



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

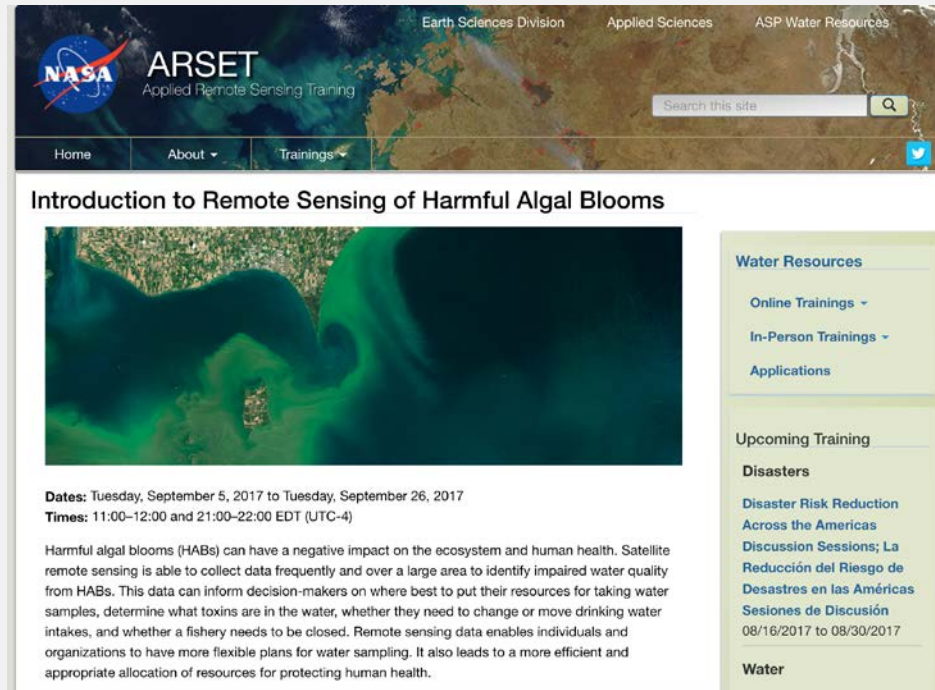
Trainers: Sherry Palacios
Amita Mehta

Course Structure

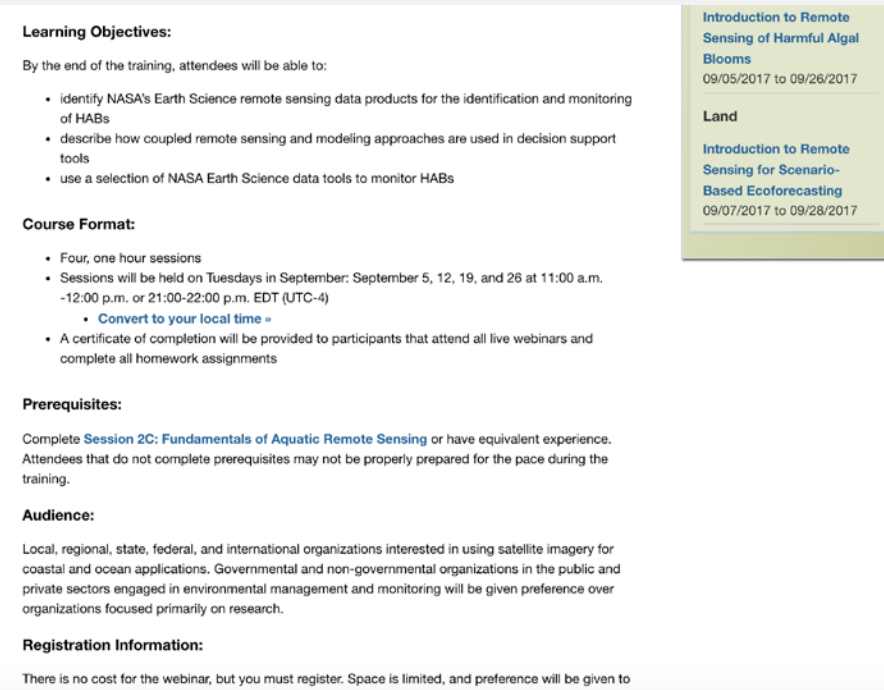
- Four, 1-hour sessions: Tuesdays in September (5, 12, 19, 26)
- Each session will be given twice:
 - Session A: 11:00 – 12:00 EDT (UTC-4)
 - Session B: 21:00 – 22:00 EDT (UTC-4)
- Presentations:
 - Overview of Harmful Algal Blooms (HABs)
 - Platforms and sensors, data access, and data processing
 - 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>



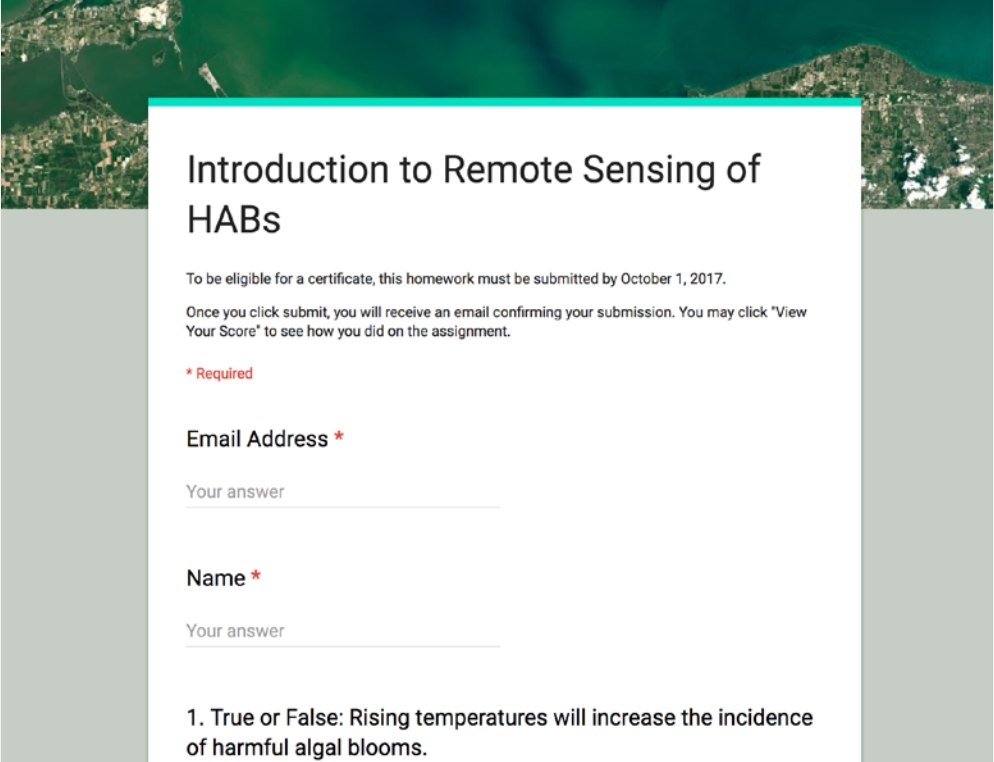
The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo and the text 'ARSET Applied Remote Sensing Training'. Navigation links for 'Home', 'About', and 'Trainings' are visible. The main content area features a satellite image of a coastal area with green algal blooms. The course title is 'Introduction to Remote Sensing of Harmful Algal Blooms'. Below the image, the dates are listed as 'Tuesday, September 5, 2017 to Tuesday, September 26, 2017' and the times as '11:00-12:00 and 21:00-22:00 EDT (UTC-4)'. A paragraph of text describes the impact of HABS and the role of satellite remote sensing. On the right side, there are navigation menus for 'Water Resources' (Online Trainings, In-Person Trainings, Applications), 'Upcoming Training' (Disasters, Disaster Risk Reduction Across the Americas Discussion Sessions; La Reducción del Riesgo de Desastres en las Américas Sesiones de Discusión, 08/16/2017 to 08/30/2017), and 'Water'.



The screenshot shows the course details page. It includes sections for 'Learning Objectives', 'Course Format', 'Prerequisites', 'Audience', and 'Registration Information'. The 'Learning Objectives' section lists three bullet points: identifying NASA's Earth Science remote sensing data products, describing coupled remote sensing and modeling approaches, and using NASA Earth Science data tools. The 'Course Format' section lists four bullet points: four one-hour sessions on Tuesdays in September, session times (11:00 a.m.-12:00 p.m. or 21:00-22:00 p.m. EDT), a link to 'Convert to your local time', and a certificate of completion. The 'Prerequisites' section states that attendees must complete 'Session 2C: Fundamentals of Aquatic Remote Sensing' or have equivalent experience. The 'Audience' section lists local, regional, state, federal, and international organizations. The 'Registration Information' section states that there is no cost but registration is required and space is limited. On the right side, there are two green boxes: one for 'Introduction to Remote Sensing of Harmful Algal Blooms' (09/05/2017 to 09/26/2017) and another for 'Introduction to Remote Sensing for Scenario-Based Ecoforecasting' (09/07/2017 to 09/28/2017).

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



Introduction to Remote Sensing of HABs

To be eligible for a certificate, this homework must be submitted by October 1, 2017.

Once you click submit, you will receive an email confirming your submission. You may click "View Your Score" to see how you did on the assignment.

*** Required**

Email Address *

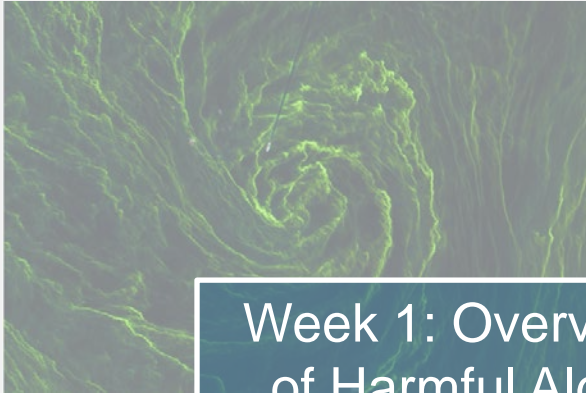
Your answer

Name *

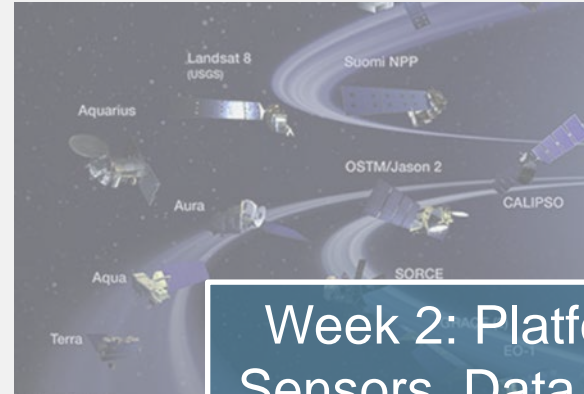
Your answer

1. True or False: Rising temperatures will increase the incidence of harmful algal blooms.

Course Outline



Week 1: Overview
of Harmful Algal
Blooms

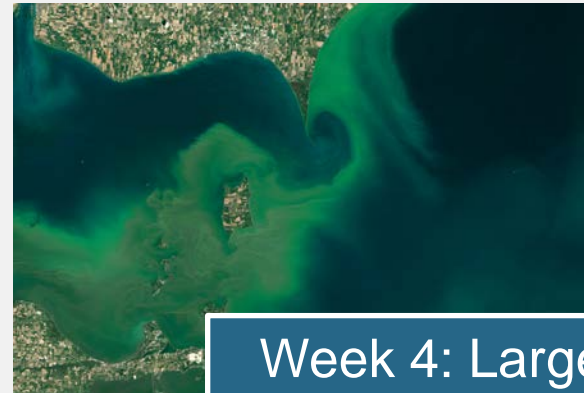


Week 2: Platforms &
Sensors, Data Access,
and Processing



Week 3: HABs in
the Coastal
Environment

Credit: Paul
Hillman/NOAA



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>)

An aerial photograph of a river delta, likely the Mississippi River delta, showing a complex network of waterways and land parcels. A semi-transparent map overlay is centered on the image, showing the same geographical area with a different color scheme and grid lines. The text "Review of Weeks 1, 2 & 3" is overlaid on the map.

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.”

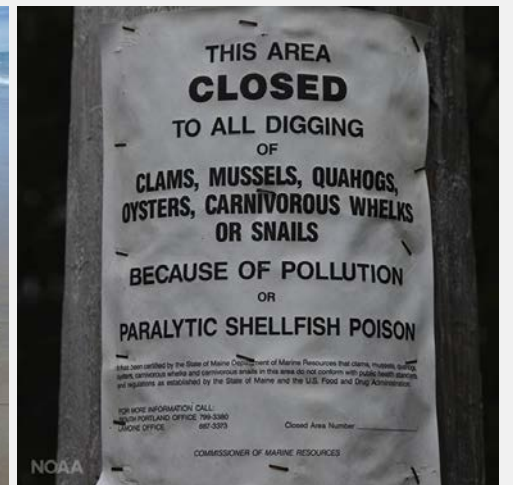
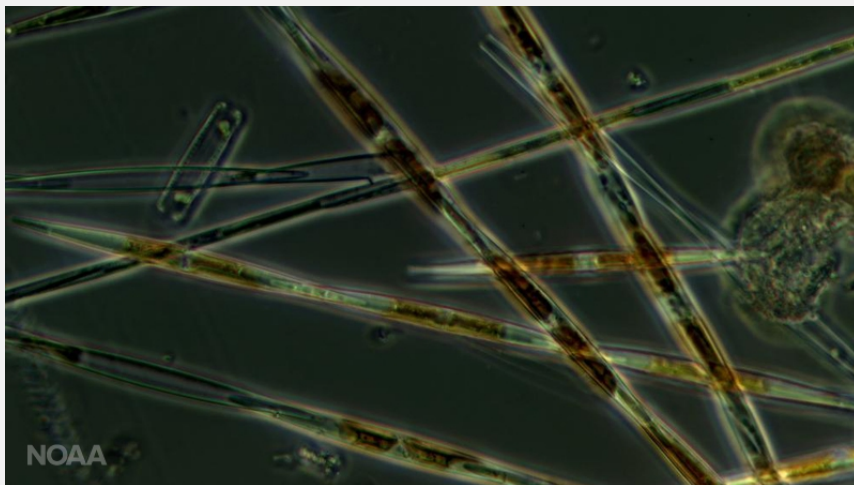


Image credit: <http://www.noaa.gov/what-is-harmful-algal-bloom>

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)



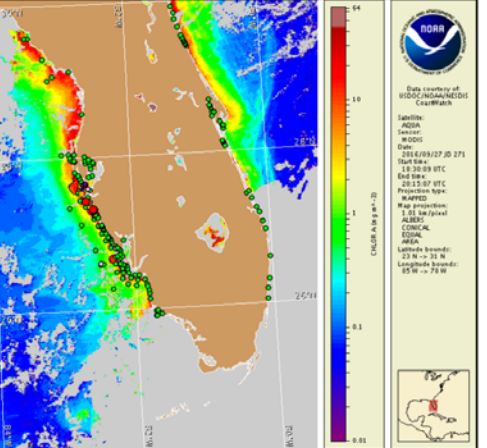
Gulf of Mexico Harmful Algal Bloom Bulletin
 Region: Southwest Florida
 Thursday, 29 September 2016
 NOAA National Ocean Service
 NOAA Satellite and Information Service
 NOAA National Weather Service
 Last bulletin: Monday, September 26, 2016

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, SCHK, 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



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>

- *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

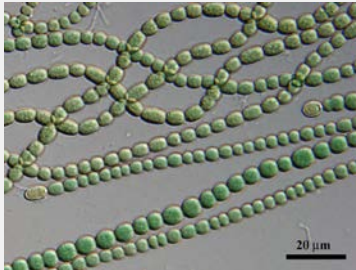
<https://tidesandcurrents.noaa.gov/hab/bulletins.html>;
https://tidesandcurrents.noaa.gov/hab/hab_publication/habfs_bulletin_guide.pdf

An aerial photograph of a large body of water, likely a bay or estuary, showing a significant cyanobacterial bloom. The water is a deep, vibrant green, contrasting with the surrounding land. The land is a patchwork of green and brown fields, with some urban areas visible. A semi-transparent map overlay is centered on the water, showing the same area with a different color scheme, possibly representing bathymetry or water depth. The map overlay is a light blue/green color, and the text 'Overview of CyanoHABs' is overlaid on it.

Overview of CyanoHABs

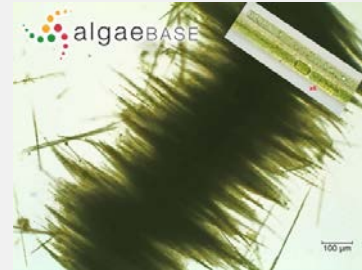
Some Common CyanoHABs and Their Toxins

Anabaena



anatoxins
microcystin
saxitoxins

Aphanizomenon



saxitoxins
cylindrospermopsins

Cylindrospermopsis



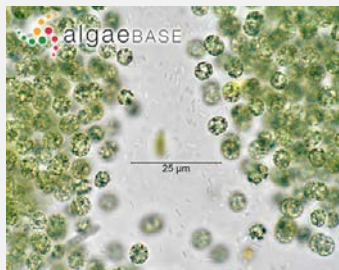
saxitoxins
cylindrospermopsins

Lyngbya



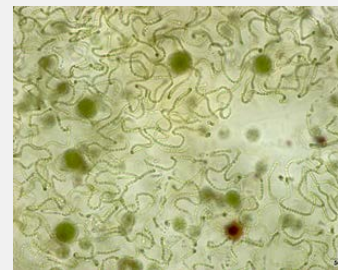
aplysiatoxins
lyngbyatoxin a

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

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)

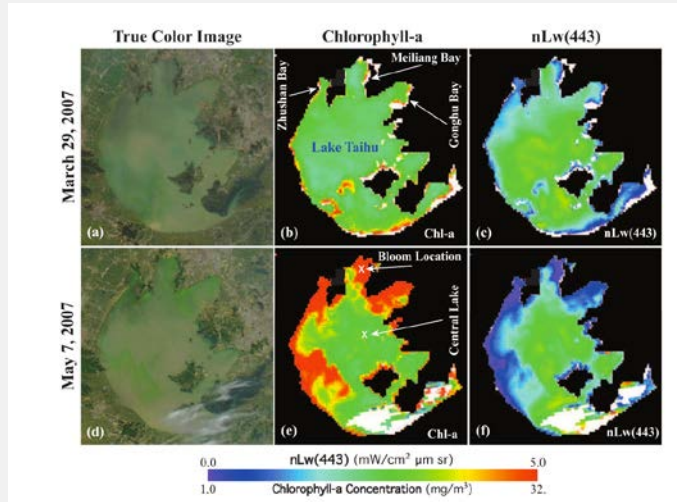


By [James F. McCarty, The Plain Dealer](#), jmccarty@plaind.com

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

Remote Sensing of CyanoHABs

Lake Taihu, China

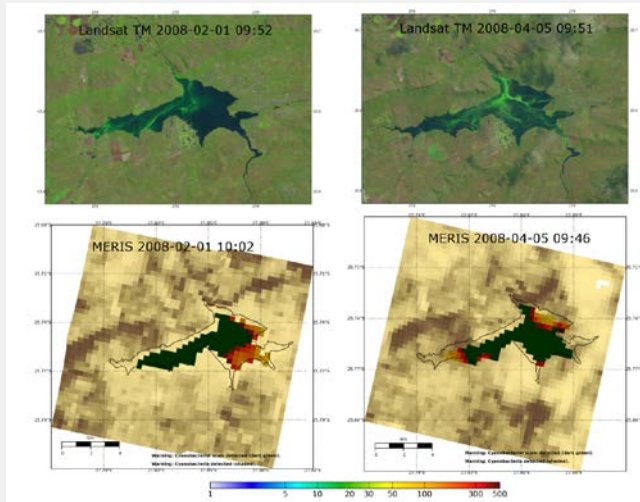


Lake Erie, USA



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

Hartbeespoort Dam South Africa



Nodularia bloom, Baltic Sea

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

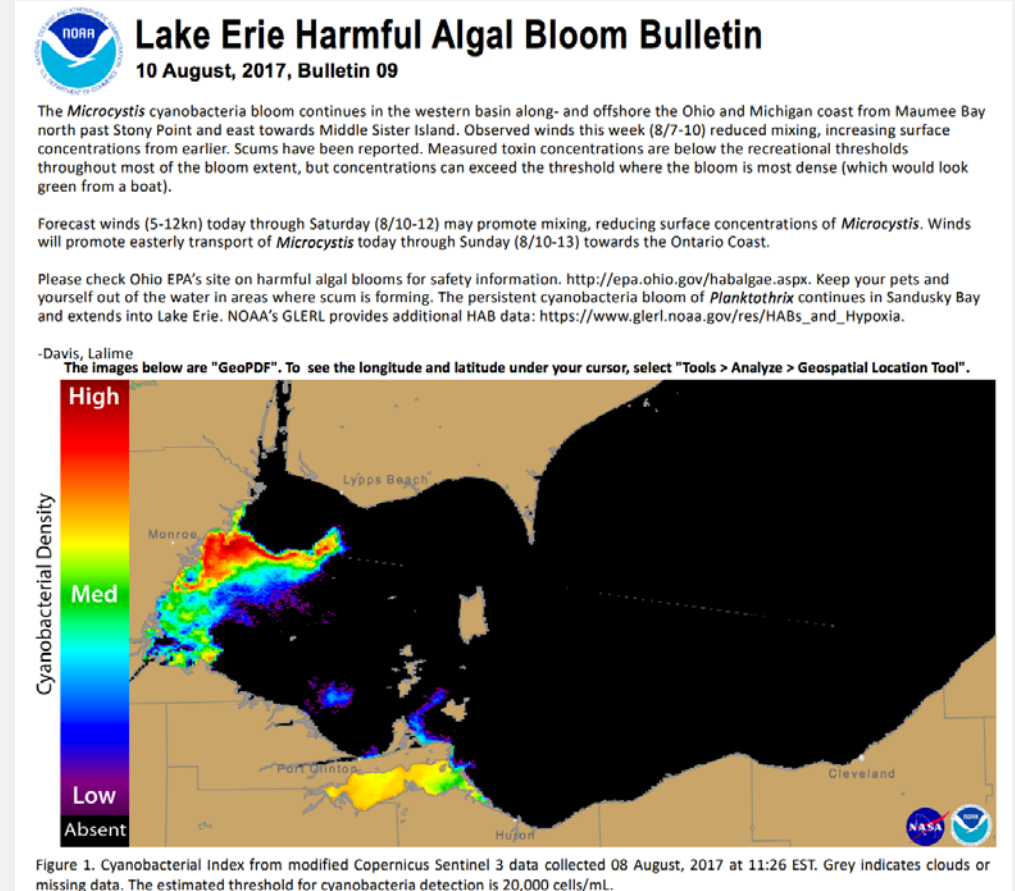
An aerial photograph of a river system, likely the Mississippi River, showing a large body of water with a prominent cyanobloom (greenish discoloration) in the lower portion. The surrounding land is a mix of urban areas with grid patterns and agricultural fields. A semi-transparent grey rectangular overlay covers the central part of the image, containing the title text.

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



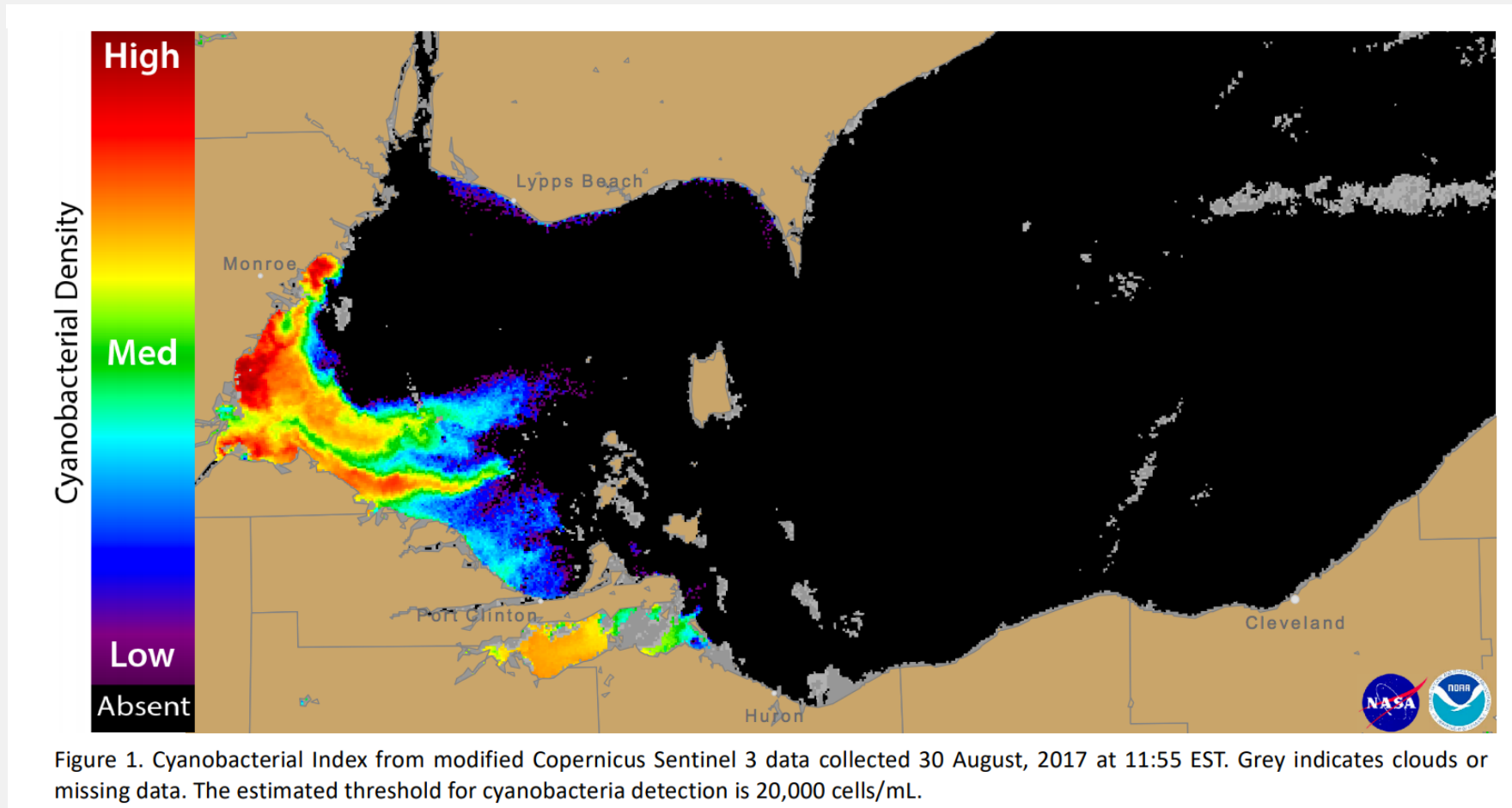
<https://tidesandcurrents.noaa.gov/hab/lakeerie.html>

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

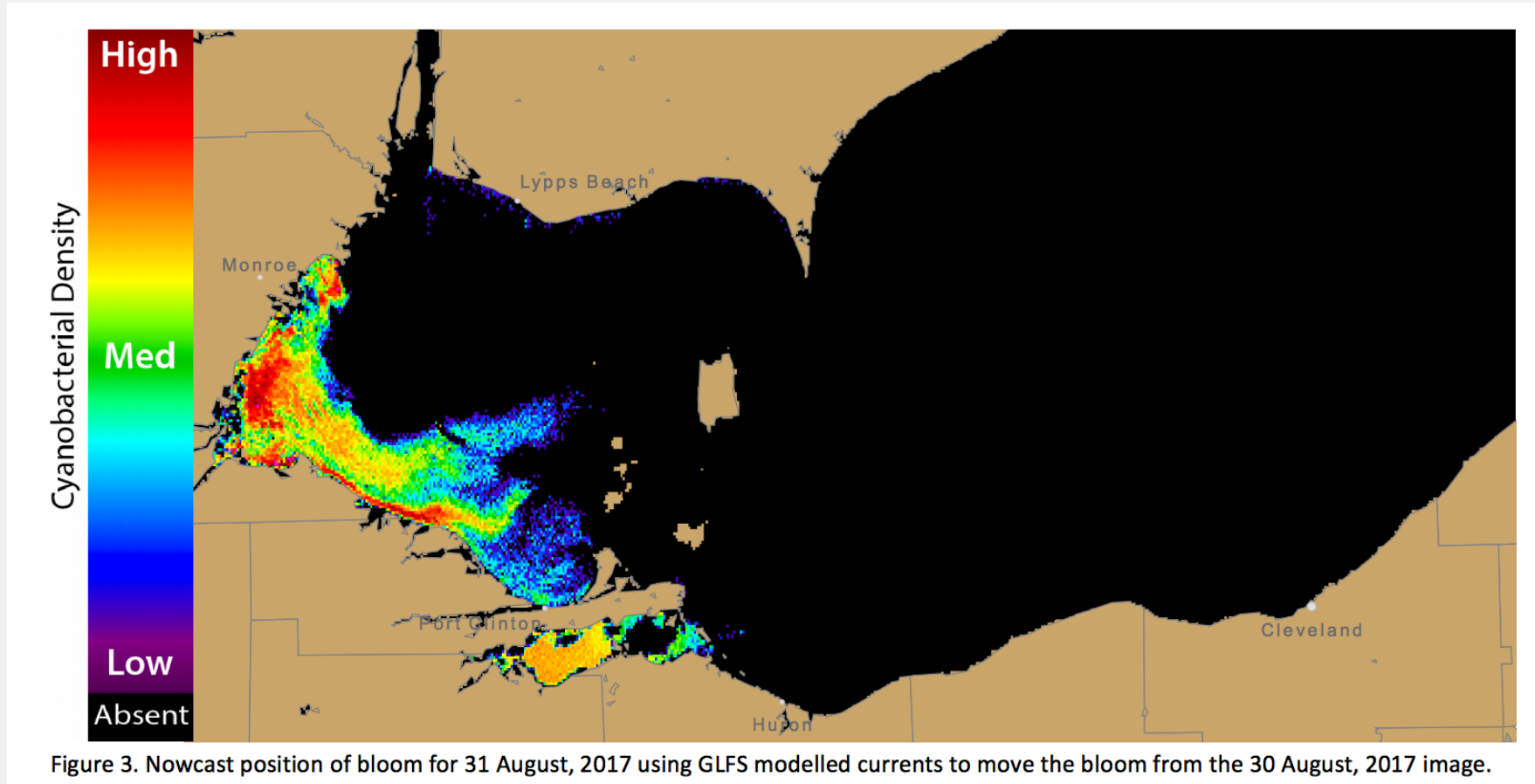


<https://tidesandcurrents.noaa.gov/hab/lakeerie.html>

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

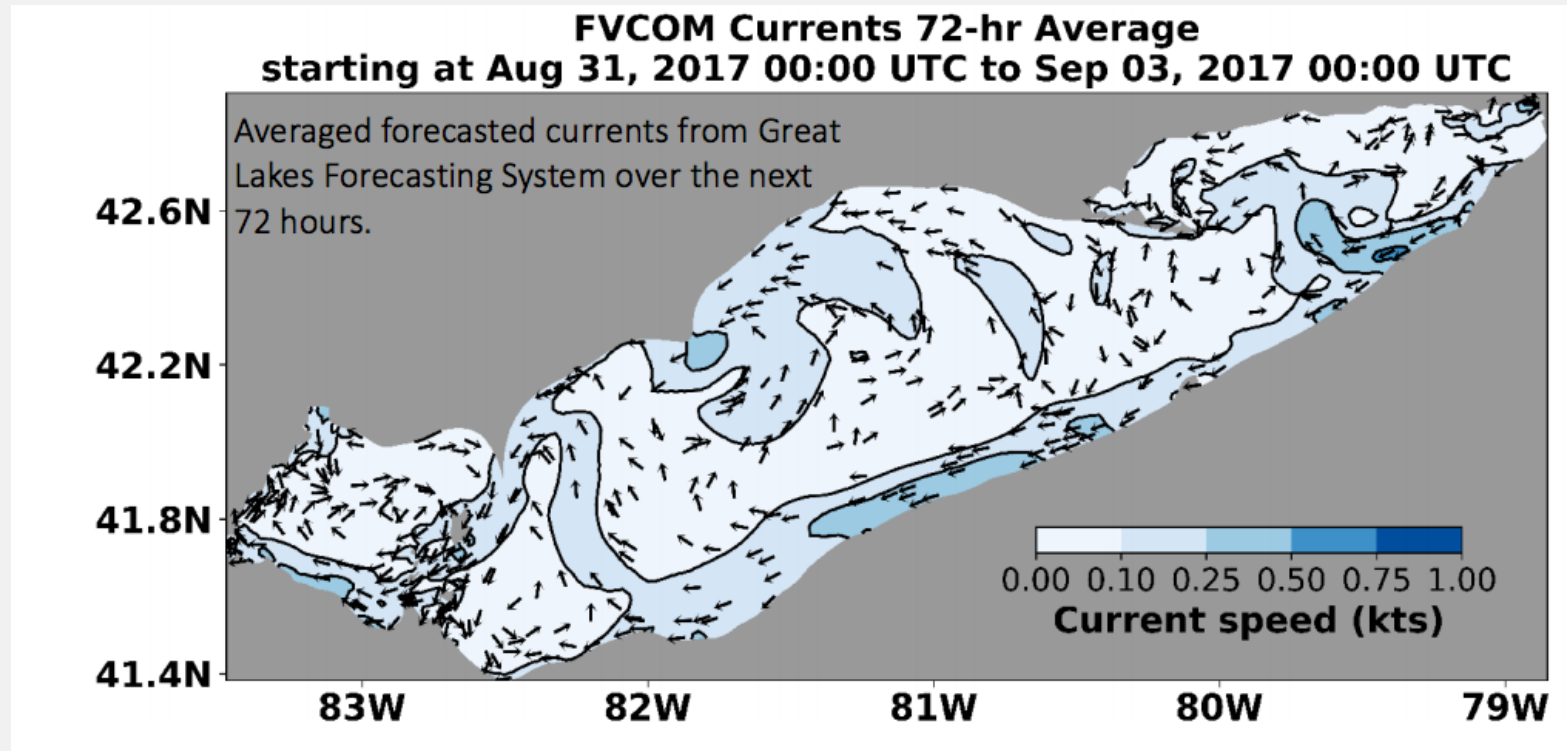


<https://tidesandcurrents.noaa.gov/hab/lakeerie.html>

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

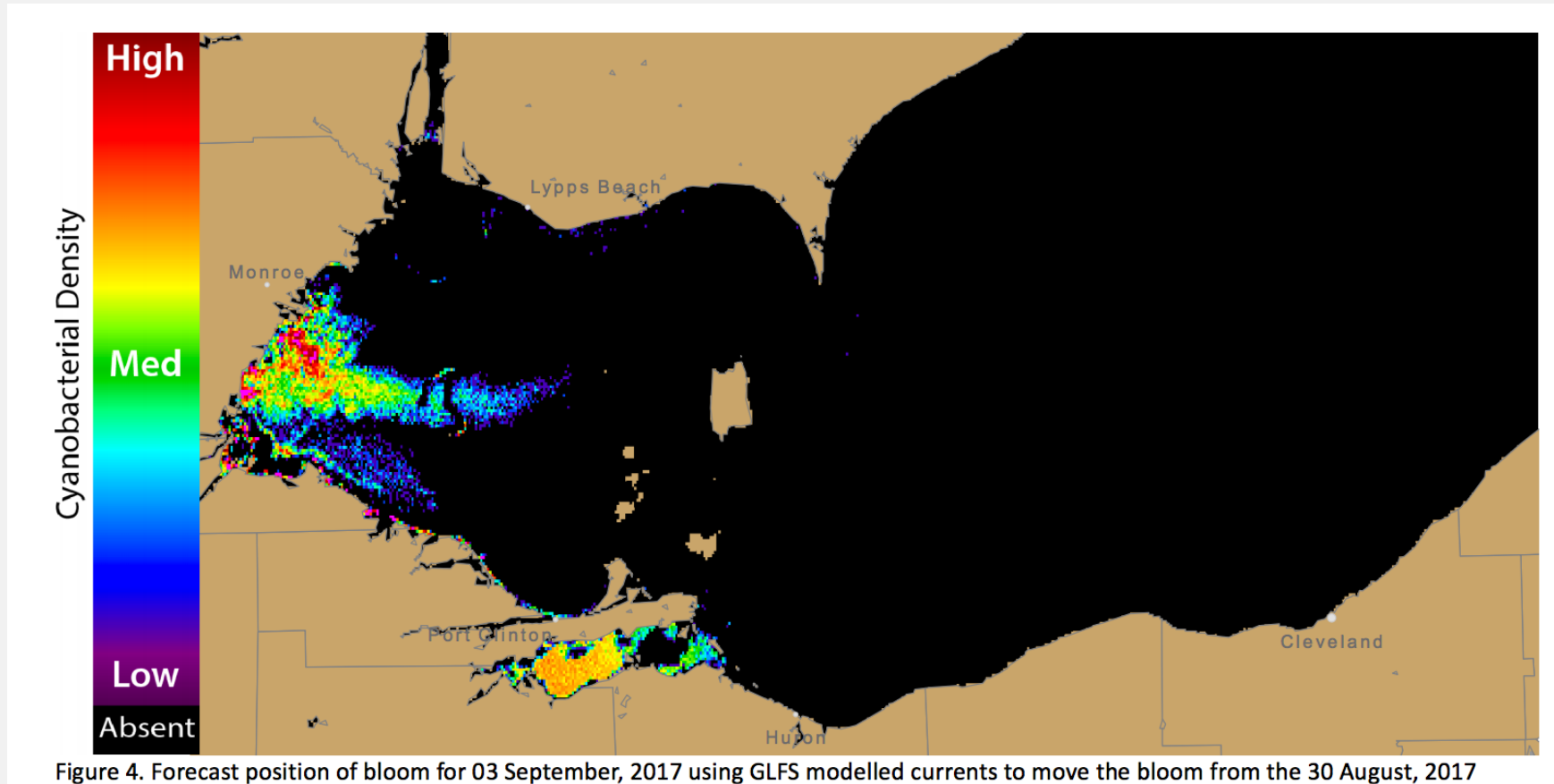


<https://tidesandcurrents.noaa.gov/hab/lakeerie.html>

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



<https://tidesandcurrents.noaa.gov/hab/lakeerie.html>

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

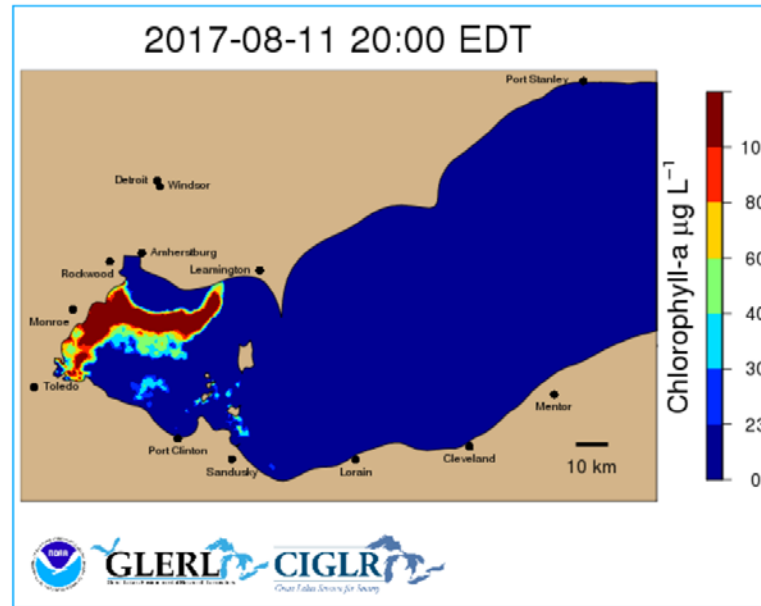
Coupled Remote Sensing Data and Geophysical Models

Case Study – HAB Tracker

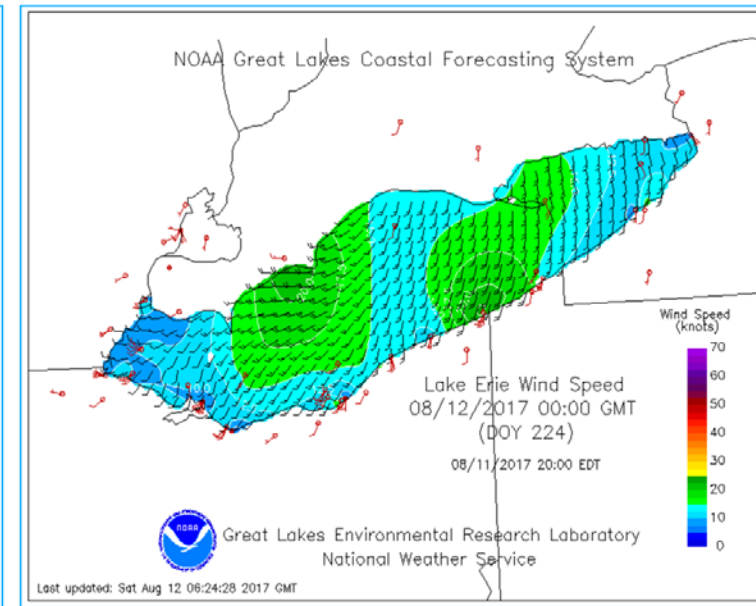
Experimental Lake Erie Harmful Algal Bloom (HAB) Tracker

The upper left panel below shows the HAB Tracker lake surface forecast. The other panels provide additional information on lake conditions. See [panel descriptions](#) below. For more information on the HAB Tracker, visit the [About the Lake Erie HAB Tracker](#) page. For the latest images, refresh your browser and/or clear its cache.

HAB Tracker forecast



GLCFS nowcast & 5-day wind speed forecast



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

An aerial photograph of a river system, likely the Mississippi River, showing a large body of water with a greenish tint, possibly indicating a harmful algal bloom (HAB). The surrounding land is a mix of urban areas with grid patterns and agricultural fields. A semi-transparent grey rectangle is overlaid on the image, containing the title text.

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/>

The National Centers for Coastal Ocean Science is the research office of the NOAA National Ocean Service Search NCCOS

NCCOS Phytoplankton Monitoring Network

Home About Us Our Research Projects Publications Products News Where We Work Funding Contact Us

You are here: PMN

Phytoplankton Monitoring Network

Promoting a better understanding of harmful algal blooms by way of volunteer monitoring

[SUBMIT DATA](#) [EXPLORE DATA](#)

Volunteering and Training



Current and Prospective Volunteers: Access everything you need to monitor or to get started monitoring with the PMN. [Schedule a Training Session.](#) [\(more\)](#)

Access Data



Submit current data collections and view historical data. If you have trouble submitting data, please contact [Steve Morton.](#) [\(more\)](#)

Phyto In the News



- [Study Provides Nutrient Reduction Targets to Reach](#)

Mobile Phyto App



Developed by a PMN volunteer, Phyto helps you learn to

INSIDE THIS SITE

- [Overview](#)
- [About the Project](#)
- [In The News](#)
- [Volunteering](#)
- [Image Gallery](#)
- [Data](#)
- [HABs](#)
- [Contact Us](#)

Phytoplankton Monitoring Network

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



Cyanobacteria Monitoring Collaborative

<https://cyanos.org/>



The image shows a screenshot of the Cyanobacteria Monitoring Collaborative website. At the top, there is a navigation menu with the following items: OVERVIEW, BLOOMWATCH, CYANOSCOPE, MONITORING, and NEWS. Below the navigation menu is a large banner image showing a satellite view of a water body with green and blue patches, indicating cyanobacteria blooms. The text "CYANOBACTERIA MONITORING COLLABORATIVE" is overlaid on the banner in large, white, sans-serif font. Below this, in smaller white text, it says "THREE COORDINATED MONITORING PROJECTS TO LOCATE AND UNDERSTAND HARMFUL CYANOBACTERIA". At the bottom of the banner, there are three black buttons with white text: "GET INFORMED", "GET INVOLVED", and "GET IN TOUCH". Below the banner is a light blue horizontal bar with the text "We work with citizen scientists, trained water professionals, and the general public to find and study cyanobacteria in waterbodies."

General Aviation Pilots as Citizen Scientists

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

The image is a screenshot of a NASA website page. At the top left is the NASA logo. To its right is a navigation menu with the following items: Overview, A Global Problem, Get Involved, Gallery, Field Testing, What's New, and Contact. The main content area features a large green semi-transparent box with white text. The title of the page is 'Citizen Scientists Track Algal Blooms'. Below the title, there are two lines of text: 'Harmful algal blooms (HABs) are a global problem.' and 'HABs can pose a serious risk to human health.' A paragraph follows, explaining that algae are natural components of marine and fresh water flora and that cyanobacteria (blue-green algae) are of special concern due to their potential impacts on drinking, fishing, and recreational waters. At the bottom of the green box, a yellow text box contains the following text: 'General aviation (GA) pilots functioning as citizen scientists can help develop an early warning system to alert communities of ensuing algal bloom along the coastline.' The background of the page is an aerial photograph of a coastal area with green water and a shoreline with buildings and trees.

NASA

Overview A Global Problem Get Involved Gallery Field Testing What's New Contact

Citizen Scientists Track Algal Blooms

Harmful algal blooms (HABs) are a global problem.

HABs can pose a serious risk to human health.

Algae are natural components of marine and fresh water flora that perform many roles vital for the health of ecosystems. Cyanobacteria, also known as blue-green algae, are of special concern because of their potential impacts on drinking, fishing, and recreational waters.

General aviation (GA) pilots functioning as citizen scientists can help develop an early warning system to alert communities of ensuing algal bloom along the coastline.

General Aviation Pilots as Citizen Scientists

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



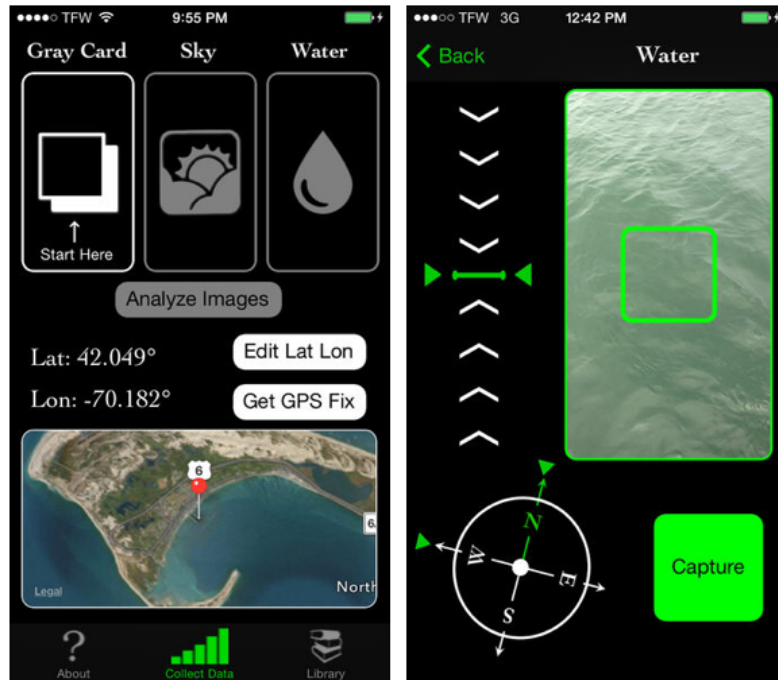
Citizen Science Tools

Case Studies – Apps!



HydroColor: A
Water Quality App
Thomas Leeuw

OPEN



Phyto
Gano Technologies...
★★★★☆ (7)

OPEN



Measuring Reflectance from a Smart Phone

HydroColor 

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

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



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

Parameter	Equation	Source	Uncertainty
Remote Sensing Reflectance	$R_{rs} = \frac{L_{water} - 0.028L_{sky}}{0.18L_{card}}$	Mobley 1999	±15% (mean absolute relative error from figure 4, for all channels)
Turbidity	$Turbidity = \frac{27.7R_{rs}(Red)}{0.05 - R_{rs}(Red)}$	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	$r_{rs} = 0.0949\left(\frac{b_b}{b_b + a_p + a_w}\right) + 0.0794\left(\frac{b_b}{b_b + a_p + a_w}\right)^2$ Solved for b_b assuming constant a_p^*	Gordon et al. 1998	±41% (propagation of error in SPM and R_{rs})





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

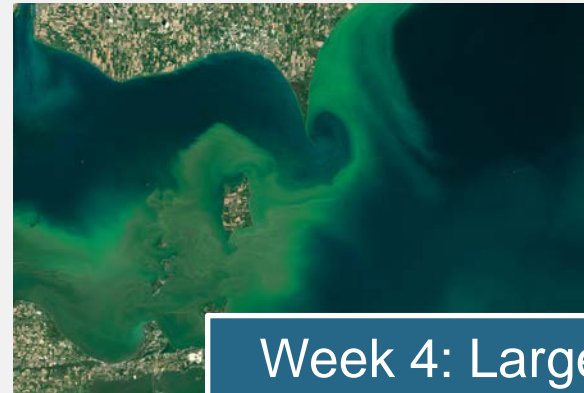


Week 2: Platforms &
Sensors, Data Access,
and Processing



Credit: Paul
Hillman/NOAA

Week 3: HABs in
the Coastal
Environment



Week 4: Large Scale
Monitoring



ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

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Thank you!
