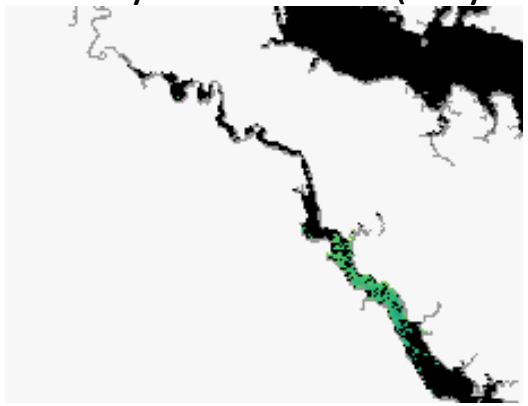
Bloom surveillance from Space, an update on CyAN and other bloom monitoring activities at NOAA

Shelly Tomlinson

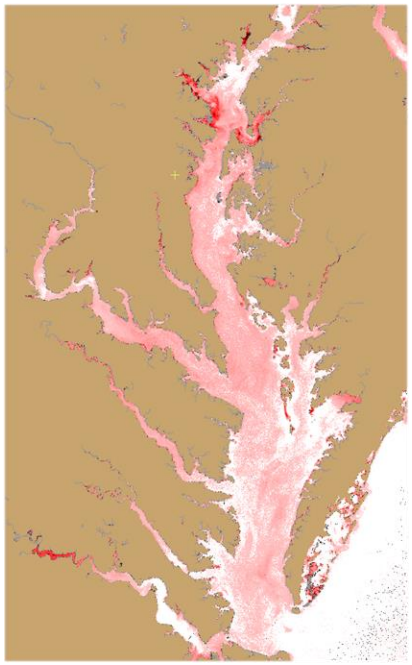
National Oceanic and Atmospheric Administration, NCCOS

Custom Satellite-derived products for algal bloom monitoring

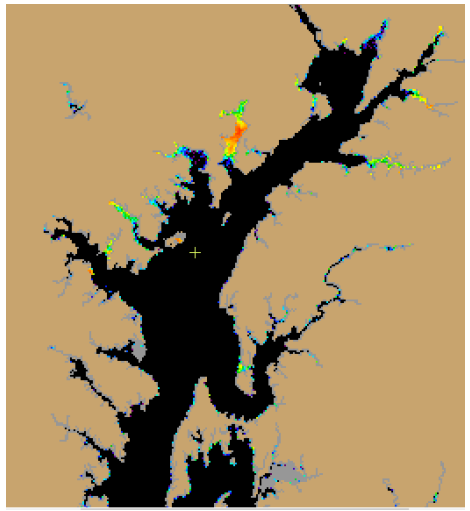
OLCI Cyanobacteria (CIcyano)



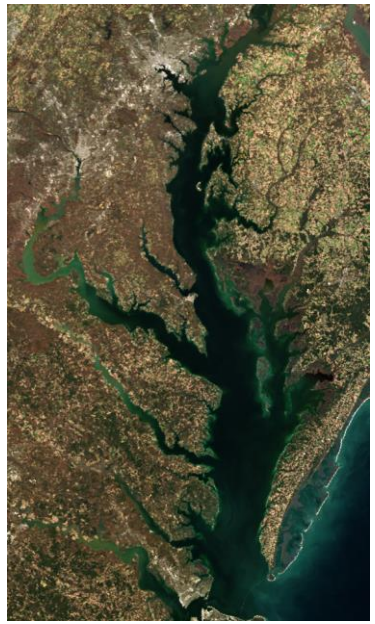
Relative Chlorophyll (Gilerson)



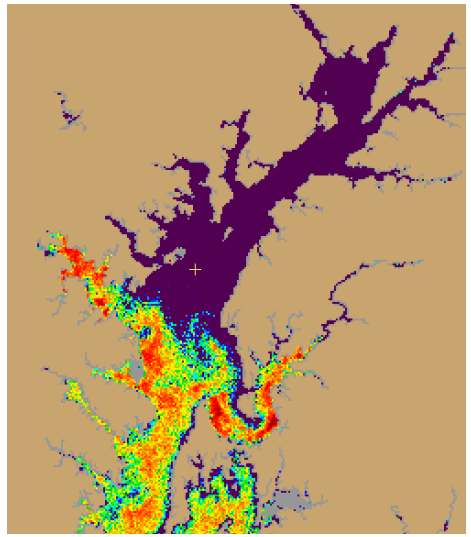
Non-Cyano Index (chl-a with negligible fluorescence)



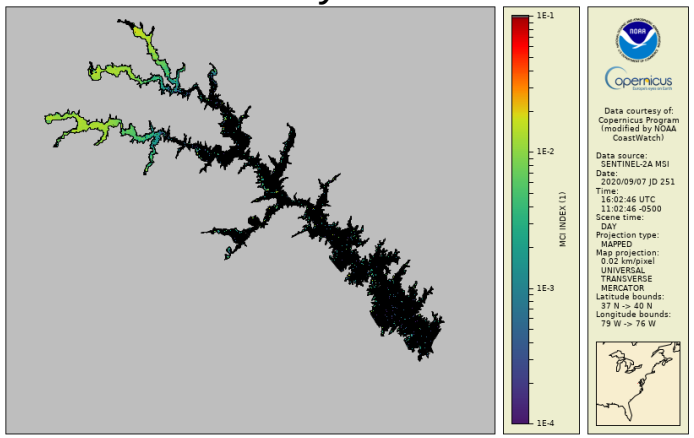
True Color



RBD Fluorescence



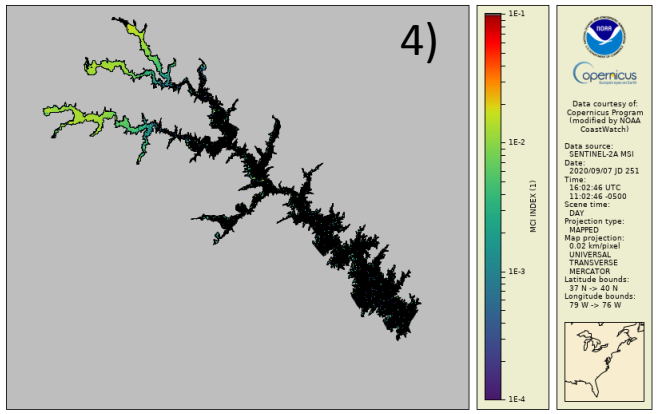
Hi-res MCI for cyanobacteria



Note: Imagery derived from Copernicus Sentinel data from EUMETSAT
Available from Chesapeake Bay at https://coastwatch.noaa.gov/cw_html/NCCOS.html

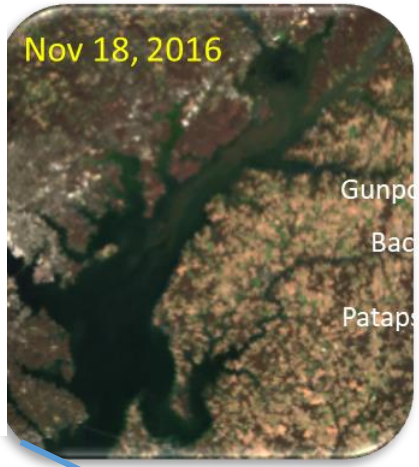
Algal Bloom Monitoring

MCI and Cyano Index for cyanobacteria

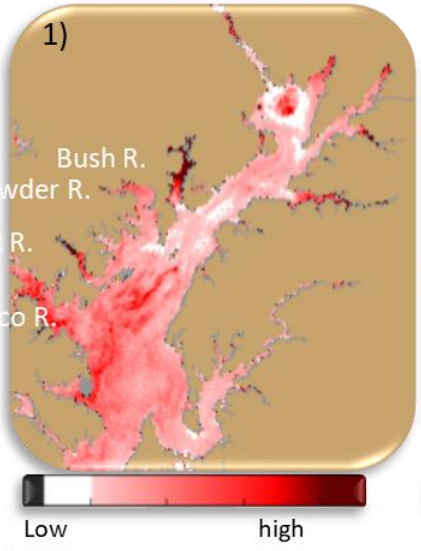


EUMETSAT esa

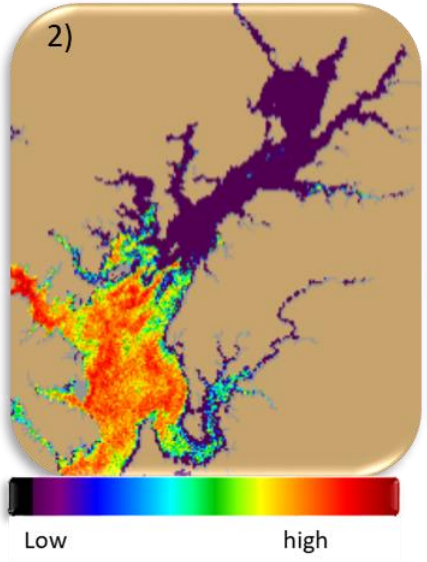
True color



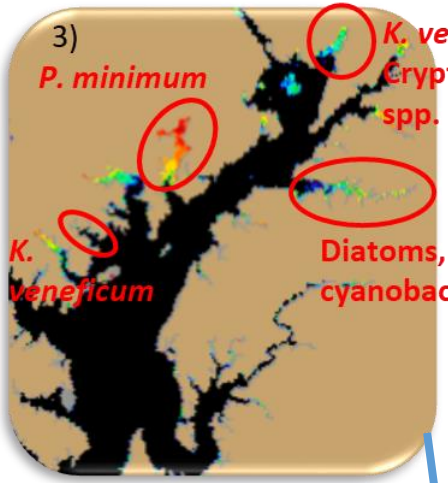
Relative Chl *a*



Chl fluorescence

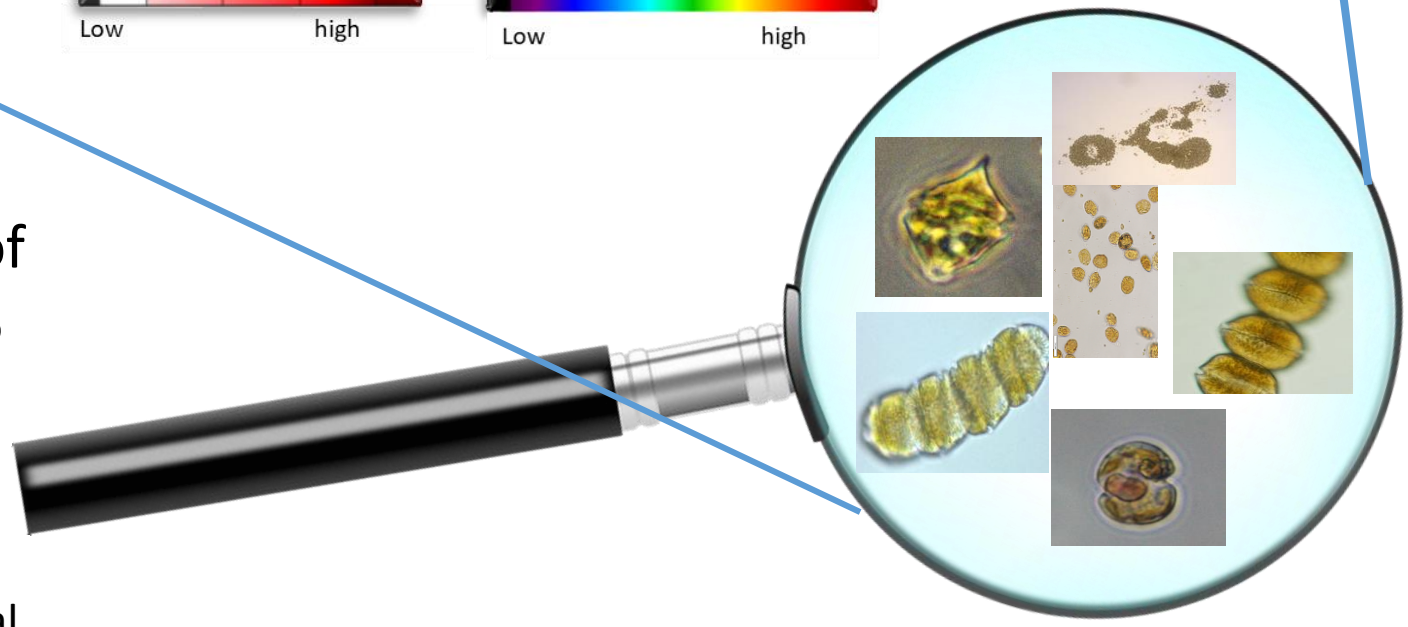


Non-fluorescing



Developing and providing algorithms for bloom monitoring routinely to MD DNR, MDE, VA Dept. of Health and VIMS from OLCI since 2016

(1) Red Band Difference (RBD) (Amin et al., 2009)
(2) Red-Edge (Gilerson, 2010)
(3) Cyanobacteria Index (Wynne et al., 2008) modified by a negative shape at 620 nm
(4) Maximum Chlorophyll Index (MCI) (Gower et al., 2008)



https://coastwatch.noaa.gov/cw_html/NCCOS.html

https://coastwatch.noaa.gov/cw_html/NCCOS.html

NCCOS Algal Bloom Beta/Experimental Products

Search Criteria

Region:

Chesapeake Bay

Product:(CTRL-click multiple)

True Color
Chlorophyll-a (Gilerson)
Relative Fluorescence
Cyanobacteria Index

Sensor: ☑OLCI ☐MSI

From: (MM/DD/YYYY)

08/22/2020

To: (MM/DD/YYYY)

08/27/2020

Search

The Harmful Algal Bloom - Forecasting Branch (HAB-FB) is a research group within the National Oceanic and Atmospheric Administration (NOAA), National Centers for Coastal Ocean Science (NCCOS) tasked with forecasting and monitoring HABs. One of the more effective ways to do so is through satellite based monitoring, which provides a synoptic view at high temporal resolution. The HAB-FB has established a routine and automated processing capability for satellite-derived products pertaining to the color of water. Water color can be used as proxy for various geophysical parameters, such as chlorophyll-*a*, turbidity, and water depth. All of our products are generated from mapped reflectance products, which we refer to as "level 3" products:

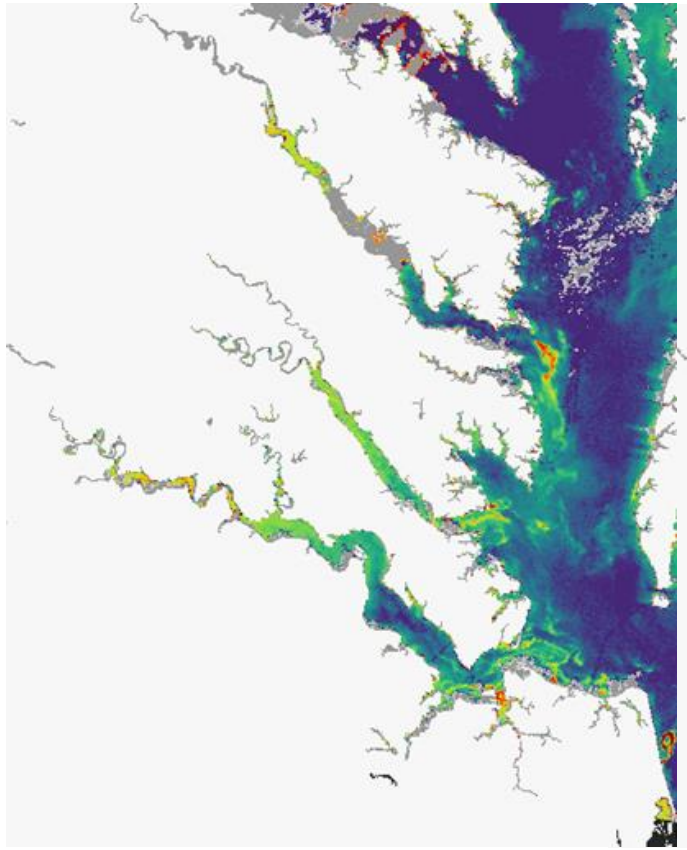
- True Color : a Red, Green, Blue (RGB) composite image
- Chlorophyll-*a* (Gilerson) : chlorophyll *a* concentration determined by a near-Infrared to red ratio as described by Gilerson et al. (2010).
- Cyanobacteria Index : the relative abundance of cyanobacteria biomass as determined by the cyanobacteria index algorithm developed by Wynne et al. (2008).
- Low fluorescing Algae : the relative abundance of phytoplankton which are low or non-fluorescing and do not contain phycocyanin (non-cyanobacteria).
- Relative Fluorescence : the relative chlorophyll fluorescence representative of chlorophyll concentration for high biomass blooms, determined by the Red-Band Difference developed by Amin et al. (2009).
- Maximum Chlorophyll Index (MCI): The Maximum Chlorophyll Index (MCI) detects high biomass blooms and shows relative density patches of Chl-a, as developed by Gower et al. (1999).

Sentinel-2 MSI imagery does not have a cloud mask applied at this time. Please consult the true color, as black pixels may indicate clouds or no bloom. For more information on these products, refer to the NCCOS products website.

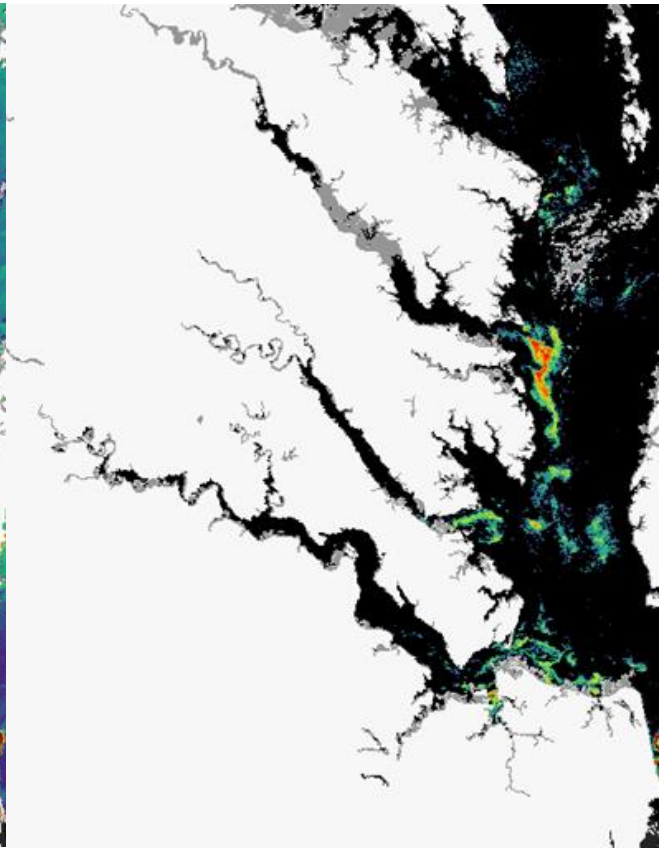
Bloom Case Scenarios

Margelefidinium polikrikoides

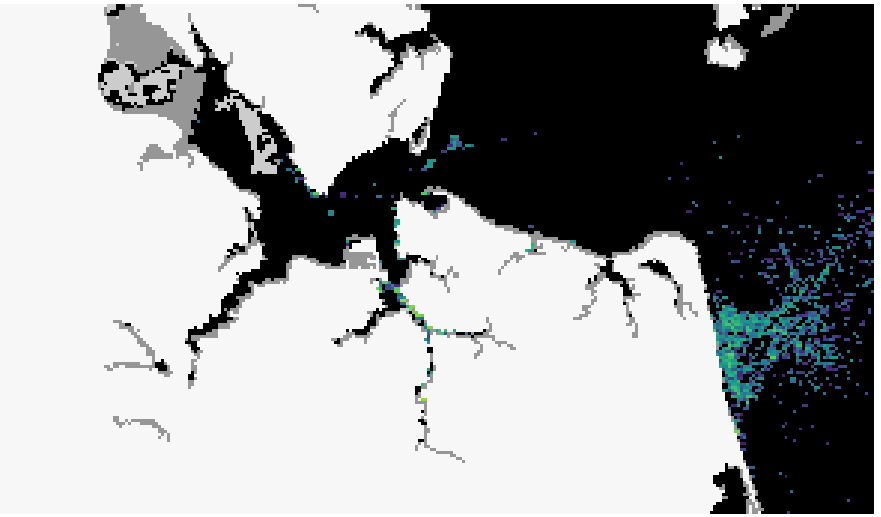
Gilerson Chl a: Aug 12, 2020



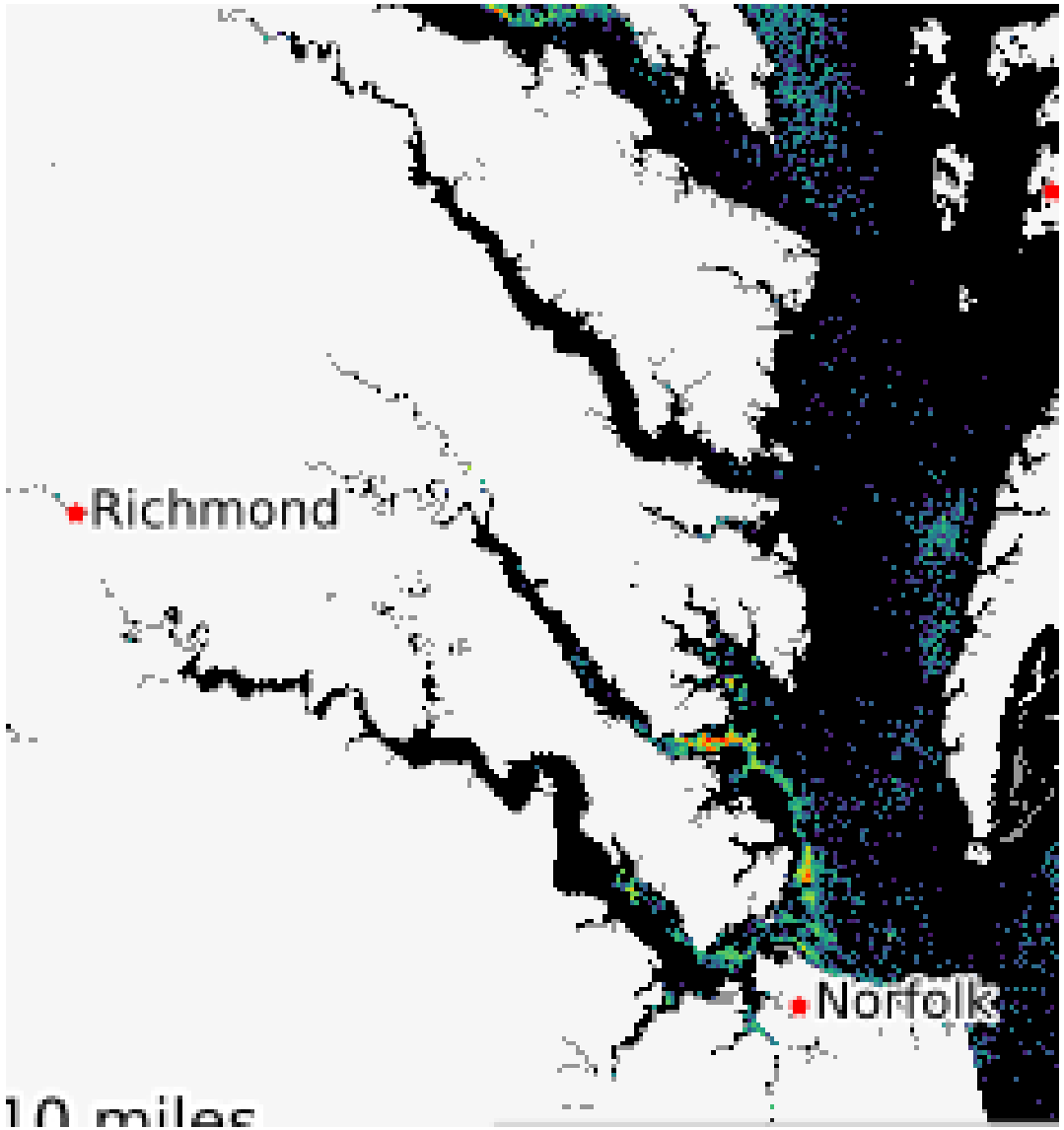
Chl Fluorescence (RBD): Aug 12, 2020

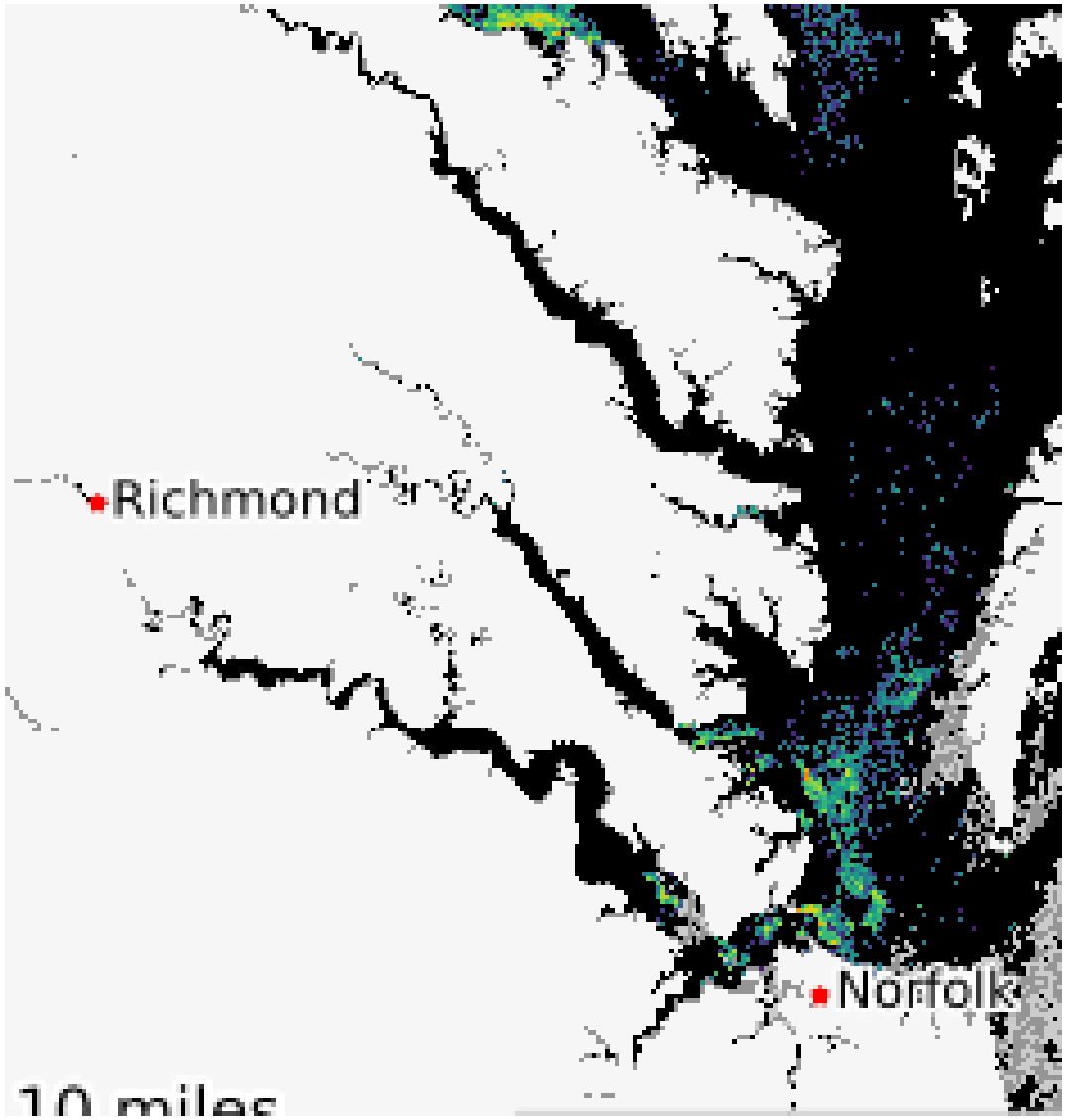


Lafayette River-Atlantic RBD
July 20-Aug 11, 2020



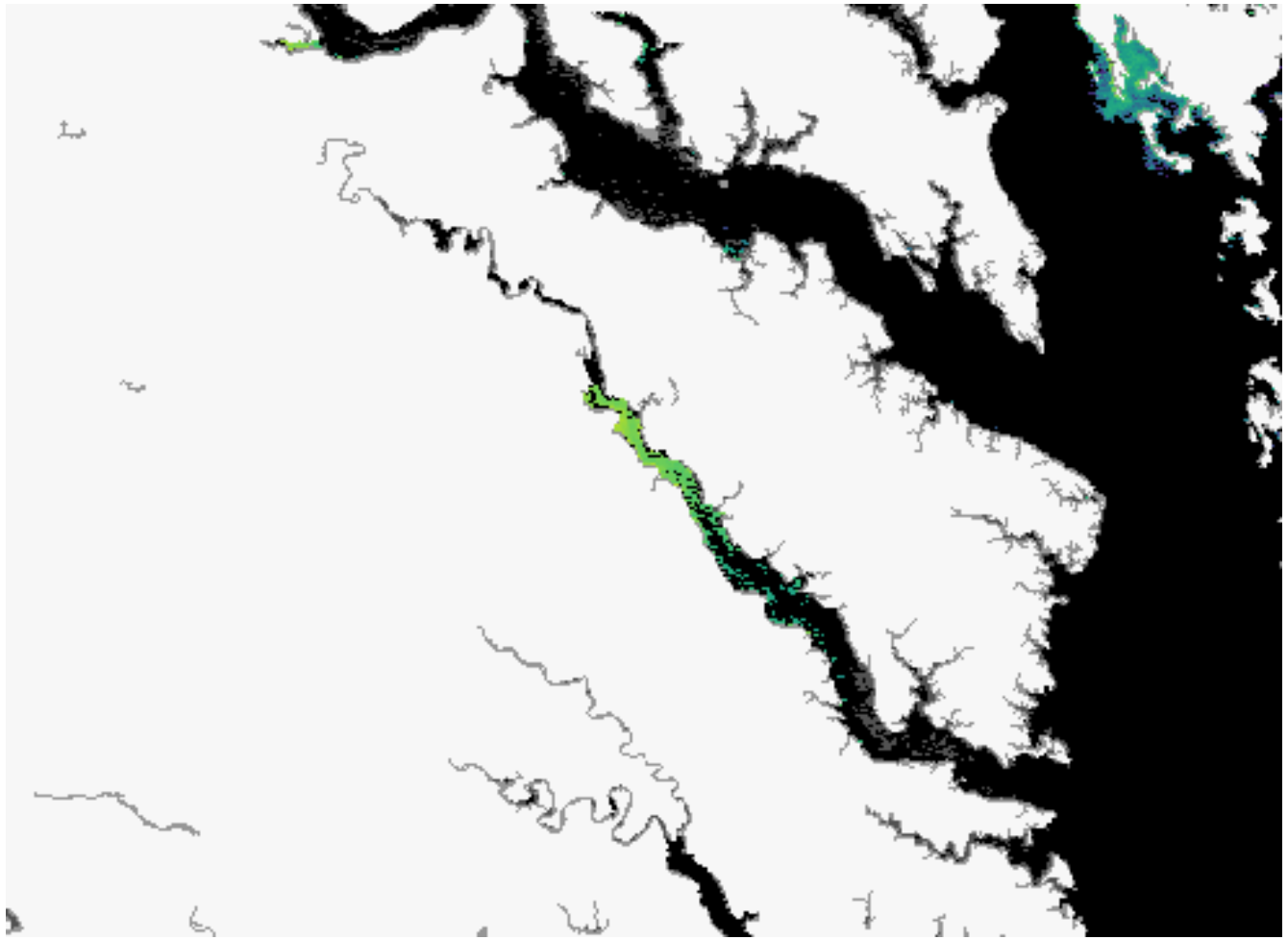
Alexandrium monilatum
OLCI RBD Sep 4, 2020





Rappahannock River
August 26, 2020
Event date: August 28 had 150,000cells/ml

Sentinel 3, OLCI CIcyano



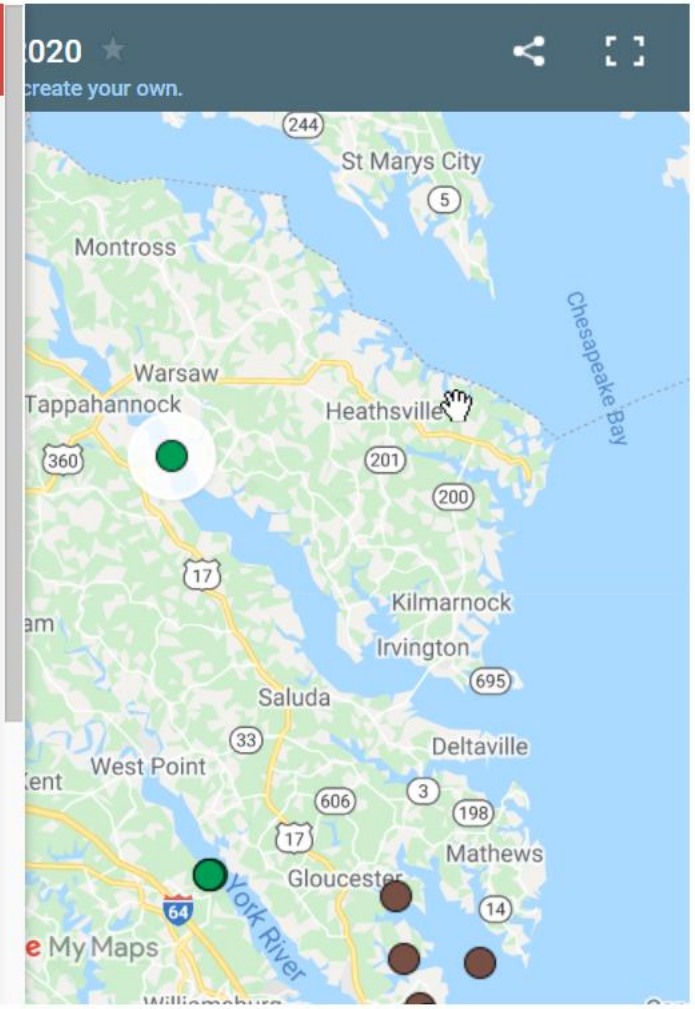
Rappahannock River
October 7, 2020
Event date: ~11,000 cells/mL on October 8, 2020

Rappahannock River

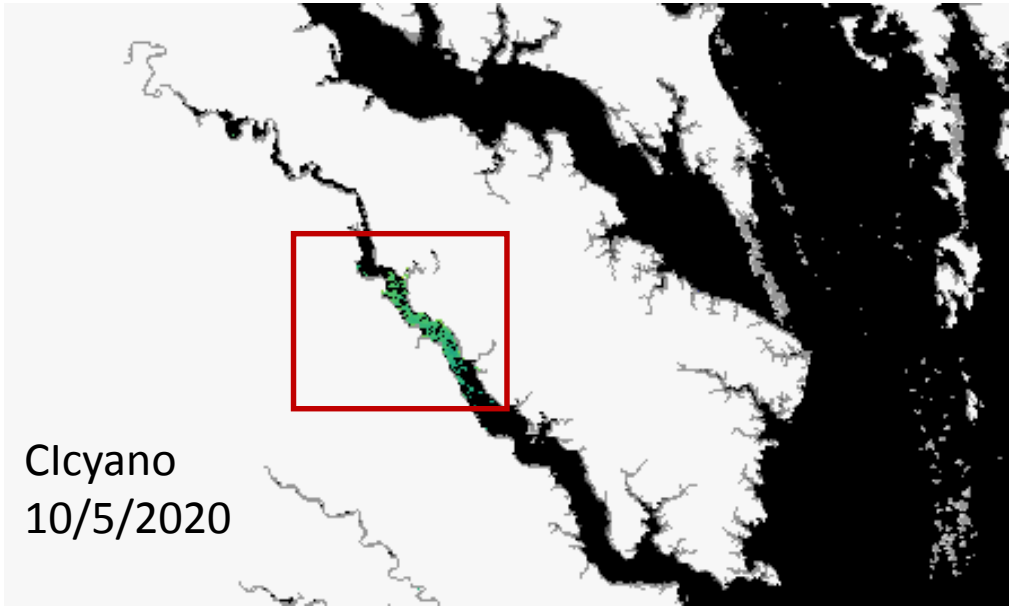
name
Rappahannock River

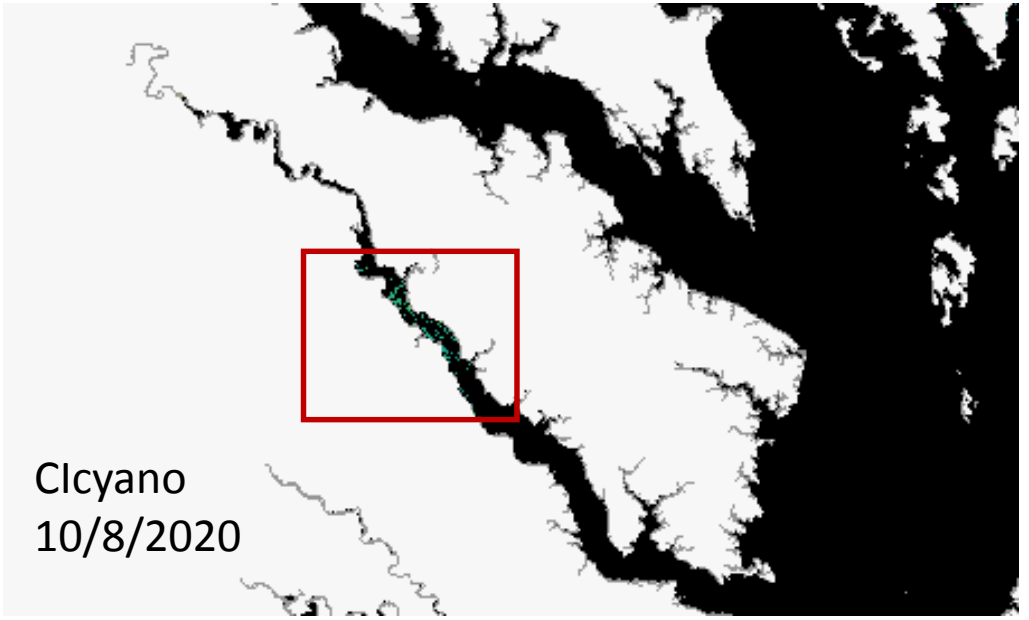
Sample Date
8/28/20

description
Results of samples collected on 8/28/20 indicated cyanobacteria (primarily Planktolyngbya) at densities which would typically trigger the issuance of a swimming advisory in recreational waters. However, due to the multiple rain events which subsequently occurred prior to the receipt of results from the laboratory, continued surveillance using satellite imagery was opted over the issuance of an advisory. Satellite imagery indicated the dissipation of the bloom as results were received. Toxin analyses were all near or below detection limits and far below advisory levels. The rain

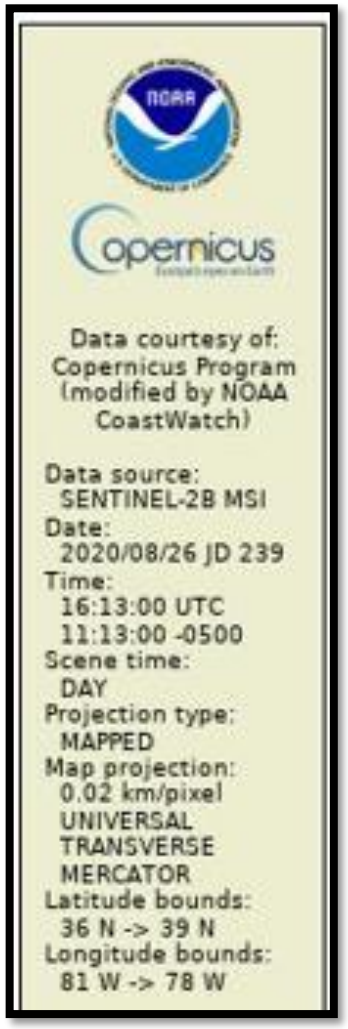


Sentinel 3, OLCI



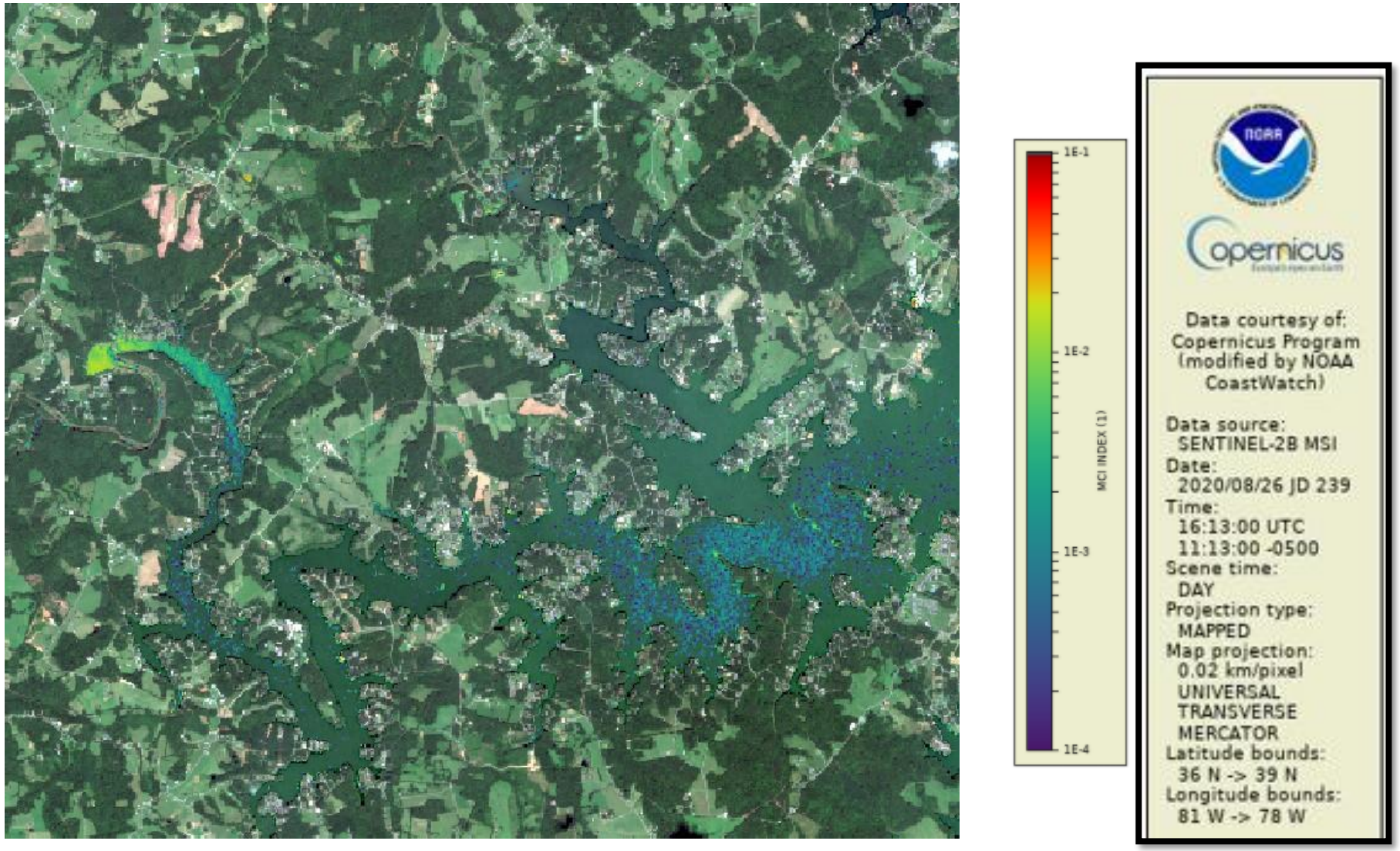


Smith Mountain Lake
August 26, 2020
Event date: 8/24/2020



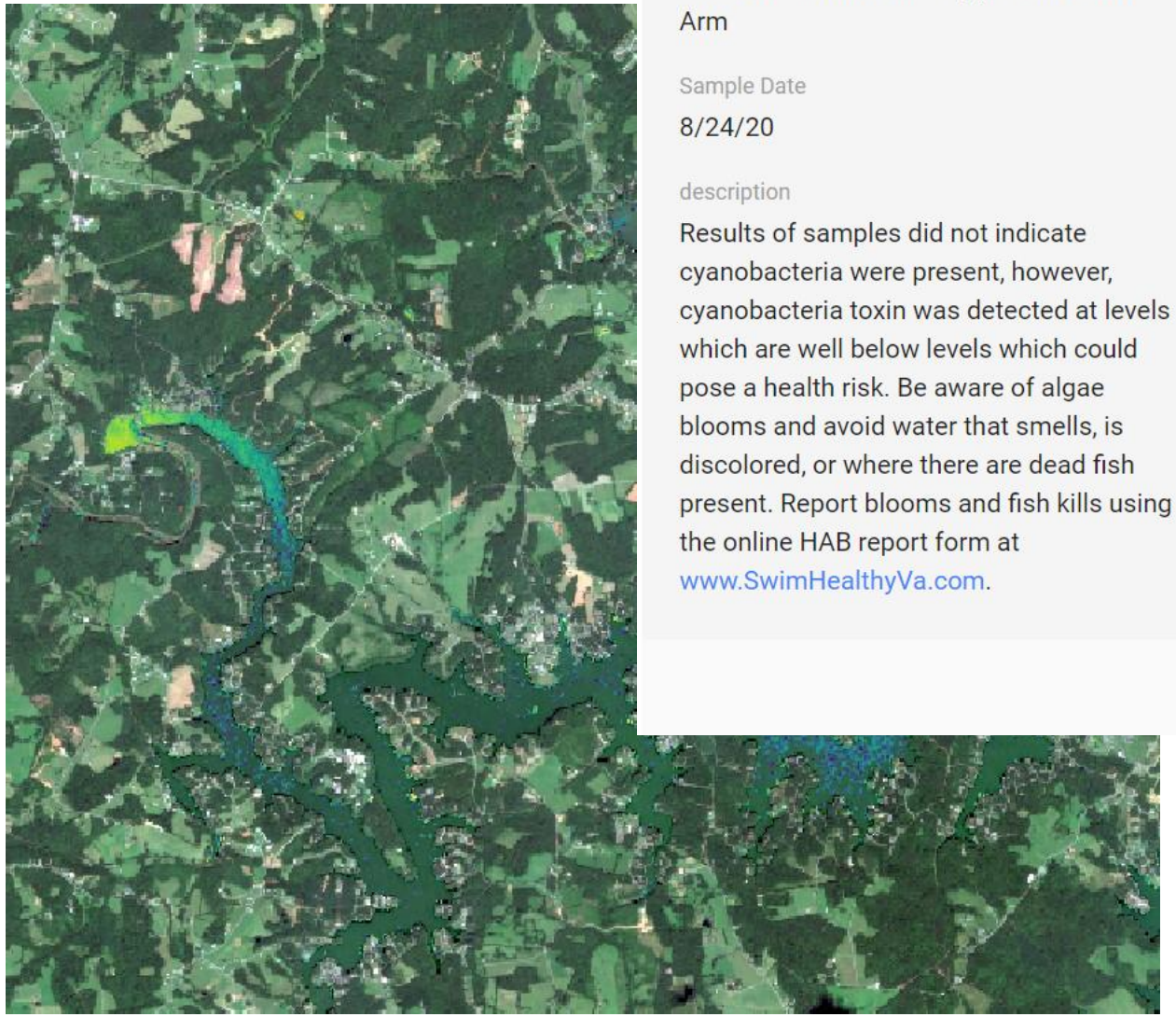
Imagery thanks to Michael Sorocco, NOAA CoastWatch

Smith Mountain Lake
August 26, 2020
Event date: 8/24/2020



Imagery thanks to Michael Sorocco, NOAA CoastWatch

Smith Mountain Lake
August 26, 2020
Event date: 8/24/2020



Smith Mountain Lake - Upper Bl...

name

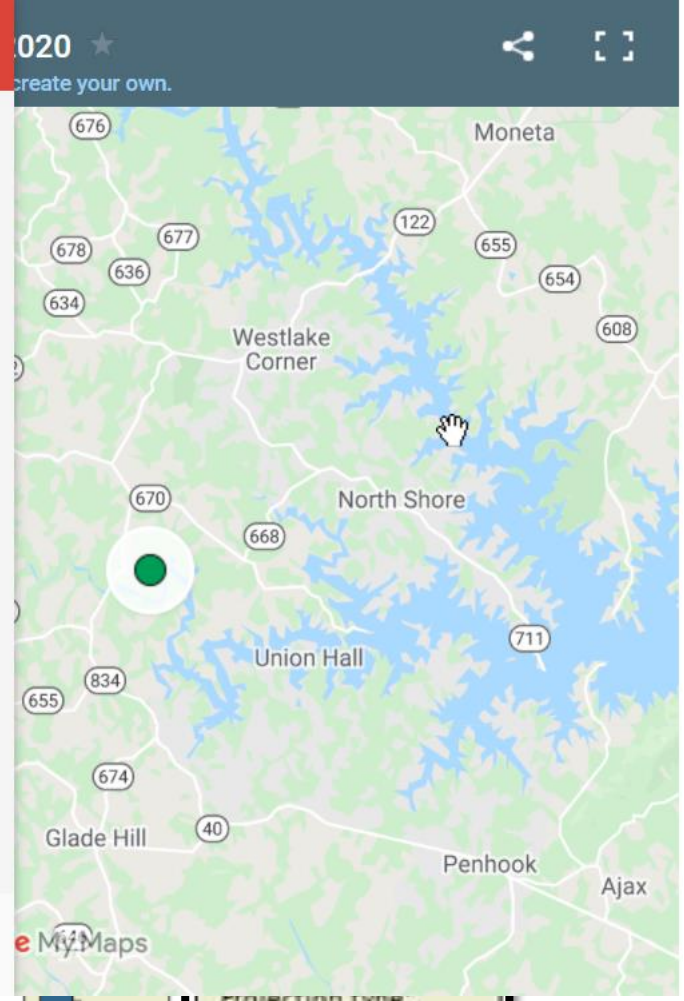
Smith Mountain Lake - Upper Blackwater Arm

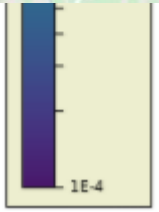
Sample Date

8/24/20

description

Results of samples did not indicate cyanobacteria were present, however, cyanobacteria toxin was detected at levels which are well below levels which could pose a health risk. Be aware of algae blooms and avoid water that smells, is discolored, or where there are dead fish present. Report blooms and fish kills using the online HAB report form at www.SwimHealthyVa.com.



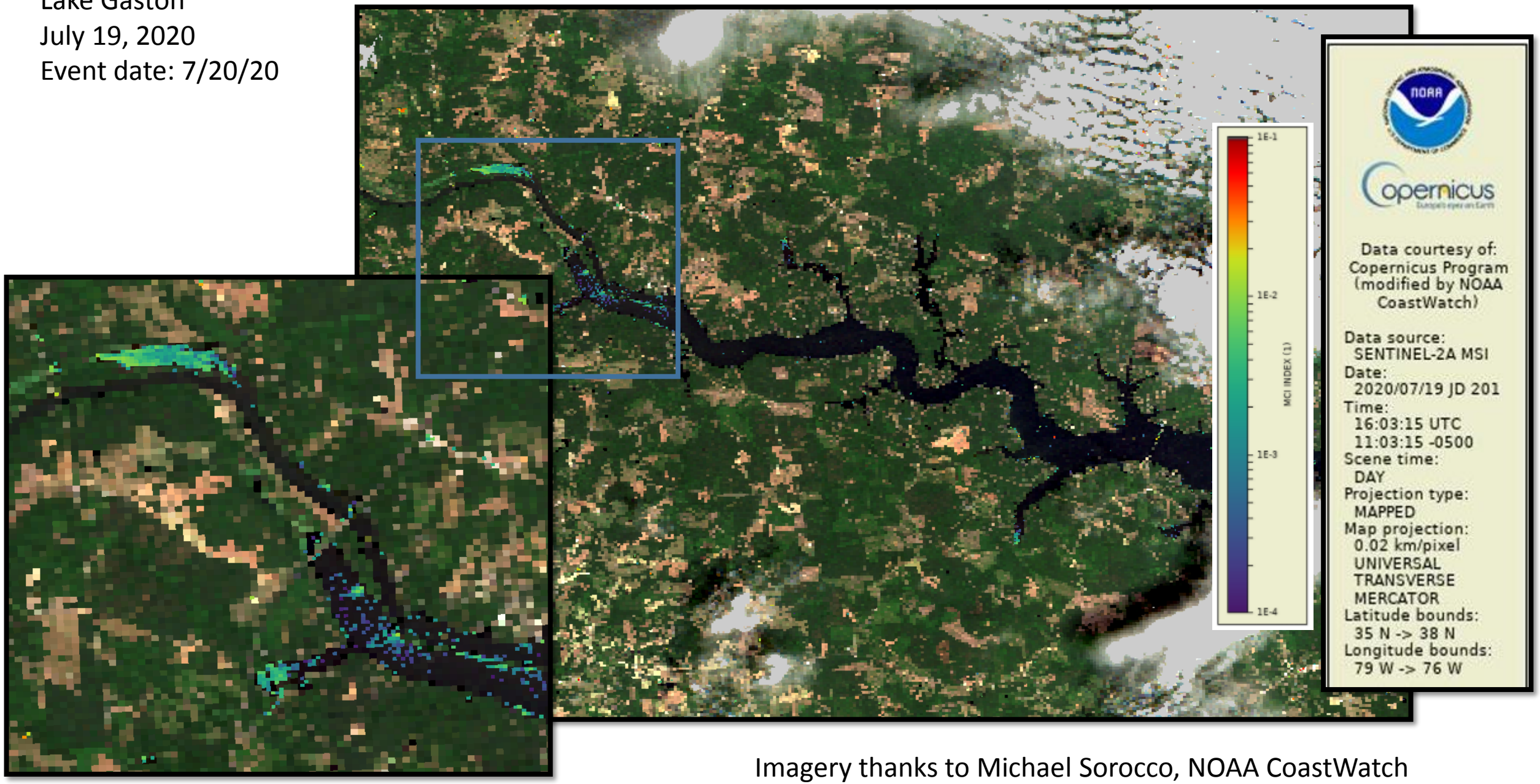


Imagery thanks to Michael Sorocco, NOAA CoastWatch

Smith Mountain Lake
August 26, 2020

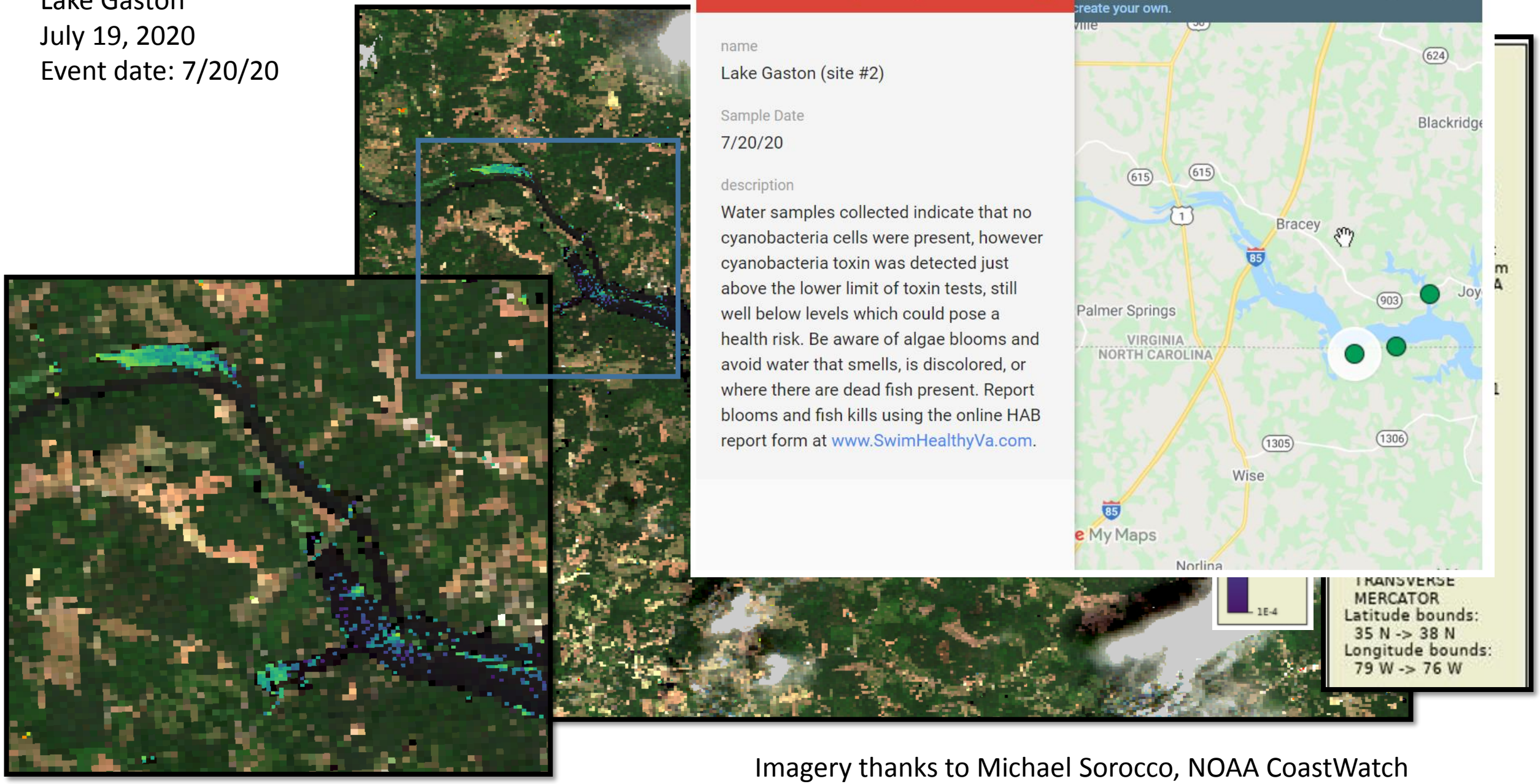
Imagery thanks to Michael Sorocco, NOAA CoastWatch

Lake Gaston
July 19, 2020
Event date: 7/20/20



Imagery thanks to Michael Sorocco, NOAA CoastWatch

Lake Gaston
July 19, 2020
Event date: 7/20/20



Imagery thanks to Michael Sorocco, NOAA CoastWatch

Cyanobacteria Assessment Network

epa.gov/cyanoproject

Slides courtesy of Blake Schaeffer, EPA and Bridget Seegers, NASA/USRA

Cyanobacteria Assessment Network (CyAN)

Multi-agency project EPA, NOAA, USGS, NASA

GOAL: Support the environmental management and public use of U.S. lakes by detecting and quantifying algal blooms and related water quality indicators using satellite data records.

Approach

Remote Sensing

Uniform and systematic approach for identifying cyanobacteria blooms.

Strategy for evaluation and refinement of algorithms across platforms.

Information Distribution

Bring the technology to EPA, states and tribal partners. Provide notifications and decision support

Economics

Behavioral responses and economic value of the early warning system.

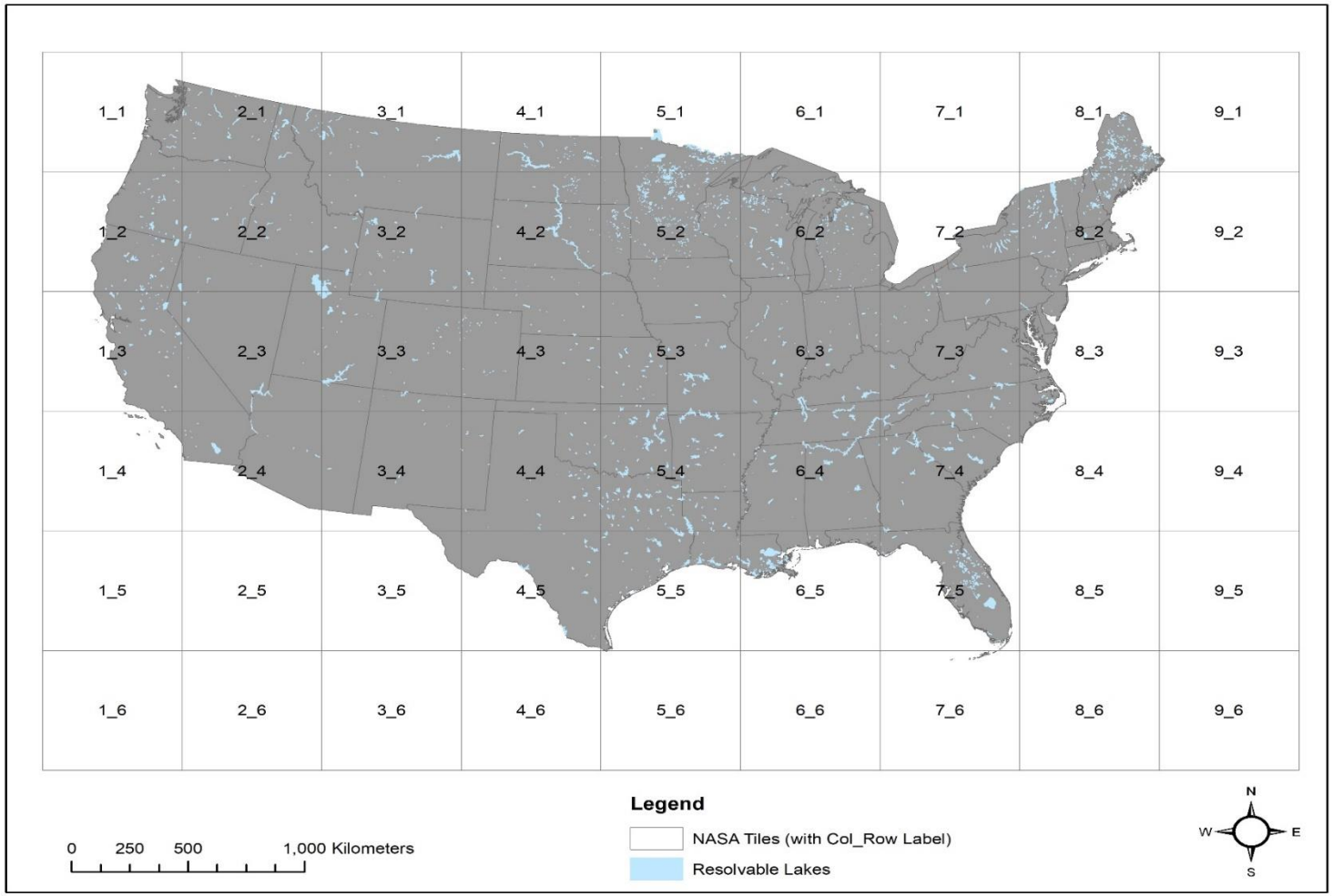
Environment

Identify landscape linkages causes of chlorophyll a and cyanobacteria.

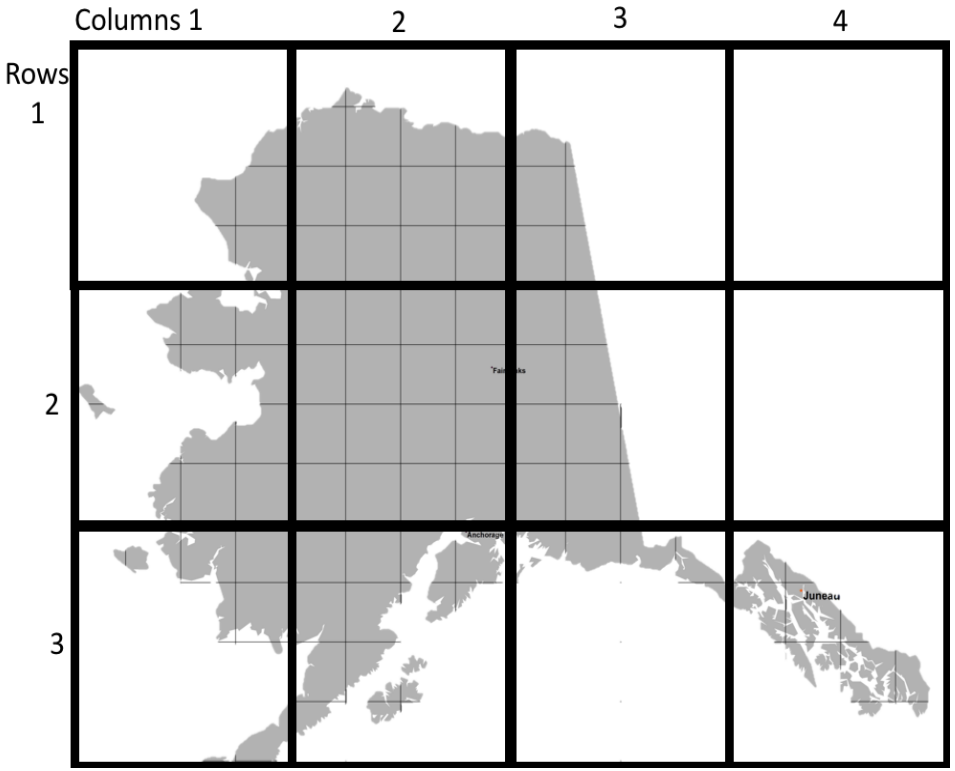
Health

Exposure and human health effects in drinking and recreational waters.

Contiguous US (CONUS) tiles



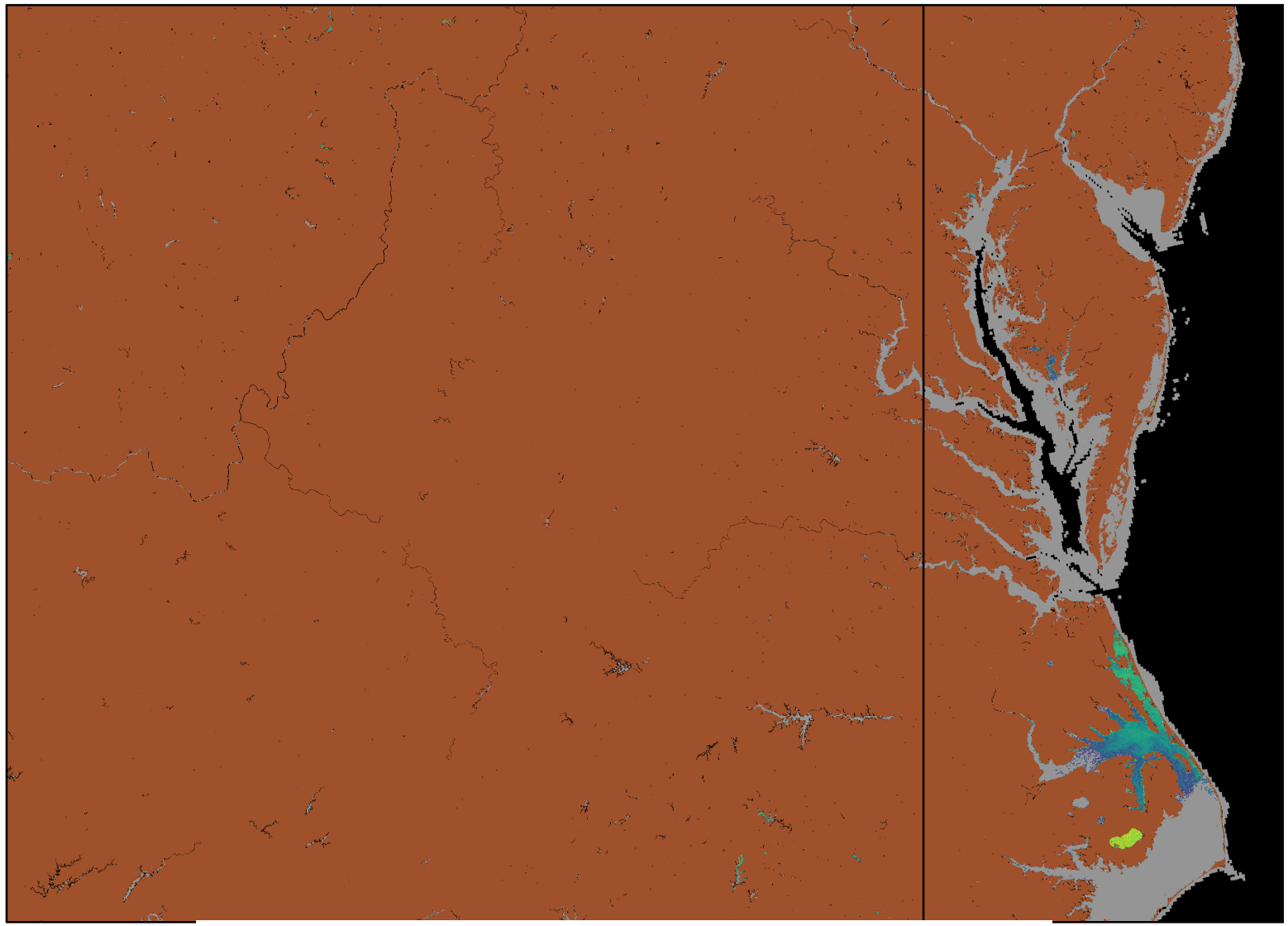
Alaska tiles



Cyanobacteria Assessment Network

MERIS (2002-2012) and OLCI (2016-) Full resolution (300 m)

Website with entire time-series will be available at NASA soon!



Cyanobacterial Density

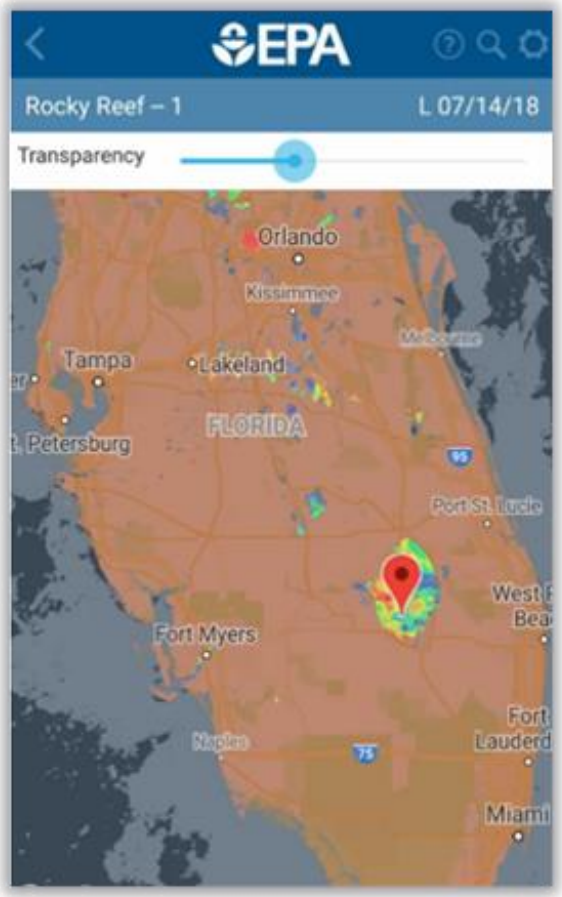
VA 2 Tiles
Mapped @300m
Nov 4, 2020, 1 day image
Cyanobacteria Index (CI)

OLCI Image
Spatial 300m
Temporal 2-3 days

MERIS (2002-2012)
OLCI (2016-)
OLCI Images
from ESA satellite Sentinel 3a (soon 3b)

CYAN
Cyanobacteria
Assessment Network

CyAN App



App makes it possible to

- easily share data and information with large numbers of people
- focus on individual lakes, current conditions and historic
- compare lakes of interest

https://www.epa.gov/water-research/cyanobacteria-assessment-network-mobile-application-cyan-app

(12) **United States Patent**
Schaeffer et al.

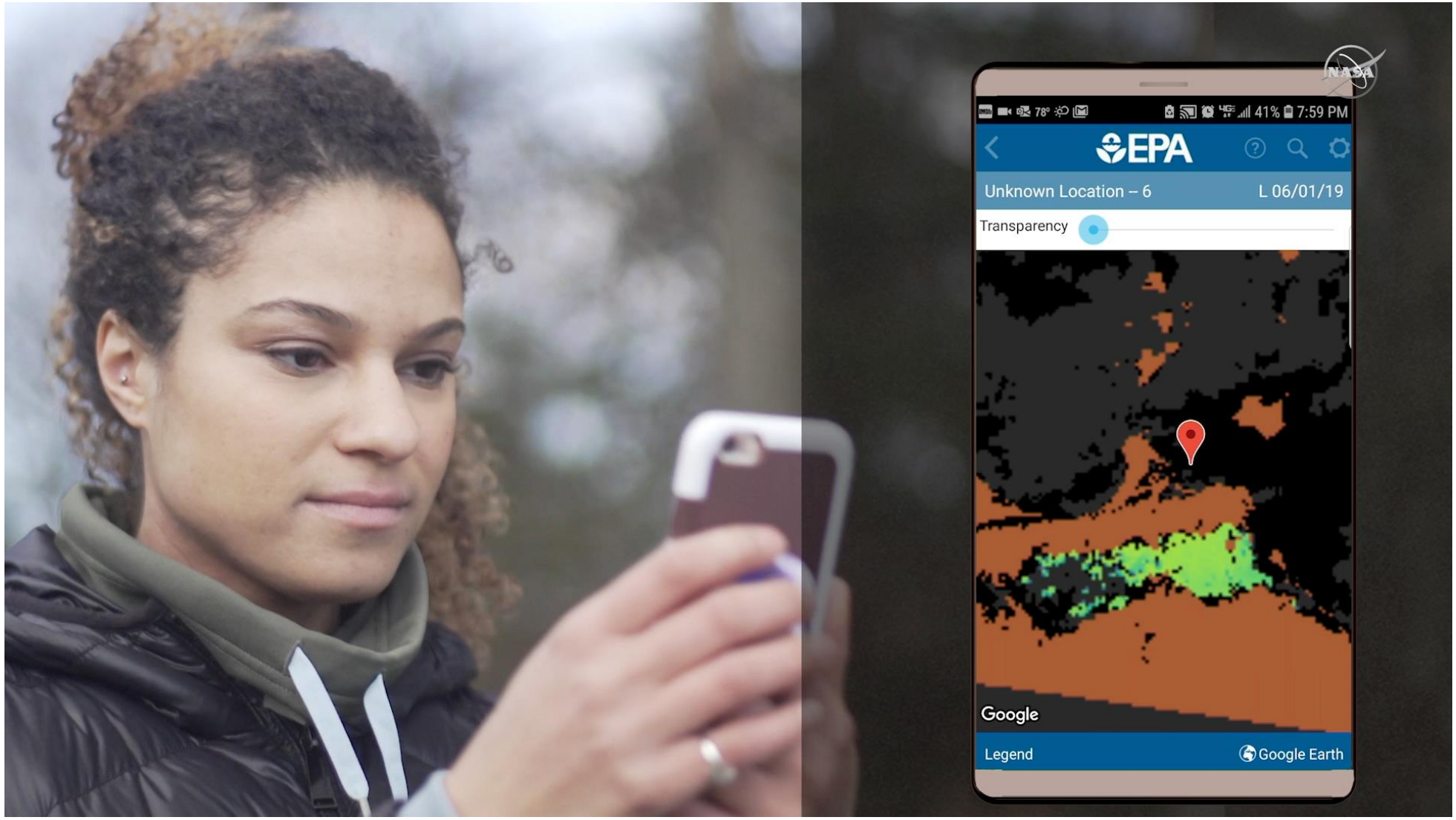
(10) **Patent No.: US 10,290,089 B2**
(45) **Date of Patent: May 14, 2019**

(54) **CYANOBACTERIA ASSESSMENT NETWORK**

H04W 4/02	(2018.01)
G06F 16/9537	(2019.01)
H04L 29/08	(2006.01)

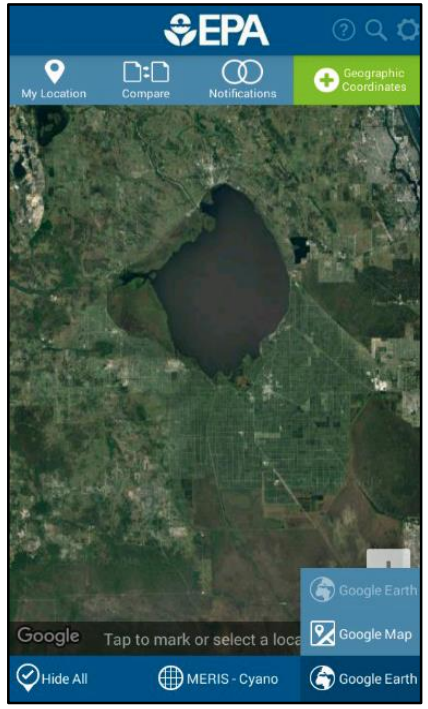
CYAN App

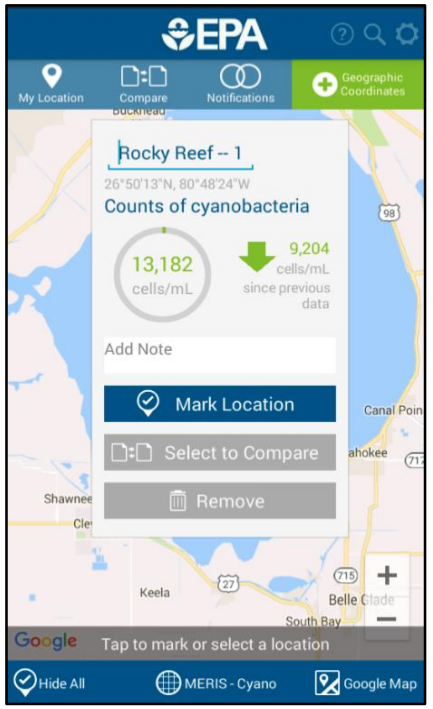
App uses weekly images

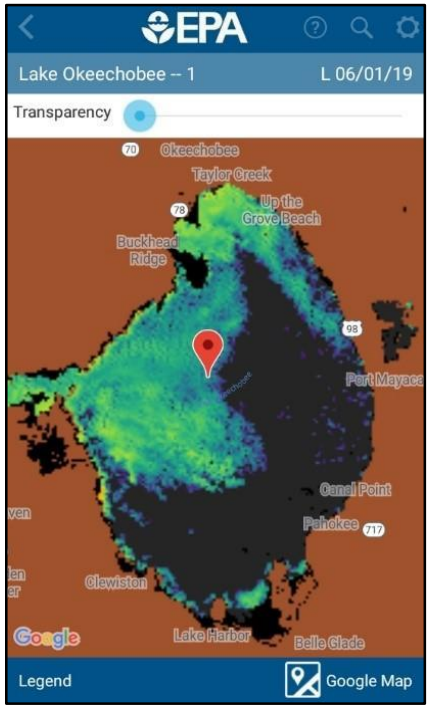


CYAN App

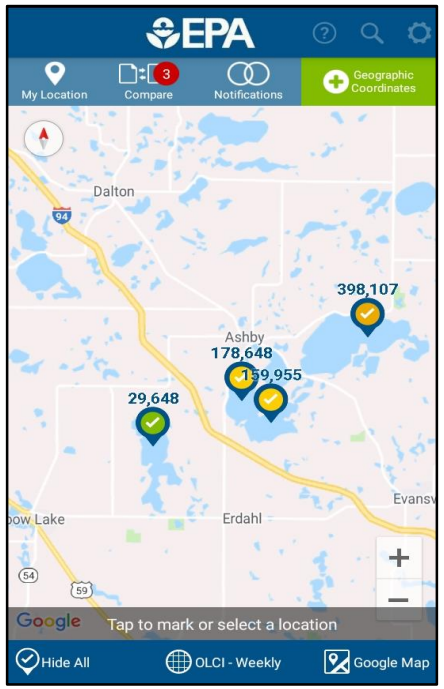
Look at lake of interest

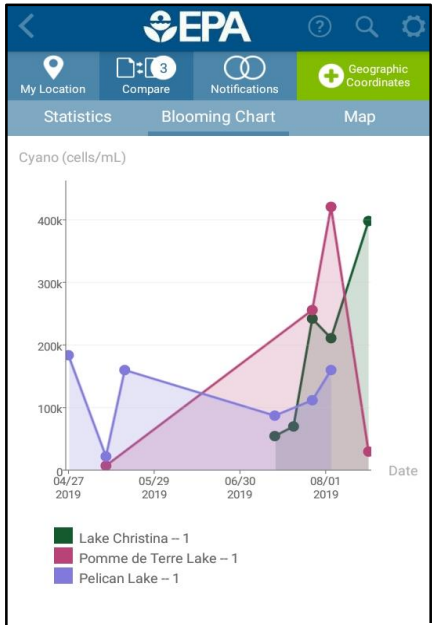






Compare lakes and locations





GET IT ON Google Play

Android only

Web interface available to management agencies

For Access email Michelle.Tomlinson@noaa.gov or Galvin.Mike@epa.gov

https://ceamstg.ceeopdev.net/login/?next=/cyanweb/

CyAN App Love

Aaron Borisenko, State of Oregon Department of Environmental Quality:

"… **using CyAN app as an early warning system**."

Benjamin Holcomb, Utah Department of Water Quality:

"… **allows UDWQ to better target field sampling and more efficiently use our limited resources to protect public health**..."

Angela Shambaugh, Vermont Department of Environmental Conservation:

"… **visualize that patchiness and provides additional context**..."

Bart Johnsen-Harris, Environment America:

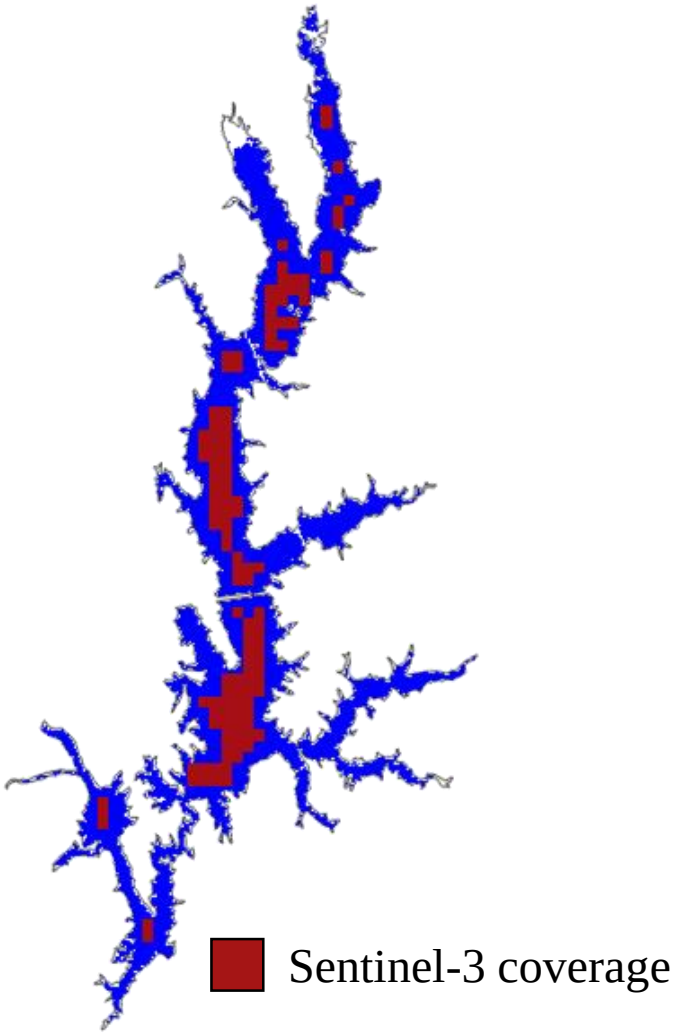
"…**CyAN has proved to be a uniquely helpful tool**."

Lenard Long, Lake Cascade Citizen Scientist Monitoring Group:

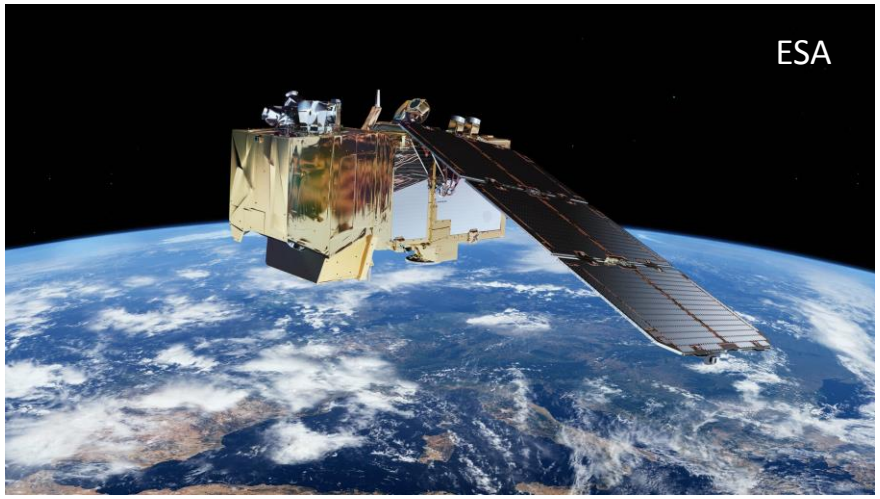
"…**enhance the community's ability to rapidly respond to and manage the growing threat posed by toxic algae**…**the CyAN app helps us do that**….**has been extremely useful**…."

Challenges and limitations

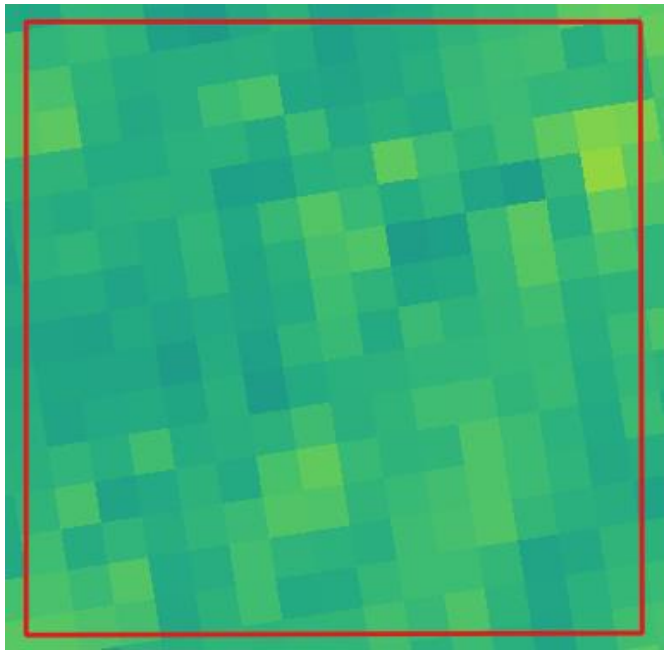
- Toxins
- Depth
- Clouds, snow/ice
- Lake level change
- Small lakes, shorelines, rivers



Sentinel-2



Sentinel-3 pixel

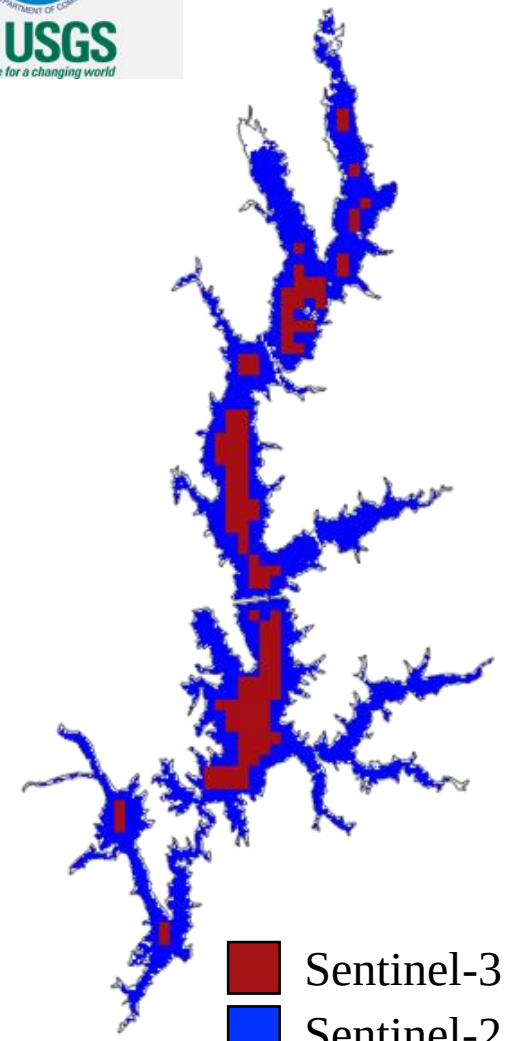


300 m

Sentinel-2 pixel

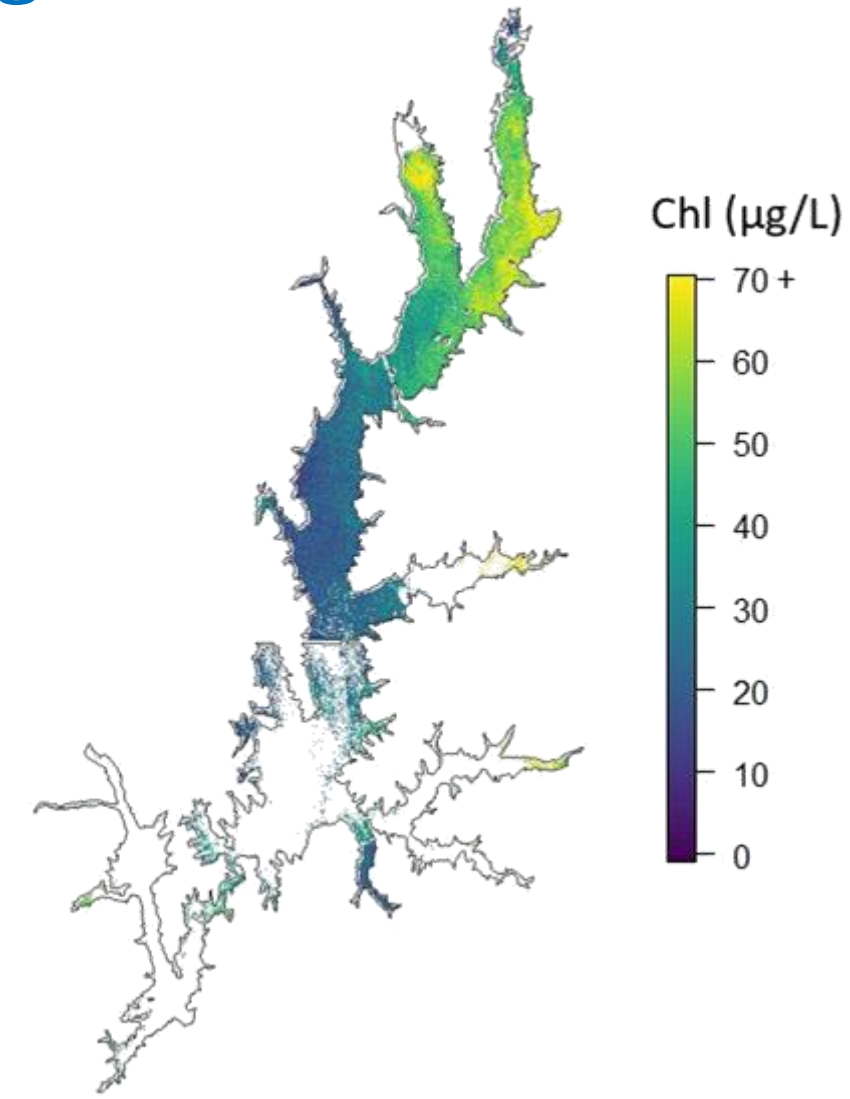
20 m

Expanding coverage



Sentinel-3 coverage

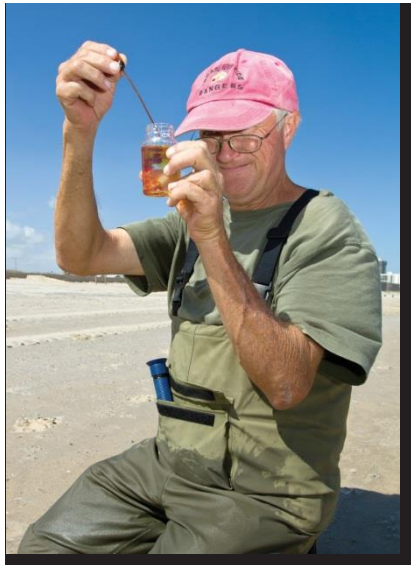
Sentinel-2 coverage

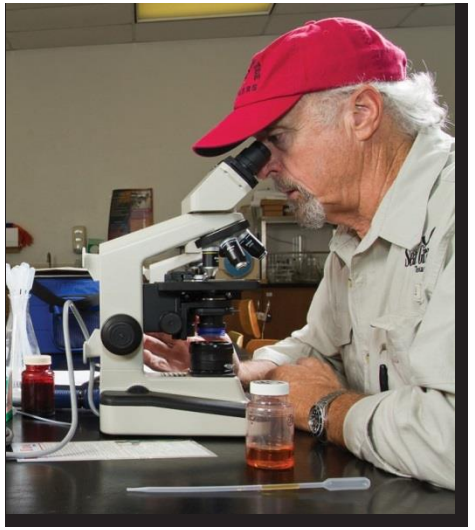


Salls et al., *In Review.* Environ. Monit. Assess.

HABscope Integrated Approach

- Satellite imagery drives where and when to start sampling
- Sampling
- User groups provide continual feedback on cell phone microscope, presentation of data, accuracy, etc.
- Build on existing networks, Docent programs, Master Naturalist (e.g. Texas Red Tide Rangers), community groups, etc.
- Move from “lab” to the beach for analysis

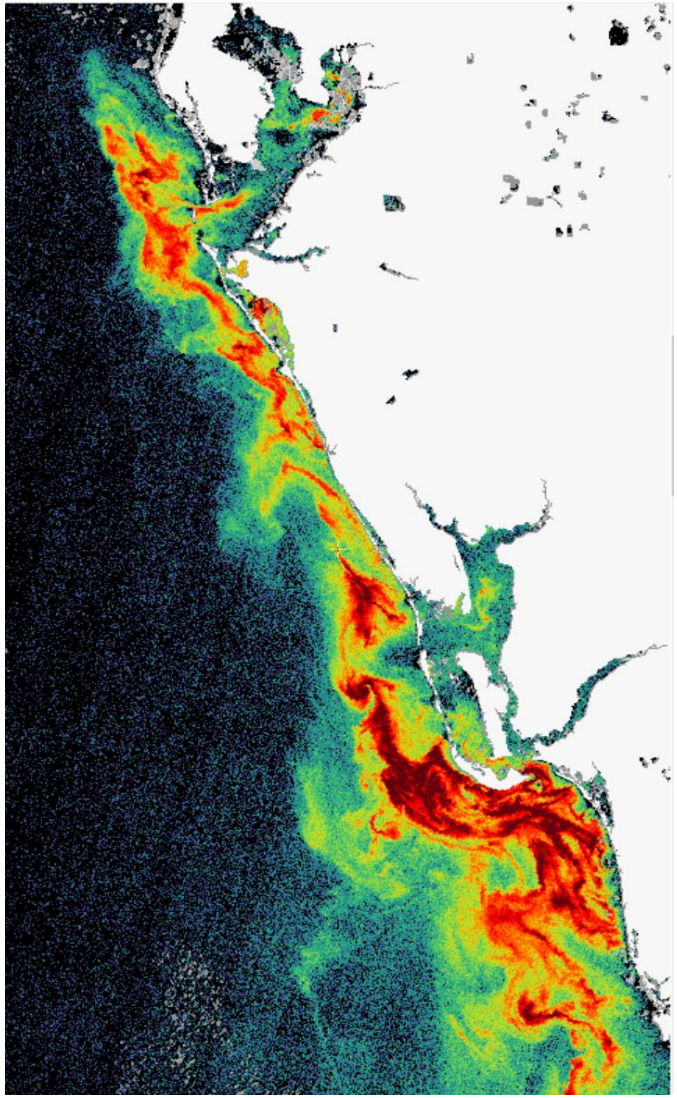




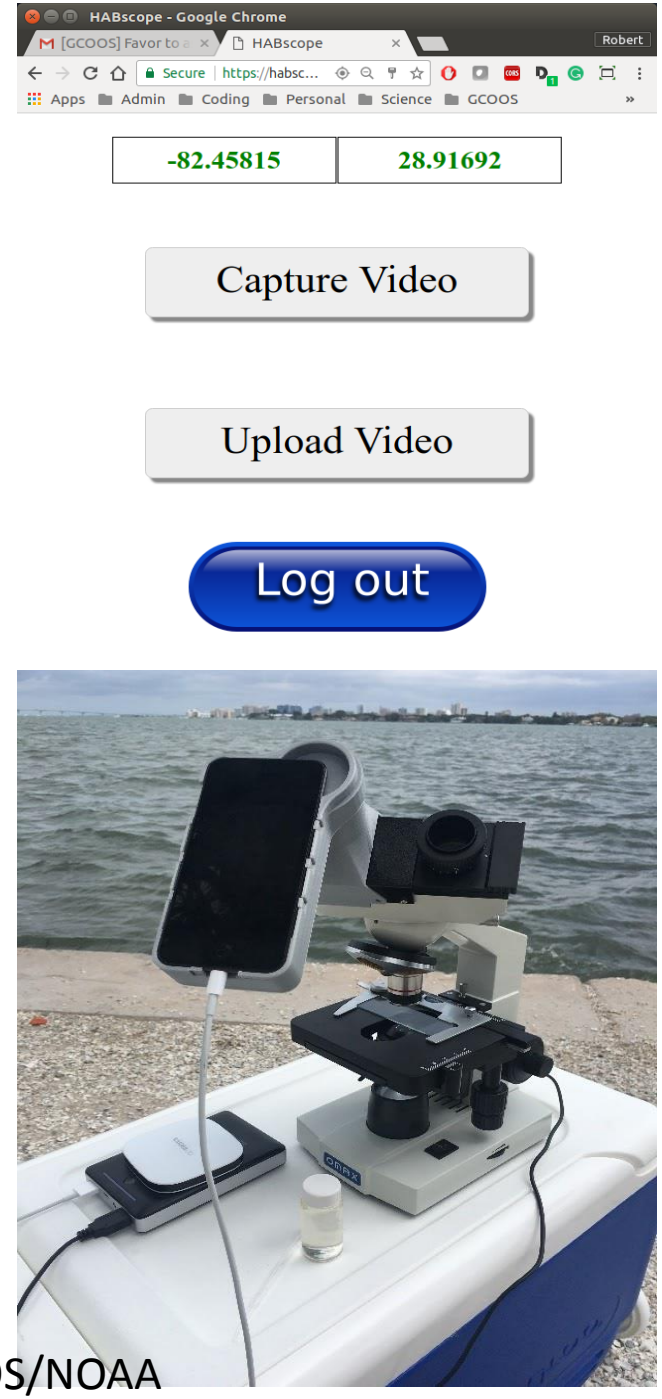
Red Tide Ranger analyzing samples in lab

Slides courtesy of Chris Holland, NCCOS/NOAA

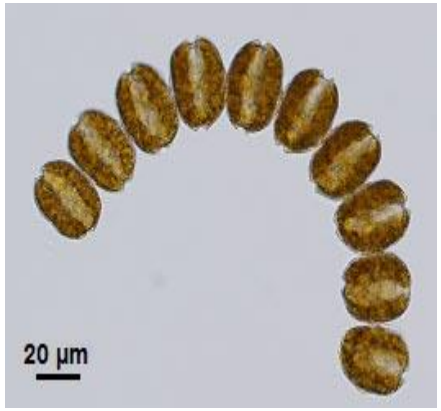
August 22, 2018

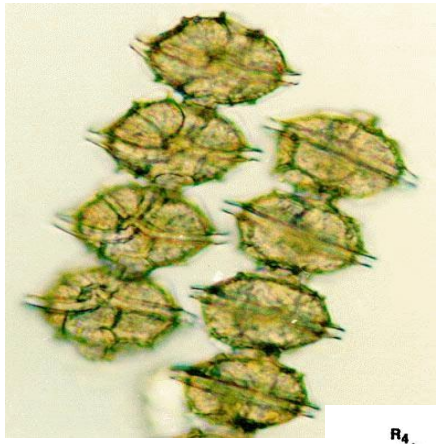


Fluorescence provides area of likely bloom (Sentinel-3)

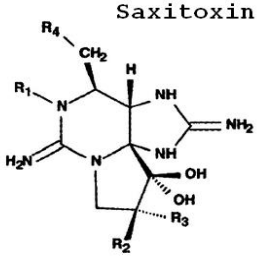


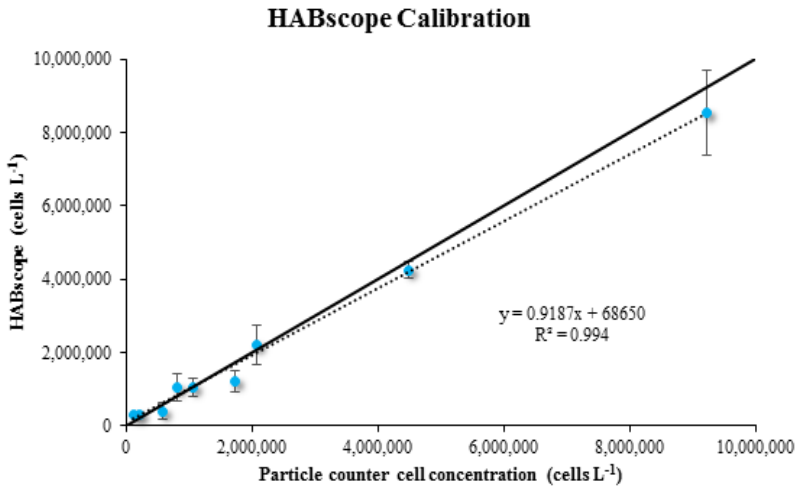
Slides courtesy of Chris Holland, NCCOS/NOAA





Saxitoxin





- With NOAA Innovation Grant we can create new algorithms on other HAB species (*Pyrodinium bahamense)*
- First step is to properly train HABscope algorithm to detect *Alexandrium monolatum* (Blooms in Chesapeake Bay and can cause damage to oyster farms). We will need to calibrate the scope using videos of cultured cells compared to coulter counter measurements to ensure accuracy.
- Eventually forecast will be available for the Chesapeake for *Alexandrium monolatum*

Slides courtesy of Chris Holland, NCCOS/NOAA

Summary

- Satellites are a good way to monitor
- End-user engagement early
    - trainings (product and software)
    - product feedback
    - success stories
- Easy Data Access and Interface
- Outreach

Thank you!

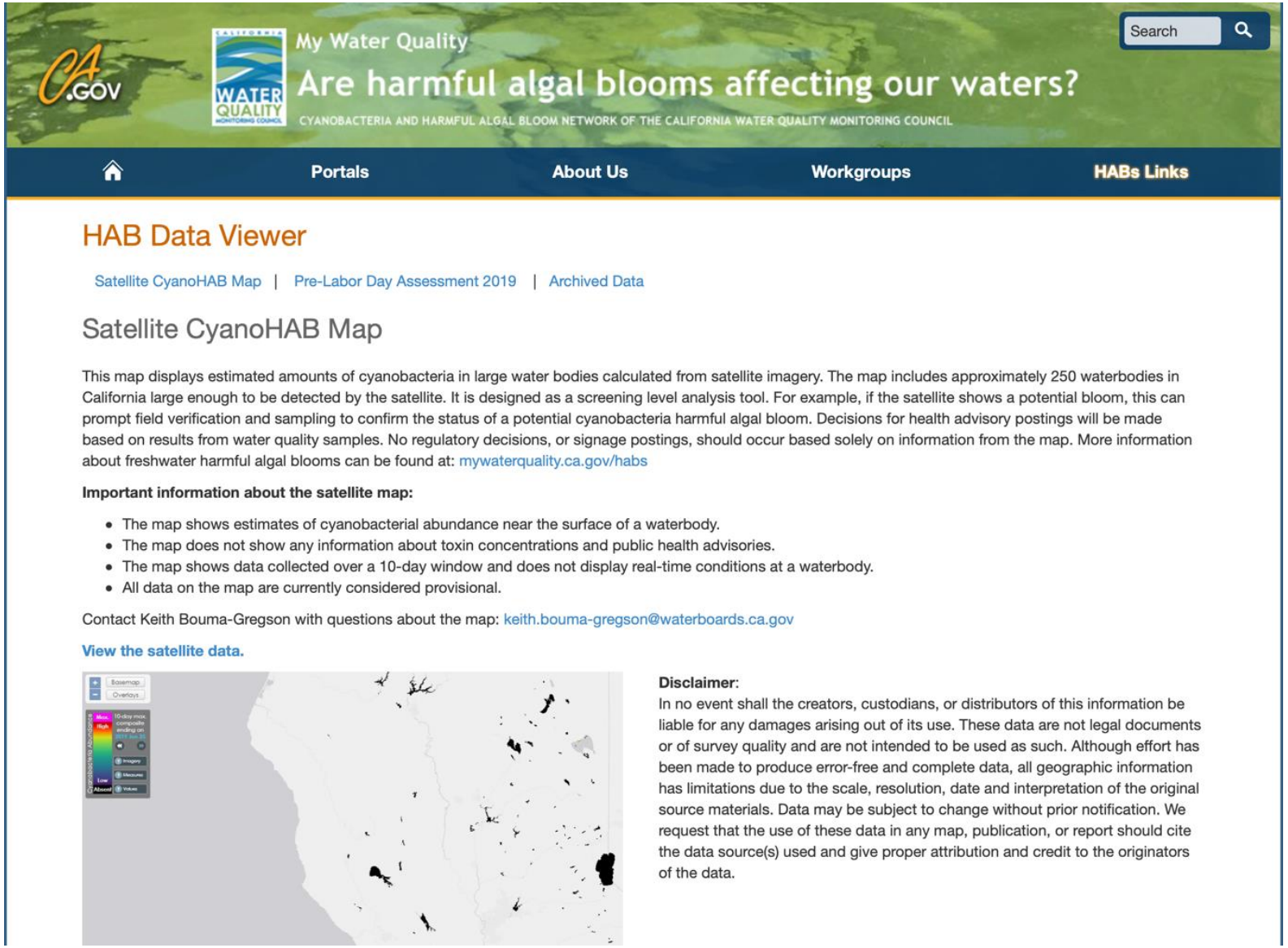
Contact: Michelle.Tomlinson@noaa.gov

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.
The views expressed are those of the authors and do not necessarily reflect the views or policies of the U.S. Government."

Extra Slides For Application developed for California

California Cyanobacteria and HAB Network Website:

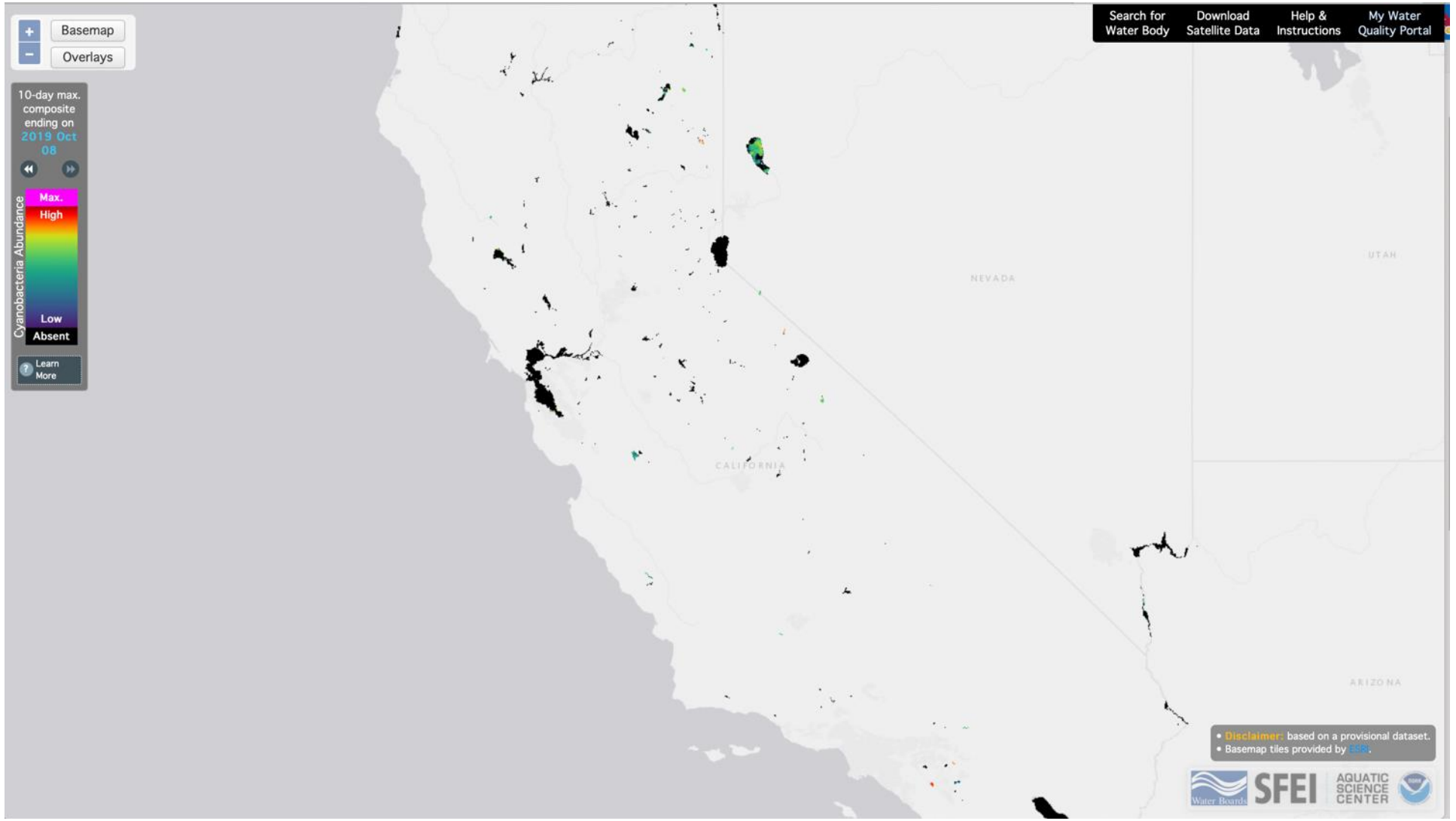
mywaterquality.ca.gov/habs/data_viewer



Slides Courtesy of Keith Bouma-Gregson
CA Water Board in collaboration with
San Francisco Estuary Institute

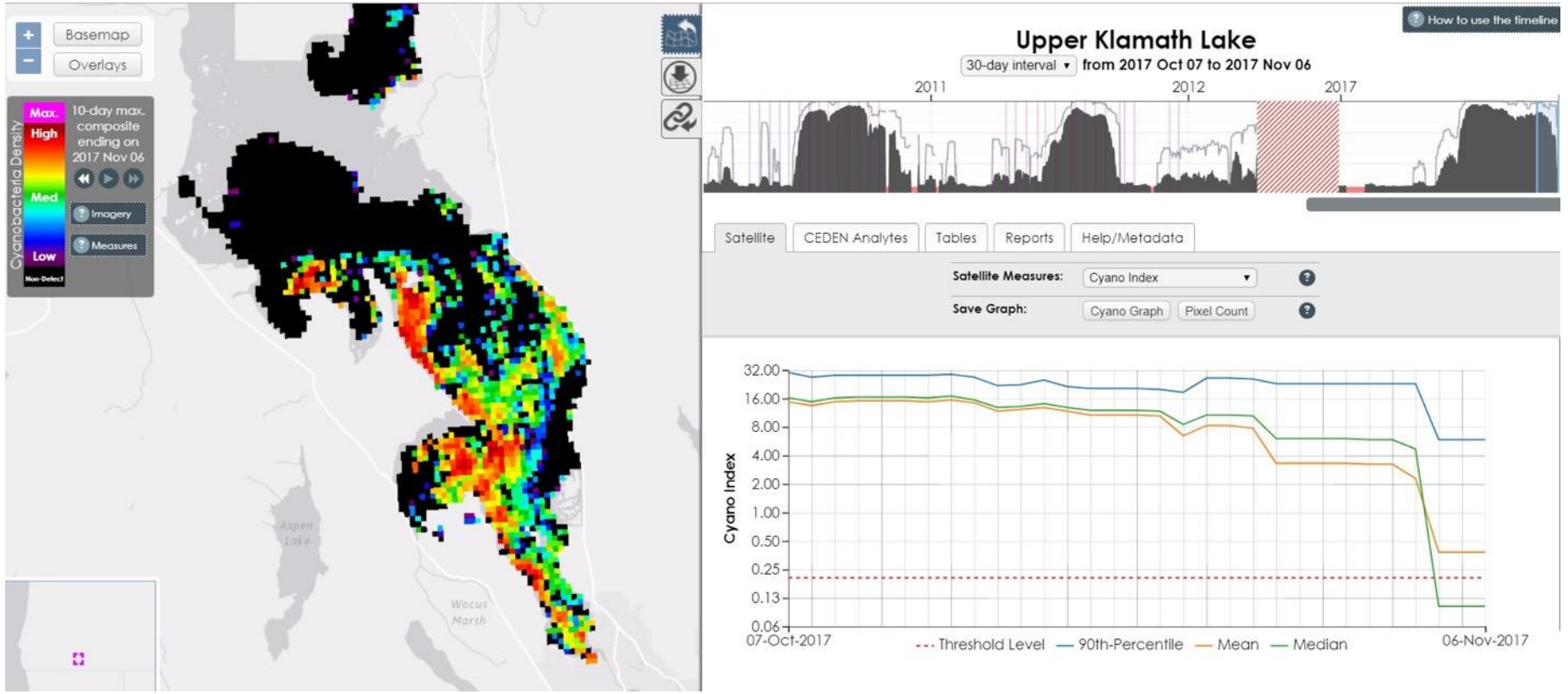
Contacts:
Keith.Bouma-Gregson@waterboards.ca.gov
randyt@sfei.org

Website: mywaterquality.ca.gov/habs/data_viewer



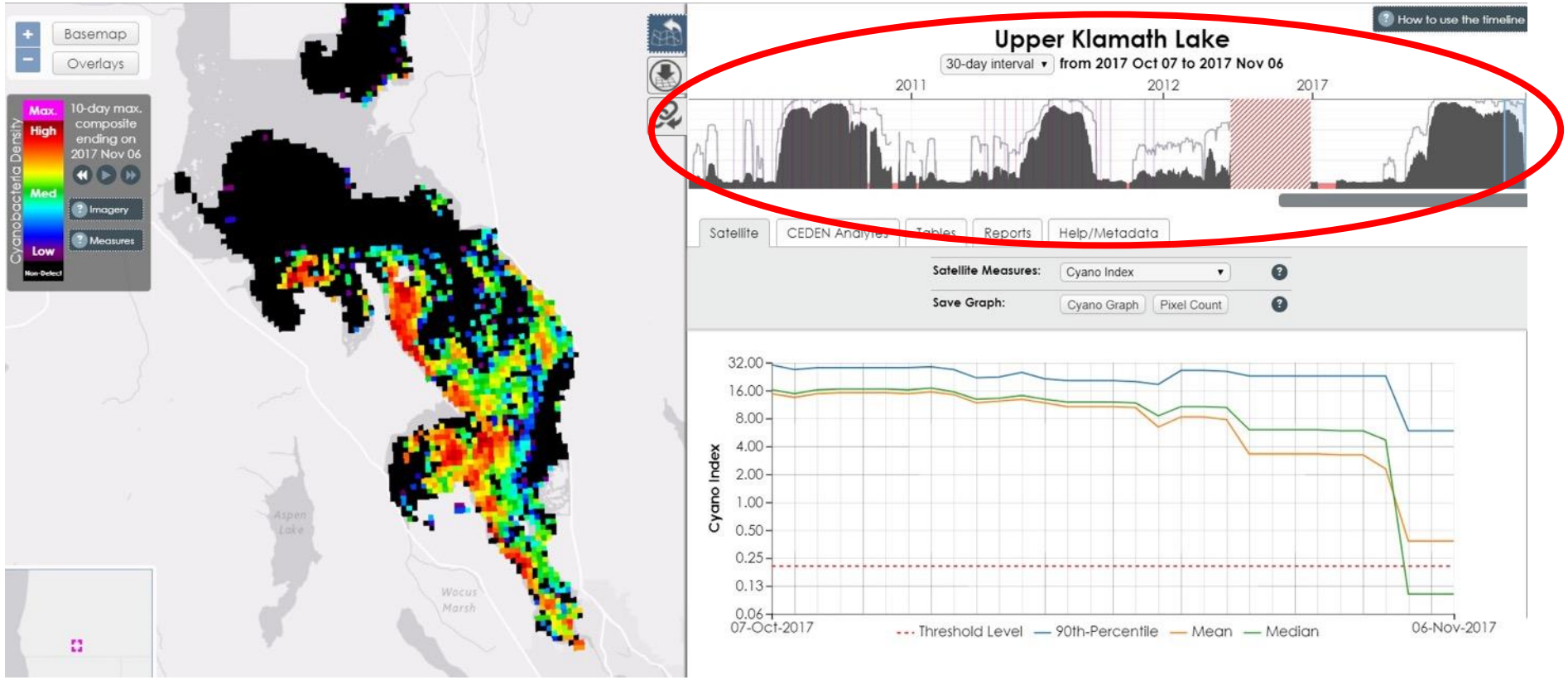
Website visualization interface

mywaterquality.ca.gov/habs/data_viewer



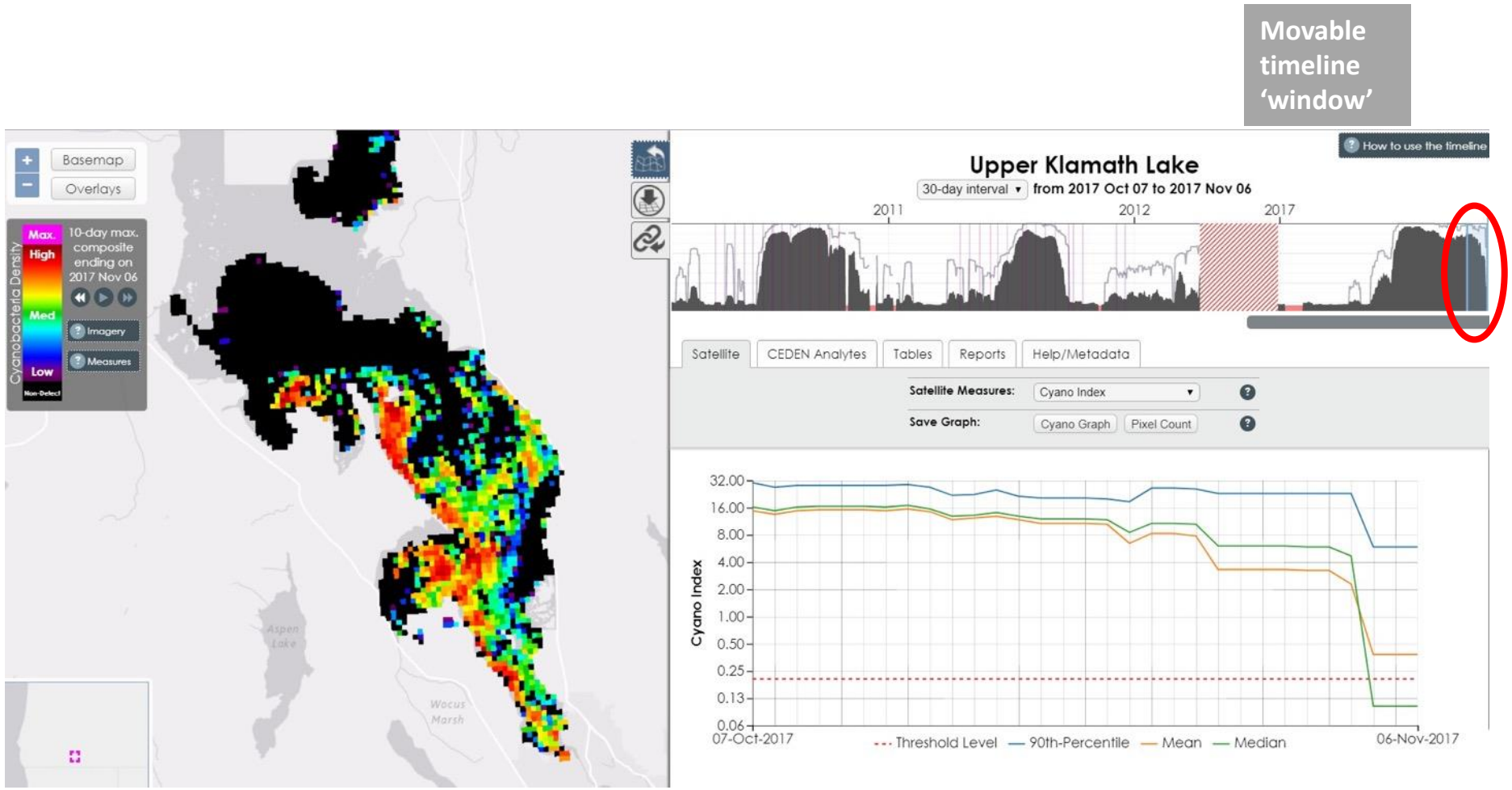
Website visualization interface

mywaterquality.ca.gov/habs/data_viewer



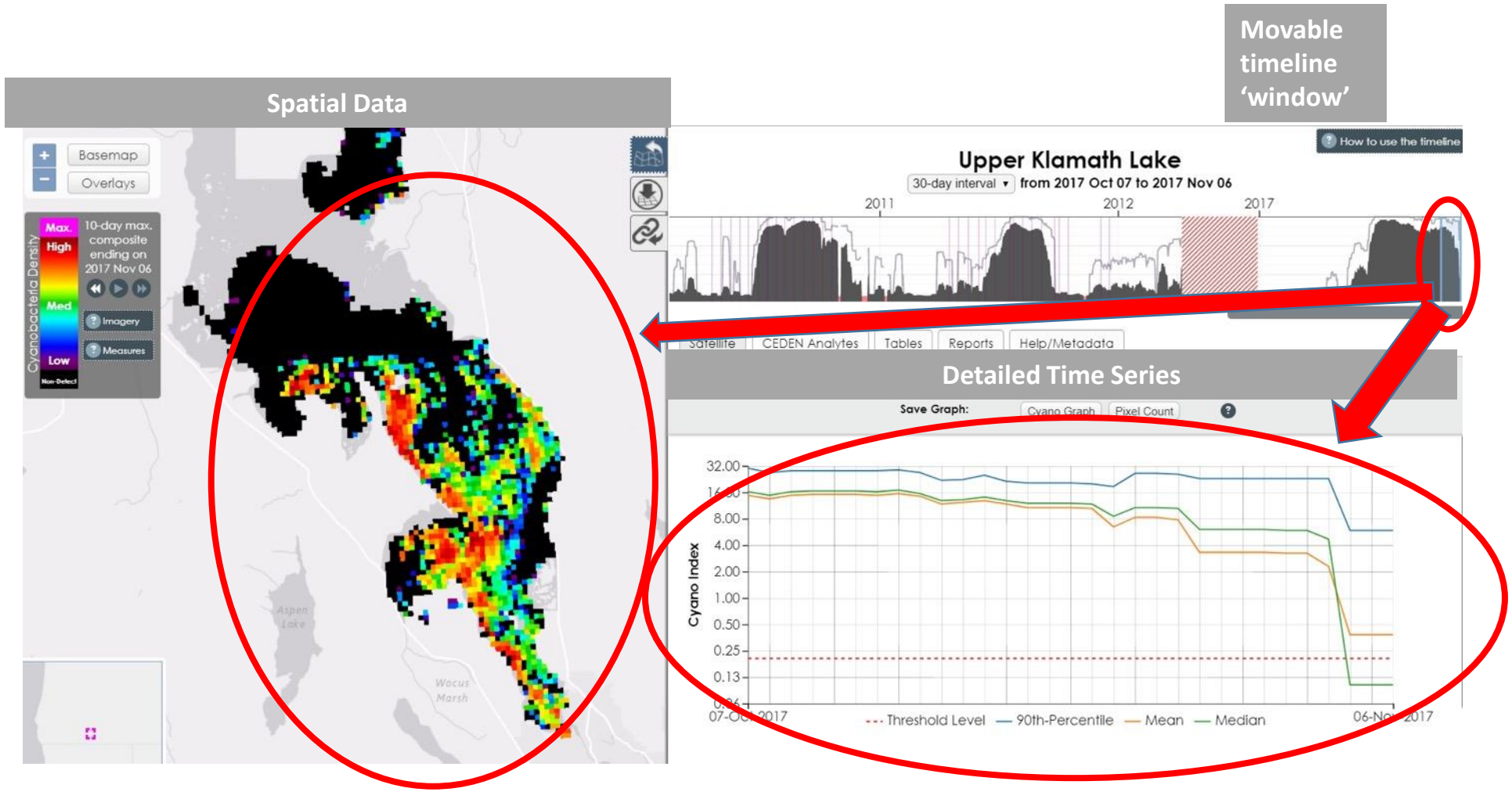
Website visualization interface

mywaterquality.ca.gov/habs/data_viewer



Website visualization interface

mywaterquality.ca.gov/habs/data_viewer



Management uses

- Data considered provisional, no postings
- Screening tool for waterbody field assessments

    Emails sent out when above the CIcyano threshold of 3.2

- Early warning tool
- Shoreline pixel masking limits its application
- Chose not to display any cells/mL equivalents due to uncertainty about the correlations with cell density
- Plans to expand and improve fhab.sfei.org with new Water Boards and SFEI contract in 2021

Future potential use for:

- Historical trends
- Landscape risk assessment
- Secondary lines of evidence for 303d impairment listings