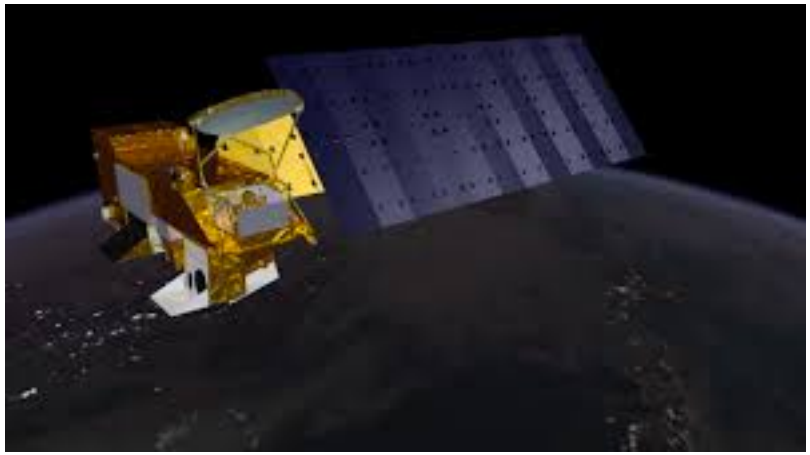
Monitoring & Experiments
Timothy Davis
Tom Johengen*
Greg Doucette
Duane Gossiaux
Ashley Burtner*
Danna Palladino*
Heidi Purcell*
Hank Vanderploeg
Alicia Ritzenthaler*

Remote Sensing
Steve Ruberg
Richard Stumpf
Andrea Vander Woude*
Steve Constant
George Leshkevich
Ron Muzzi
Russ Miller

Modeling
Richard Stumpf
Eric Anderson
Craig Stow
Tim Wynne
Danielle Dupuy
Mark Rowe*
Greg Lang

Communications
Joe Smith*





BOLD = HAB team leads
*** = CILER employees**

Western Lake Erie Monitoring Stations

Lake Erie

WE08 - Continuous & Weekly

WE04 - Continuous & Weekly

WE02 - Continuous & Weekly

WE13 - Continuous & Weekly

WE09 - Weekly

WE12 - Weekly

WE06 - Weekly

Toledo

WE15 - Weekly

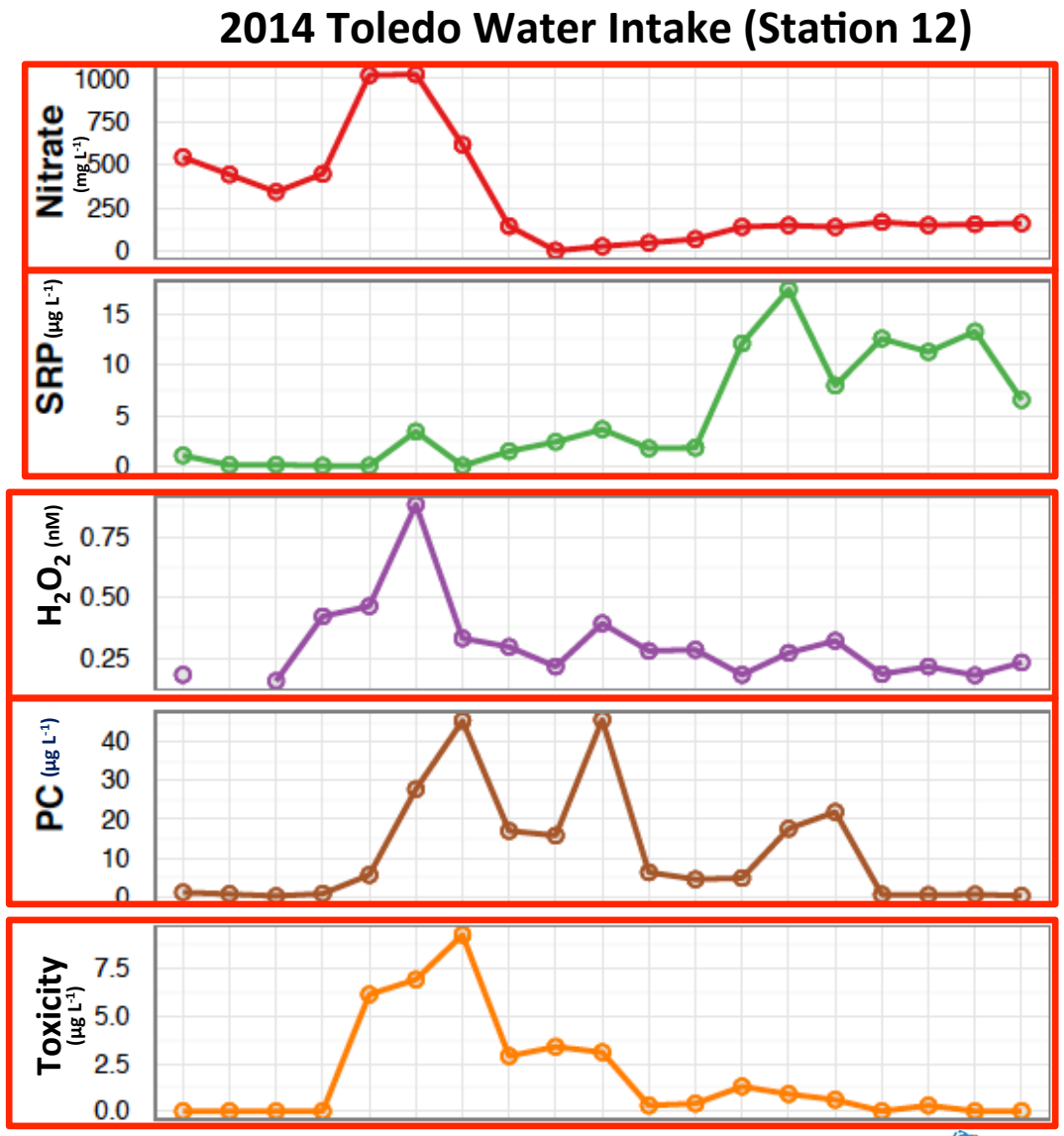
0 2 4 8 12 16 Miles

N

NOAA GLERL Great Lakes Environmental Research Laboratory

Weekly sampling reveals important seasonal trends that highlight potential environmental drivers and inform future experiments

- Toxicity changes throughout the bloom
- Relationship between nitrogen and toxicity
- *Microcystis* blooms occur even when phosphorus concentrations are low
- Other factors beyond nutrients may be important in driving bloom structure and function



NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

Great Lakes RESTORATION

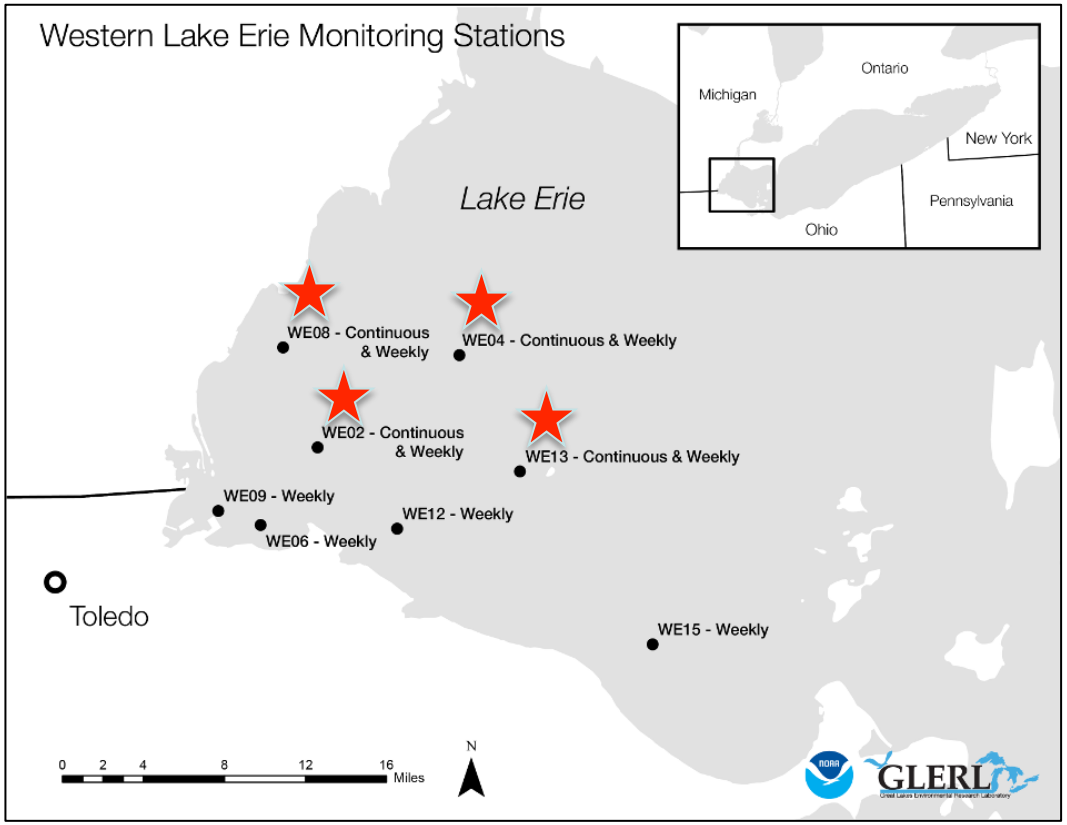
Blooms are patchy!

Western Lake Erie Real-time HABs Monitoring

Sensors:

. YSI EXO sondes

. Chlorophyll, Phycocyanin, Turbidity, CDOM



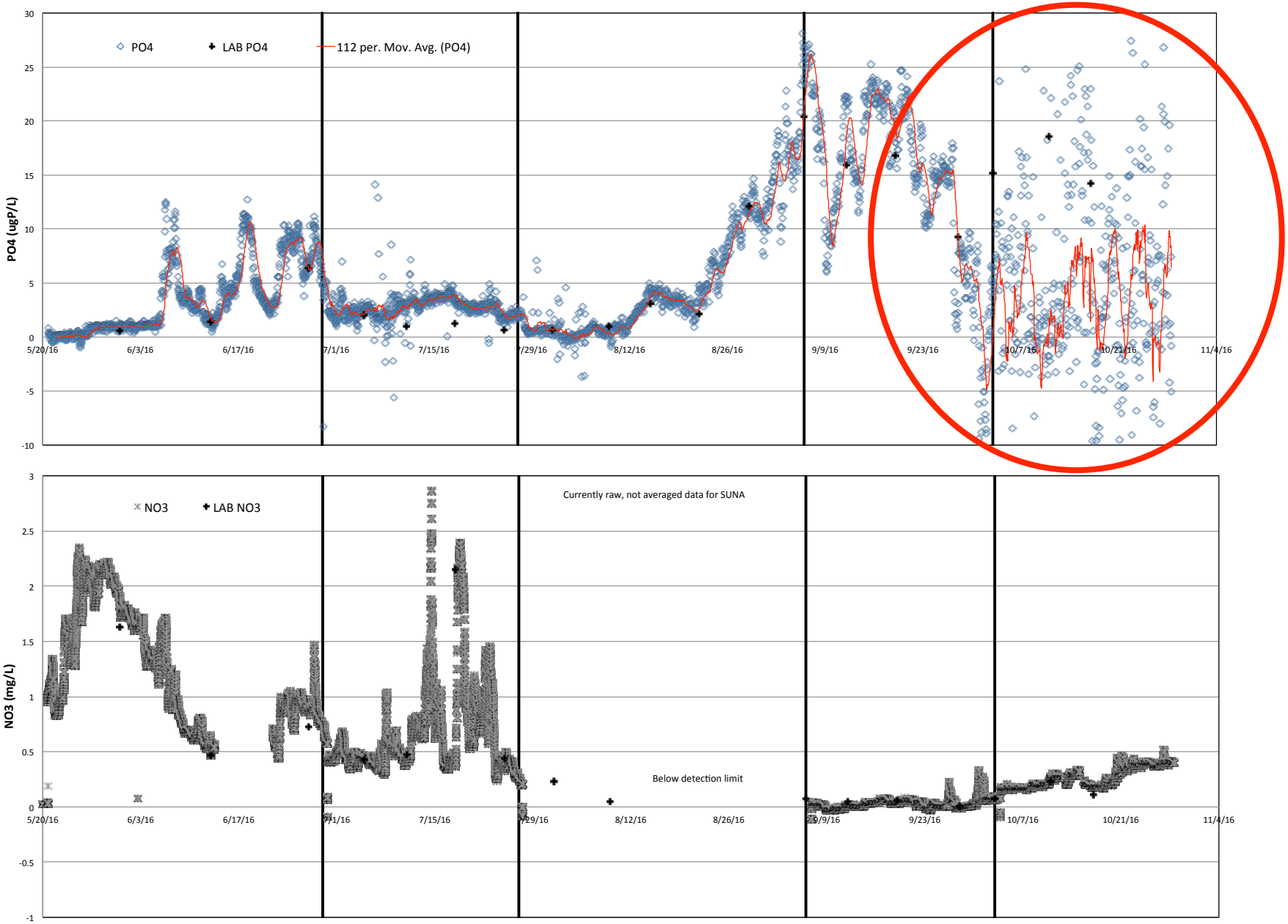
= Real-time observation station in 2016

. Wetlabs Cycle -SRP

. SeaBird SUNA nitrate sensor

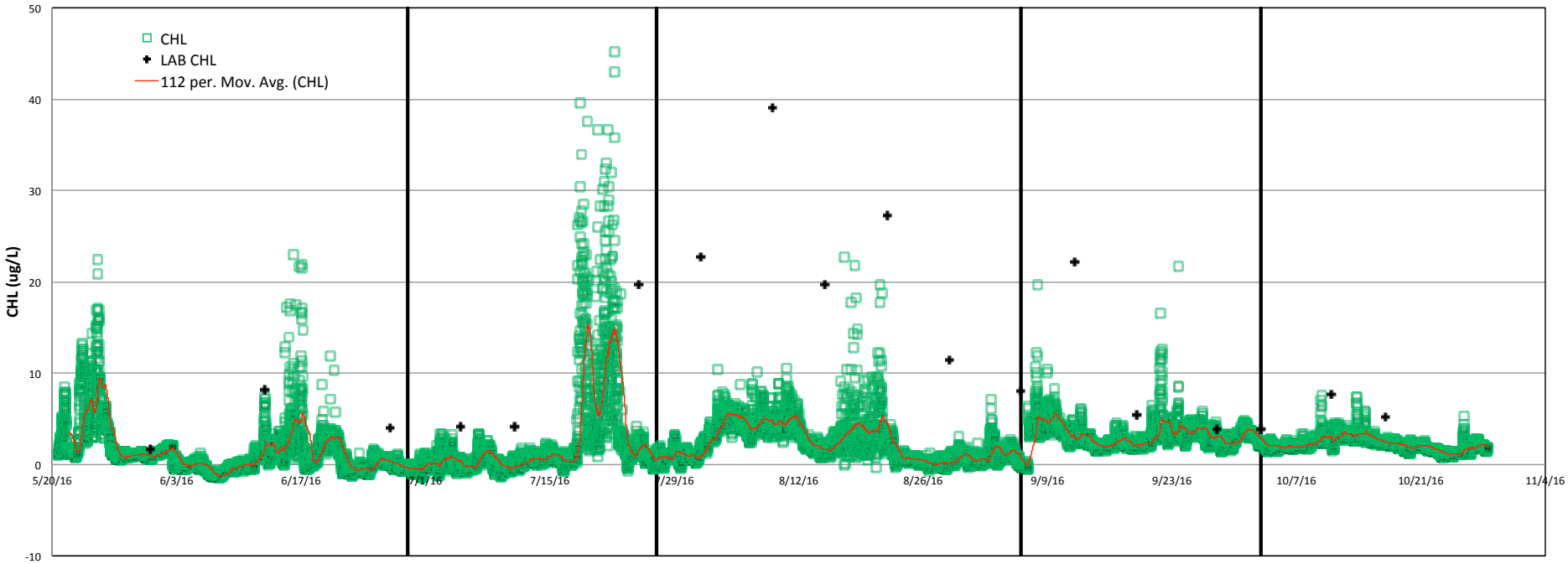
Continuous nutrient monitoring tracks field collections well

Continuous sensor work being conducted by Tom Johengen, Steve Ruberg, Danna Palladino, Heidi Purcell, Steve Constant, Ron Muzzi and Russ Miler



Continuous pigment monitoring yielded more variability

Continuous sensor work being conducted by Tom Johengen, Steve Ruberg, Danna Palladino, Heidi Purcell, Steve Constant, Ron Muzzi and Russ Miler

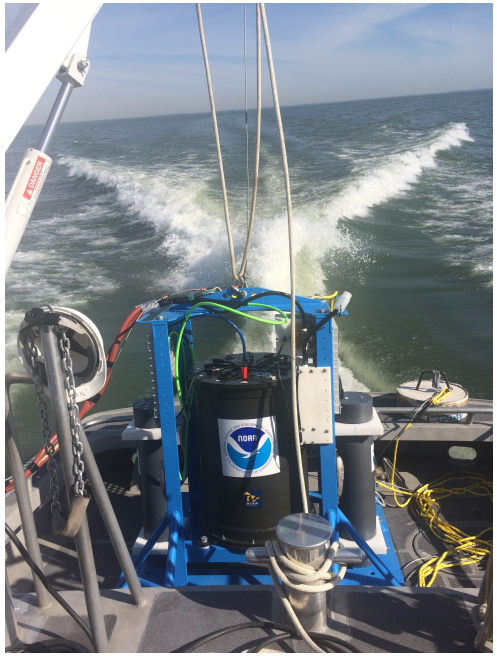


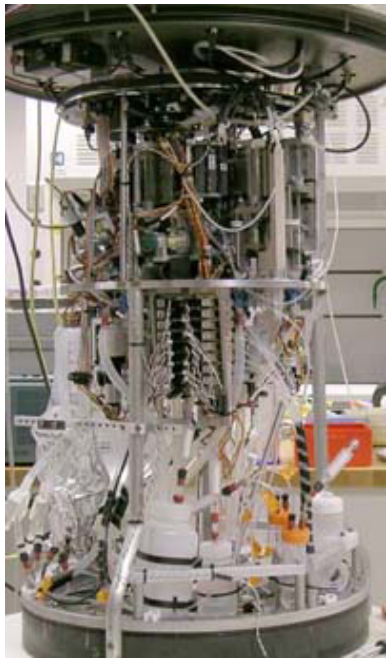
- Overall trend is seen but much greater variation between grab and continuous data than the nutrient sensors
- 'Packaging effects' of colonies interferes with the ability to accurately detect fluorescence signal
- Buoy setup instruments record data about 2m below the surface whereas Niskin samples are taken at 1m
- Highlights the need to be careful when integrating datasets

Autonomous near real-time toxin detection for Lake Erie

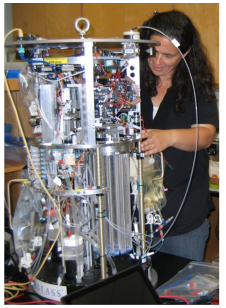
- Purchased with GLRI funds post-Toledo water crisis
- Collaboration between NOAA, MBARI, WHOI, OSU
- Truly emerging technology
  - Fewer than 20 worldwide
  - ESPniagara is the first to study freshwater CHABs
  - **Fine-scale MC observations are critical for toxicity models**

    Stumpf, **Davis** et al., 2016; Harmful Algae



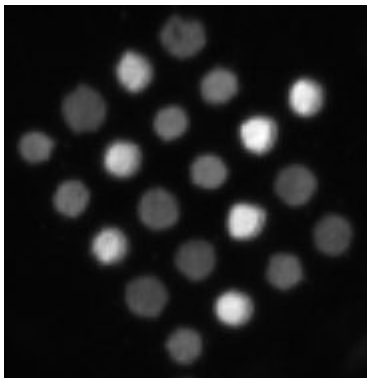


ESP microcystins assay design

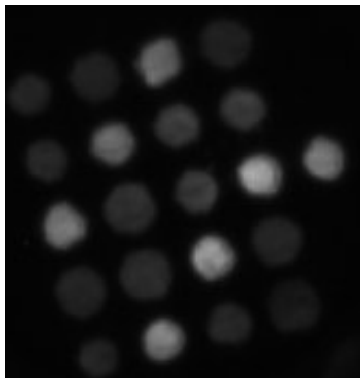


Work being conducted by Greg Doucette and Tina Mikulski

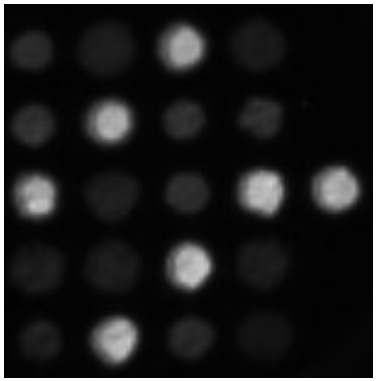
- Using mAb against ADDA moiety and MC-BSA conjugate – for comparison with Abraxis ELISA
- Compatible with extraction solvent
- Good range of detection on benchtop "mimic"
- Good overall intensity values



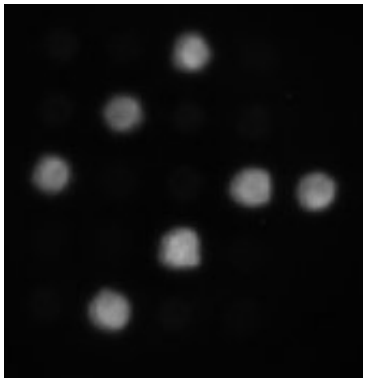
0.2 ng/mL MCLR



2.0 ng/mL MCLR



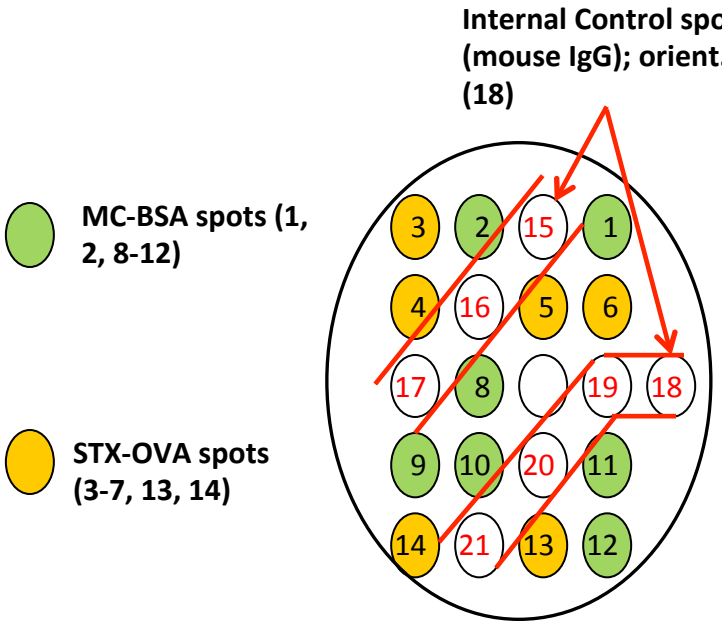
20.0 ng/mL MCLR



200.0 ng/mL MCLR

Potential for multiplexed detection of MC & STX

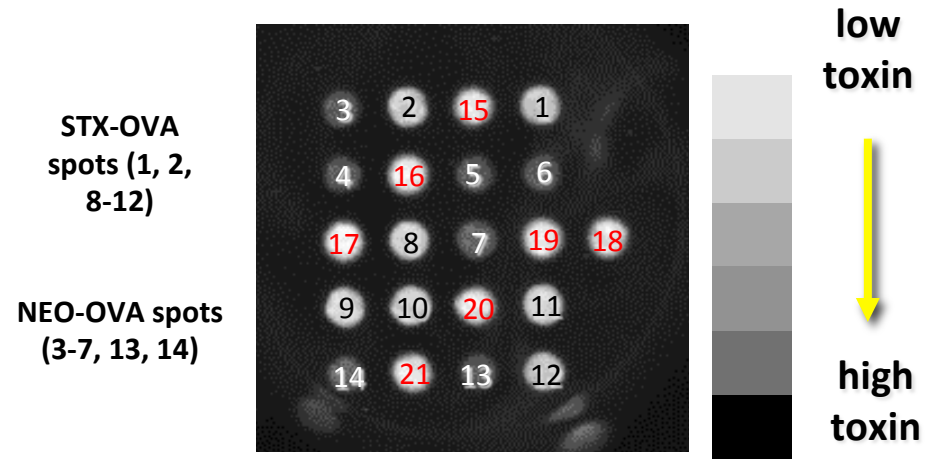
Work being conducted by Greg Doucette and Tina Mikulski



Proposed array map for MC + STX assay using α-MC & α-STX MAb

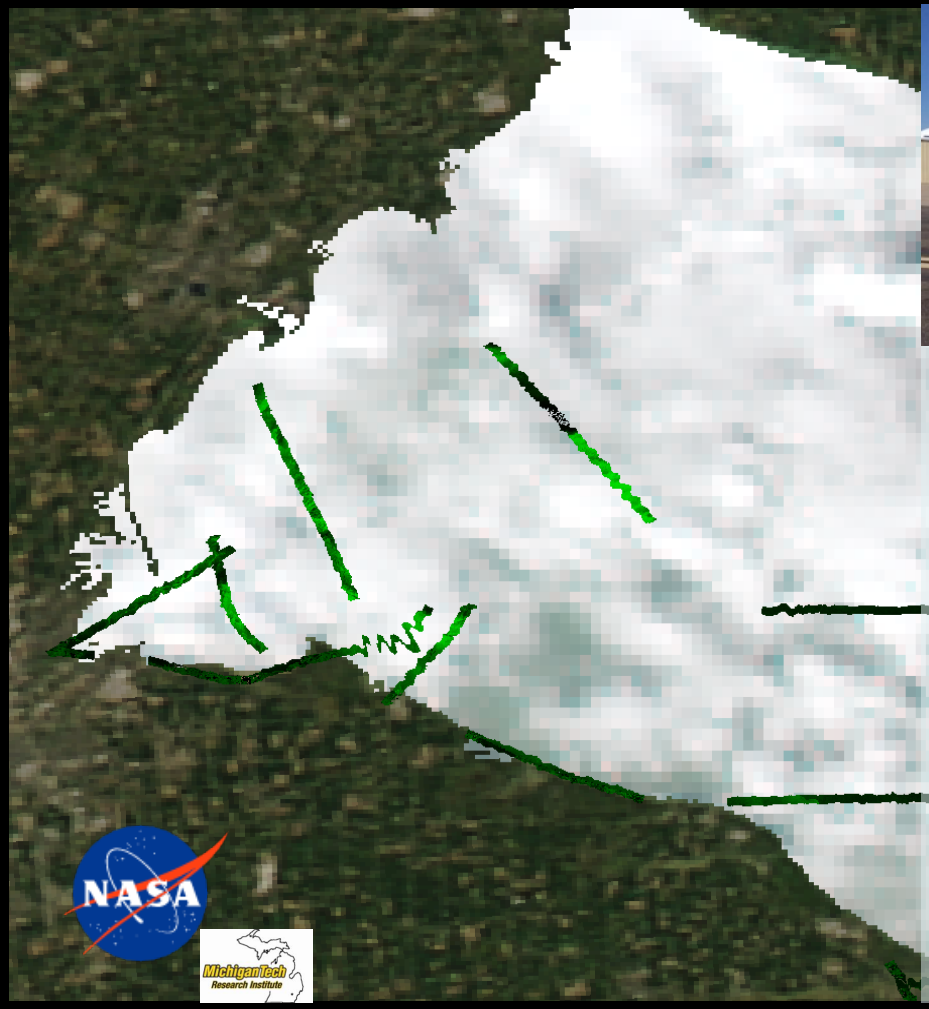
- competitive (c) ELISA membrane-based array employs MCLR-BSA & STX-OVA spots
- concurrent application of α-MC and α-STX MAbs in 'cocktail' yields two assay results generated simultaneously on the same array
- will broaden ESP cELISA detection capabilities to include MC, CYL, STX for single sample
- requires development of efficient extraction protocol for MC, CYL, and STX

example of analogous, multiplexed PST array for simultaneous detection of congener groups without (e.g., STX) and with (e.g., NEO) N-1 OH moiety



Start of Hyperspectral Detection of Cyanobacteria: Data in small areas; plane and UAS systems.

Lead by Andrea VanderWoude and Steve Ruberg



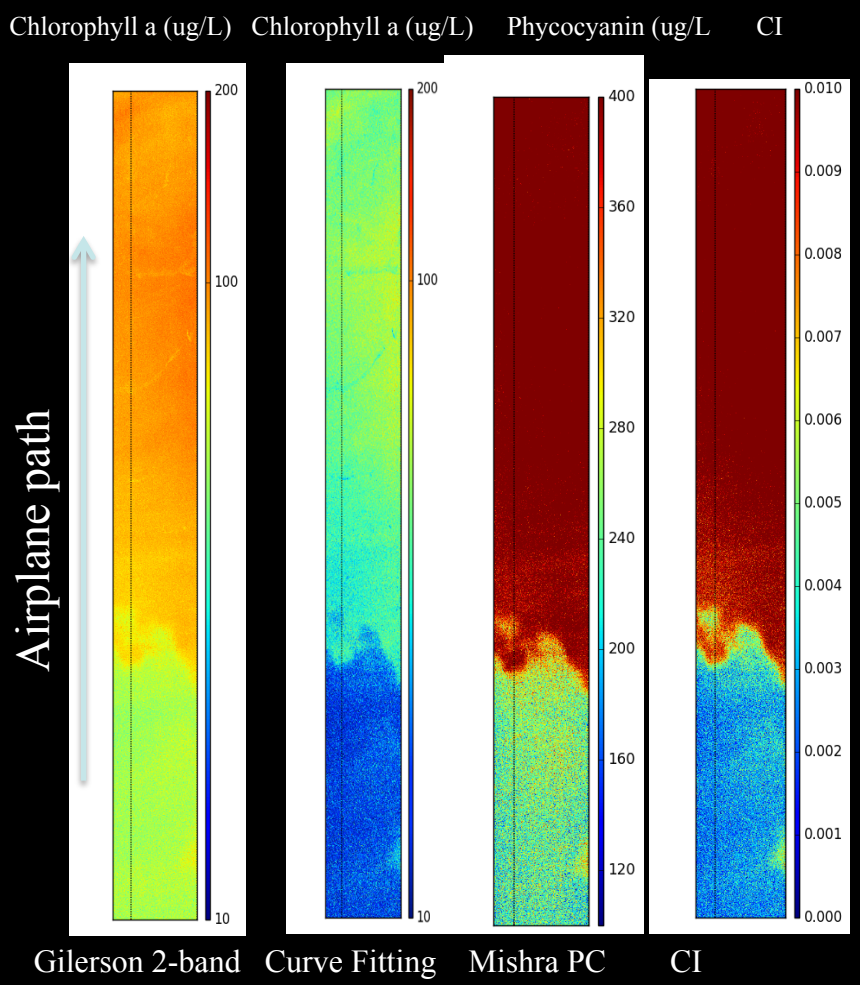
Typical swath is 640 m

240 spectral bands

1.1 m spatial resolution

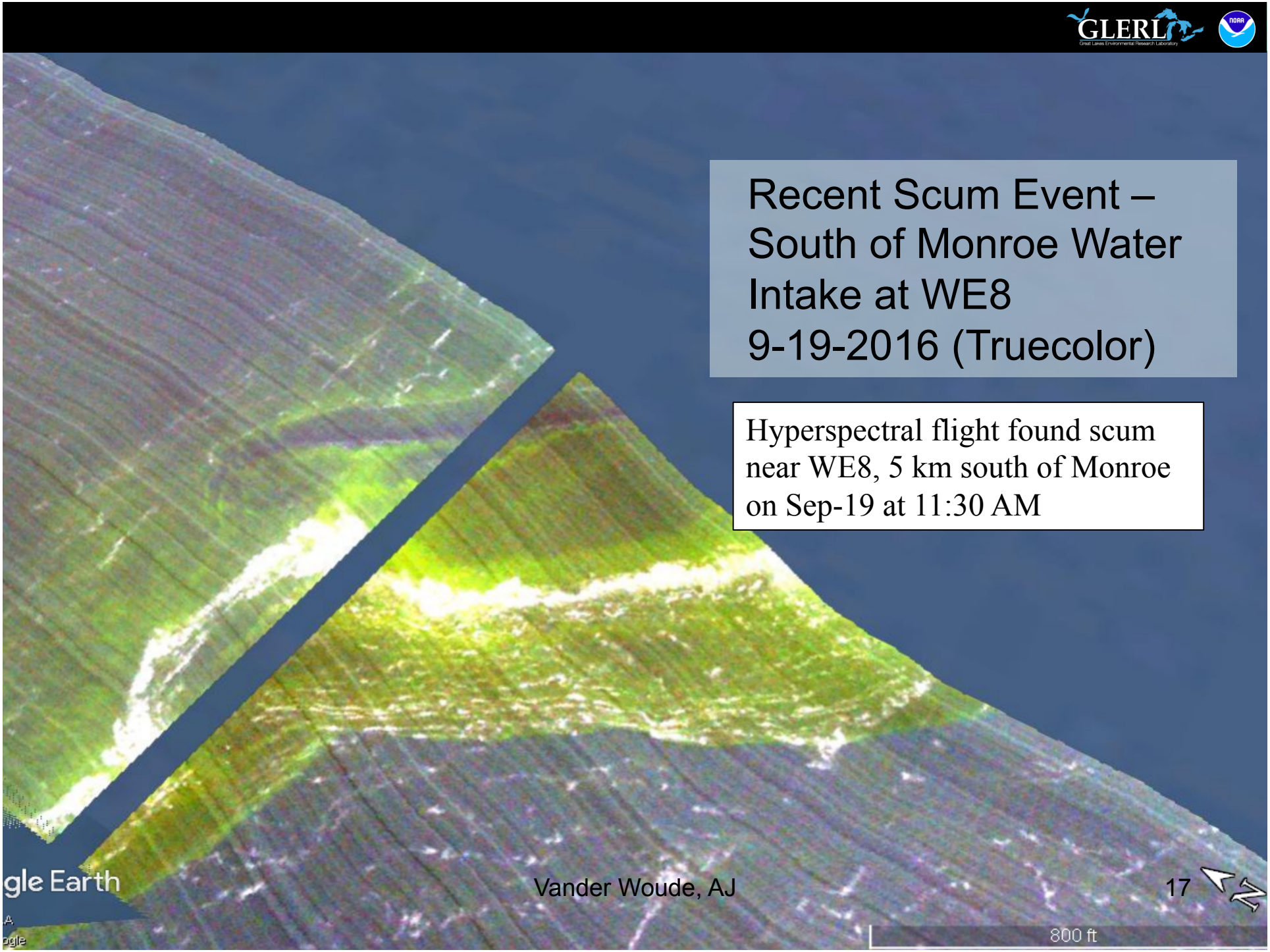
400-900 nm

Algorithm Development; and potential match to satellite to fit into bulletin in the future



(*Images are along track)

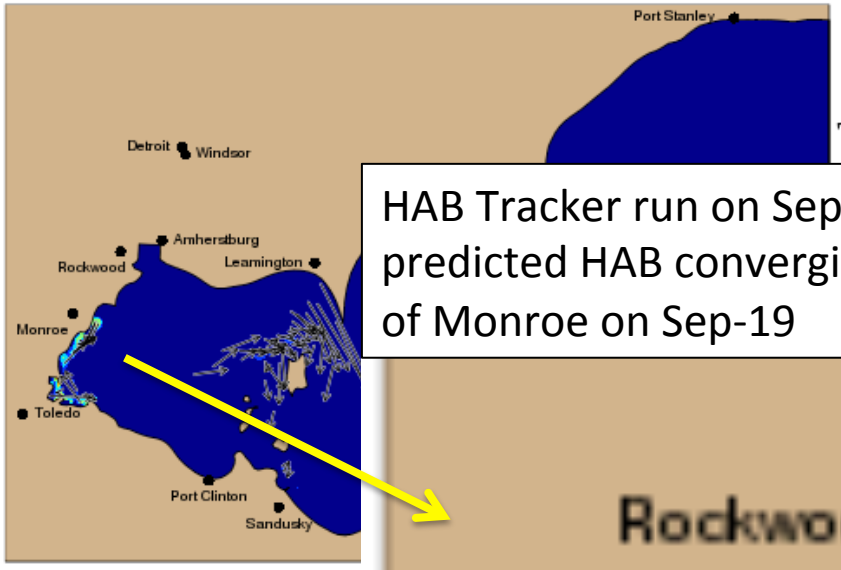
August 17, 2015



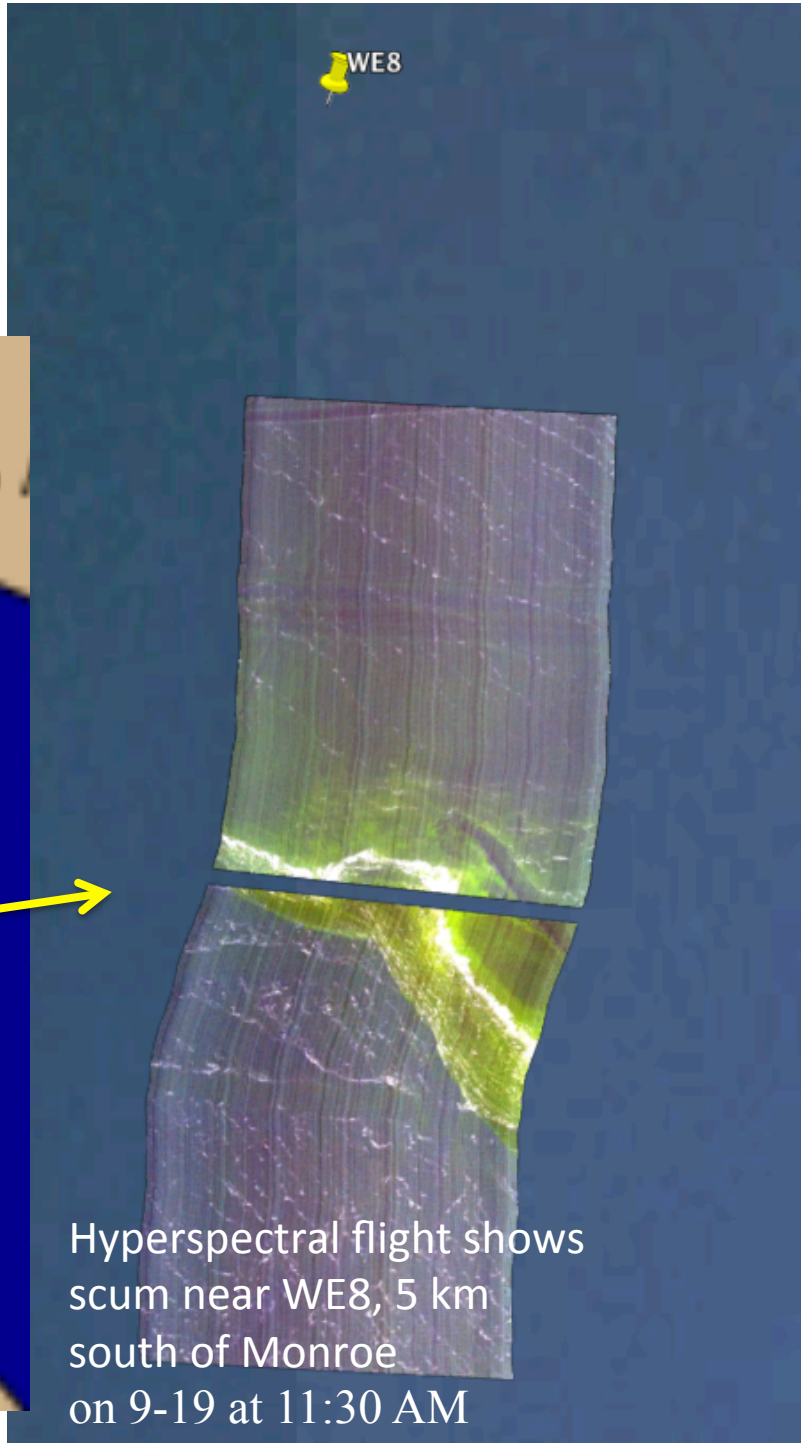
Recent Scum Event – South of Monroe Water Intake at WE8 9-19-2016 (Truecolor)

Hyperspectral flight found scum near WE8, 5 km south of Monroe on Sep-19 at 11:30 AM

2016-09-19 20:00 EDT

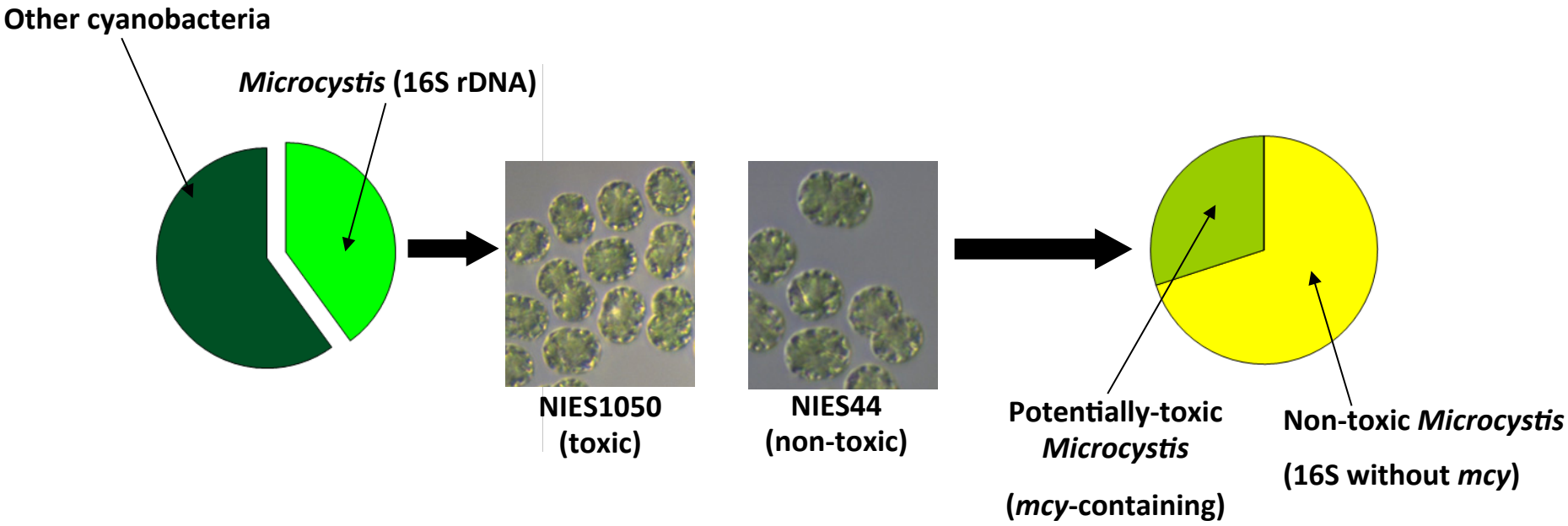


HAB Tracker run on Sep-16 predicted HAB converging south of Monroe on Sep-19



Hyperspectral flight shows scum near WE8, 5 km south of Monroe on 9-19 at 11:30 AM

Using molecular tools to monitor CHABs:

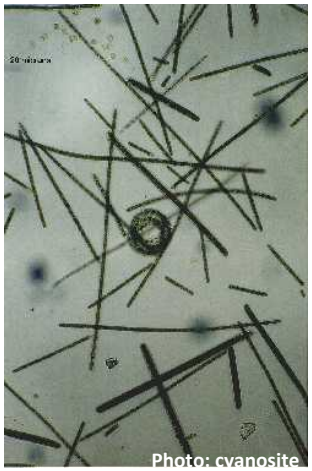


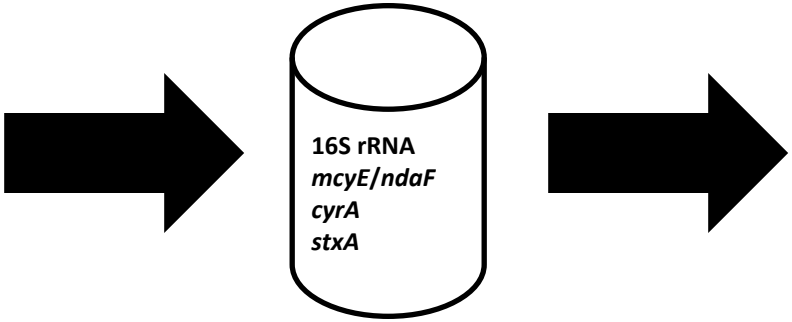
% toxic *Microcystis* = proportion of *Microcystis* cells containing the genetics to produce microcystins (*mcyD* or *E* / 16S x 100)

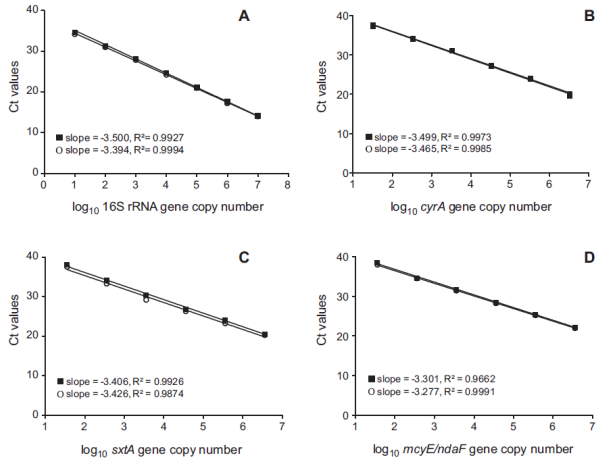
Determined by (1) qPCR and (2) metagenomics

Multiplex qPCR assay

Contact: Mark VanAsten, Mark.Vanasten@diagnostictechnology.com.au





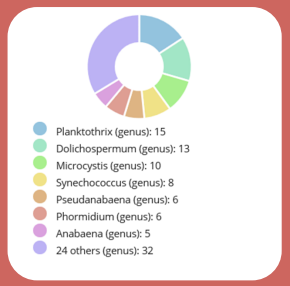


Where is this assay being used?

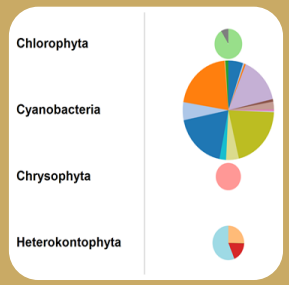
- USA
  - Part of Ohio EPA water testing algorithm rules
  - North East Ohio Regional Sewer District Laboratory (service offering)
  - Evaluations at Kansas (EPA Region 7) Californian Water Board, Fish & Game, Indiana Office of Water, US EPA Office R&D
- Australia
  - Sydney and Melbourne Water Utility, NSW Water
- Elsewhere
  - WLN, Netherlands
  - PUB Singapore

Rapid assessment of CHAB community composition using DNA Barcoding

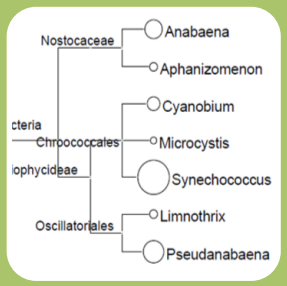
Work being conducted by Natalia Ivanova and Jerome Comte



Building 16S BOLD Reference Database for cyanobacteria and eukaryotic algae



Testing NGS protocols on mock communities generated from known cultures



Targeted NGS on field samples to simultaneously detect cyanobacteria and eukaryotic algae

Centre for Biodiversity Genomics

GLERL Great Lakes Environmental Research Laboratory

BGSU Bowling Green State University

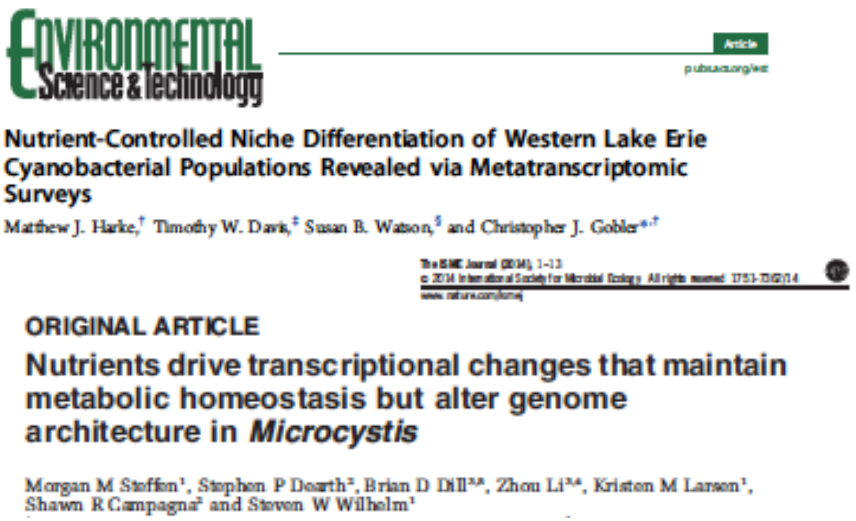
Environment and Climate Change Canada

Environnement et Changement climatique Canada

What is omics?

process:		transcription →		translation →
biomolecule:	**DNA**		**mRNA**	**protein**
cellular function:	encodes genes and stores hereditary information		an intermediate of genes and proteins	structural (e.g., cell wall) and catalytic (mediates biochemical reactions)
omics approach:	genomics		transcriptomics	proteomics
half-life:	days to years		minutes	hours to days
information provided:	the biological/geochemical potentials of an organism or community		which genes are actually being expressed	the identity and quantity of proteins present

Dick and Lam, *Elements Magazine*, in review



ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

Nutrient-Controlled Niche Differentiation of Western Lake Erie Cyanobacterial Populations Revealed via Metatranscriptomic Surveys

Matthew J. Harke,[†] Timothy W. Davis,[‡] Susan B. Watson,[§] and Christopher J. Gobler*[,†]

The ISME Journal (2014), 1–13
© 2014 International Society for Microbial Ecology All rights reserved 1751-7362/14
www.nature.com/ismej

ORIGINAL ARTICLE

Nutrients drive transcriptional changes that maintain metabolic homeostasis but alter genome architecture in *Microcystis*

Morgan M Steffen[1], Stephen P Dearth[2], Brian D Dill[3,4], Zhou Li[3,4], Kristen M Larsen[1], Shawn R Campagna[2] and Steven W Wilhelm[1]

OPEN ACCESS Freely available online

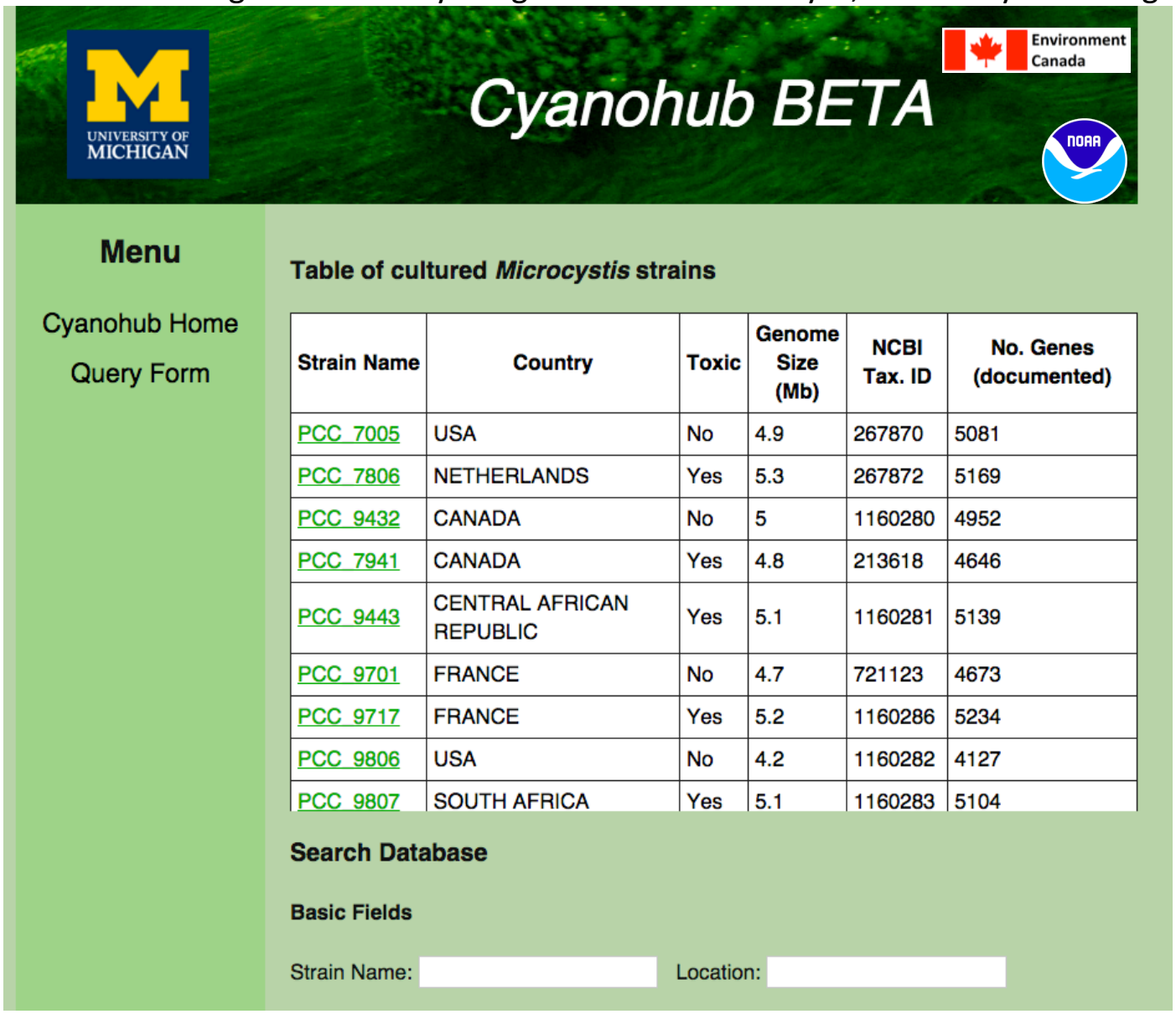
PLOS ONE

Phylogenies of Microcystin-Producing Cyanobacteria in the Lower Laurentian Great Lakes Suggest Extensive Genetic Connectivity

Timothy W. Davis[1*], Susan B. Watson[1], Mark J. Rozmarynowycz[2], Jan J. H. Ciborowski[3], Robert Michael McKay[2], George S. Bullerjahn[2]

Genomic database will fuel research in the Great Lakes and beyond

Work being conducted by Greg Dick and Kevin Meyer, University of Michigan



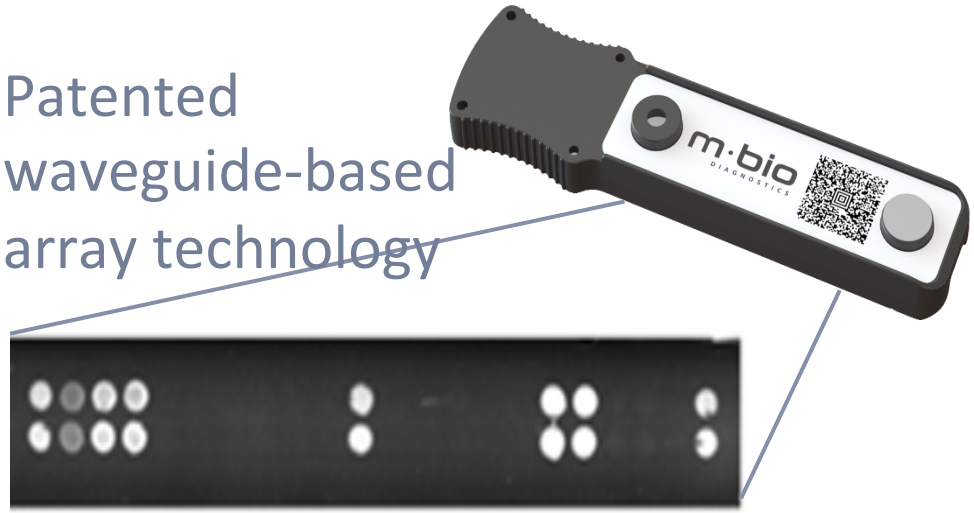
- Searchable genomic database for CHAB genera including Great Lakes strains
- Publicly available resource
- Serves as a link between environmental and genomic data
- Critical to further understand the response of CHAB genera to environmental drivers

MBio Diagnostics Multiplexed Toxin Assay System

Contact: Mike Lochhead, mike.lochhead@mbiodx.com

- Cartridge-based multiplexed immunoassays for toxin detection
- Portable fluorescence reader
- Assay time < 15 minutes
- On-board reagents & waste

Patented waveguide-based array technology



m·bio DIAGNOSTICS

Development of an inexpensive and user-friendly DNA preservation method

- Collaboration with George Bullerjahn, Steve Giglio, Susan Watson
- 12 strains were pipetted onto duplicate FTA cards and allowed to dry at room temperature and left at 24°C or 37°C for ~2 weeks
- DNA was then extracted and purified

Strain	Toxic?
Anabaena variabilis NIVA 19	+ mcy
Synechococcus sp. ARC 11	-
Synechococcus sp. CP1181	-
Anabaena vigueri	-
Pseudanabaena sp. LE011-01	-
Planktothrix sp. LE011-012	-
Anabaena variabilis NIVA 19	+ mcy
Microcystis aeruginosa 15A	unknown
Anabaena planktonica	-
Anabaena sp. A102	-
Microcystis viridis NIVA169/9	+ mcy
Pseudanabaena limnetica NIVA 111	unknown

Cyanobacterial DNA can be extracted and sequenced

Ambient (24°C)				**Elevated (37°C)**			
Strain	Toxic?	cyano16S	mcyA	Strain	Toxic?	cyano16S	mcyA
Anabaena variabilis NIVA 19	+ mcy	+	-	*Anabaena variabilis* NIVA 19	+ mcy	+	-
Synechococcus sp. ARC 11	-	+	-	*Synechococcus* sp. ARC 11	-	+	-
Synechococcus sp. CP1181	-	+	-	*Synechococcus* sp. CP1181	-	+	-
Anabaena vigueri	-	+	-	*Anabaena vigueri*	-	+	-
Pseudanabaena sp. LE011-01	-	-	-	*Pseudanabaena* sp. LE011-01	-	-	-
Planktothrix sp. LE011-012	-	-	-	*Planktothrix* sp. LE011-012	-	-	-
Anabaena variabilis NIVA 19	+ mcy	+	+	*Anabaena variabilis* NIVA 19	+ mcy	+	+
Microcystis aeruginosa 15A	unknown	+	-	*Microcystis aeruginosa* 15A	unknown	+	-
Anabaena planktonica	-	+	-	*Anabaena planktonica*	-	+	-
Anabaena sp. A102	-	+	-	*Anabaena* sp. A102	-	+	-
Microcystis viridis NIVA169/9	+ mcy	+	+	*Microcystis viridis* NIVA169/9	+ mcy	+	+
Pseudanabaena limnetica NIVA 111	unknown	+	+	*Pseudanabaena limnetica* NIVA 111	unknown	+	+

- DNA was extracted from 83% of samples with 100% amplification of the cyano16S gene in all samples yielding DNA and 2 of the 3 of known toxic strains
- PCR products from *Synechococcus* sp. ARC 11 was sequenced for verification
- Cards are cheap, easy to use, do not need specialized storage, and inexpensive to send
- FTA cards are a valuable tool for water managers, park rangers and citizen scientists