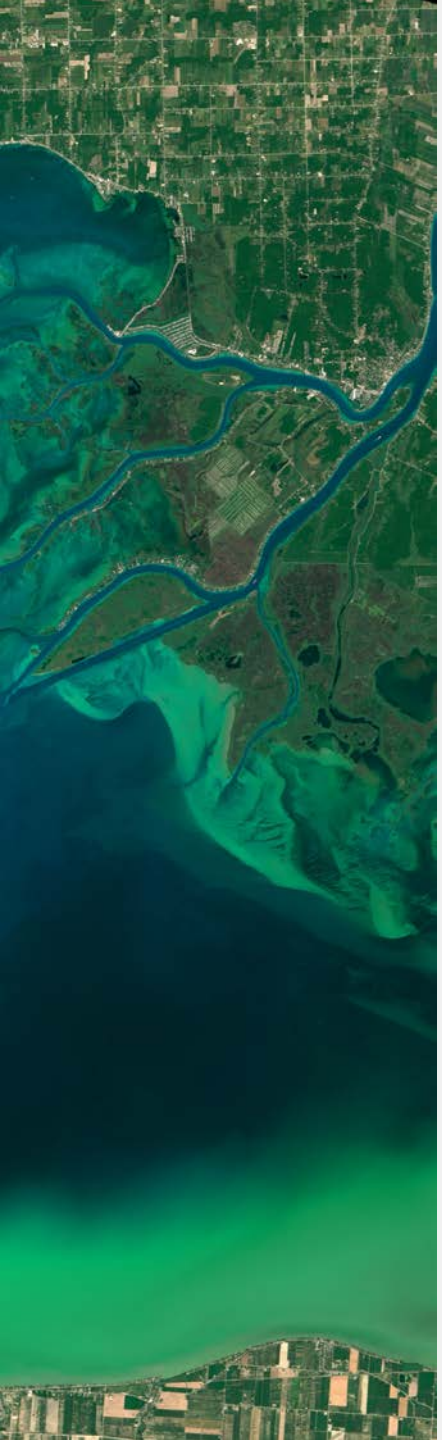


National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Understanding HABs in the Coastal Environment

September 19, 2017

Week 3

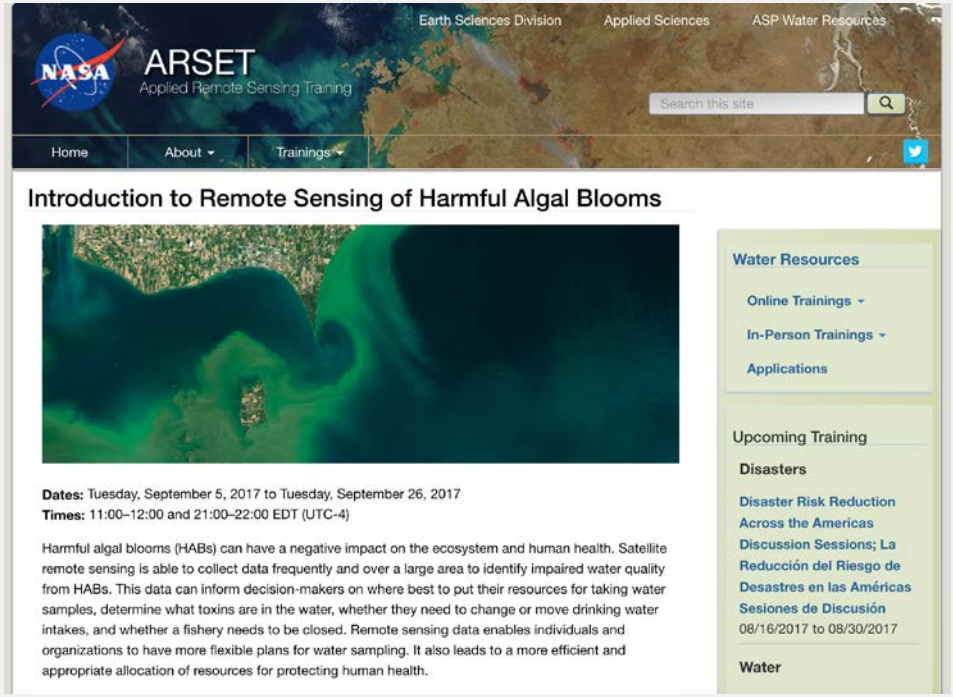
Trainers: Sherry Palacios
Amita Mehta

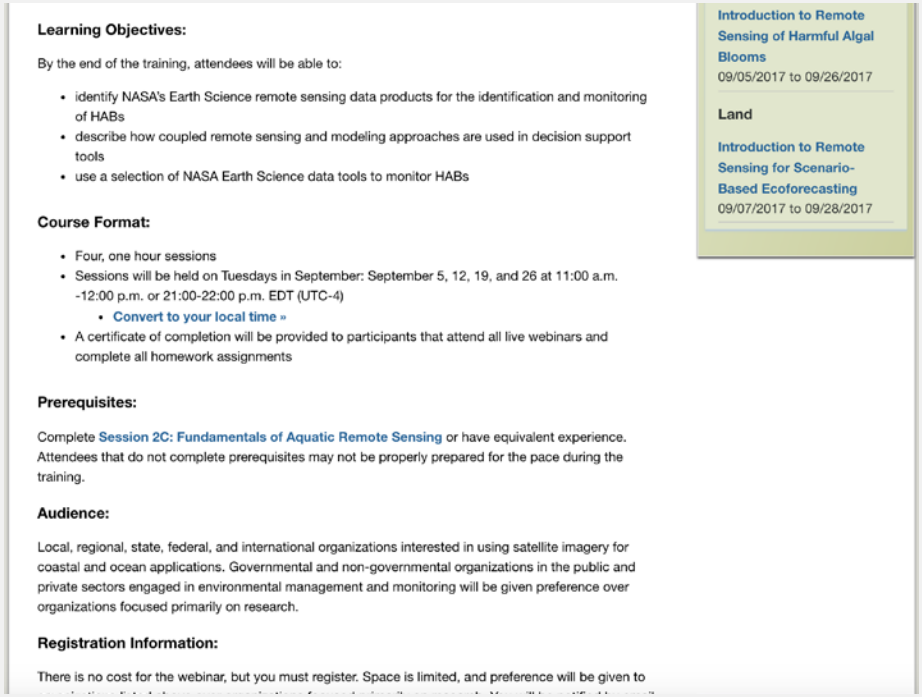
Course Structure

- 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

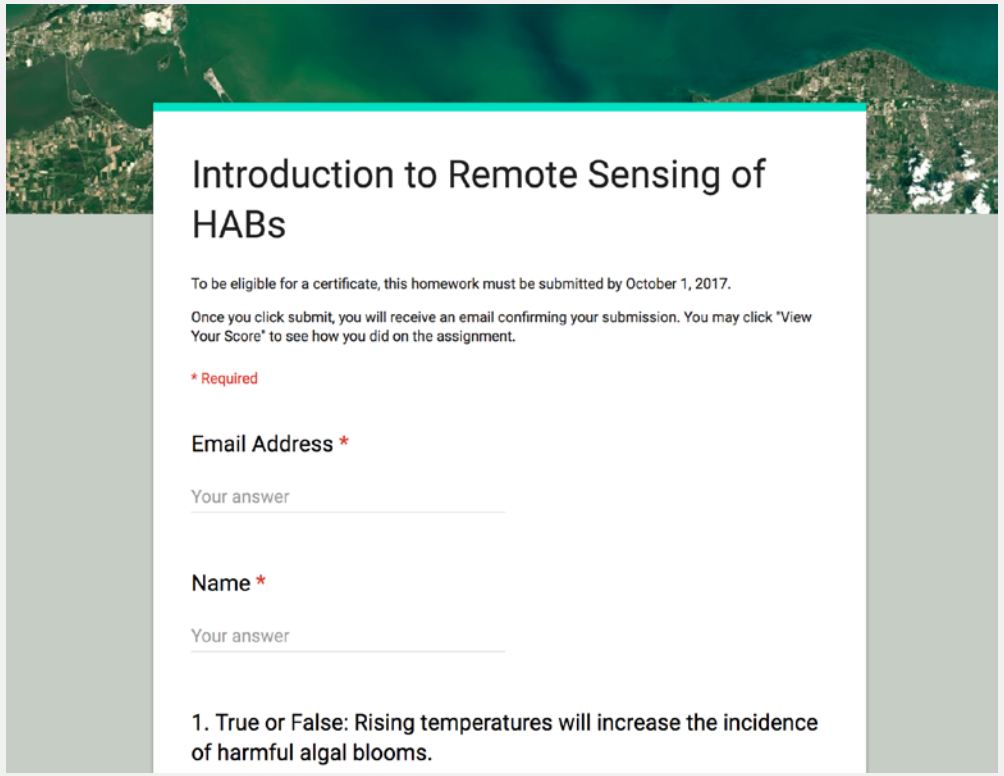
Webinar recordings, presentations, in class exercises, and homework are available at: http://arset.gsfc.nasa.gov/water/webinars/HABs17/



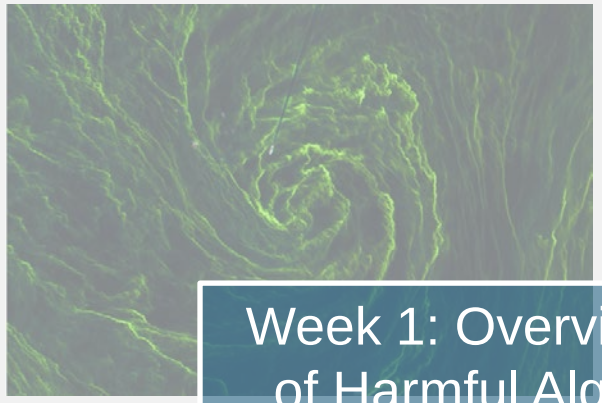


Homework and Certificates

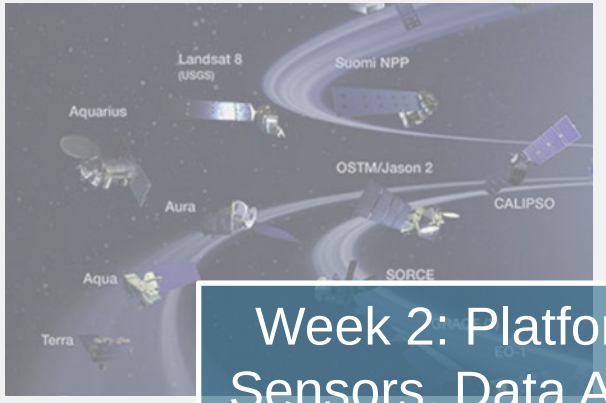
- Homework
  - **Answers must be submitted via Google Form**
- Certificate of Completion:
  - Attend all webinars
  - Complete homework assignments by the deadline (access from ARSET website)
    - **HW Deadlines: October 1st and 15th**
  - You will receive certificates approx. two months after the completion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

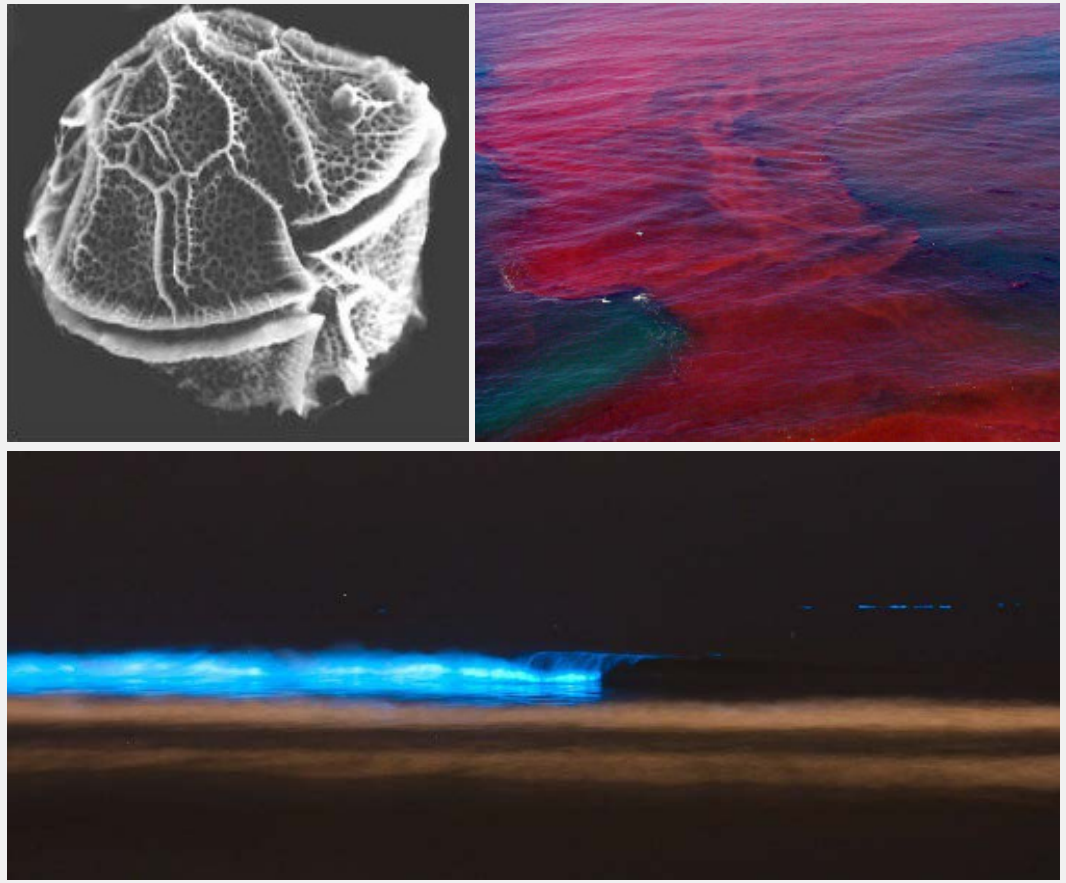
Credit: Paul Hillman/NOAA

Week 3: HABs in the Coastal Environment

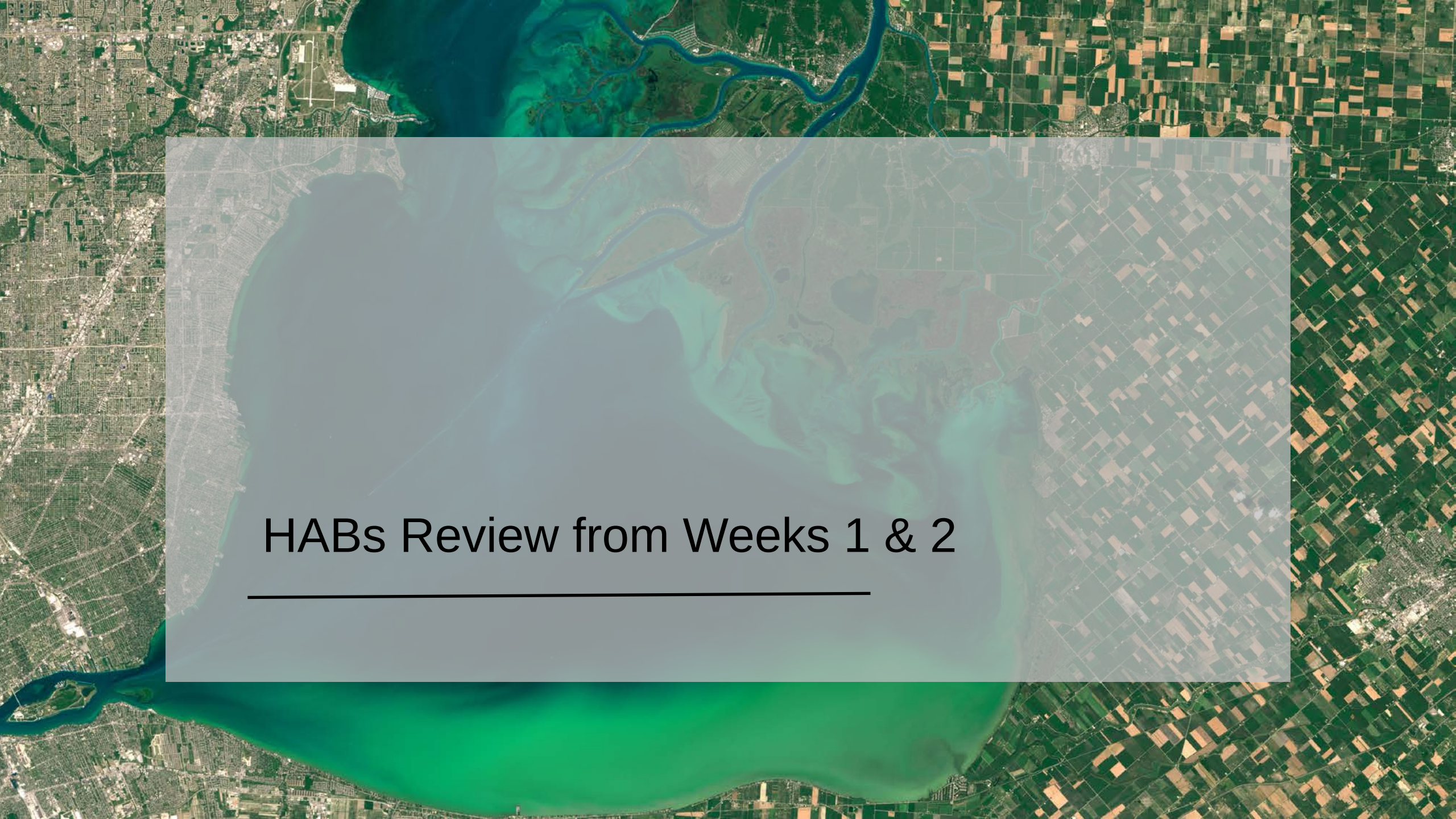
Week 4: Large Scale Monitoring

Outline – Session 3

- HABs review from weeks 1 & 2
- Remote sensing as a tool for decision support
- Overview of coupled model and remote sensing tools for understanding HABs
- California Harmful Algae Risk Mapping (C-HARM) System
  – Guest Speaker: Dr. Clarissa Anderson



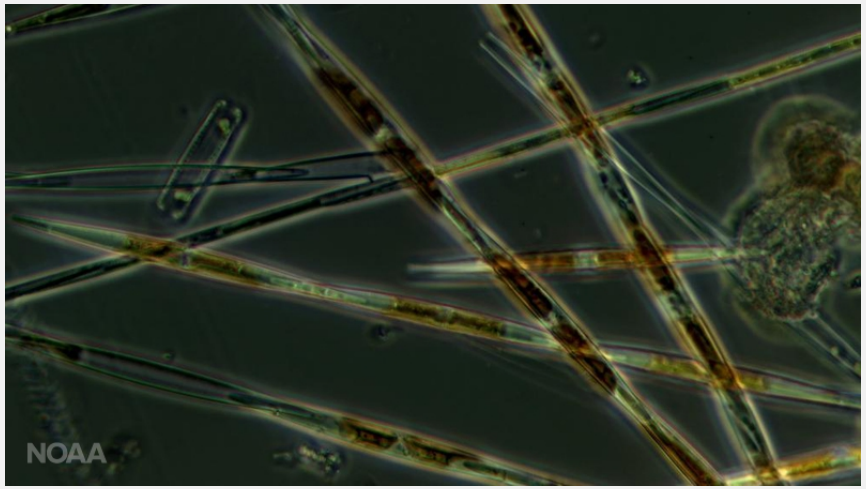
Lingulodinium sp. produces intense red tides that are bioluminescent. These blooms are often non-harrmful, but can sometimes can be when they produce yessotoxin. Photo credit: (clockwise from upper left) MKB Kuylenstierna, Kai Schumann, Kevin Baird



HABs Review from Weeks 1 & 2

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.”



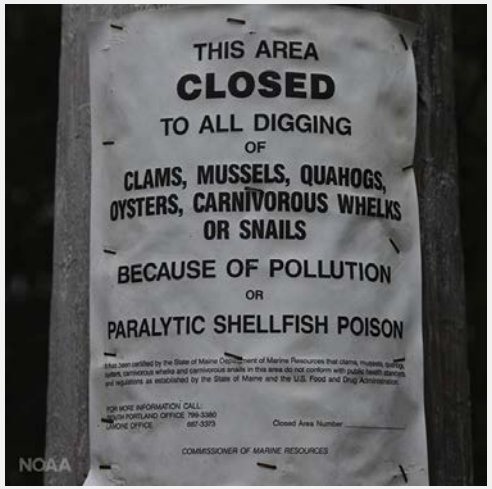


Image credit: http://www.noaa.gov/what-is-harmful-algal-bloom

How HABs Can Be Harmful

- Produce toxins
- Cause economic losses
- Contaminate drinking water
- Smother benthic organisms
- Deplete oxygen
- Impede visual predators
- Attenuate light to benthic submerged aquatic vegetation or corals

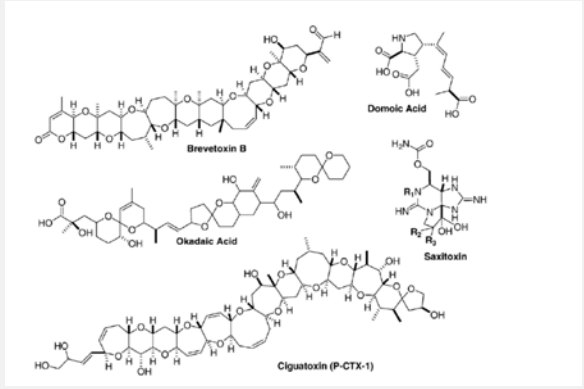


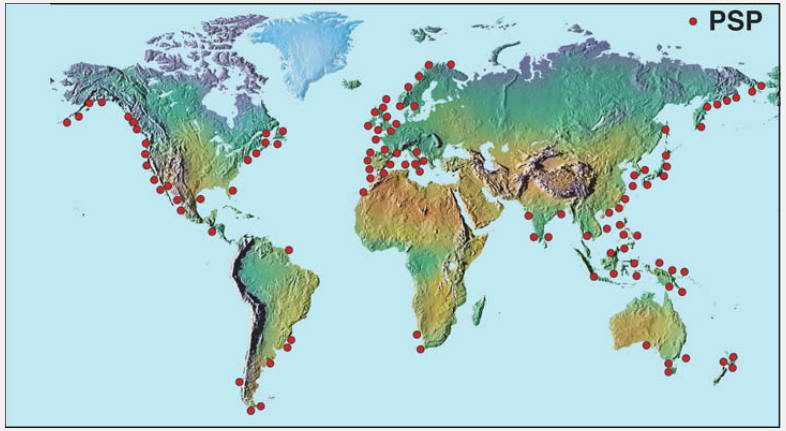
Photo Credits (clockwise from top left) Karina Cardozo (Cardozo et al., 2007); NASA Earth Observatory; NOAA Northwest Fisheries Science Center; Linda Preskitt

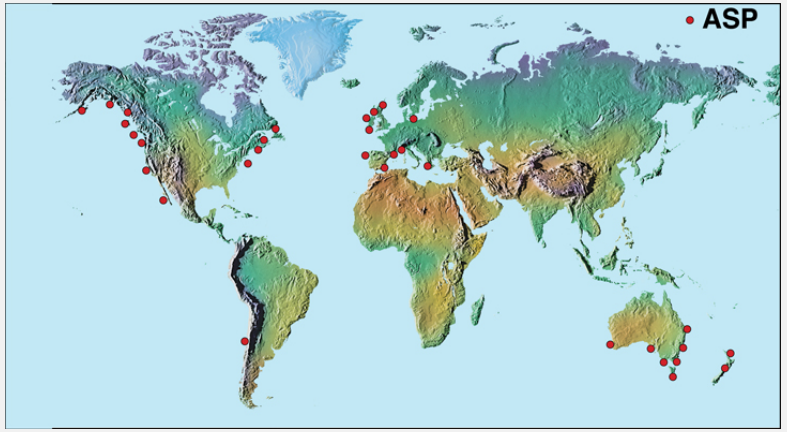
What Causes HABs?

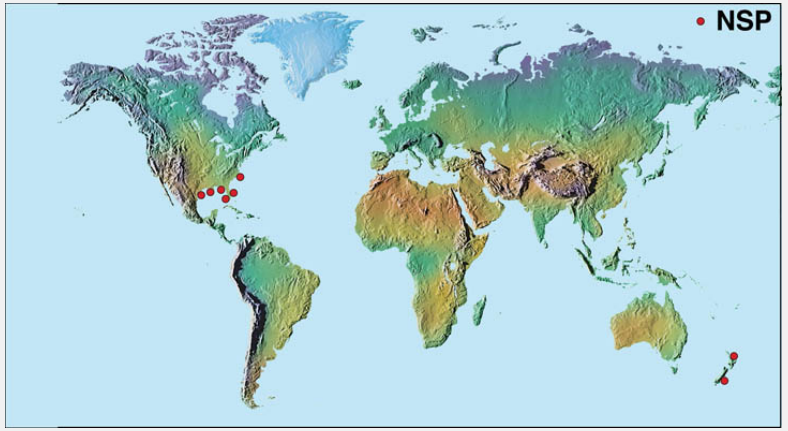
- Nutrient loading “eutrophication”
- Pollution
- Warm water
- Food web changes
- Introduced species
- Changes in water flow
  – e.g., after major events like hurricanes, drought, or floods
- Other, yet unknown, factors

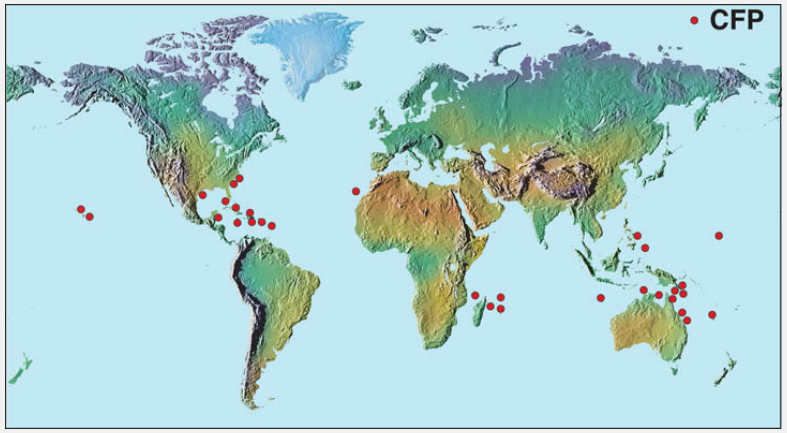
Global Distribution of HAB Toxins

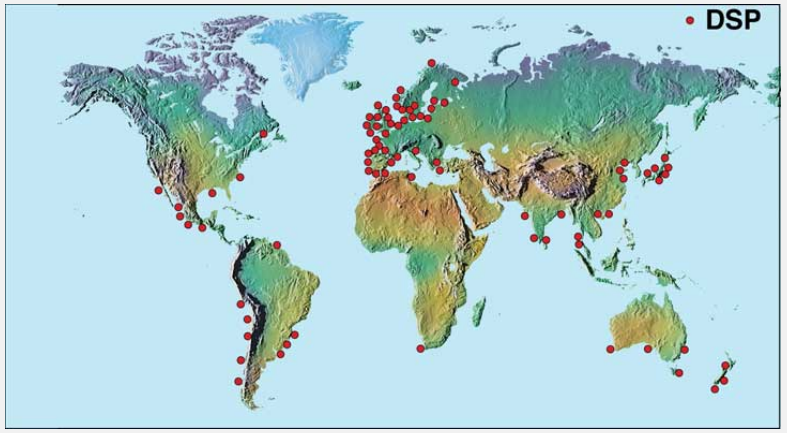
Recorded as of 2016









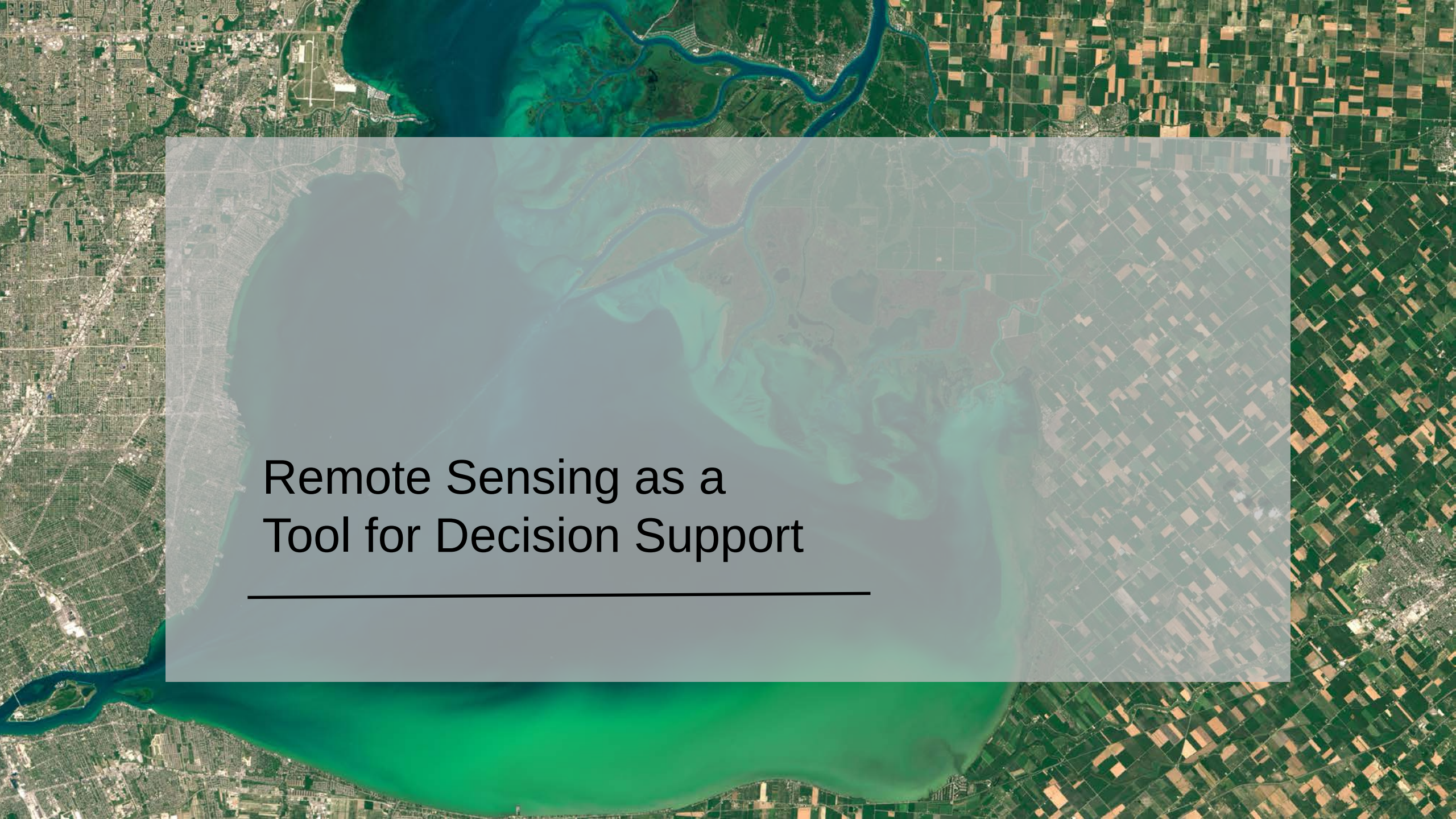


PSP - Paralytic Shellfish Poisoning
ASP - Amnesic Shellfish Poisoning
NSP - Neurotoxic Shellfish Poisoning
CFP - Ciguatera Fish Poisoning
DSP - Diarrheic Shellfish Poisoning

Images: WHOI http://www.whoi.edu/redtide/regions/world-distribution

Main Take-Away for the Webinar Series…

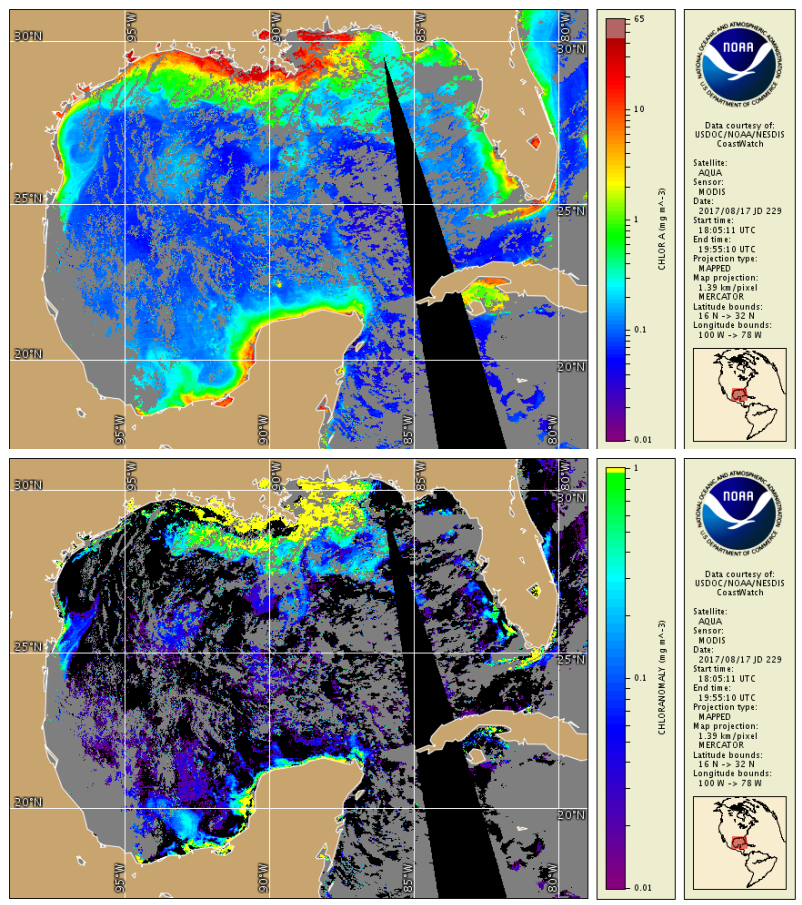
- Remote sensing imagery is a tool to aid in the monitoring and forecasting of HAB events to understand impacts to the ecosystem and/or human health
- Remote sensing imagery does not replace sampling on-the-ground
- Imagery, with associated algorithms and ecosystem models, informs adaptive sampling approaches used by resource managers



Remote Sensing as a Tool for Decision Support

Parameters Relevant for HAB Detection

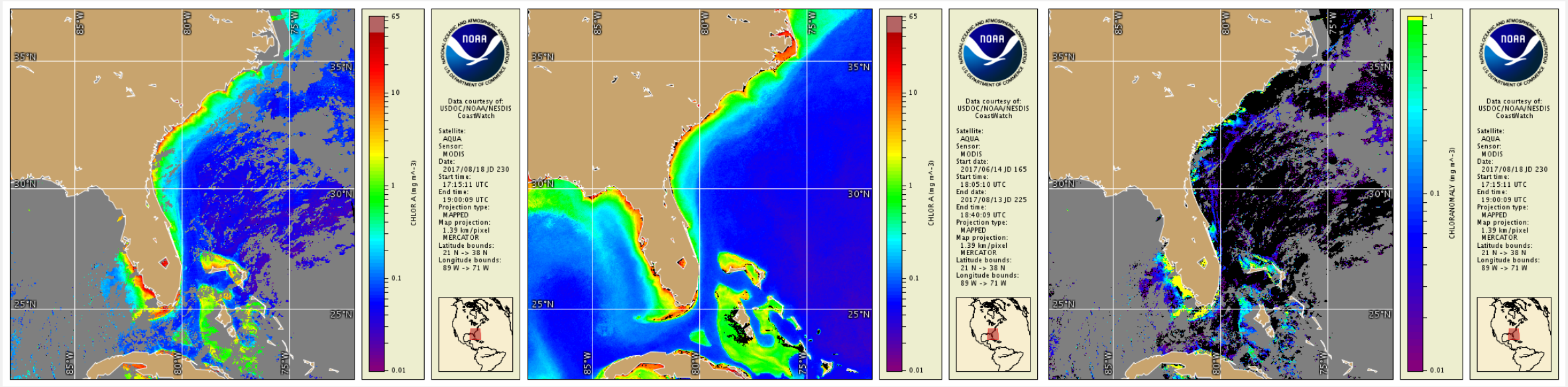
- The following parameters, available from remote sensing observations, are commonly used to detect the presence of an algal bloom
  - Chlorophyll-a Concentration (Chl-a)
  - Chlorophyll-a Concentration Anomalies
  - Taxon-Specific Bio-optical Properties
  - Sea Surface Temperature (SST) and other environmental proxies



Parameters Relevant for HAB Detection

e.g., Chlorophyll-a Concentrations and Chlorophyll-a Anomalies

[Chl-a] – Bimonthly Mean $[Chl\text{-}a]_{2\ weeks\ ago}$ = Chl-a Anomaly



Chl-a Concentration

Chl-a Concentration Bimonthly Mean

Chl-a Anomaly

Chl-a=Chlorophyll-a. Image Credit: http://www.ospo.noaa.gov/Products/ocean/color/swir_chla_daily.html#table

Chlorophyll-a Concentration

- Chlorophyll-a concentration gives an estimate of phytoplankton biomass
- Chlorophyll-a concentration alone, without prior knowledge of the system, is difficult to use as a metric for the presence of a bloom
- Chlorophyll-a does not provide information about the type of organism present

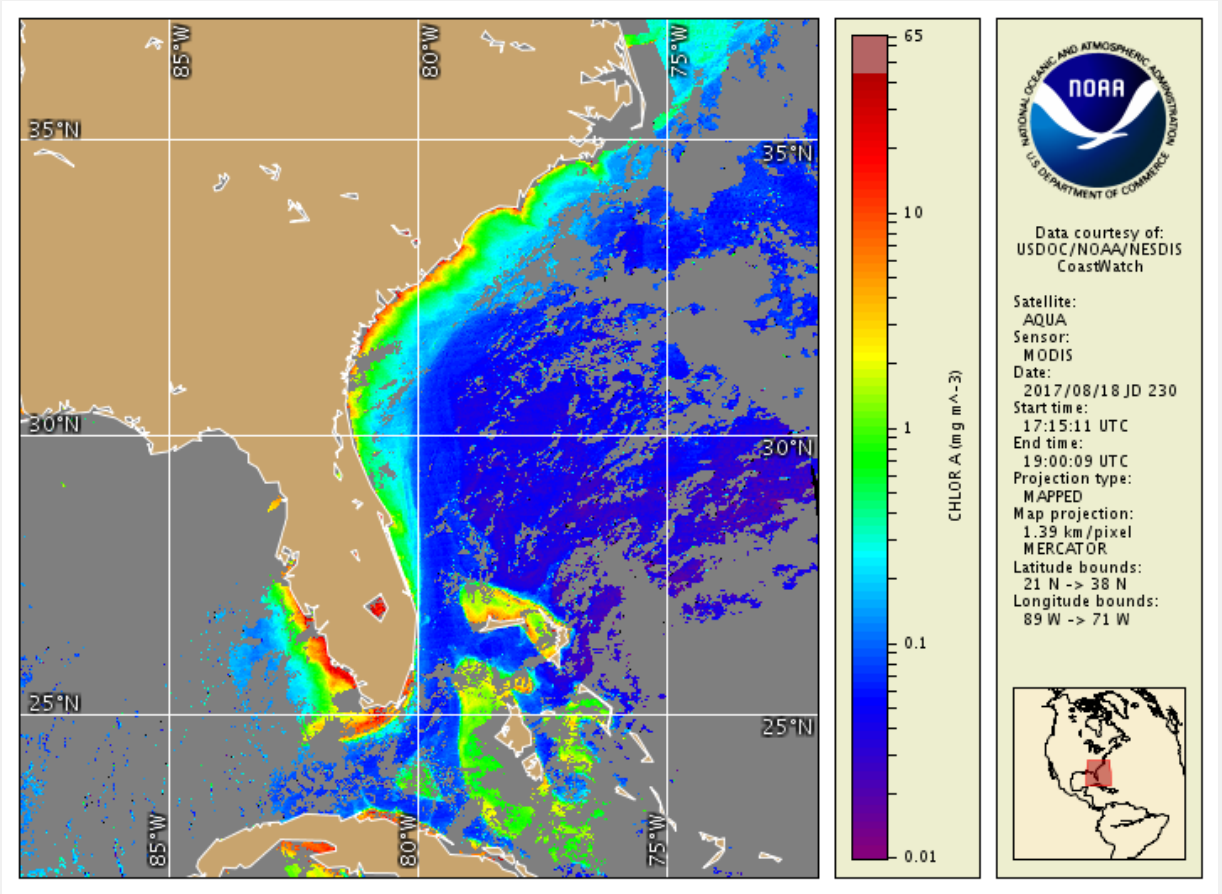
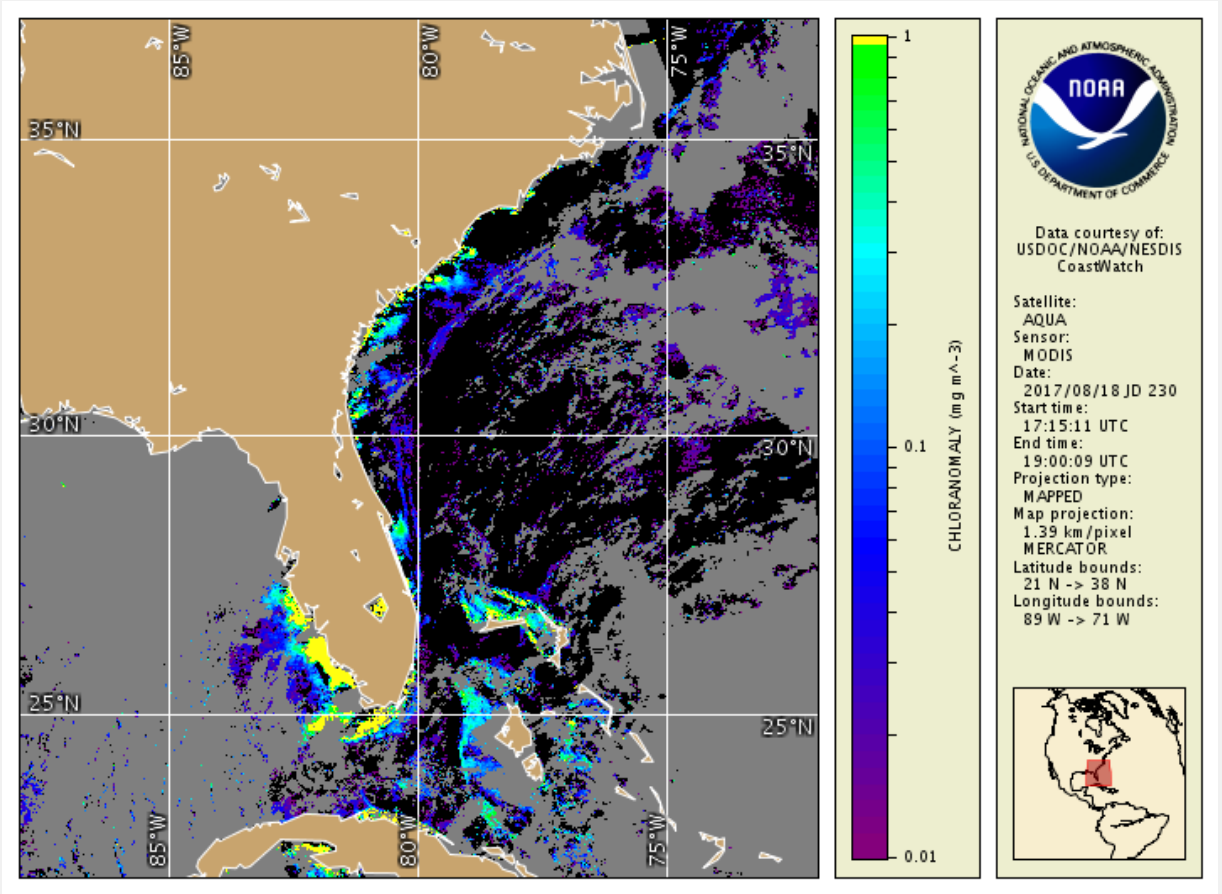


Image Credit: http://www.ospo.noaa.gov/Products/ocean/color/swir_chla_daily.html

Chlorophyll-a Anomaly

- In the case of the West Florida Shelf, an anomaly value of 1 mg m^{-3} is considered a bloom condition, possibly a red tide
- What defines ‘bloom condition’ depends on the system being studied
- Chlorophyll-a anomaly does not provide information about the type of organism present



http://www.ospo.noaa.gov/Products/ocean/color/swir_chla_anomaly.html#table

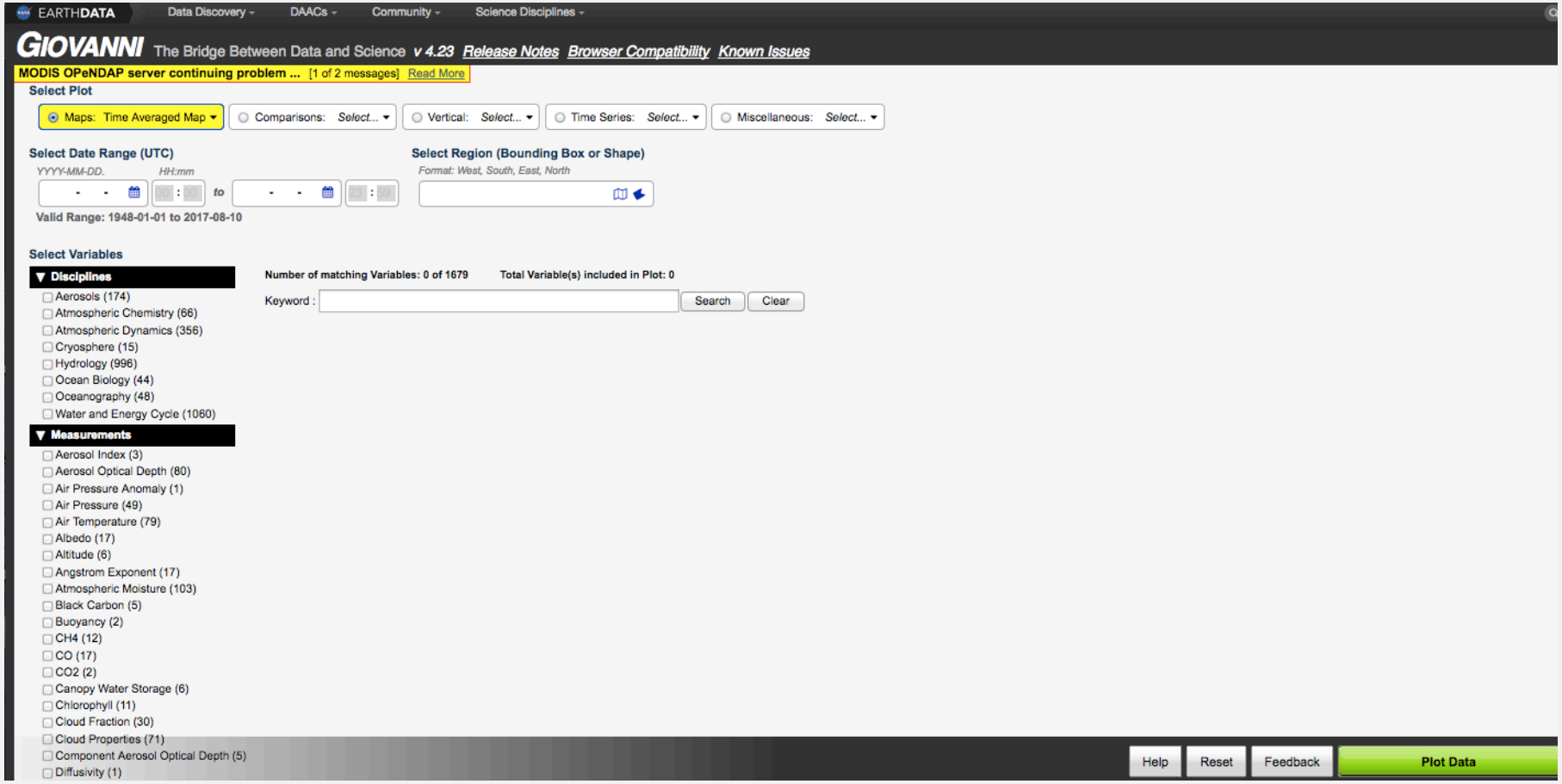
Chlorophyll-a Anomaly Is an Effective Tool…

- when one bloom-forming organism dominates (e.g., Karenia brevis)
- and provides a rapid assessment of an increase in phytoplankton biomass
- that is easily computed by beginning users of remote sensing imagery
- that can be applied to many regions of the world that experience HABs

Understanding the Chlorophyll-a Anomaly

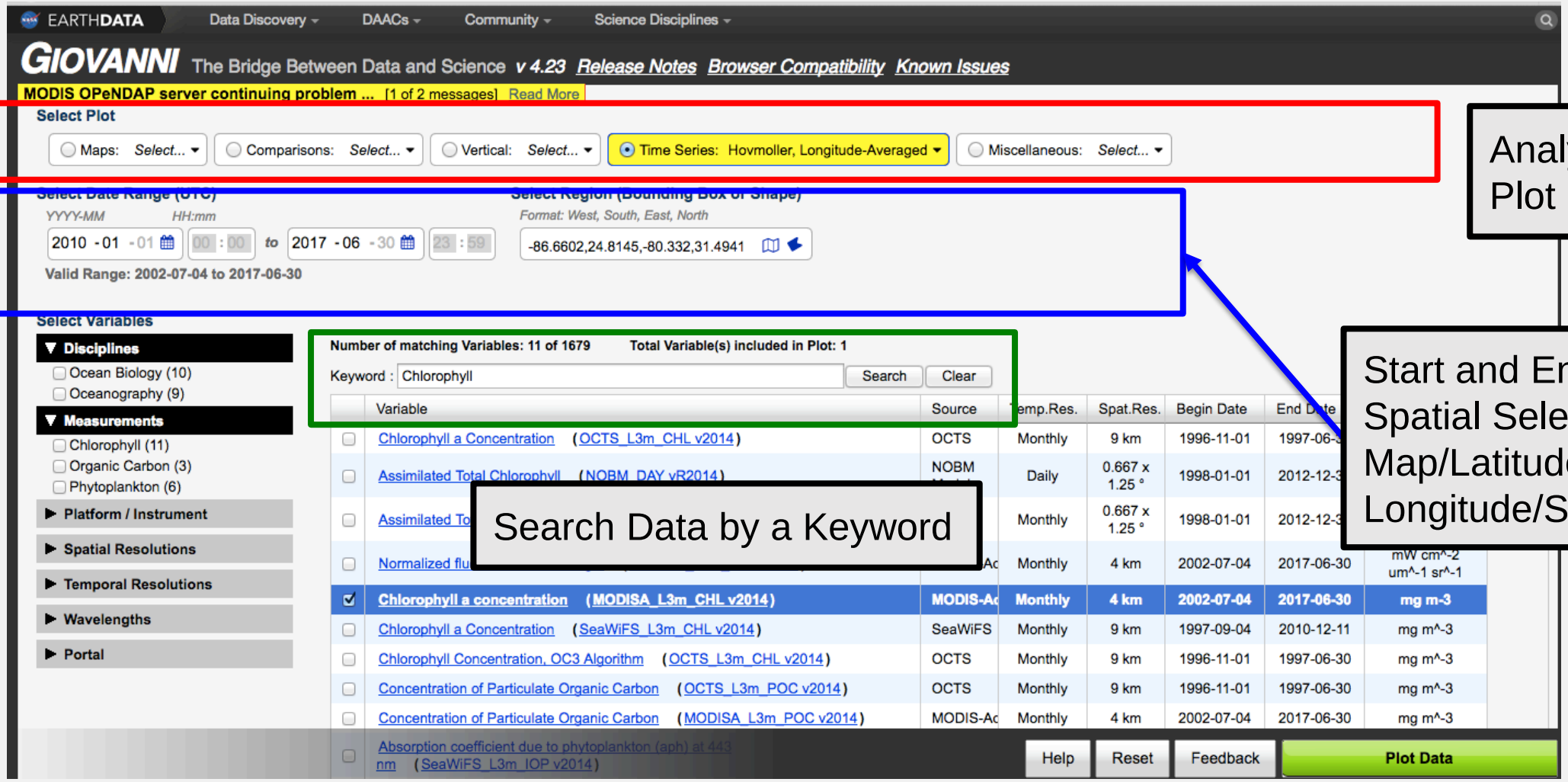
Giovanni

http://giovanni.gsfc.nasa.gov/giovanni



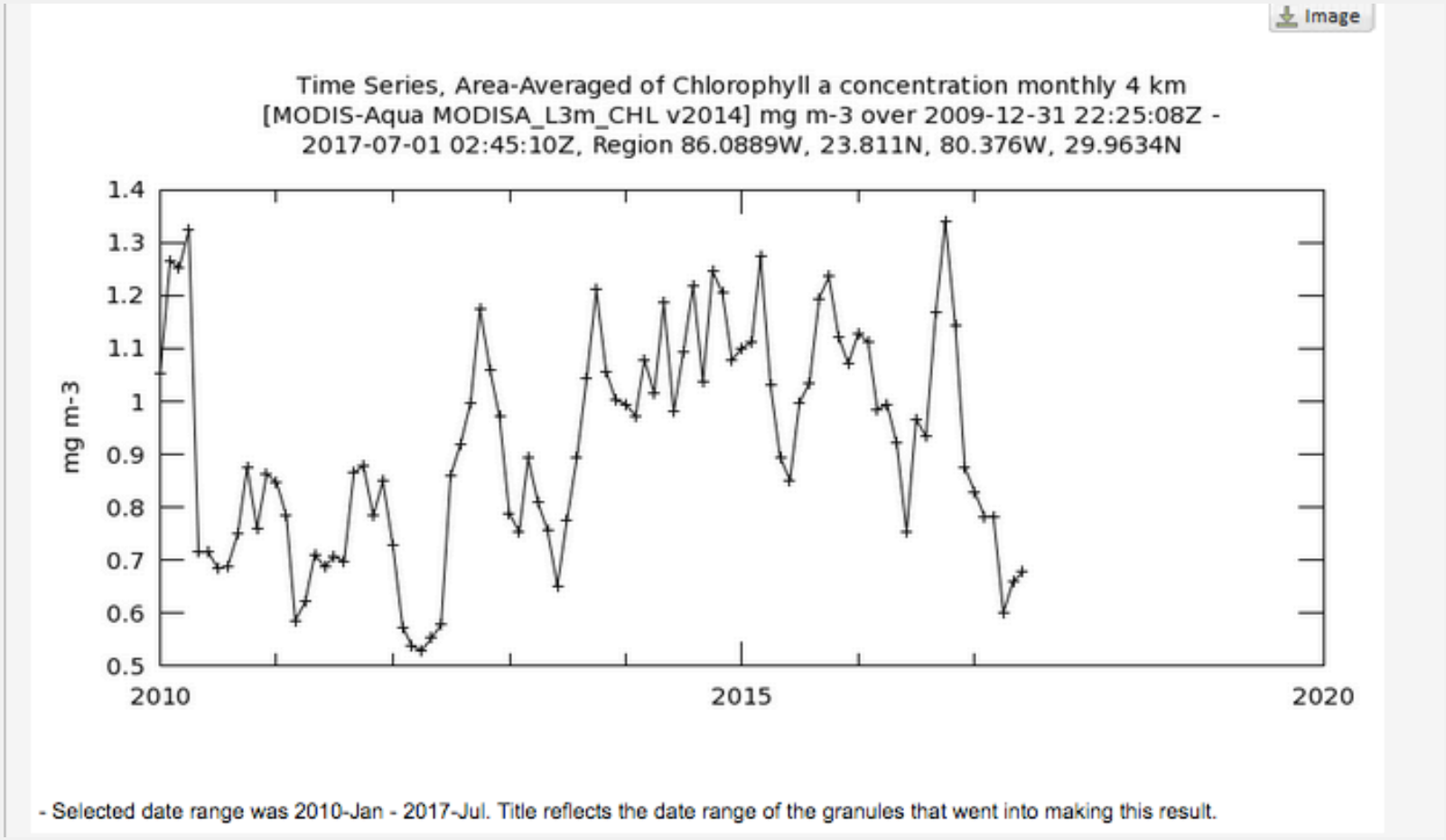
Understanding the Chlorophyll-a Anomaly

http://giovanni.gsfc.nasa.gov/giovanni/



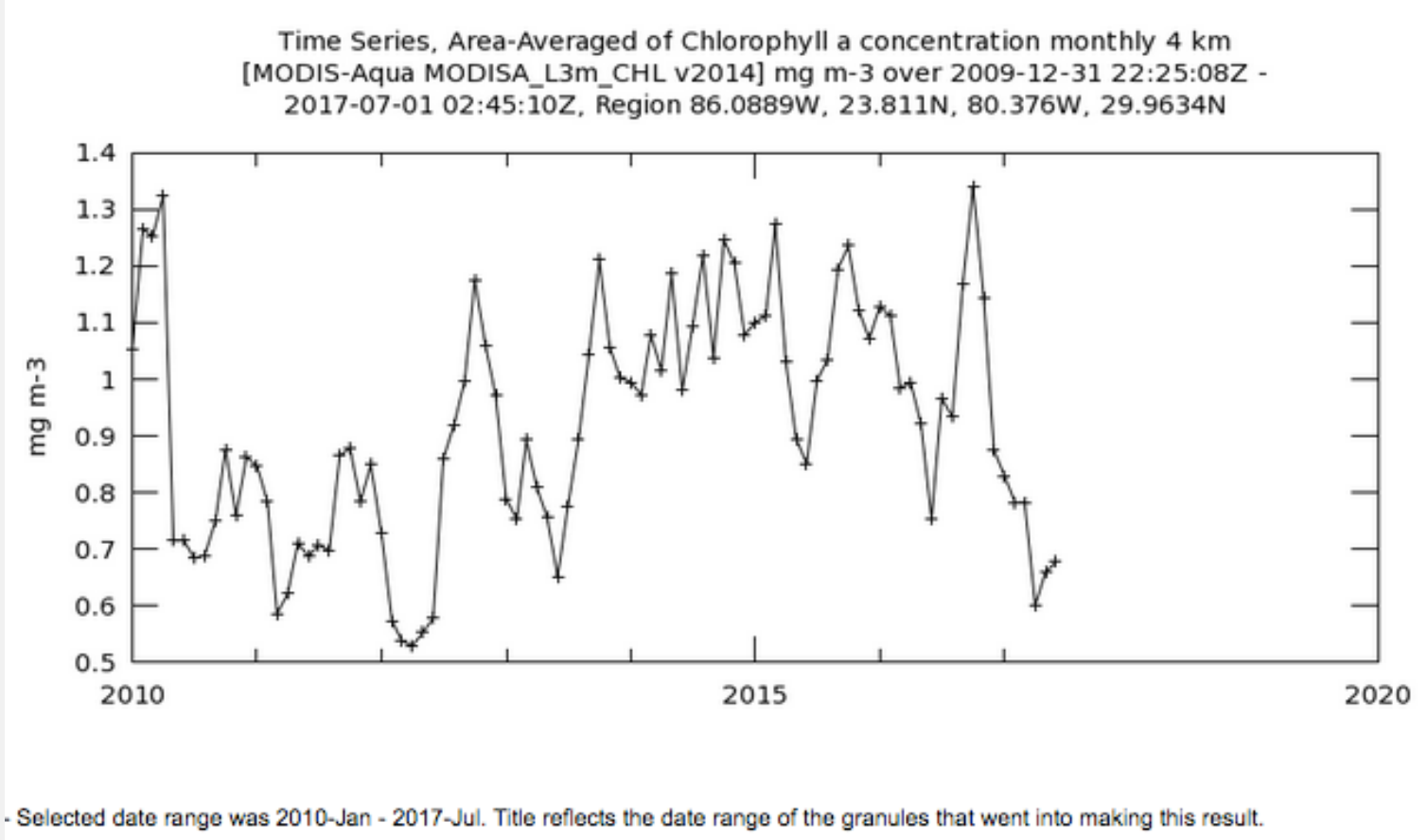
Giovanni Can Be Used to Visualize Chl-a Anomalies Globally

http://giovanni.gsfc.nasa.gov/giovanni/

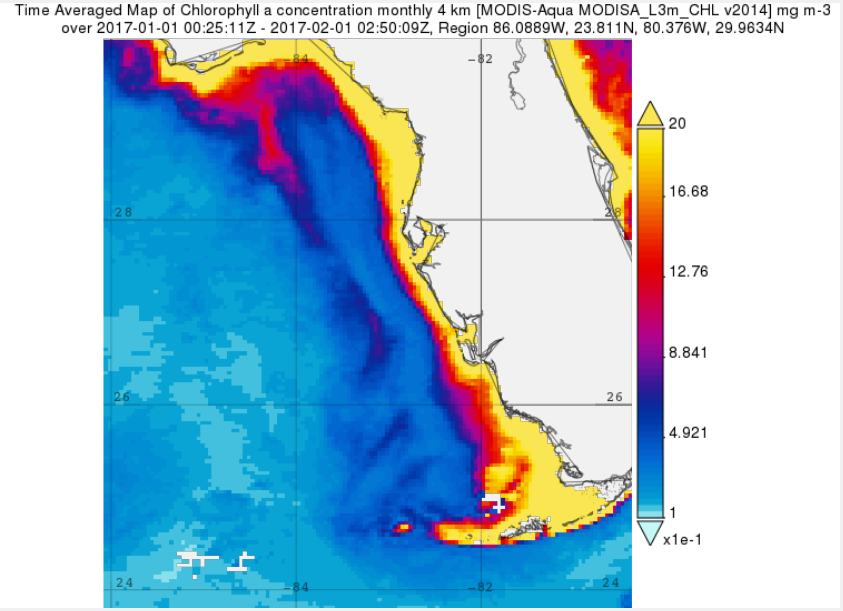


Giovanni: Chlorophyll Concentration in the Gulf of Mexico

http://giovanni.gsfc.nasa.gov/giovanni/



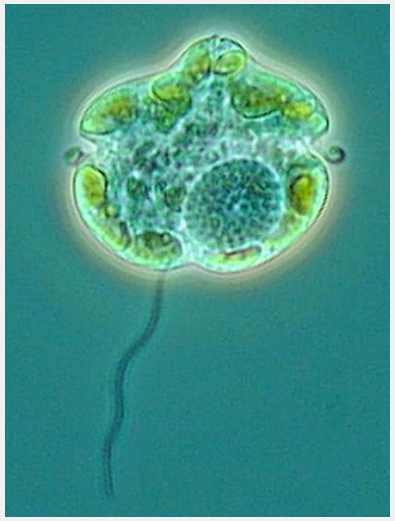
January 2017



Taxon-Specific Bio-Optical Properties

Case Studies

- *Karenia brevis*
  - large phytoplankton with distinctive optical backscattering characteristics



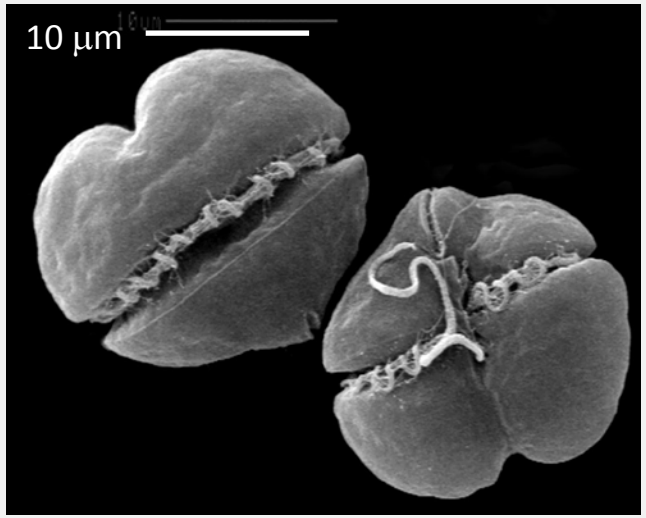


Photo Credit: Florida Fish and Wildlife Conservation Commission

- *Microcystis aeruginosa*
  - cells contain gas filled vesicles that cause the organism to float to the surface during blooms, forming surface scums

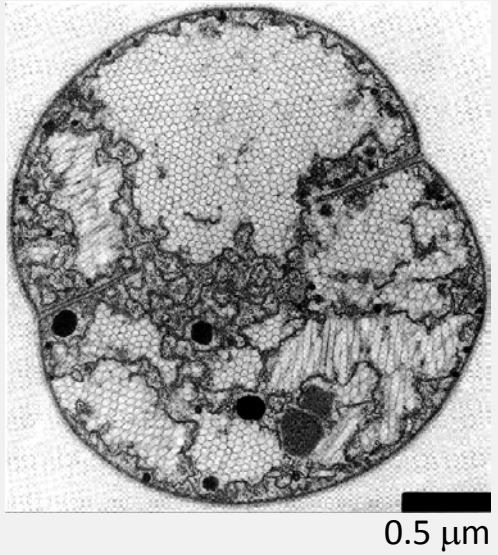
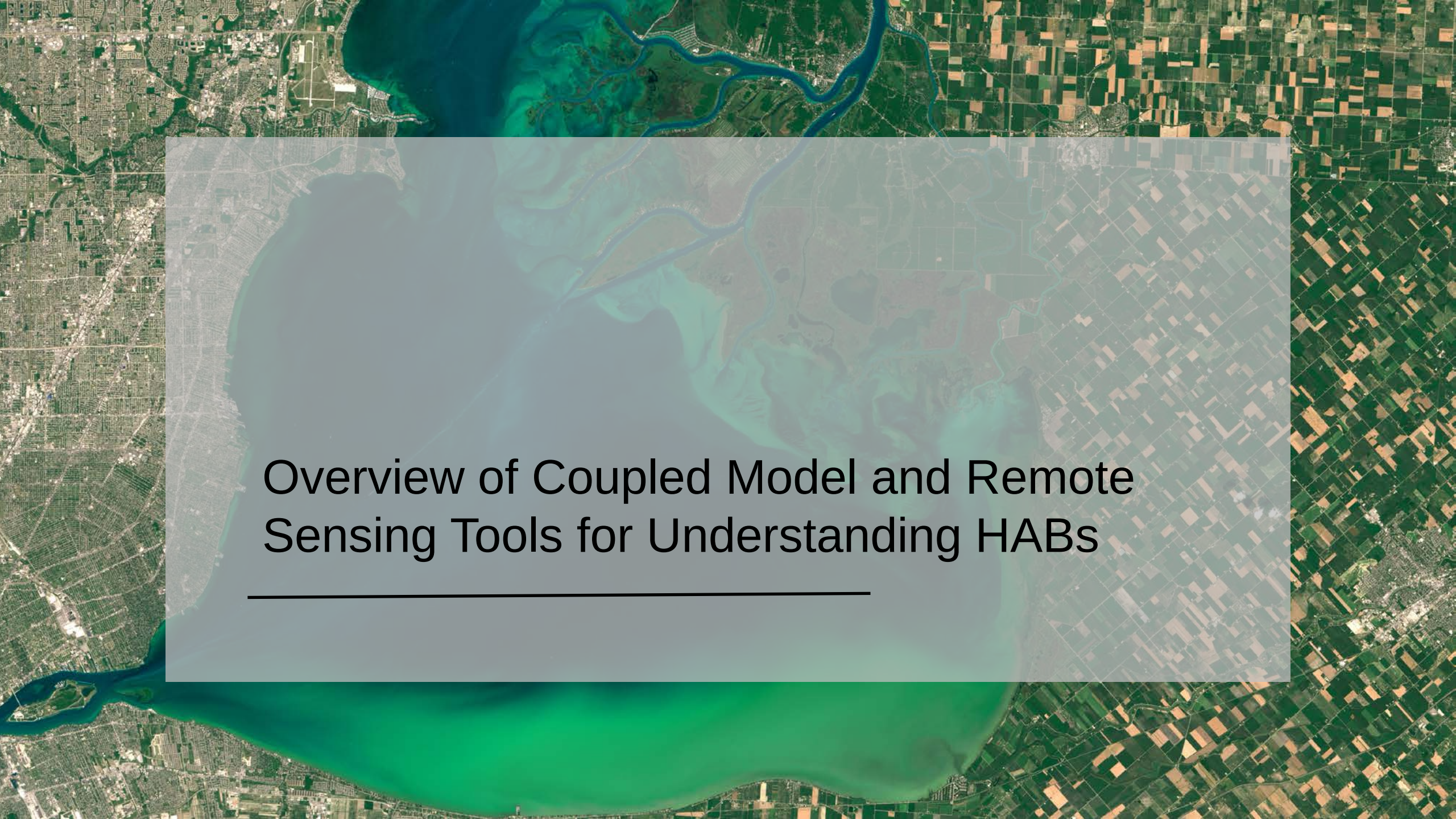


Photo Credit: H.S. Pankratz

SST and Other Environmental Proxies

- Some HABs ‘like it hot’ and so SST can be useful for identifying habitable waters, and forecasting HAB events

- SST can be a used as proxy for environmental variables (e.g., nutrients) that are not directly detectable with remote sensing observations

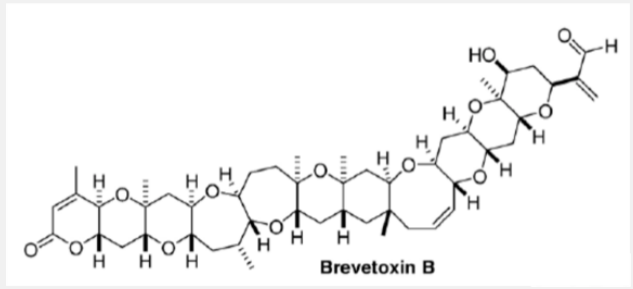


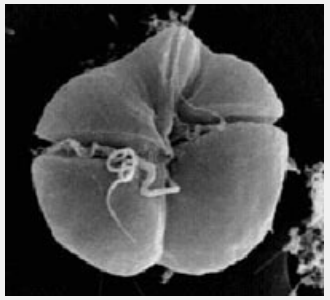
Overview of Coupled Model and Remote Sensing Tools for Understanding HABs

Food Web Vectoring & Airborne Toxic Events

Neurotoxic Shellfish Poisoning – e.g., *Karenia brevis*

- *Karenia brevis* forms intense blooms named ‘Florida Red Tide’ and releases a toxin known as brevetoxin
- Has gastrointestinal and neurologic effects that result from consumption of shellfish
- Cells and toxin can be lofted into the overlying atmosphere from wave action and cause respiratory problems in people downwind





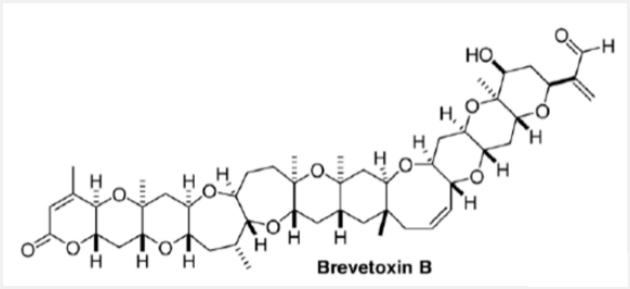
Credit: WHOI https://www.whoi.edu/redtide/human-health/neurotoxic-shellfish-poisoning

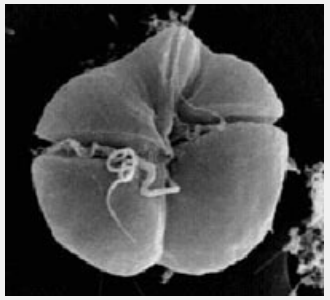
Photo Credit (Clockwise from Top): Karina Cardozo (Cardozo et al., 2007); John Dutton; P. Schmidt, Charlotte Sun Times

Food Web Vectoring & Airborne Toxic Events

Neurotoxic Shellfish Poisoning – e.g., *Karenia brevis*

- Typically not life threatening, hospitalization sometimes needed
- Symptoms
  - Gastrointestinal: nausea, vomiting
  - Neurological: prickling sensation in mouth, lips, and tongue, dizziness, slurred speech, partial paralysis, respiratory distress



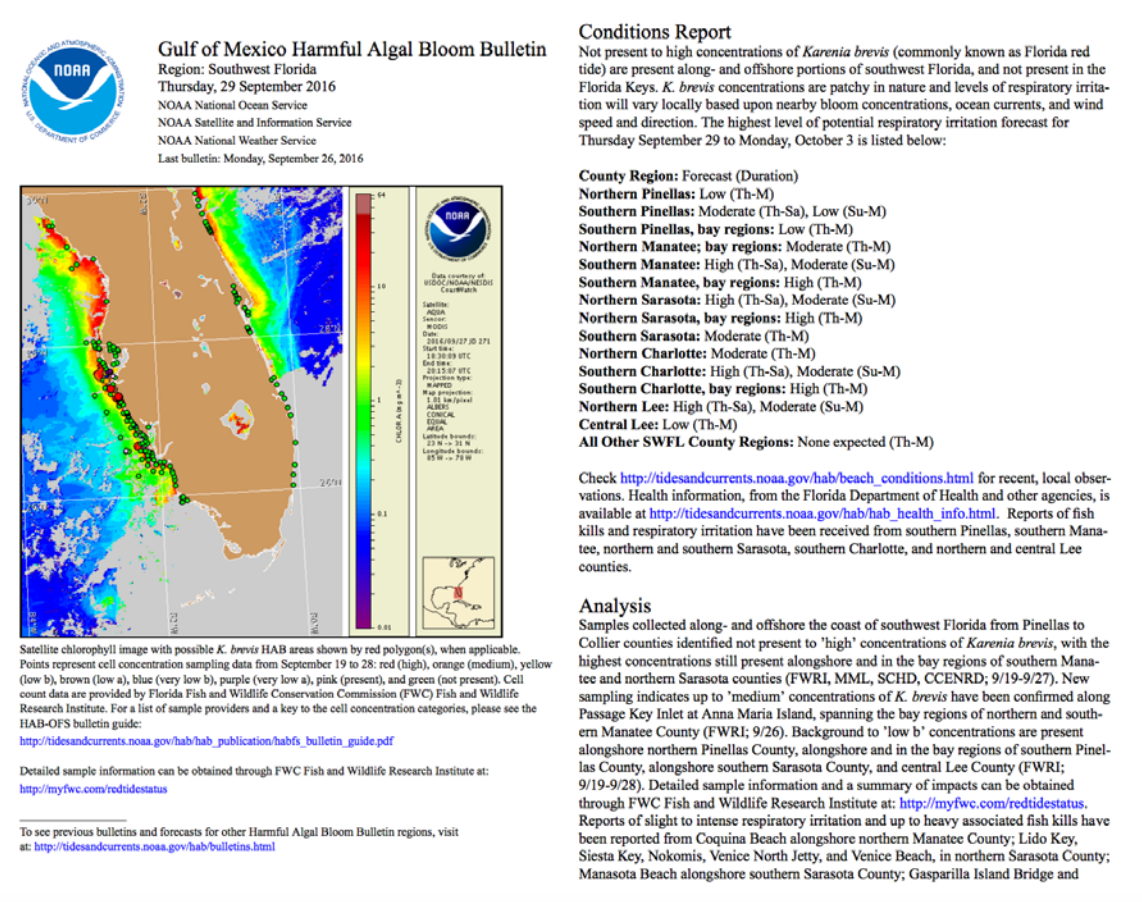


Credit: WHOI https://www.whoi.edu/redtide/human-health/neurotoxic-shellfish-poisoning

Photo Credit (Clockwise from Top): Karina Cardozo (Cardozo et al., 2007); John Dutton; P. Schmidt, Charlotte Sun Times

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

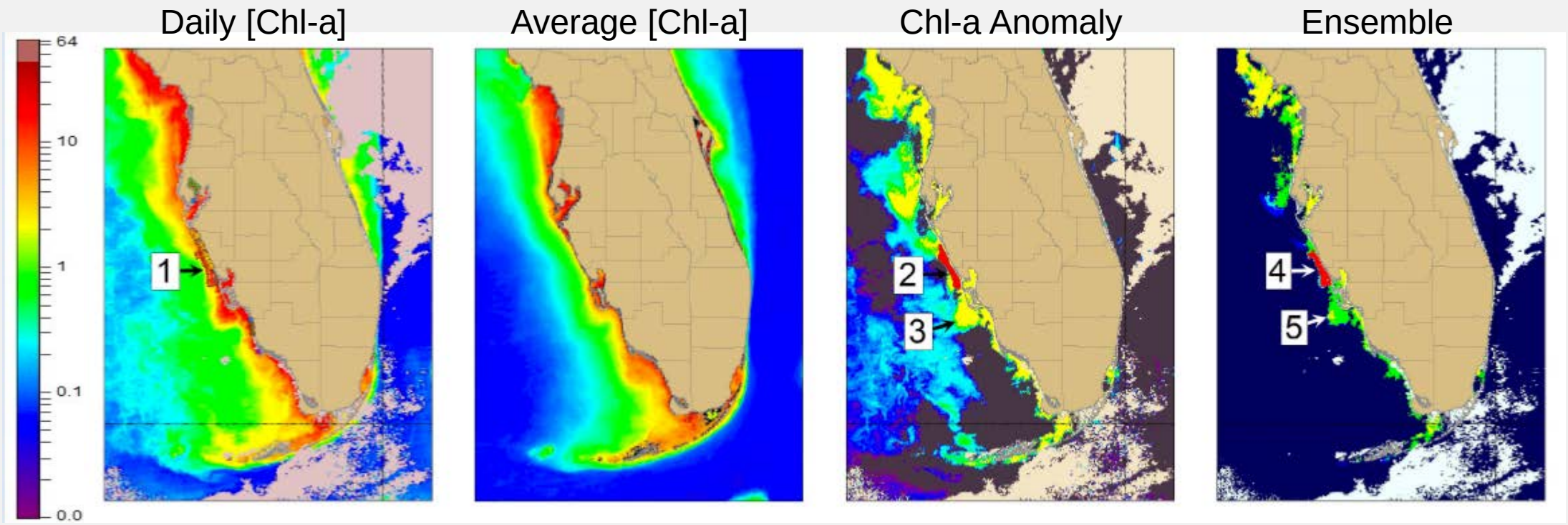
Samples collected along- and offshore the coast of southwest Florida from Pinellas to Collier counties identified not present to 'high' concentrations of *Karenia brevis*, with the highest concentrations still present alongshore and in the bay regions of southern Manatee and northern Sarasota counties (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

NOAA HAB-OFS Gulf of Mexico Model Overview

Ensemble Approach Combines Chl-a Anomaly and Taxon-Specific Information



https://tidesandcurrents.noaa.gov/hab/gomx.html

Food Web Vectoring

Paralytic Shellfish Poisoning – e.g., *Alexandrium catanella*

- Caused by consuming shellfish containing toxins such as saxitoxin
- Onset of symptoms is within 24 hours
- A life threatening neurological syndrome
- Symptoms: tingling, numbness, burning in the abdomen, loss of bodily movements, giddiness, fever, and rash
- Large-scale monitoring in the U.S. with rapid response and regulation of fisheries
- Rapid response is key to protecting human health

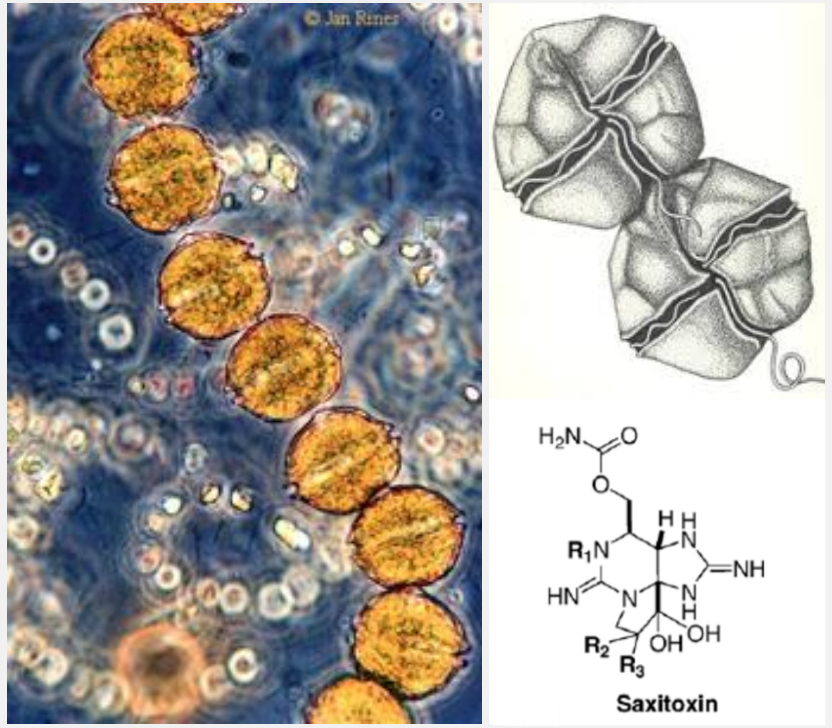


Image Credit: Left: Jan Rines (U. of Rhode Island) http://oceandatacenter.ucsc.edu; Right: Karina Cardozo (Cardozo et al., 2007)

Credit: WHOI https://www.whoi.edu/redtide/human-health/paralytic-shellfish-poisoning

Forecasting Bloom Events Aids in Rapid Response

Case Study: Gulf of Maine *Alexandrium fundyense* Nowcast/Forecast Simulation

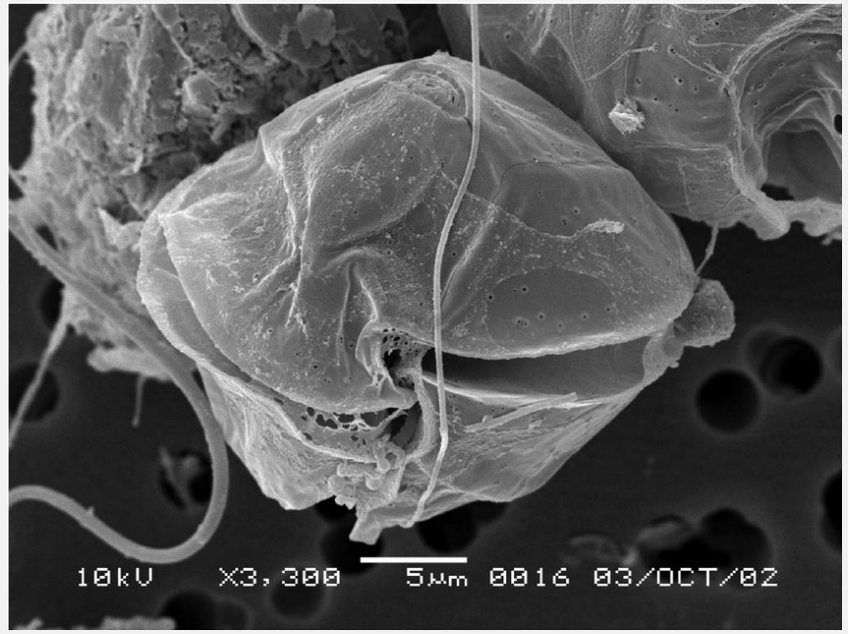
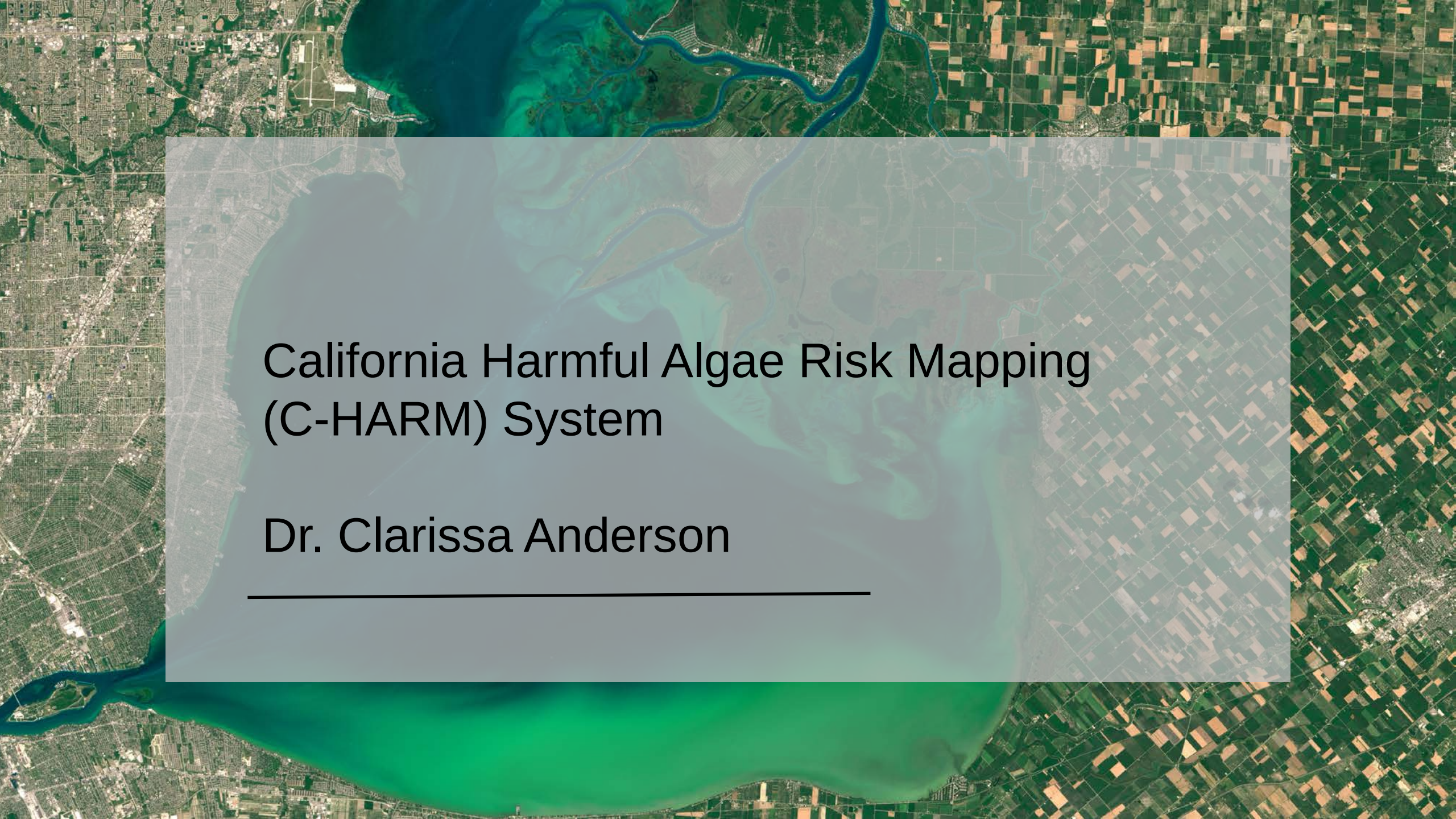


Image Credit: (L to R) NCCOS, Martin et al., 2007

Skill Assessment

- An objective measurement of how well the model nowcast or forecast guidance does when compared to observations
- Provides decision makers with a probability of a forecast being true
- Used to assess false positives and false negatives in decision making

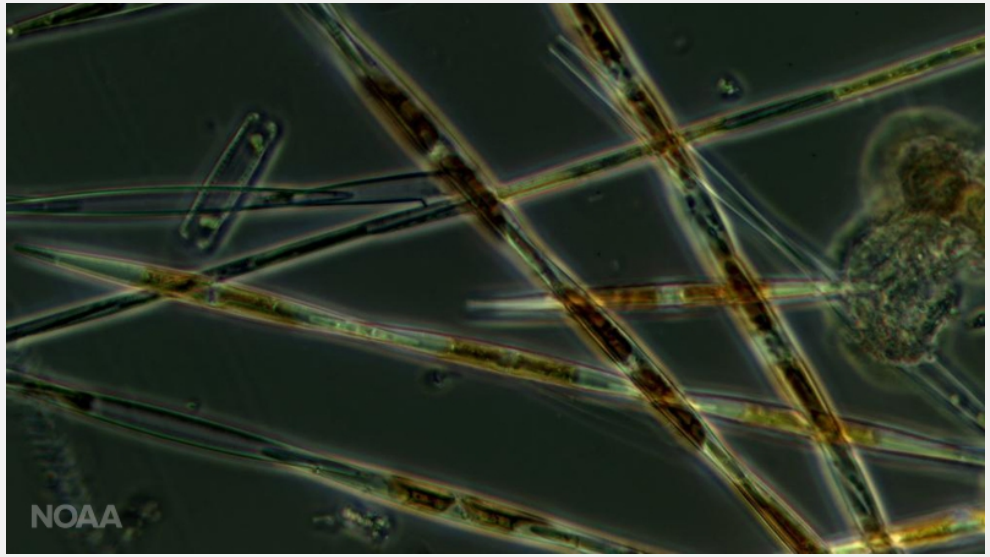


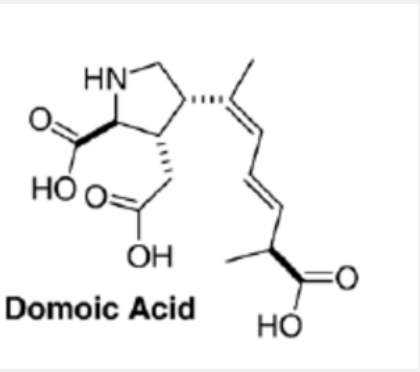
California Harmful Algae Risk Mapping (C-HARM) System

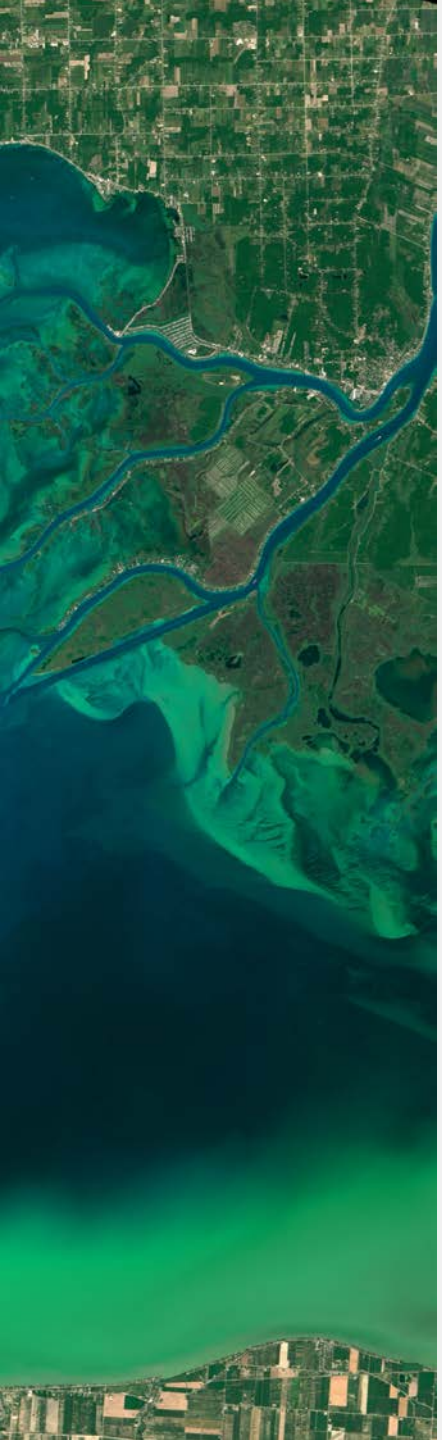
Dr. Clarissa Anderson

Summary

- Remote sensing as a tool for decision support
- Overview of coupled model and remote sensing tools for understanding HABs
- California Harmful Algae Risk Mapping (C-HARM) System
  – Guest Speaker: Dr. Clarissa Anderson







National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

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Thank you!

Next Week:

Large-Scale Monitoring Using Remote Sensing and Citizen Science