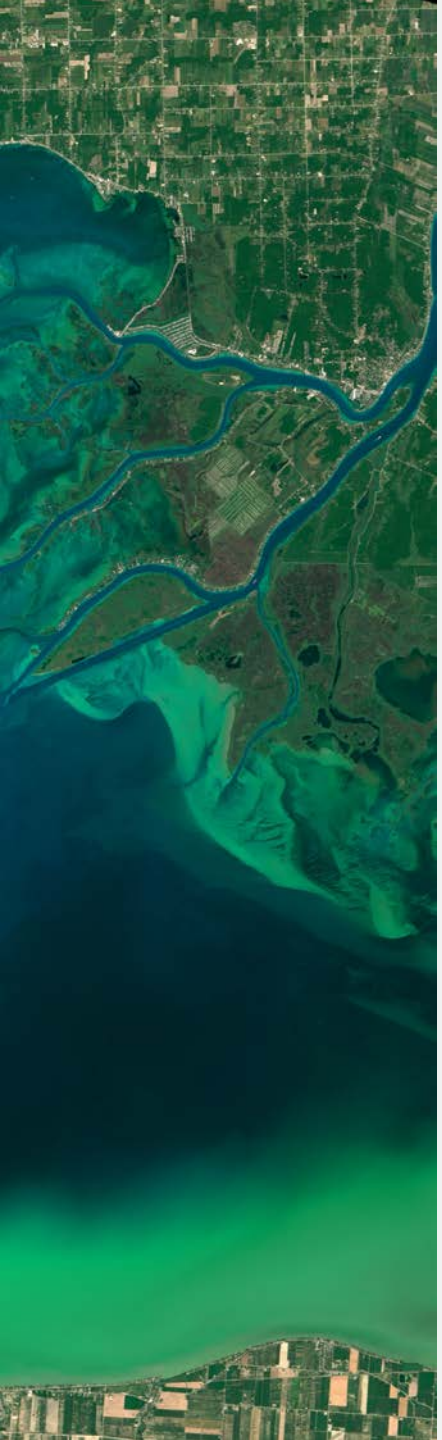


National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Large-Scale Monitoring Using Remote Sensing and Citizen Science

September 26, 2017

Week 4

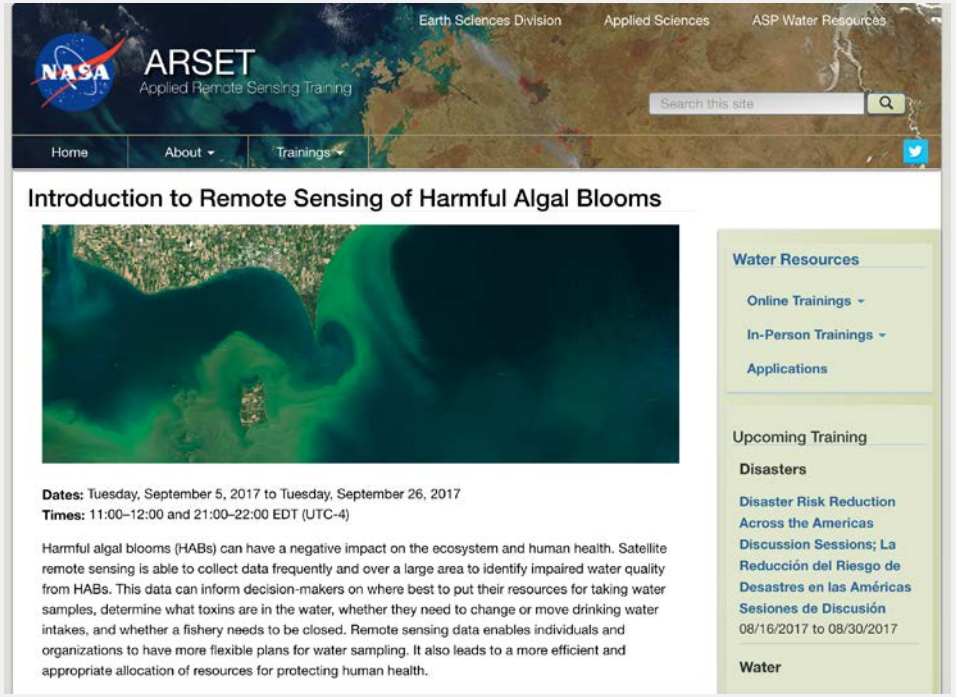
Trainers: Sherry Palacios
Amita Mehta

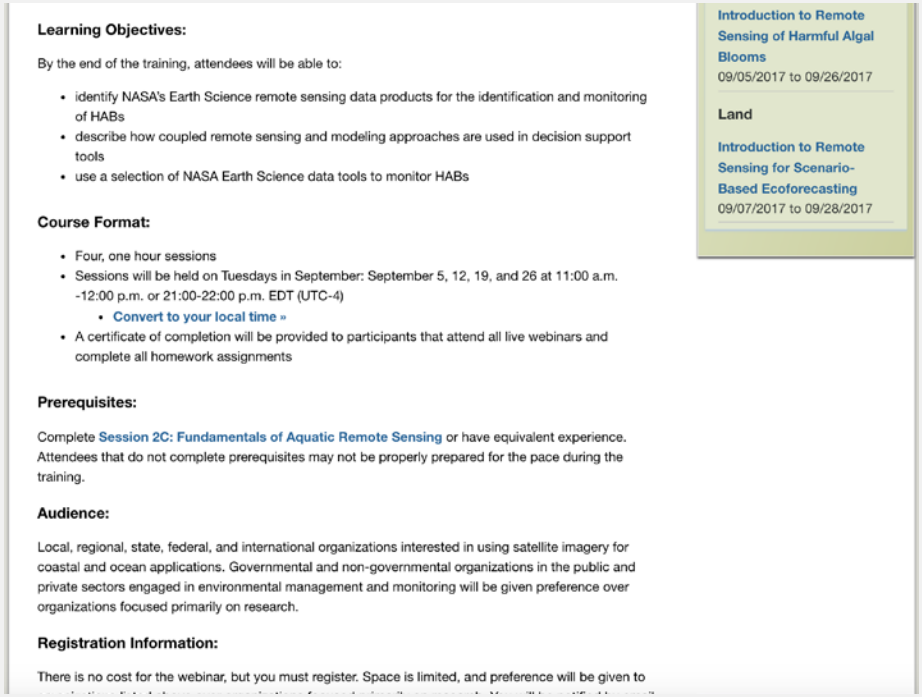
Course Structure

- Four, 1-hour sessions: Tuesdays in September (5, 12, 19, 26)
- Each session will be given twice:
  – Session A: 11:00 – 12:00 EDT (UTC-4)
  – Session B: 21:00 – 22:00 EDT (UTC-4)
- Presentations:
  – Overview of Harmful Algal Blooms (HABs)
  – Platforms and sensors, data access, and data processing
  – Understanding HABs in the coastal environment
  – Large scale monitoring and citizen science
- Two Homework Exercises: after weeks 2 and 4.
- Q and A after each session, and by email to instructors

Course Material

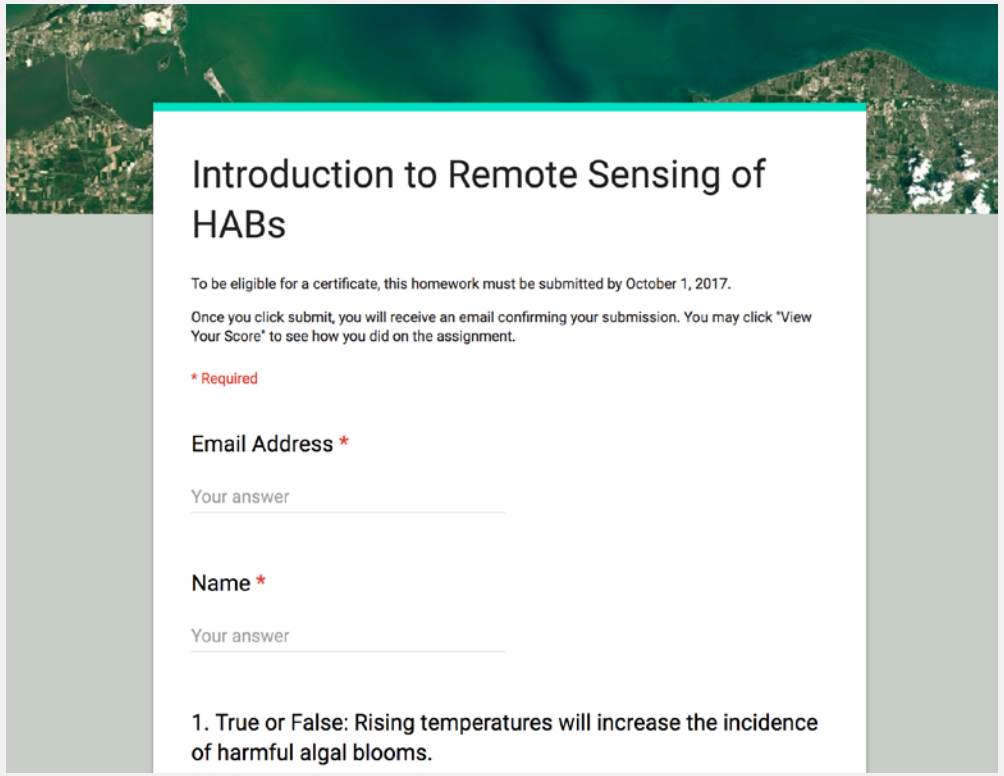
Webinar recordings, presentations, in class exercises, and homework are available at: https://arset.gsfc.nasa.gov/water/webinars/HABs17



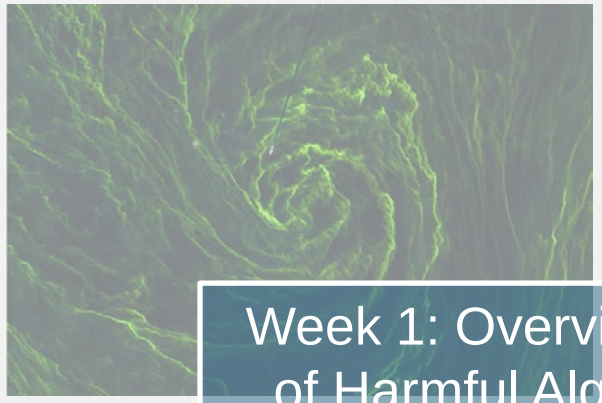


Homework and Certificates

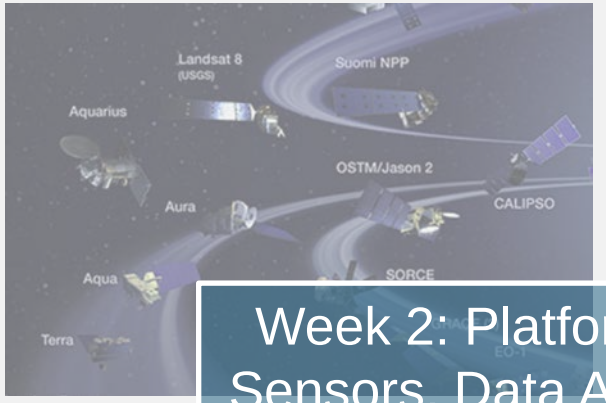
- Homework
  - **Answers must be submitted via Google Form**
- Certificate of Completion:
  - Attend all webinars
  - Complete homework assignments by the deadline (access from ARSET website)
    - **HW Deadlines: October 1st and 15th**
  - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com



Course Outline



Week 1: Overview of Harmful Algal Blooms



Week 2: Platforms & Sensors, Data Access, and Processing

Credit: Paul Hillman/NOAA

Week 3: HABs in the Coastal Environment

Week 4: Large Scale Monitoring

Outline – Session 4

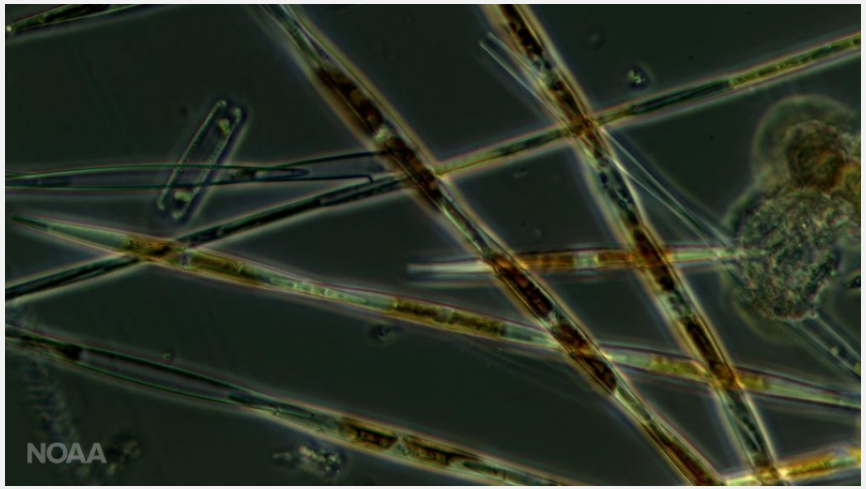
- HABs review from weeks 1, 2, & 3
- Overview of cyanobacterial HABs (cyanoHABs)
- Examples of freshwater cyanoHAB monitoring tools (e.g., HAB Tracker, Great Lakes HAB Bulletin)
- Examples of how citizen science can be used for HAB monitoring
- Cyanobacteria Assessment Network (CyAN)
  – Guest Speaker: Wilson Salls, EPA

Photo Credit: Aerial Associates Photography (http://skypics.com)

Review of Weeks 1, 2 & 3

What is a Harmful Algal Bloom?

“Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal.”



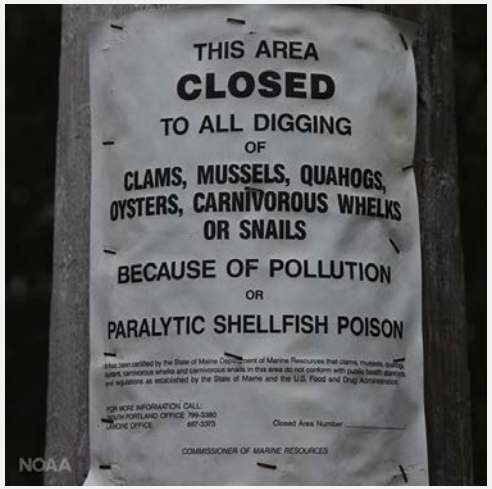


Image credit: http://www.noaa.gov/what-is-harmful-algal-bloom

Satellites for HAB Monitoring

- Current Satellite Missions:
  - Landsat 7 & Landsat 8
  - Terra
  - Aqua
  - Suomi National Polar Partnership (SNPP)
  - Sentinel-2 and Sentinel-3

Data Access & Processing Tools for HAB Monitoring

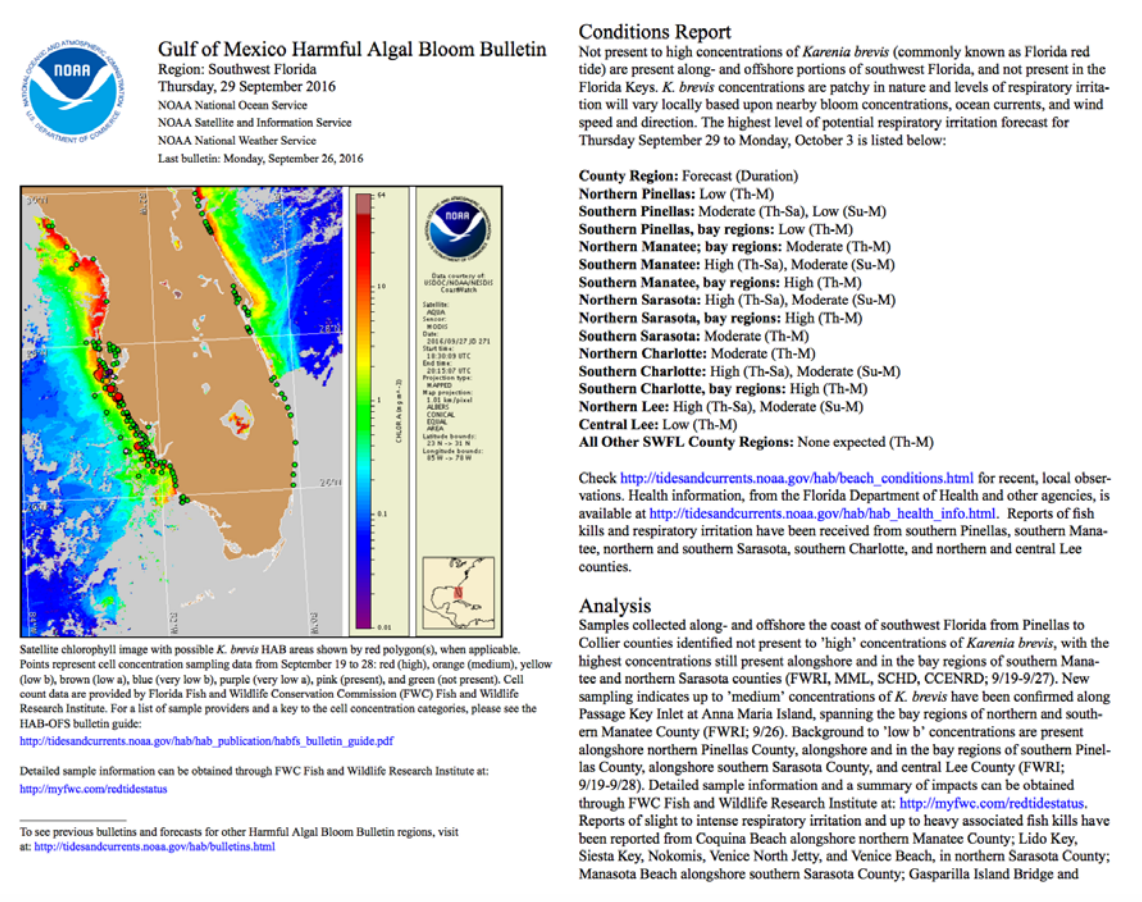
- These tools enable data search, spatial and temporal subsetting, analysis, and/or visualization:
  - OceanColor Web: https://oceancolor.gsfc.nasa.gov/
  - Giovanni: http://giovanni.gsfc.nasa.gov/giovanni/
  - CoastWatch https://coastwatch.pfeg.noaa.gov/data.html
- Image Processing and Visualization Software:
  - SeaDAS: http://seadas.gsfc.nasa.gov/

Summary

- Remote sensing provides continuous global coverage with consistent observations compared to limited point measurements from surface or ship-based water sampling
- Optical and NIR remote sensing observations from Landsat, Terra/Aqua MODIS, SNPP VIIRS, Sentinel-2 MSI and Sentinel-3 OLCI are used operationally for qualitative and quantitative HAB (Chl, and SST) monitoring

Forecasting HAB Events is Helpful for Predicting Impacts

NOAA HAB Operational Forecast System (HAB-OFS)



Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Southwest Florida
Thursday, 29 September 2016
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Monday, September 26, 2016

Satellite chlorophyll image with possible *K. brevis* HAB areas shown by red polygon(s), when applicable. Points represent cell concentration sampling data from September 19 to 28: 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 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 the 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 high 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 Thursday September 29 to Monday, October 3 is listed below:

County Region: Forecast (Duration)
Northern Pinellas: Low (Th-M)
Southern Pinellas: Moderate (Th-Sa), Low (Su-M)
Southern Pinellas, bay regions: Low (Th-M)
Northern Manatee; bay regions: Moderate (Th-M)
Southern Manatee: High (Th-Sa), Moderate (Su-M)
Southern Manatee, bay regions: High (Th-M)
Northern Sarasota: High (Th-Sa), Moderate (Su-M)
Northern Sarasota, bay regions: High (Th-M)
Southern Sarasota: Moderate (Th-M)
Northern Charlotte: Moderate (Th-M)
Southern Charlotte: High (Th-Sa), Moderate (Su-M)
Southern Charlotte, bay regions: High (Th-M)
Northern Lee: High (Th-Sa), Moderate (Su-M)
Central Lee: Low (Th-M)
All Other SWFL County Regions: None expected (Th-M)

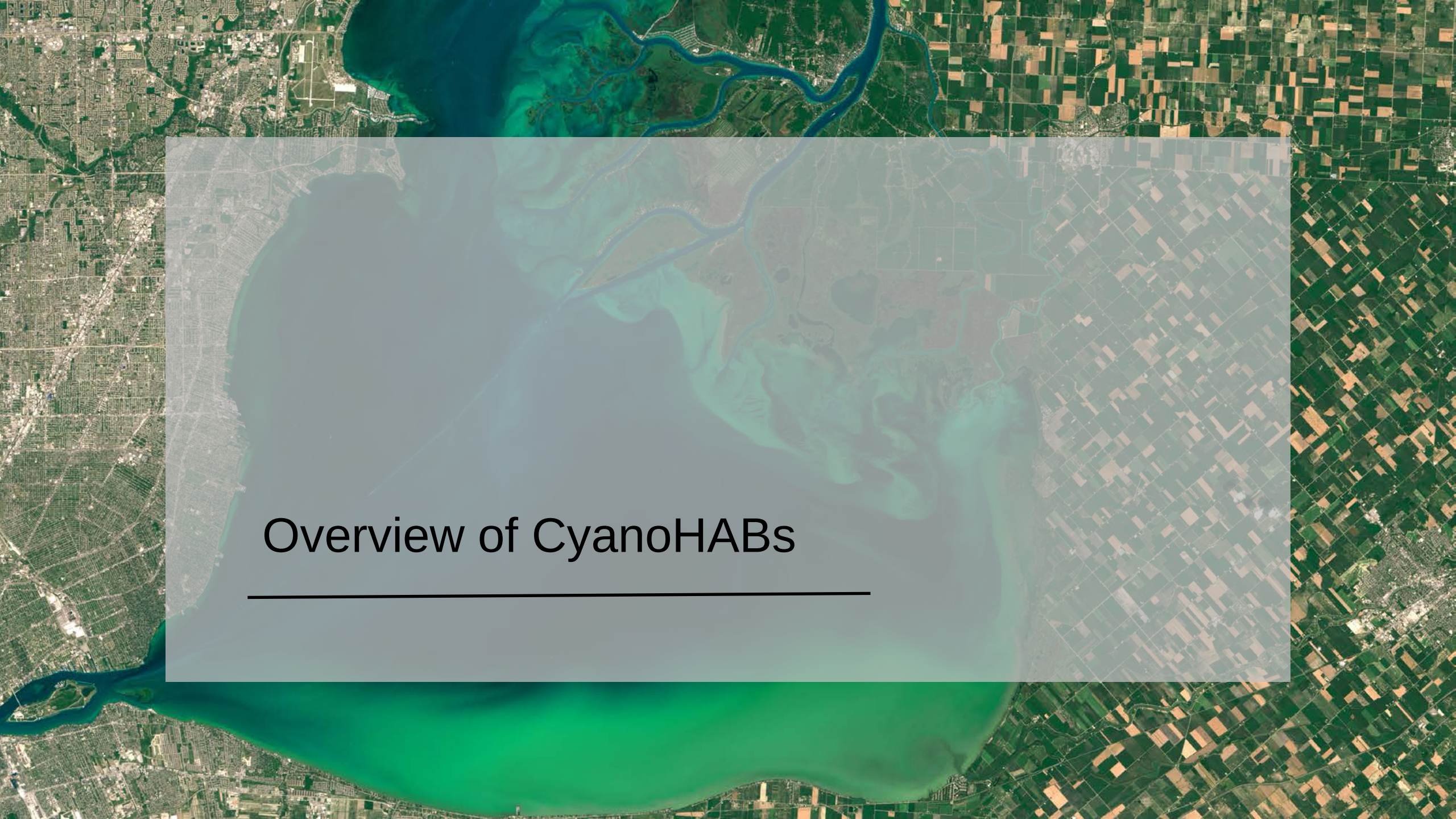
Check http://tidesandcurrents.noaa.gov/hab/beach_conditions.html for recent, local observations. Health information, from the Florida Department of Health and other agencies, is available at http://tidesandcurrents.noaa.gov/hab/hab_health_info.html. Reports of fish kills and respiratory irritation have been received from southern Pinellas, southern Manatee, northern and southern Sarasota, southern Charlotte, and northern and central Lee counties.

Analysis

Samples collected along- and offshore the coast of southwest Florida from Pinellas to Collier counties identified not present to 'high' concentrations of *Karenia brevis*, with the highest concentrations still present alongshore and in the bay regions of southern Manatee and northern Sarasota counties (FWRI, MML, SCHD, CCENRD; 9/19-9/27). New sampling indicates up to 'medium' concentrations of *K. brevis* have been confirmed along Passage Key Inlet at Anna Maria Island, spanning the bay regions of northern and southern Manatee County (FWRI; 9/26). Background to 'low b' concentrations are present alongshore northern Pinellas County, alongshore and in the bay regions of southern Pinellas County, alongshore southern Sarasota County, and central Lee County (FWRI; 9/19-9/28). Detailed sample information and a summary of impacts can be obtained through FWC Fish and Wildlife Research Institute at: http://myfwc.com/redtidestatus. Reports of slight to intense respiratory irritation and up to heavy associated fish kills have been reported from Coquina Beach alongshore northern Manatee County; Lido Key, Siesta Key, Nokomis, Venice North Jetty, and Venice Beach, in northern Sarasota County; Manasota Beach alongshore southern Sarasota County; Gasparilla Island Bridge and

- *Karenia brevis* forms patchy blooms and the impact can vary by location
- To build its forecast, the NOAA HAB Bulletin combines:
  - ocean satellite imagery
  - field observations
  - models
  - public health reports
  - ocean buoy data

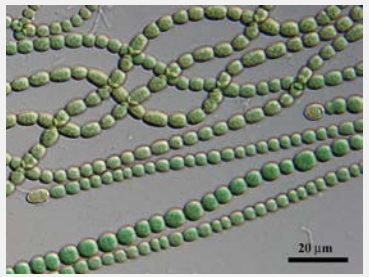
https://tidesandcurrents.noaa.gov/hab/bulletins.html;
https://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf



Overview of CyanoHABs

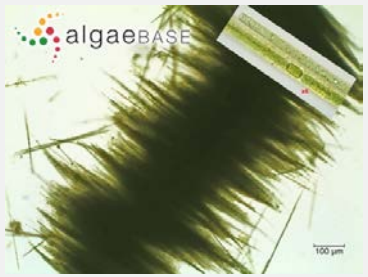
Some Common CyanoHABs and Their Toxins

Anabaena



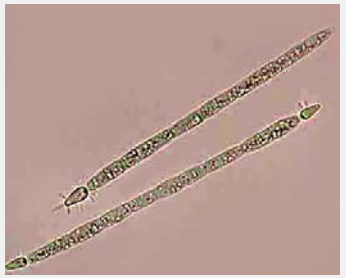
anatoxins
microcystin
saxitoxins

Aphanizomenon



saxitoxins
cylindrospermopsins

Cylindrospermopsis

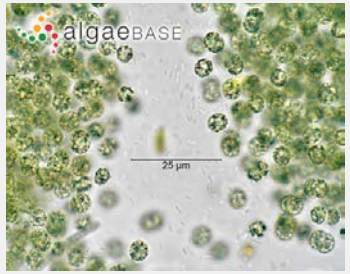


saxitoxins
cylindrospermopsins

Lyngbya

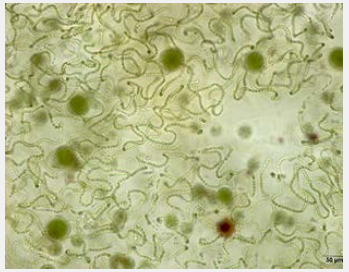
aplysiatoxins
lyngbyatoxin a

Microcystis



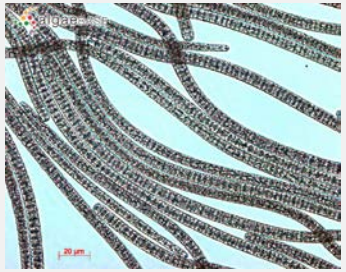
microcystins

Nostoc



microcystins

Planktothrix



anatoxins, aplysiatoxins
microcystins, saxitoxins

Neurotoxin
Liver toxin
Contact irritant

photo credits: CCLA, C.F. Carter, UNH Center for Freshwater Biology, R. Barone

CyanoHABs - Up Close

Lake Taihu, China

Pinto Lake, California

credit (L to R): H. Paerl, UNC-Chapel Hill, R.Kelty

Management Impact

Case Study: Toledo, Ohio (USA)

Science News *from research organizations*

Significant harmful algal bloom predicted in western Lake Erie this summer

Date: July 10, 2014

Source: National Oceanic and Atmospheric Administration

Summary: NOAA and its research partners predict that western Lake Erie will have a significant bloom of cyanobacteria, a toxic blue-green algae, during the 2014 bloom season in late summer. However, the predicted bloom is expected to be smaller than last year's intense bloom, and considerably less than the record-setting 2011 bloom. Bloom impacts will vary across the lake's western basin and are classified by an estimate of both its concentration and how far it spreads.

ENVIRONMENT

Toledo Residents Cut Off From Water Supply After Tests Show Toxins

August 3, 2014 · 1:17 AM ET

THE ASSOCIATED PRESS

SCIENCE

Cyanobacteria Are Far From Just Toledo's Problem

Carl Zimmer
MATTER AUG. 7, 2014

Harmful algal blooms continue to plague Lake Erie, threaten drinking water, fish, pets

18 Updated on August 30, 2017 at 10:22 AM, Posted on August 30, 2017 at 10:20 AM

The algae-clogged waters of Lake Erie's western basin at Maumee Bay State Park east of Toledo produced the growth of cyanobacteria and a toxin called microcystin that can be dangerous for people, birds, fish and pets.(The New York Times file photo)

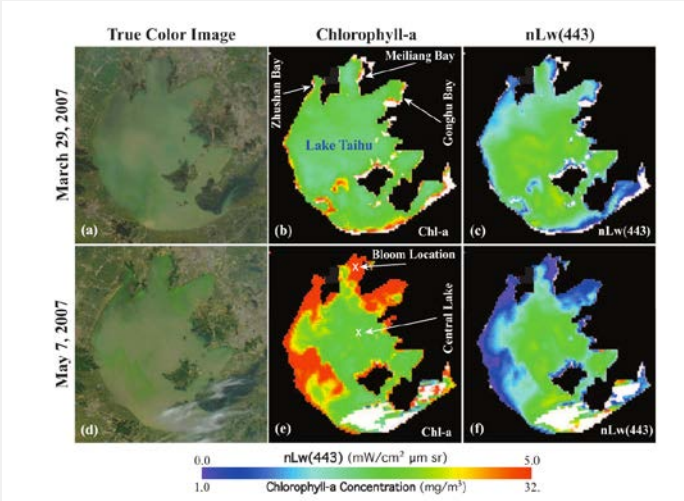
289 shares

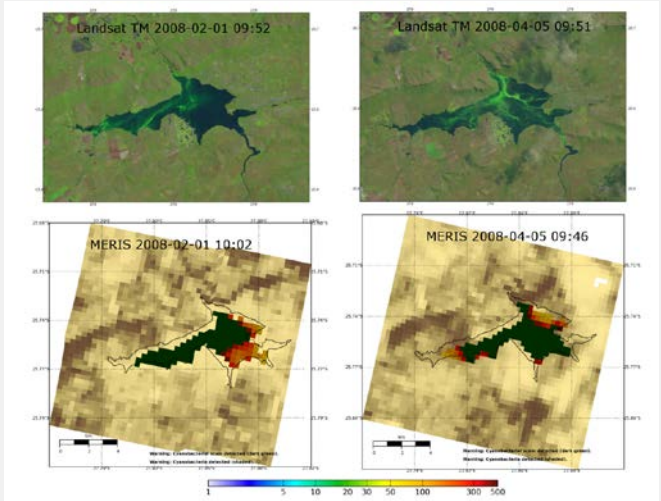
By James F. McCarty, The Plain Dealer, jmccarty@plaind.com

credits: AP, New York Times, Cleveland's The Plain Dealer

Remote Sensing of CyanoHABs

Lake Taihu, China





Hartbeespoort Dam South Africa

Lake Erie, USA

Nodularia bloom, Baltic Sea

Credits: Lake Taihu (Wang & Shi 2008), Lake Erie (NASA/NOAA-NCCOS)

Credit: Hartbeespoort Dam (Matthews & Bernard 2015), Baltic Sea (http://www.wimsoft.com/Various_HABs/Satellite_detection_of_HABs.htm)

Remote Sensing of Cyanobacterial Blooms

- Chlorophyll-a concentration
- Chlorophyll-a anomaly
- Algorithms targeting phycocyanin
- Cyanobacteria Index (CI)

Cyanobacteria Index (CI):
Wynne, TT, Stumpf, RP, Tomlinson, MC, Warner RA, Tester, PA, Dyble, J, and Fahnenstiel, GL (2008) 'Relating spectral shape to cyanobacterial blooms in the Laurentian Great Lakes', International Journal of Remote Sensing, 29:12, 3665 – 3672.

Cyanobacteria Index (CI)*

CI = - SS(681)

where SS is the spectral shape at 681 nm:

$$SS(681) = nLw(681nm) - nLw(665nm) - [nLw(709nm) - nLw(665nm)] * \frac{(681 - 665)}{(709 - 665)}$$

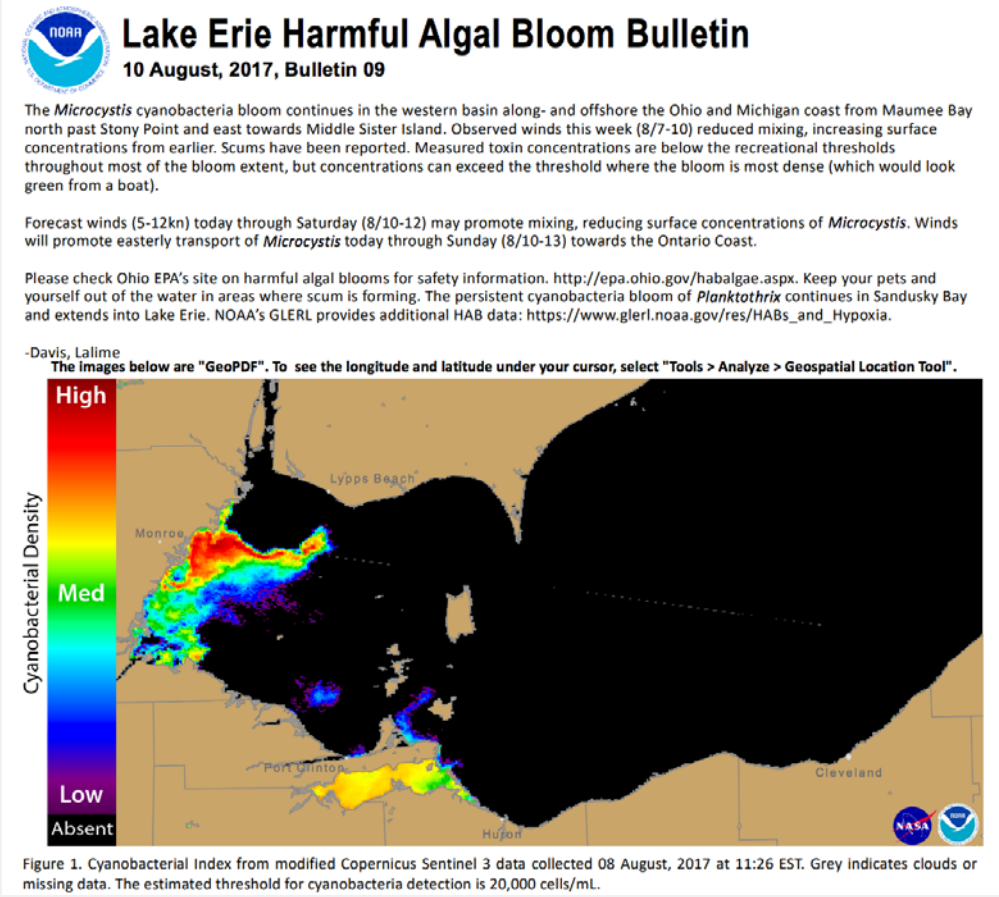
* example using L2 data for MERIS bands

CyanoHAB Tools – Case Studies

Forecasting the Location of CyanoHABs in Lake Erie

NOAA HAB Operational Forecast System

- *Microcystis aeruginosa* forms distinctive surface scums
- Bulletin helps forecast landfall of blooms
- To build its forecast, this Bulletin combines:
  - satellite imagery
  - field observations
  - fluid dynamics observations & models
  - predictive models
  - buoy data



Lake Erie Harmful Algal Bloom Bulletin
10 August, 2017, Bulletin 09

The *Microcystis* cyanobacteria bloom continues in the western basin along- and offshore the Ohio and Michigan coast from Maumee Bay north past Stony Point and east towards Middle Sister Island. Observed winds this week (8/7-10) reduced mixing, increasing surface concentrations from earlier. Scums have been reported. Measured toxin concentrations are below the recreational thresholds throughout most of the bloom extent, but concentrations can exceed the threshold where the bloom is most dense (which would look green from a boat).

Forecast winds (5-12kn) today through Saturday (8/10-12) may promote mixing, reducing surface concentrations of *Microcystis*. Winds will promote easterly transport of *Microcystis* today through Sunday (8/10-13) towards the Ontario Coast.

Please check Ohio EPA's site on harmful algal blooms for safety information. http://epa.ohio.gov/habalgae.aspx. Keep your pets and yourself out of the water in areas where scum is forming. The persistent cyanobacteria bloom of *Planktothrix* continues in Sandusky Bay and extends into Lake Erie. NOAA's GLERL provides additional HAB data: https://www.glerl.noaa.gov/res/HABs_and_Hypoxia.

-Davis, Lalime

The images below are "GeoPDF". To see the longitude and latitude under your cursor, select "Tools > Analyze > Geospatial Location Tool".

Figure 1. Cyanobacterial Index from modified Copernicus Sentinel 3 data collected 08 August, 2017 at 11:26 EST. Grey indicates clouds or missing data. The estimated threshold for cyanobacteria detection is 20,000 cells/mL.

https://tidesandcurrents.noaa.gov/hab/lakeerie.html
https://tidesandcurrents.noaa.gov/hab/hab_publication/Lake_Erie_HAB_Bulletin_Guide.pdf

Bulletin Credit: https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/bulletin.html

Forecasting the Location of CyanoHABs in Lake Erie

CI from Sentinel-3

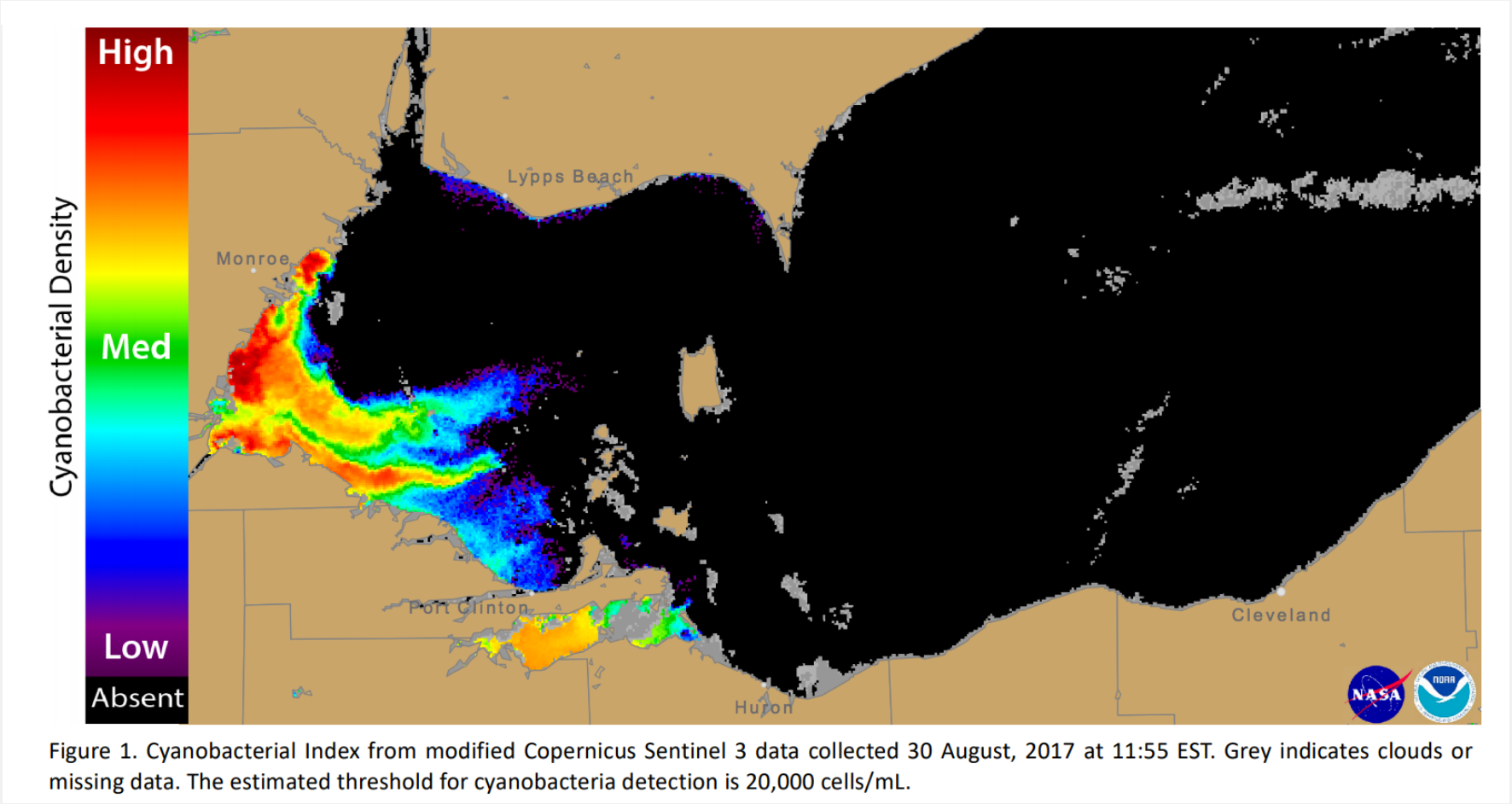


Figure 1. Cyanobacterial Index from modified Copernicus Sentinel 3 data collected 30 August, 2017 at 11:55 EST. Grey indicates clouds or missing data. The estimated threshold for cyanobacteria detection is 20,000 cells/mL.

https://tidesandcurrents.noaa.gov/hab/lakeerie.html
https://tidesandcurrents.noaa.gov/hab/hab_publication/Lake_Erie_HAB_Bulletin_Guide.pdf

Forecasting the Location of CyanoHABs in Lake Erie

‘Nowcast’ from Sentinel-3 Image

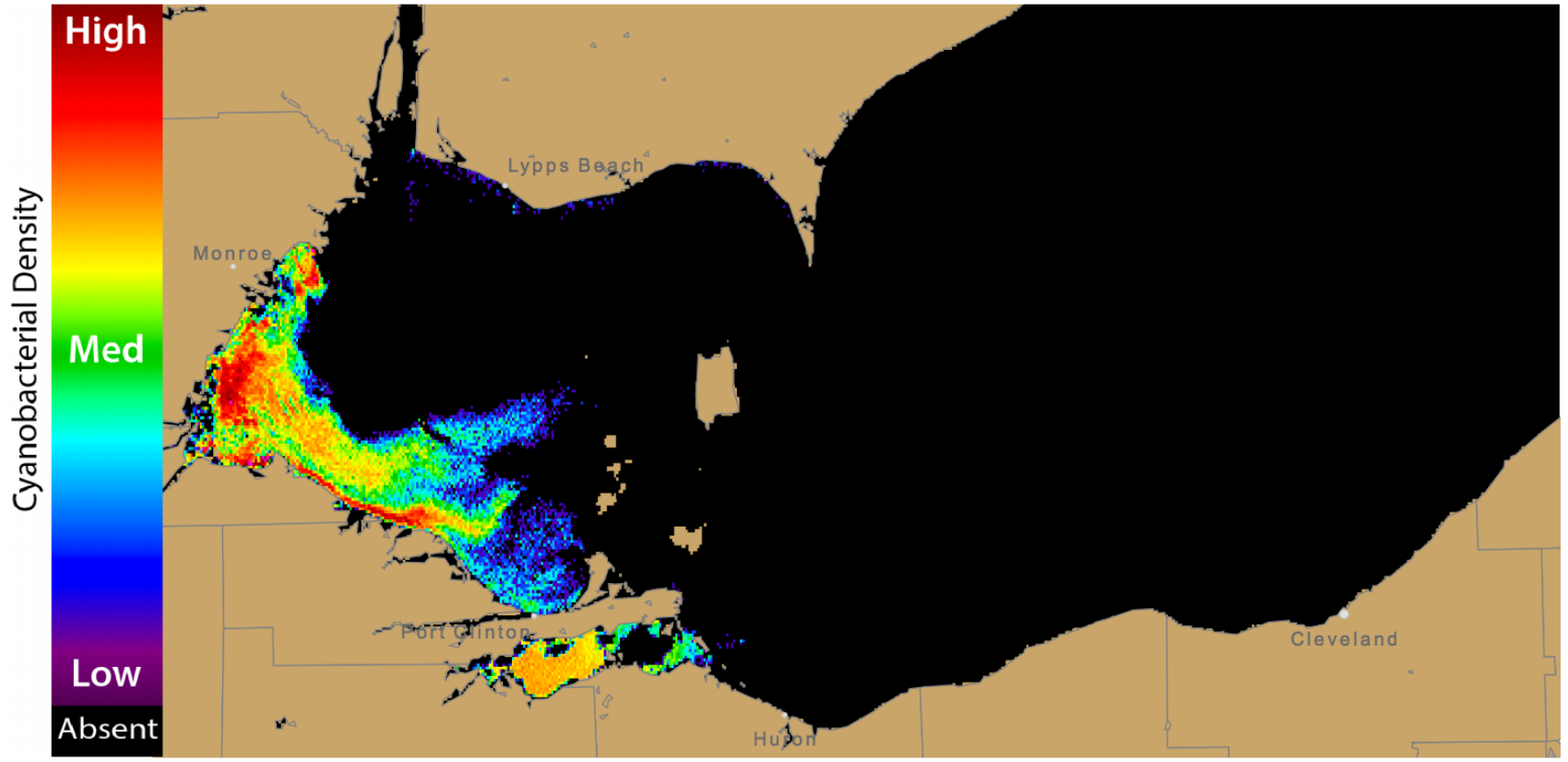
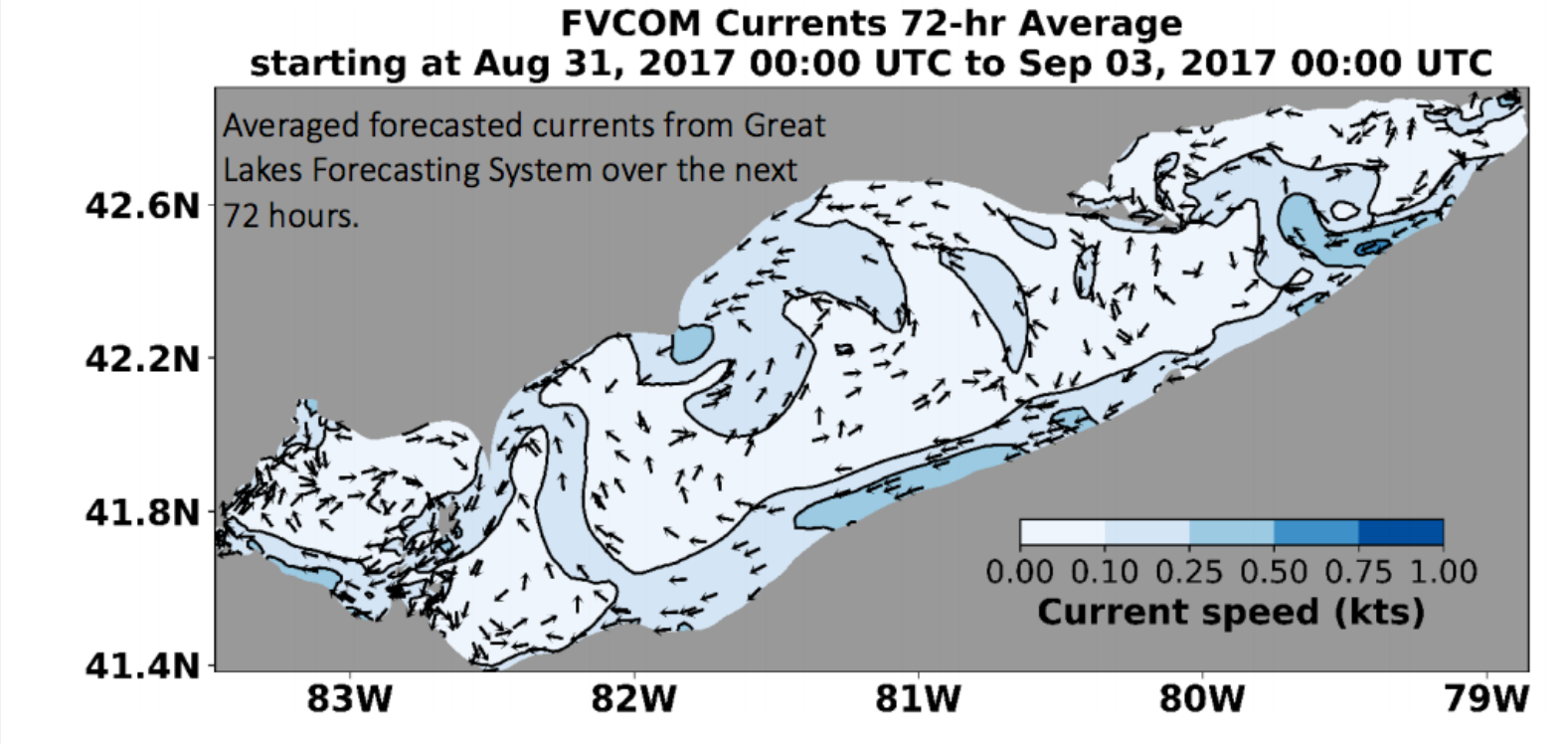


Figure 3. Nowcast position of bloom for 31 August, 2017 using GLFS modelled currents to move the bloom from the 30 August, 2017 image.

https://tidesandcurrents.noaa.gov/hab/lakeerie.html
https://tidesandcurrents.noaa.gov/hab/hab_publication/Lake_Erie_HAB_Bulletin_Guide.pdf

Forecasting the Location of CyanoHABs in Lake Erie

72 Hour Forecast of Surface Currents



https://tidesandcurrents.noaa.gov/hab/lakeerie.html
https://tidesandcurrents.noaa.gov/hab/hab_publication/Lake_Erie_HAB_Bulletin_Guide.pdf

Forecasting the Location of CyanoHABs in Lake Erie

CI Forecast 72 Hours into the Future

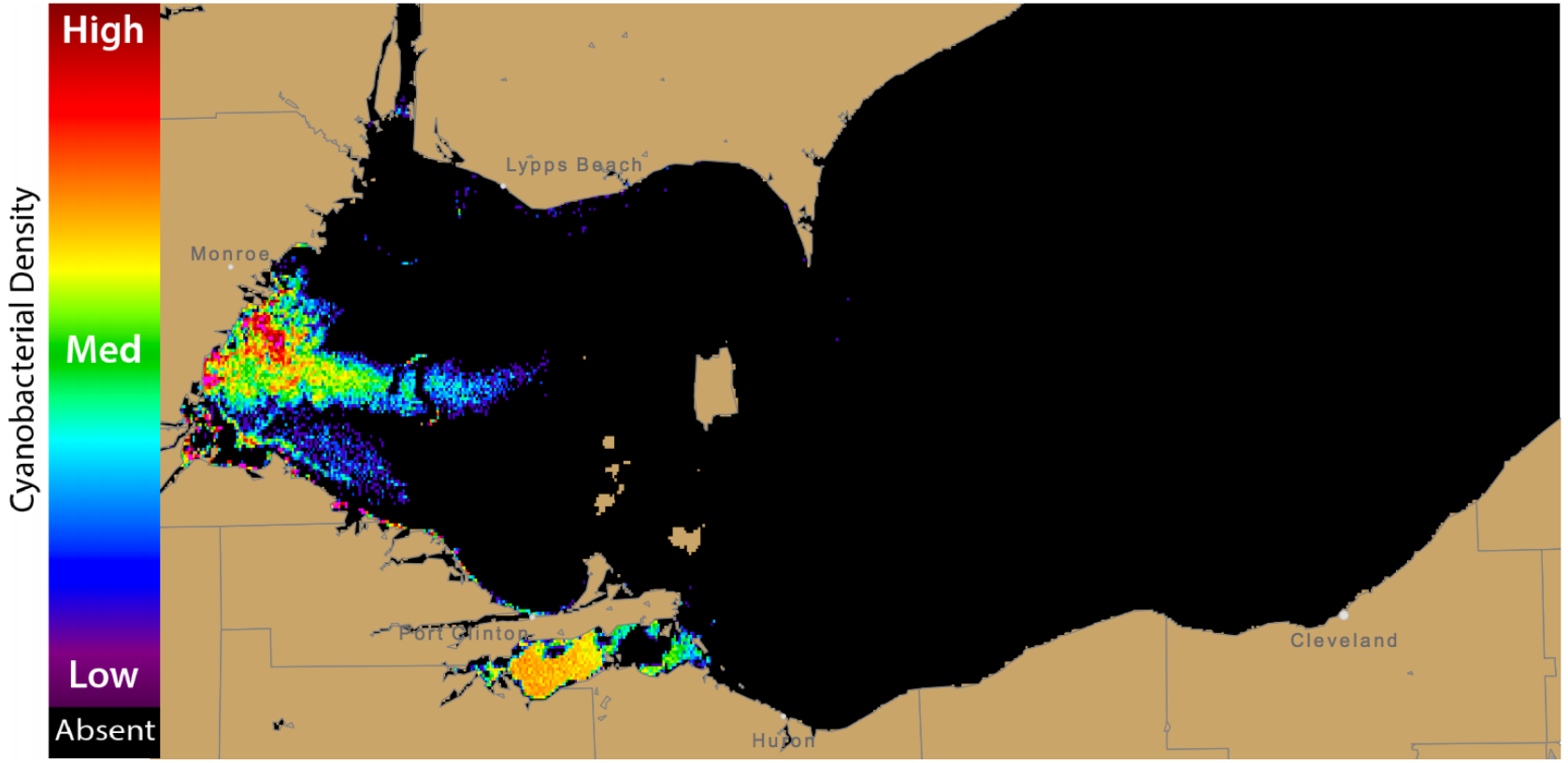
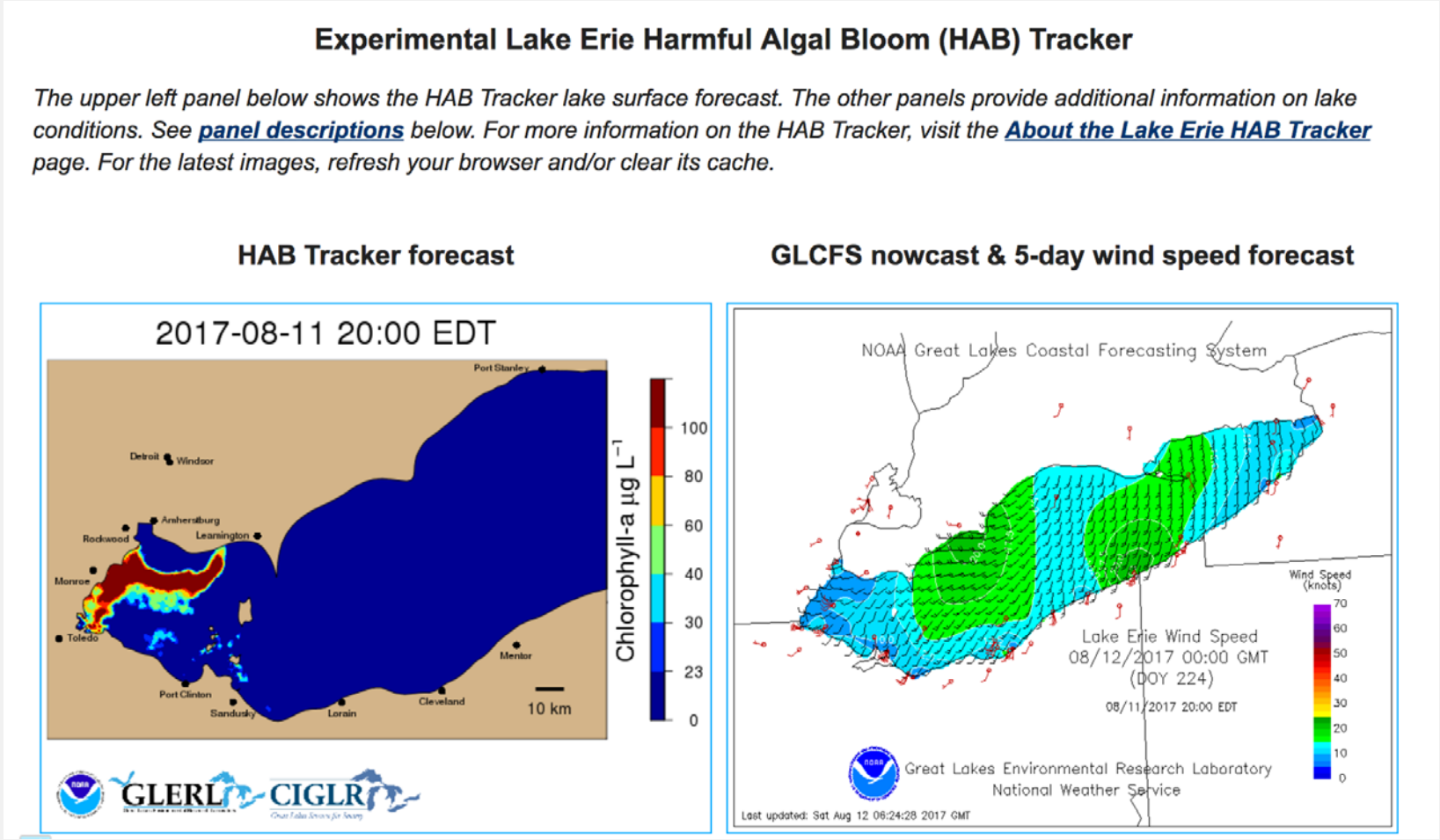


Figure 4. Forecast position of bloom for 03 September, 2017 using GLFS modelled currents to move the bloom from the 30 August, 2017

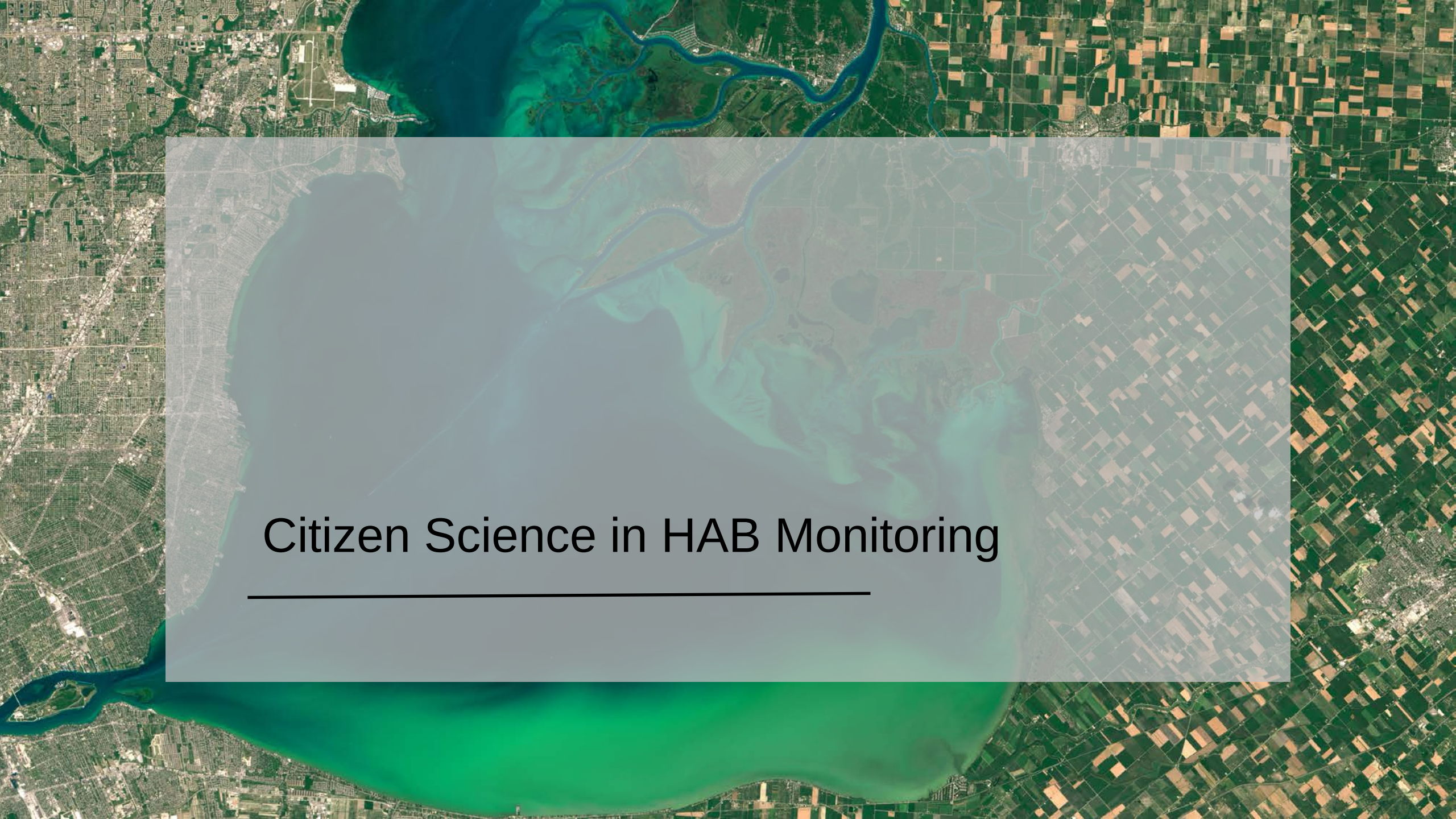
https://tidesandcurrents.noaa.gov/hab/lakeerie.html
https://tidesandcurrents.noaa.gov/hab/hab_publication/Lake_Erie_HAB_Bulletin_Guide.pdf

Coupled Remote Sensing Data and Geophysical Models

Case Study – HAB Tracker



https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/habTracker.html; https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/habTracker_about.html



Citizen Science in HAB Monitoring

Citizen Science Programs

Case Studies

- Phytoplankton Monitoring Network
- Cyanobacteria Monitoring Collaborative
- General aviation pilots collecting imagery
- CyAN (Guest Speaker Wilson Salls)

Phytoplankton Monitoring Network

https://products.coastalscience.noaa.gov/pmn/

Phytoplankton Monitoring Network

https://www.ncddc.noaa.gov/website/PMN/viewer.htm

Cyanobacteria Monitoring Collaborative

https://cyanos.org/

General Aviation Pilots as Citizen Scientists

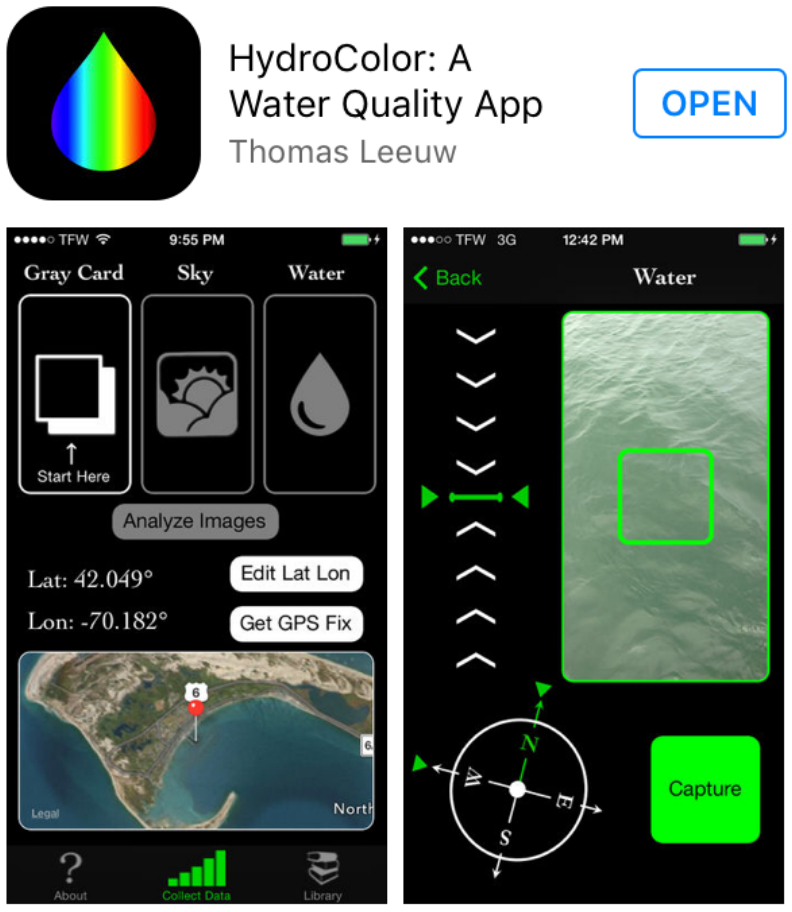
https://re.grc.nasa.gov/citizen-scientists-track-algal-blooms/

General Aviation Pilots as Citizen Scientists

https://re.grc.nasa.gov/citizen-scientists-track-algal-blooms/

Citizen Science Tools

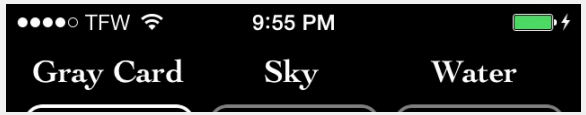
Case Studies – Apps!



Measuring Reflectance from a Smart Phone

HydroColor

- Estimates remote sensing reflectance (Rrs) using phone's spectral response curves
- Computes Turbidity, Suspended Particulate Matter (SPM), and backscatter coefficient from Rrs
- "Point-and-shoot" capability
- Available on iPhone and iPod Touch



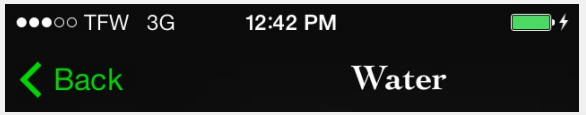
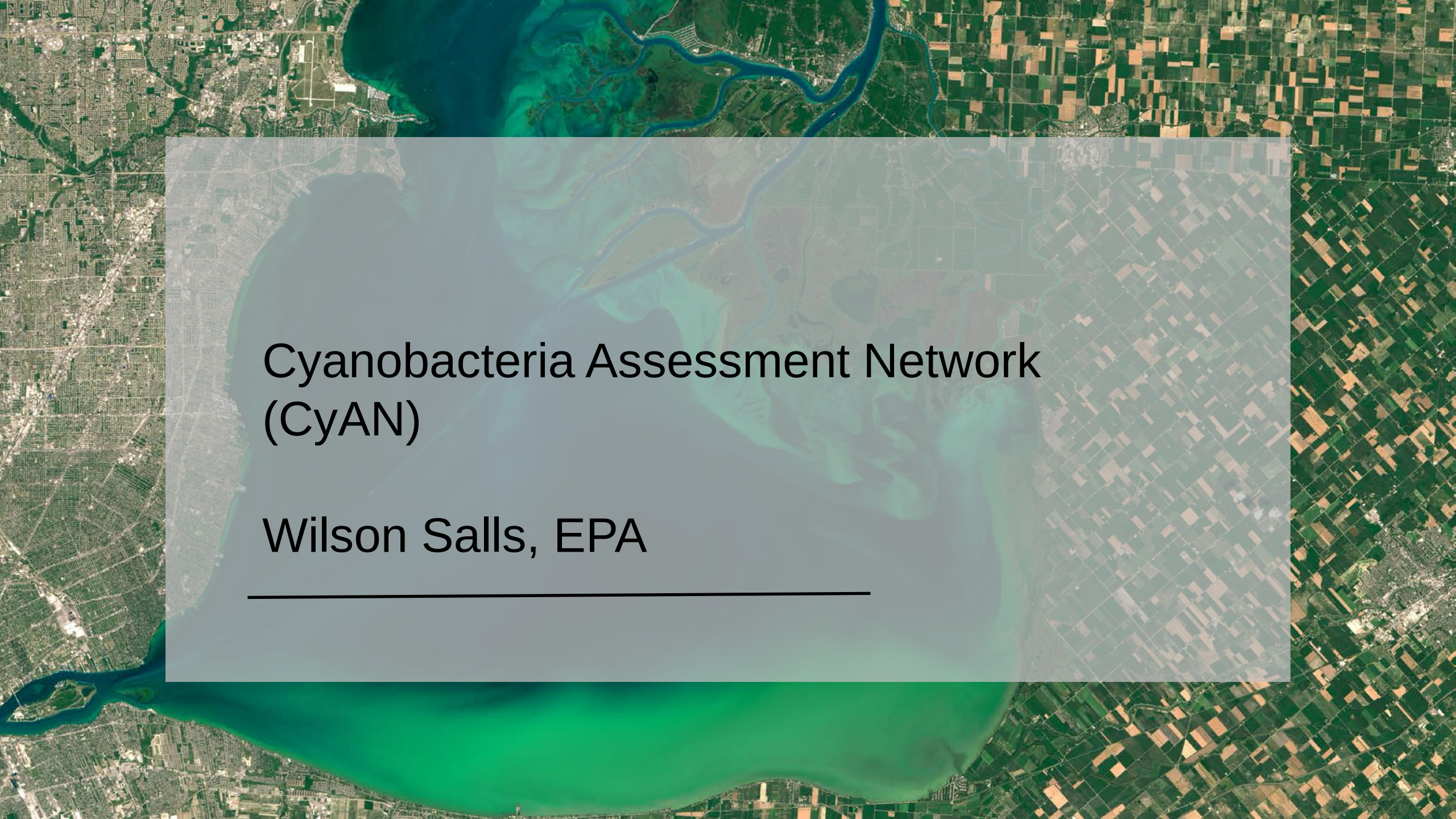


Table 1. List of parameters derived by HydroColor along with the estimated uncertainty for each method.

Parameter	Equation	Source	Uncertainty
Remote Sensing Reflectance	$R_{rs} = \frac{L_{water} - 0.028 L_{sky}}{\frac{\pi}{0.18} L_{card}}$	Mobley 1999	±15% (mean absolute relative error from figure 4, for all channels)
Turbidity	$Turbidity = \frac{27.7 R_{rs}(Red)}{0.05 - R_{rs}(Red)}$	Figure 5	±36% (mean absolute relative error from figure 5)
Suspended Particulate Matter	$log_{10}(SPM) = 1.02 log_{10}(Turbidity) - 0.04$	Neukermans et al. 2012	±38% (propagation of error in turbidity and the relationship between turbidity and SPM)
Backscatter Coefficient	$r_{rs} = 0.0949(\frac{b_b}{b_b + a_p + a_w}) + 0.0794(\frac{b_b}{b_b + a_p + a_w})^2$ Solved for b_b assuming constant a_p^*	Gordon et al. 1998	±41% (propagation of error in SPM and R_{rs})

http://misclab.umeoce.maine.edu/research/HydroColor.php



Cyanobacteria Assessment Network (CyAN)

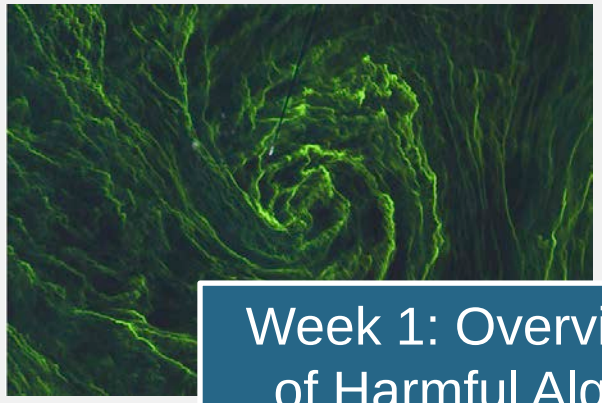
Wilson Salls, EPA

Outline – Session 4

- Overview of cyanobacterial cyanoHABs
- Examples of freshwater cyanoHAB monitoring tools
- Examples of how citizen science can be used for HAB monitoring
- Cyanobacteria Assessment Network (CyAN)

Photo Credit: Aerial Associates Photography (http://skypics.com)

Course Summary



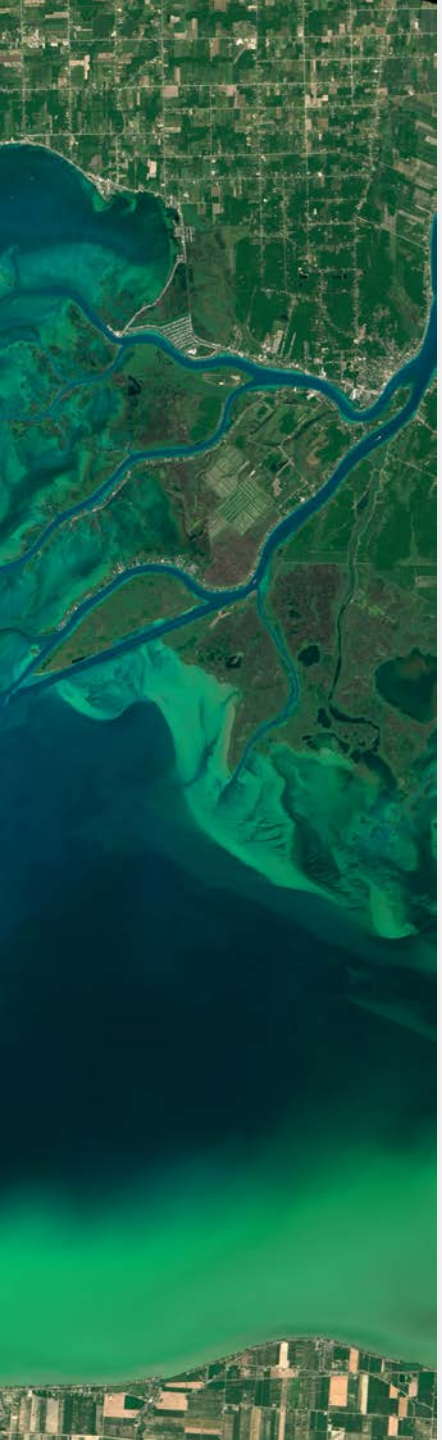
Week 1: Overview of Harmful Algal Blooms

Week 2: Platforms & Sensors, Data Access, and Processing

Credit: Paul Hillman/NOAA

Week 3: HABs in the Coastal Environment

Week 4: Large Scale Monitoring



National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Thank you!