

ARSET

Applied Remote Sensing Training

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

 @NASAARSET

Understanding HABs in the Coastal Environment

September 19, 2017

Week 3

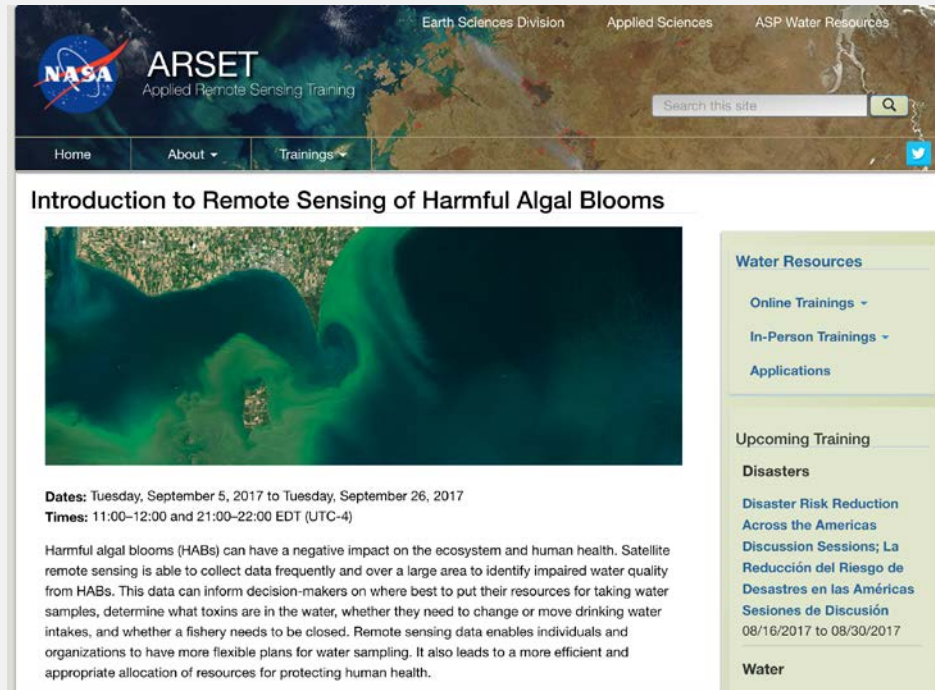
Trainers: Sherry Palacios
Amita Mehta

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/>



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

Learning Objectives:

By the end of the training, attendees will be able to:

- identify NASA's Earth Science remote sensing data products for the identification and monitoring of HABS
- describe how coupled remote sensing and modeling approaches are used in decision support tools
- use a selection of NASA Earth Science data tools to monitor HABS

Course Format:

- Four, one hour sessions
- Sessions will be held on Tuesdays in September: September 5, 12, 19, and 26 at 11:00 a.m.-12:00 p.m. or 21:00-22:00 p.m. EDT (UTC-4)
 - [Convert to your local time »](#)
- A certificate of completion will be provided to participants that attend all live webinars and complete all homework assignments

Prerequisites:

Complete [Session 2C: Fundamentals of Aquatic Remote Sensing](#) or have equivalent experience. Attendees that do not complete prerequisites may not be properly prepared for the pace during the training.

Audience:

Local, regional, state, federal, and international organizations interested in using satellite imagery for coastal and ocean applications. Governmental and non-governmental organizations in the public and private sectors engaged in environmental management and monitoring will be given preference over organizations focused primarily on research.

Registration Information:

There is no cost for the webinar, but you must register. Space is limited, and preference will be given to

Introduction to Remote Sensing of Harmful Algal Blooms

09/05/2017 to 09/26/2017

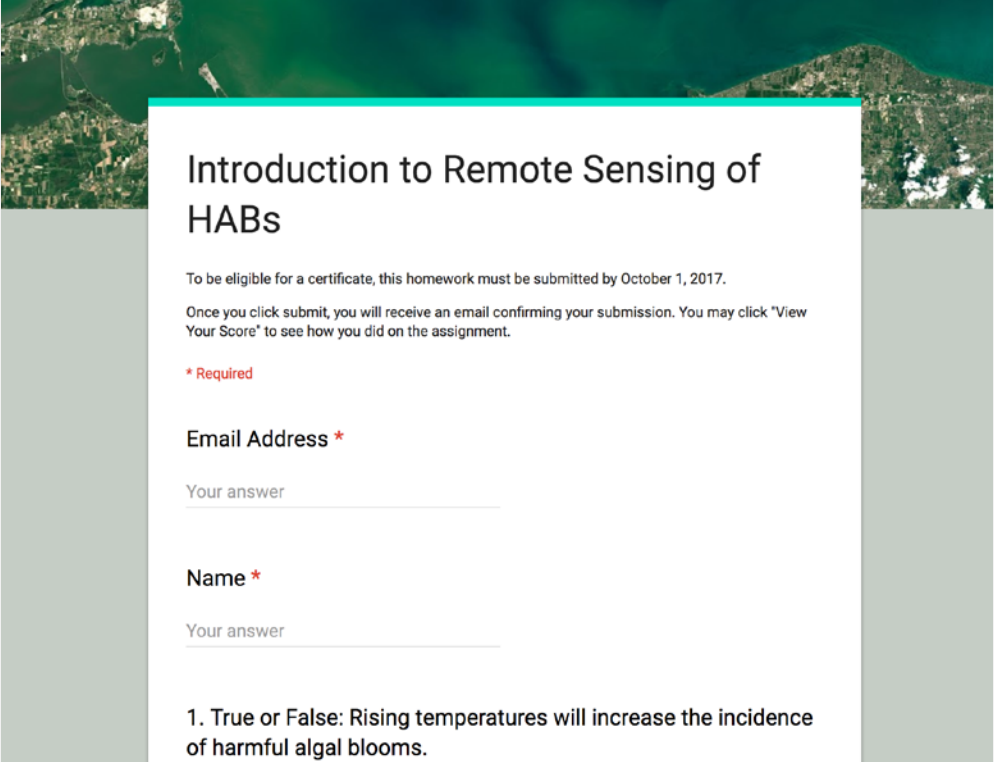
Land

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



The image shows a screenshot of a Google Form titled "Introduction to Remote Sensing of HABs". The form is set against a background of a satellite image of a coastal area. The text on the form includes:

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 *

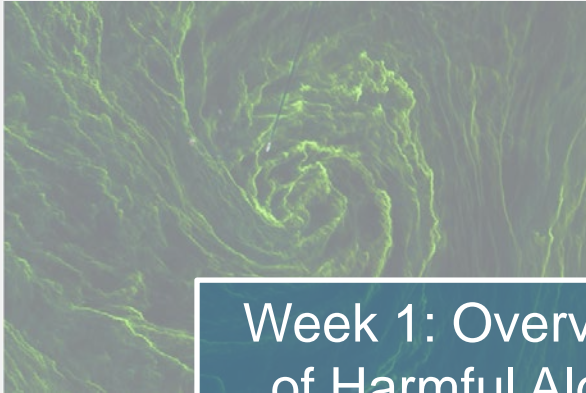
Your answer

Name *

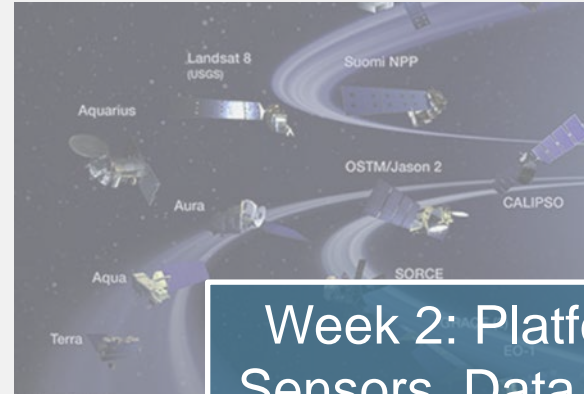
Your answer

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

Course Outline



Week 1: Overview
of Harmful Algal
Blooms

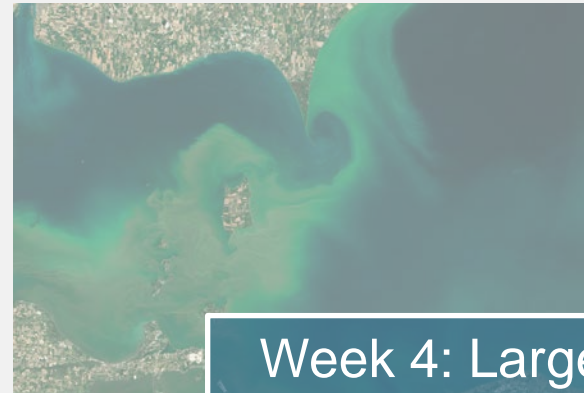


Week 2: Platforms &
Sensors, Data Access,
and Processing



Credit: Paul
Hillman/NOAA

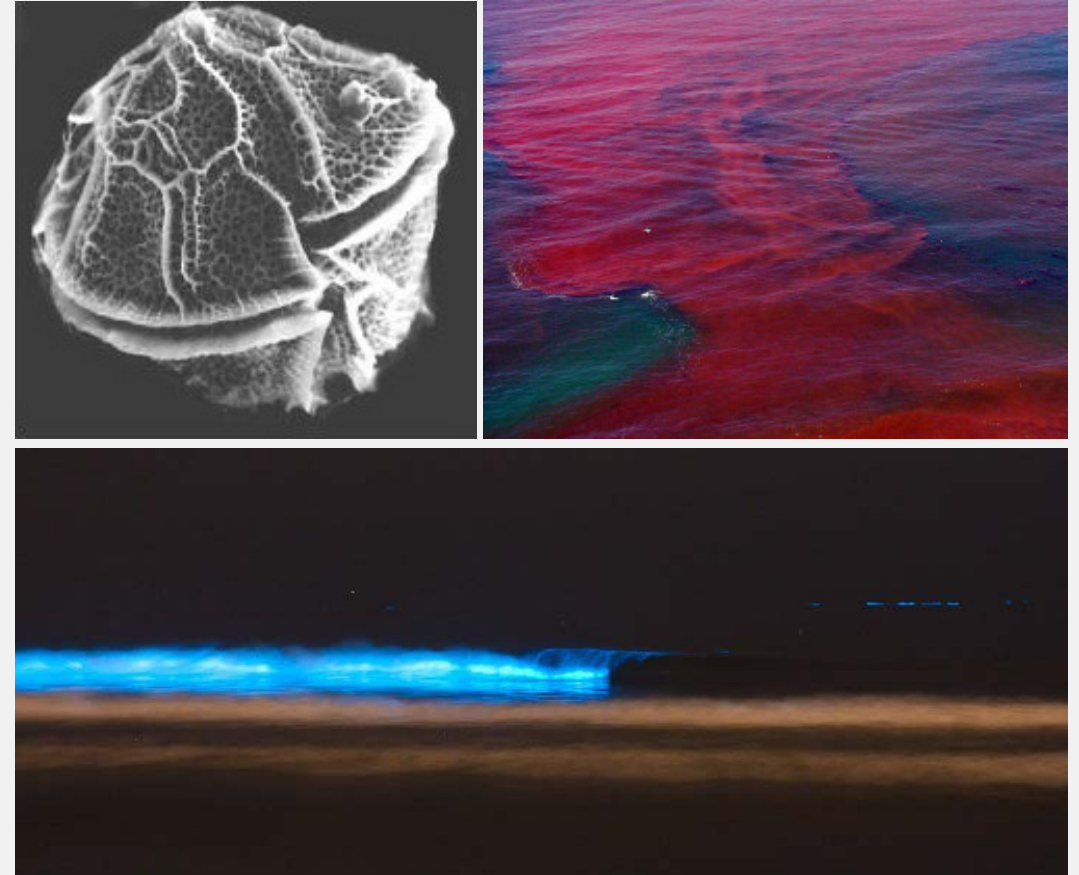
Week 3: HABs in
the Coastal
Environment



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-harmful, but can sometimes 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.”

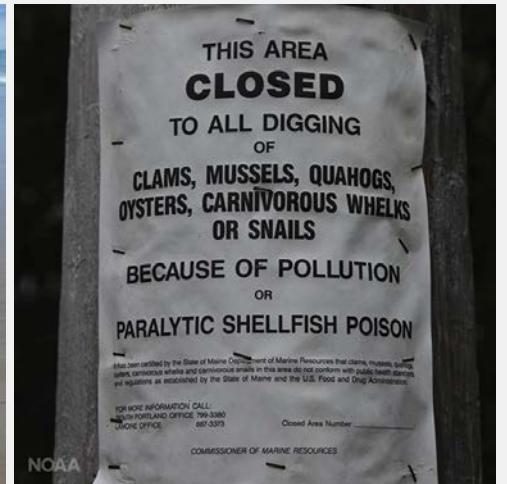
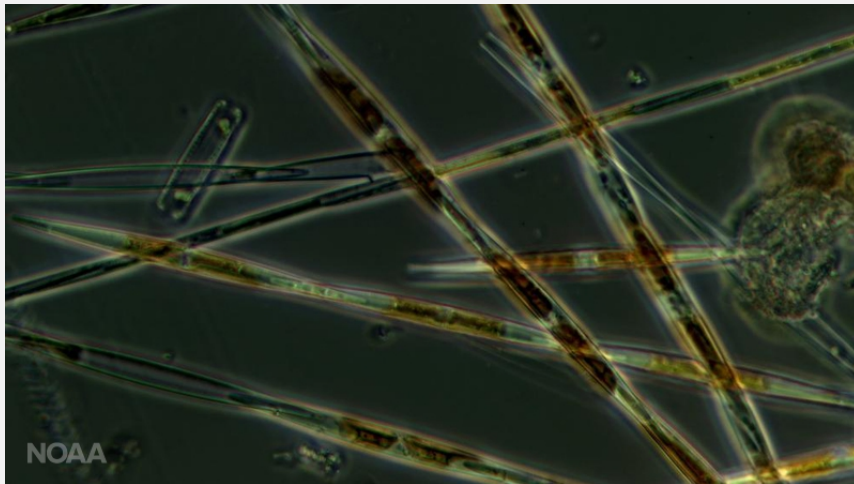


Image credit: <http://www.noaa.gov/what-is-harmful-algal-bloom>

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

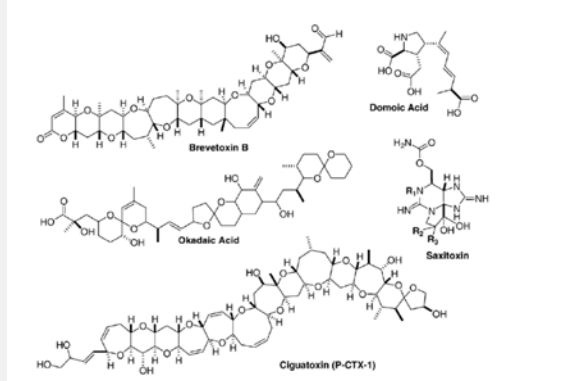


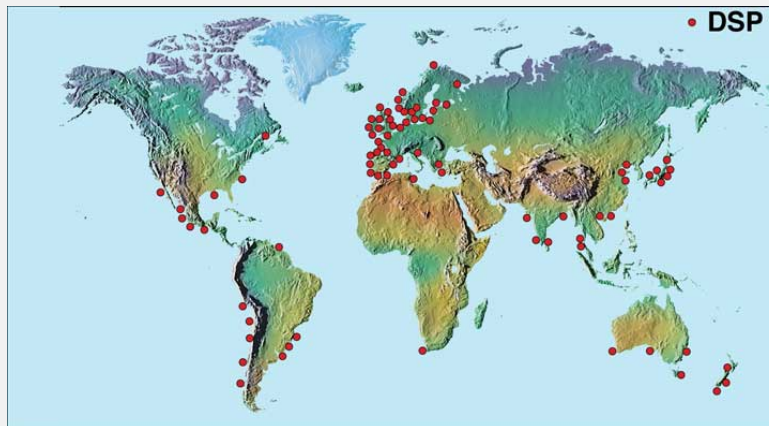
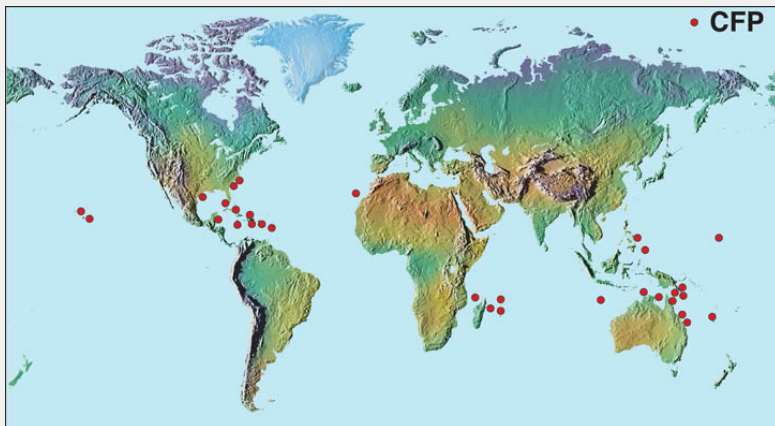
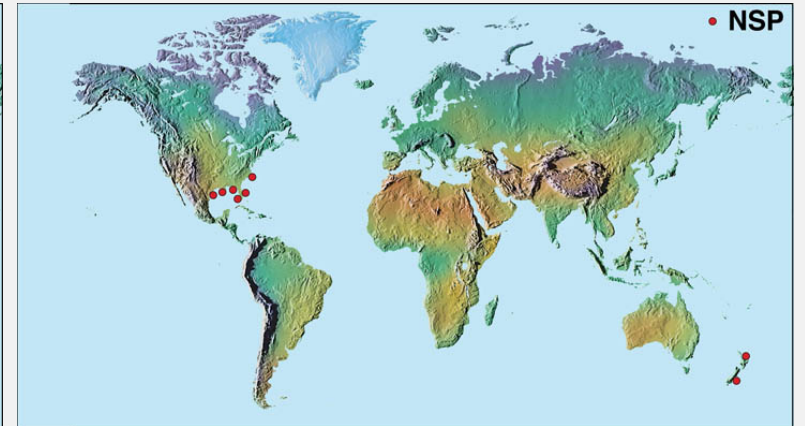
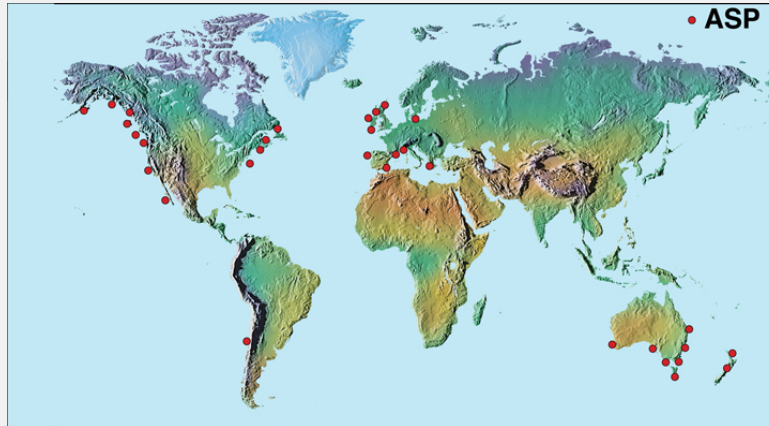
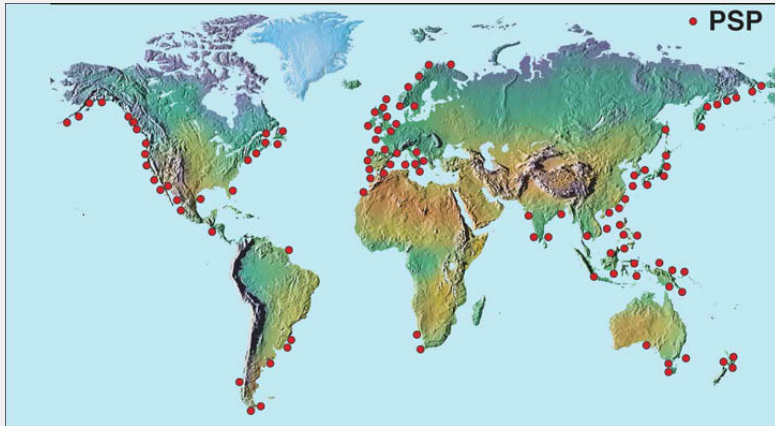
Photo Credits (clockwise from top left) Karina Cardozo (Cardozo et al., 2007); NASA Earth Observatory; NOAA Northwest Fisheries Science Center; Linda Preskitt

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

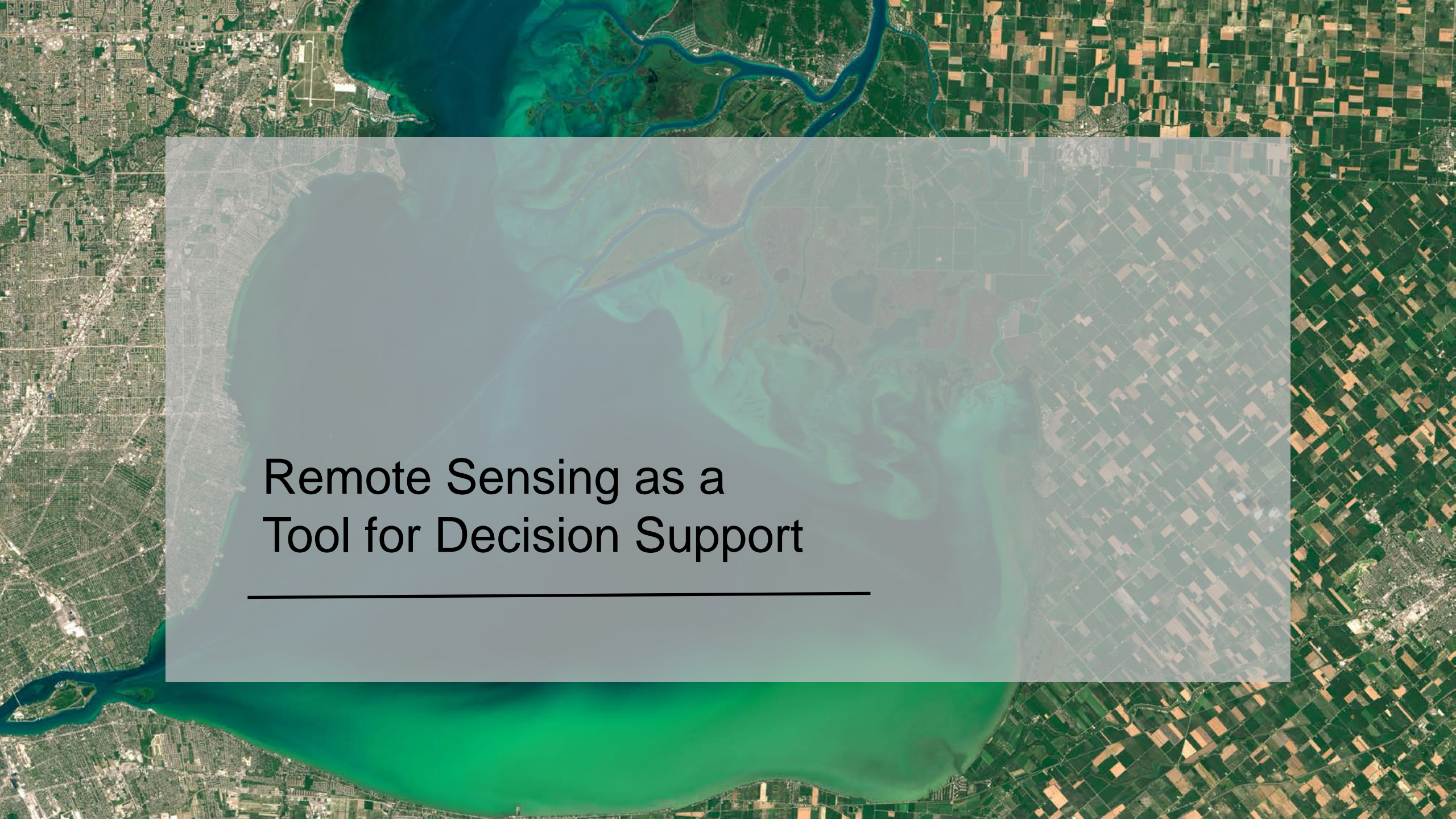


PSP - Paralytic Shellfish Poisoning
ASP - Amnesic Shellfish Poisoning
NSP - Neurotoxic Shellfish
Poisoning
CFP - Ciguatera Fish Poisoning
DSP - Diarrhetic Shellfish
Poisoning

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

Main Take-Away for the Webinar Series...

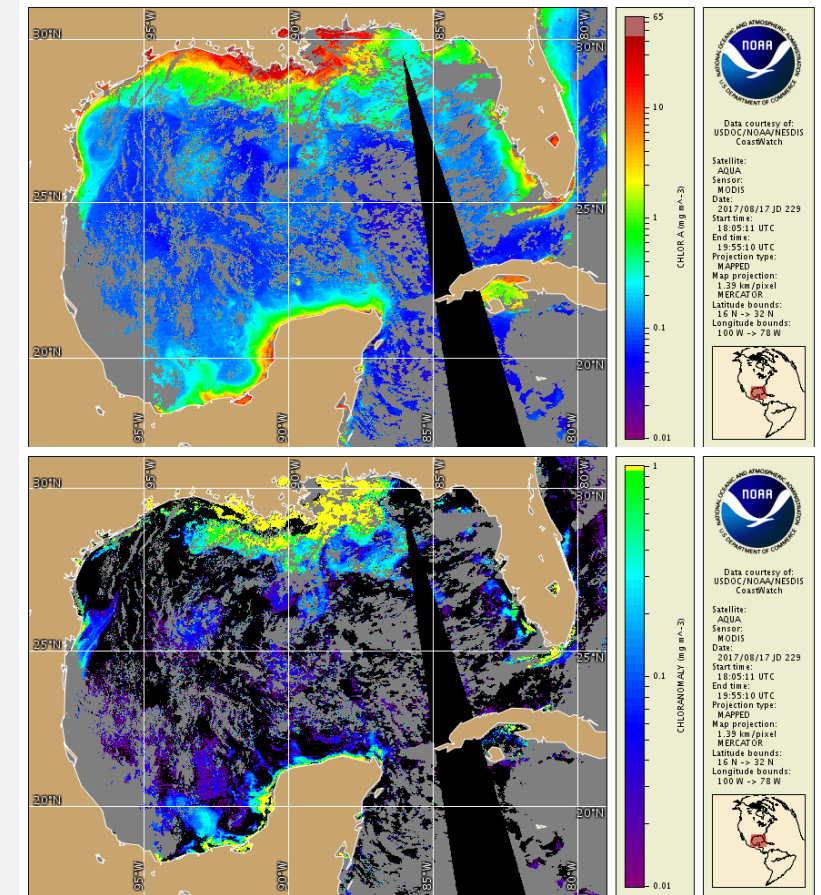
- Remote sensing imagery is a tool to aid in the monitoring and forecasting of HAB events to understand impacts to the ecosystem and/or human health
- Remote sensing imagery does not replace sampling on-the-ground
- Imagery, with associated algorithms and ecosystem models, informs adaptive sampling approaches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

An aerial photograph of a river delta, likely the Mississippi River delta, showing a complex network of waterways and land. A semi-transparent map overlay is centered on the image, showing the same geographical area with various colored regions and lines, representing a remote sensing or GIS analysis. The text is overlaid on the map area.

Remote Sensing as a Tool for Decision Support

Parameters Relevant for HAB Detection

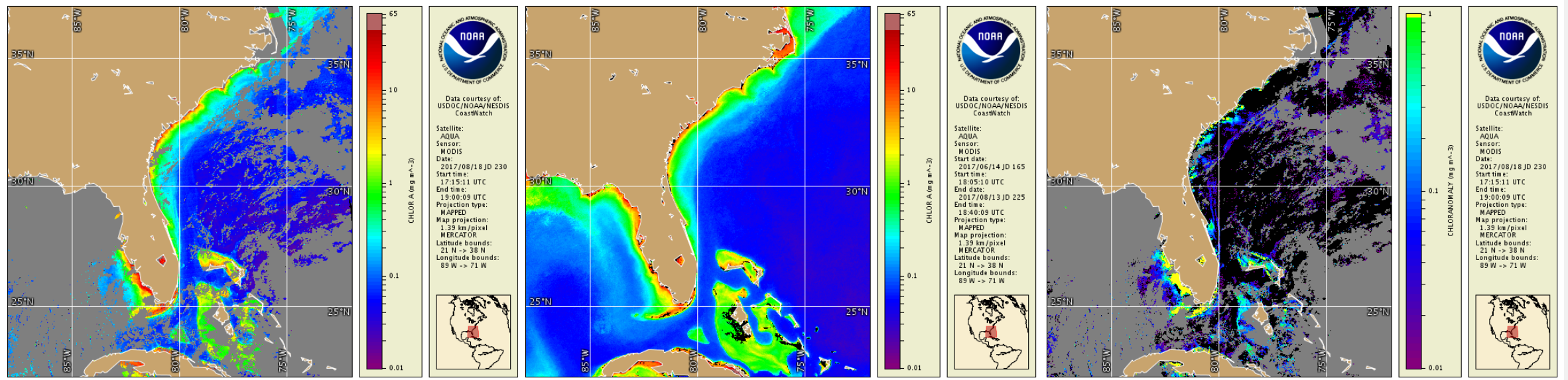
- The following parameters, available from remote sensing observations, are commonly used to detect the presence of an algal bloom
 - Chlorophyll-a Concentration (Chl-a)
 - Chlorophyll-a Concentration Anomalies
 - Taxon-Specific Bio-optical Properties
 - Sea Surface Temperature (SST) and other environmental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



Parameters Relevant for HAB Detection

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

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



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

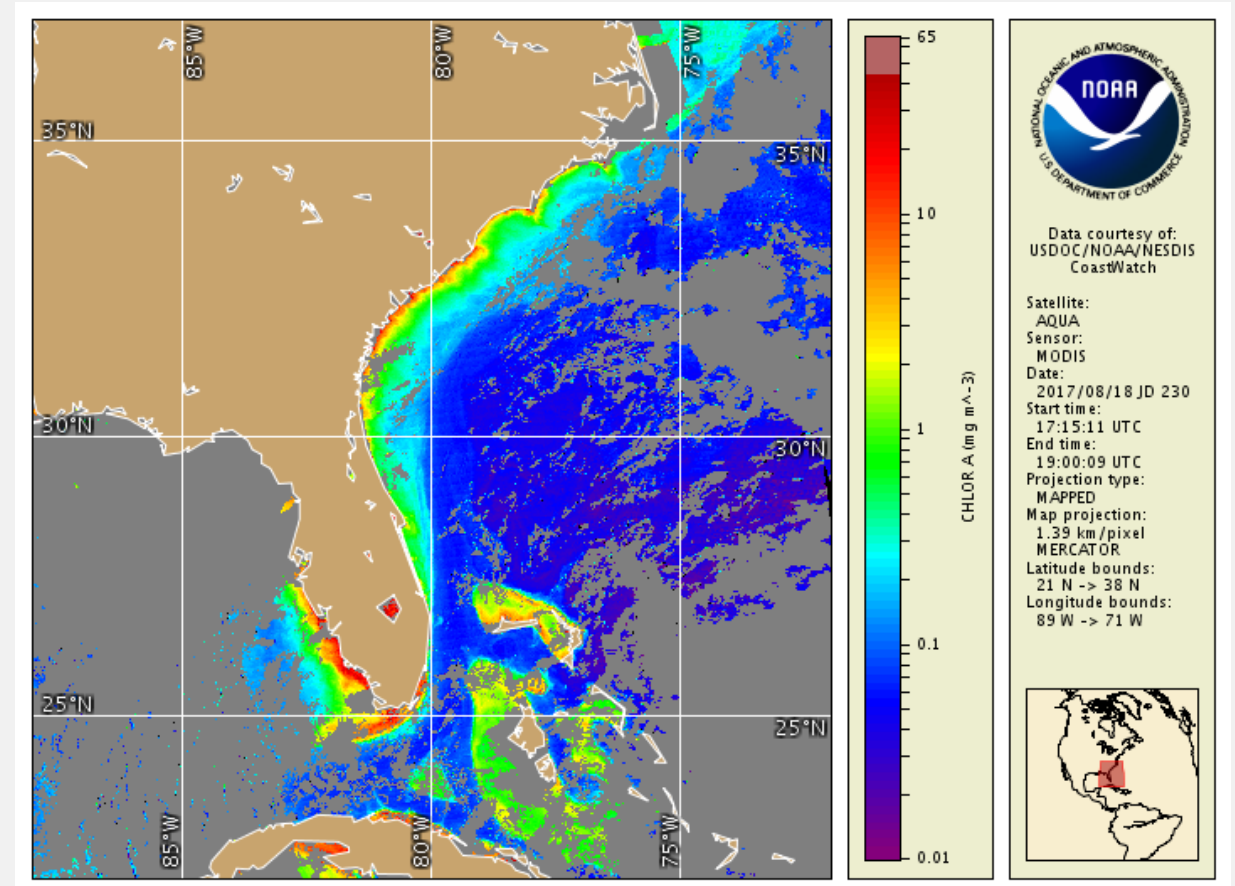
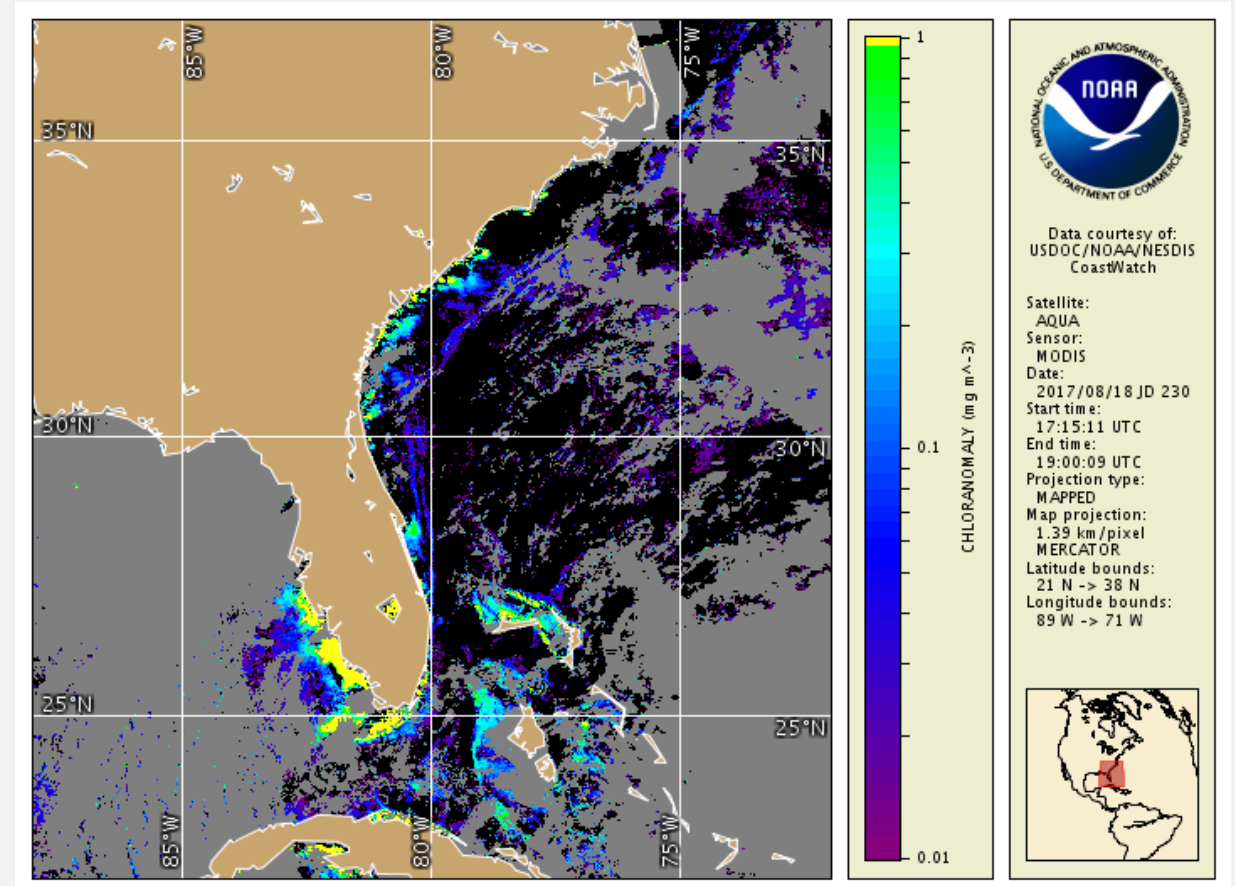


Image Credit: http://www.ospo.noaa.gov/Products/ocean/color/swir_chla_daily.html

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>

The screenshot displays the GIOVANNI web interface. At the top, there are navigation links for "EARTHDATA", "Data Discovery", "DAACs", "Community", and "Science Disciplines". The main header reads "GIOVANNI The Bridge Between Data and Science v 4.23" with links for "Release Notes", "Browser Compatibility", and "Known Issues". A yellow banner below the header states "MODIS OPeNDAP server continuing problem ..." with a "Read More" link.

The interface is divided into several sections:

- Select Plot:** Includes radio buttons for "Maps: Time Averaged Map", "Comparisons: Select...", "Vertical: Select...", "Time Series: Select...", and "Miscellaneous: Select...".
- Select Date Range (UTC):** Features input fields for "YYYY-MM-DD" and "HH:mm" with a "to" separator and a "Valid Range: 1948-01-01 to 2017-08-10" note.
- Select Region (Bounding Box or Shape):** Includes a text input field and a "Format: West, South, East, North" note.
- Select Variables:** A search interface showing "Number of matching Variables: 0 of 1679" and "Total Variable(s) included in Plot: 0". It includes a "Keyword:" input field, "Search", and "Clear" buttons.
- Disciplines:** A list of categories with checkboxes, including "Aerosols (174)", "Atmospheric Chemistry (66)", "Atmospheric Dynamics (356)", "Cryosphere (15)", "Hydrology (996)", "Ocean Biology (44)", "Oceanography (48)", and "Water and Energy Cycle (1060)".
- Measurements:** A list of specific variables with checkboxes, including "Aerosol Index (3)", "Aerosol Optical Depth (80)", "Air Pressure Anomaly (1)", "Air Pressure (49)", "Air Temperature (79)", "Albedo (17)", "Altitude (6)", "Angstrom Exponent (17)", "Atmospheric Moisture (103)", "Black Carbon (5)", "Buoyancy (2)", "CH4 (12)", "CO (17)", "CO2 (2)", "Canopy Water Storage (6)", "Chlorophyll (11)", "Cloud Fraction (30)", "Cloud Properties (71)", "Component Aerosol Optical Depth (5)", and "Diffusivity (1)".

At the bottom right, there are buttons for "Help", "Reset", "Feedback", and a prominent green "Plot Data" button.

Understanding the Chlorophyll-a Anomaly

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

The screenshot displays the GIOVANNI web interface with several key sections highlighted by colored boxes and callouts:

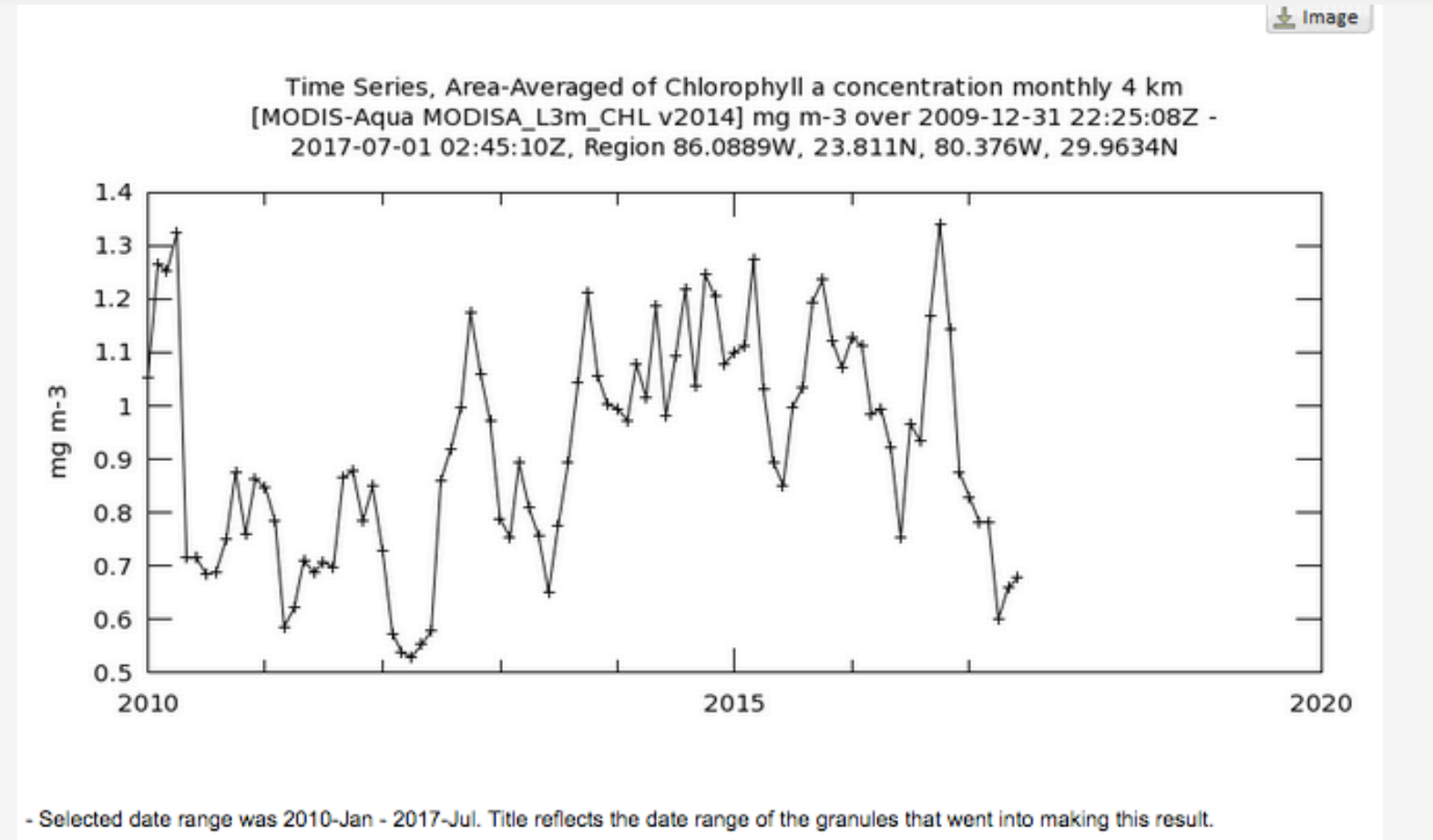
- Analysis and Plot Selection:** A red box highlights the "Select Plot" section, where the "Time Series: Hovmoller, Longitude-Averaged" option is selected.
- Start and End Date; and Spatial Selection by Map/Latitude-Longitude/Shapefile:** A blue box highlights the "Select Date Range (UTC)" and "Select Region (Bounding Box or Shape)" sections. The date range is set from 2010-01-01 to 2017-06-30, and the region is defined by coordinates -86.6602, 24.8145, -80.332, 31.4941.
- Search Data by a Keyword:** A green box highlights the search bar where the keyword "Chlorophyll" is entered.

The search results table shows the following data:

Variable	Source	Temp. Res.	Spat. Res.	Begin Date	End Date	Units
<input type="checkbox"/> Chlorophyll a Concentration (OCTS L3m_CHL v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30	mg m ⁻³
<input type="checkbox"/> Assimilated Total Chlorophyll (NOBM_DAY vR2014)	NOBM	Daily	0.667 x 1.25 °	1998-01-01	2012-12-31	mg m ⁻³
<input type="checkbox"/> Assimilated Total Chlorophyll (NOBM_MONTH vR2014)	NOBM	Monthly	0.667 x 1.25 °	1998-01-01	2012-12-31	mg m ⁻³
<input type="checkbox"/> Normalized fluorescence (SeaWiFS L3m_FLC v2014)	SeaWiFS	Monthly	4 km	2002-07-04	2017-06-30	mW cm ⁻² um ⁻¹ sr ⁻¹
<input checked="" type="checkbox"/> Chlorophyll a concentration (MODISA L3m_CHL v2014)	MODIS-Ac	Monthly	4 km	2002-07-04	2017-06-30	mg m ⁻³
<input type="checkbox"/> Chlorophyll a Concentration (SeaWiFS L3m_CHL v2014)	SeaWiFS	Monthly	9 km	1997-09-04	2010-12-11	mg m ⁻³
<input type="checkbox"/> Chlorophyll Concentration, OC3 Algorithm (OCTS L3m_CHL v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30	mg m ⁻³
<input type="checkbox"/> Concentration of Particulate Organic Carbon (OCTS L3m_POC v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30	mg m ⁻³
<input type="checkbox"/> Concentration of Particulate Organic Carbon (MODISA L3m_POC v2014)	MODIS-Ac	Monthly	4 km	2002-07-04	2017-06-30	mg m ⁻³
<input type="checkbox"/> Absorption coefficient due to phytoplankton (aph) at 443 nm (SeaWiFS L3m_IOP v2014)	SeaWiFS	Monthly	4 km	2002-07-04	2017-06-30	mg m ⁻³

Giovanni Can Be Used to Visualize Chl-a Anomalies Globally

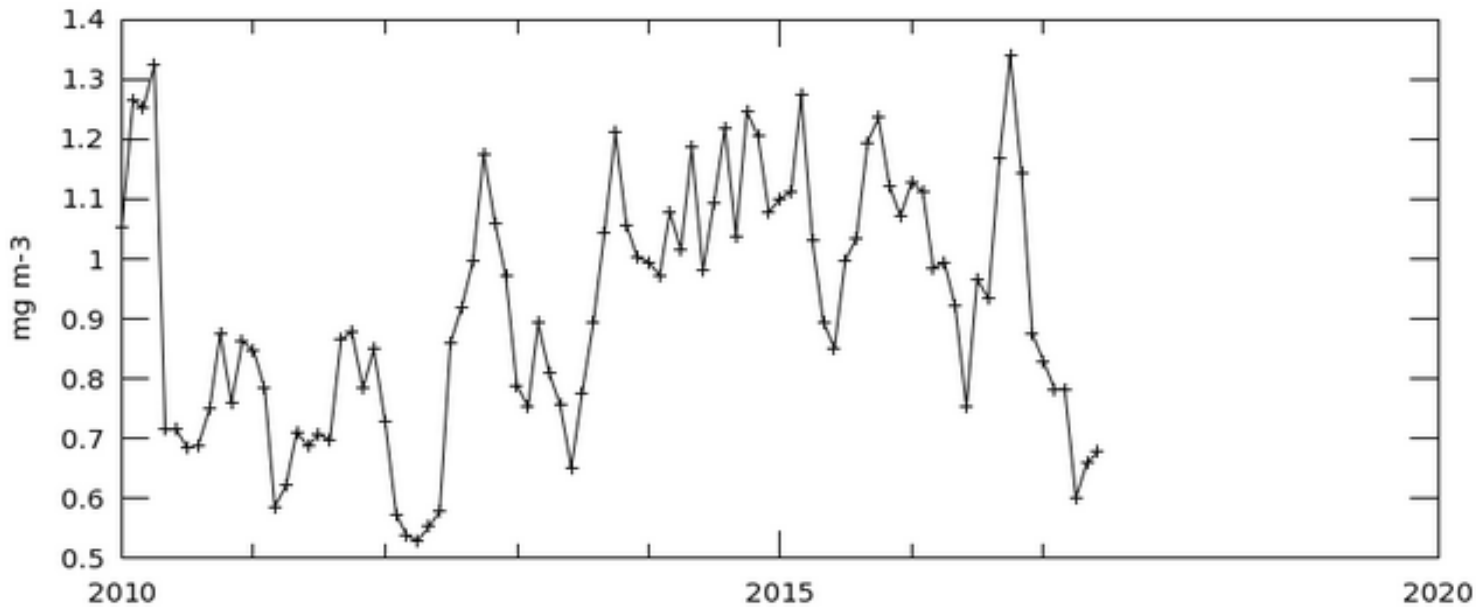
<http://giovanni.gsfc.nasa.gov/giovanni/>



Giovanni: Chlorophyll Concentration in the Gulf of Mexico

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

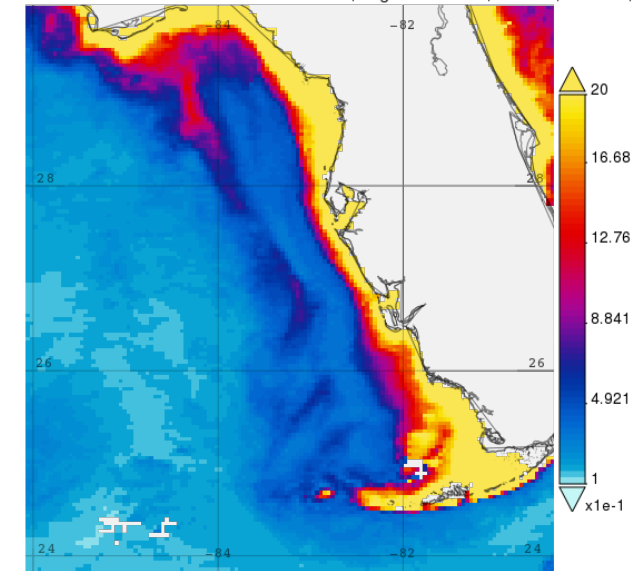
Time Series, Area-Averaged of Chlorophyll a concentration monthly 4 km
[MODIS-Aqua MODISA_L3m_CHL v2014] mg m-3 over 2009-12-31 22:25:08Z -
2017-07-01 02:45:10Z, Region 86.0889W, 23.811N, 80.376W, 29.9634N



- Selected date range was 2010-Jan - 2017-Jul. Title reflects the date range of the granules that went into making this result.

January 2017

Time Averaged Map of Chlorophyll a concentration monthly 4 km [MODIS-Aqua MODISA_L3m_CHL v2014] mg m-3
over 2017-01-01 00:25:11Z - 2017-02-01 02:50:09Z, Region 86.0889W, 23.811N, 80.376W, 29.9634N



Taxon-Specific Bio-Optical Properties

Case Studies

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

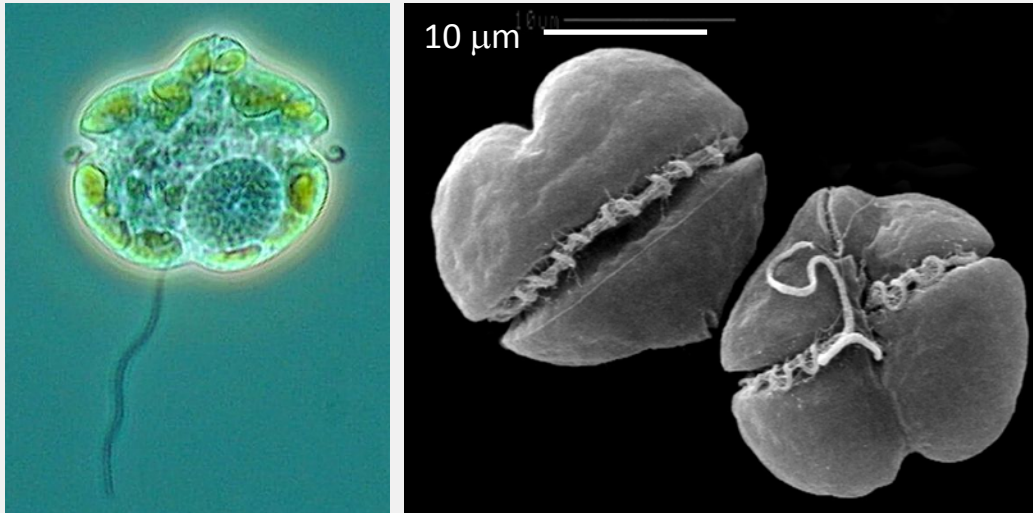


Photo Credit: Florida Fish and Wildlife Conservation Commission

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

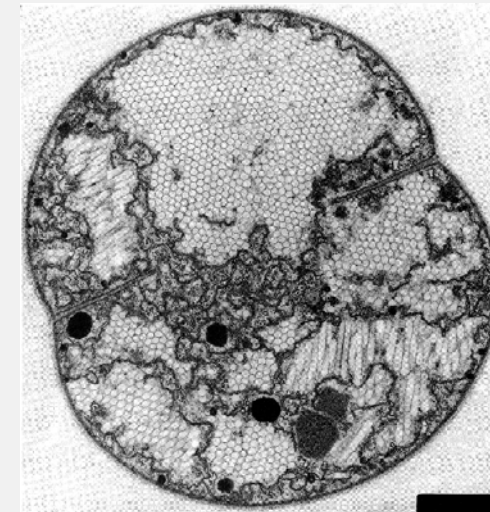
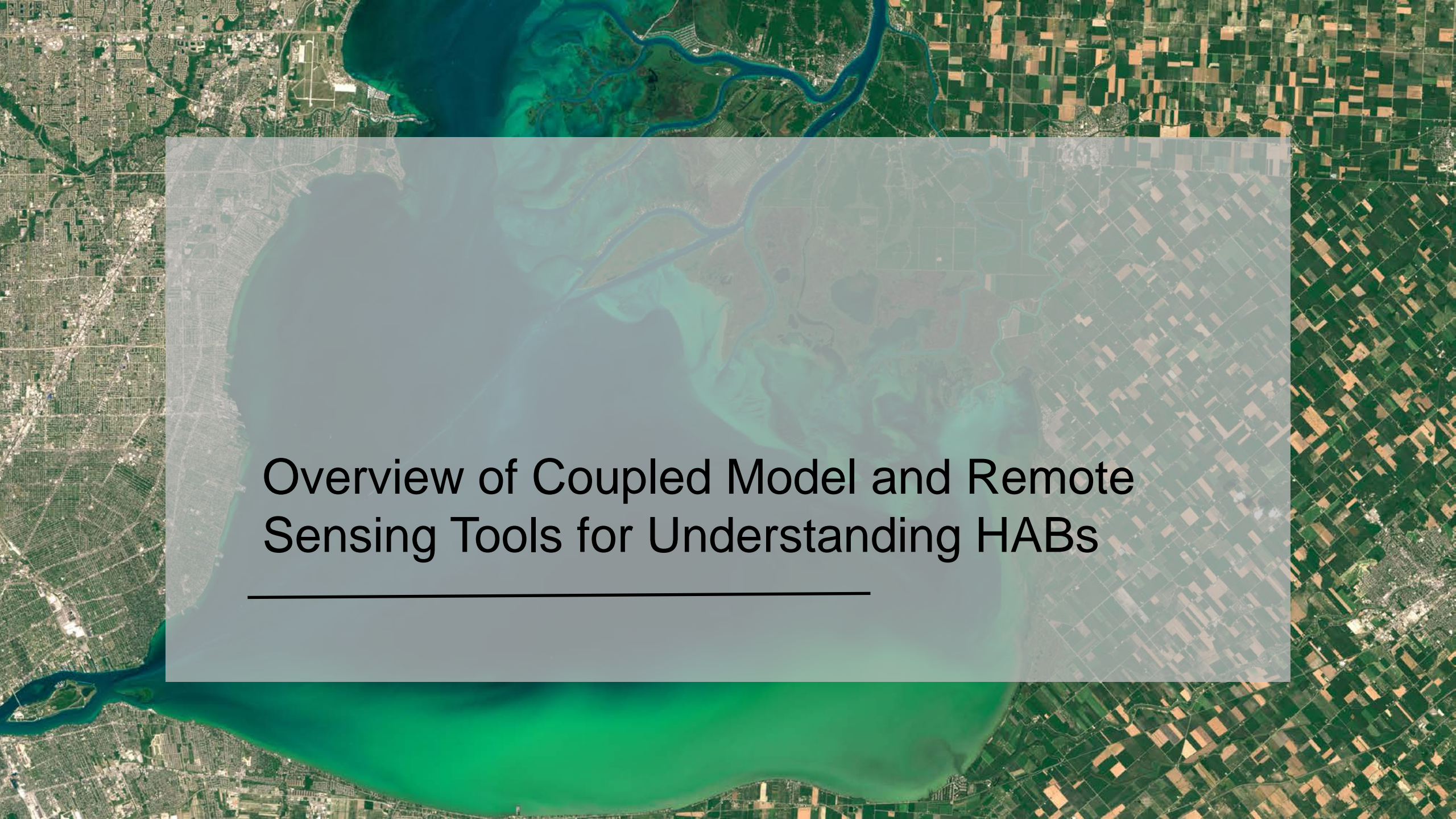


Photo Credit: H.S. Pankratz

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

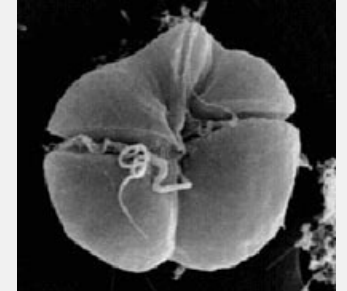
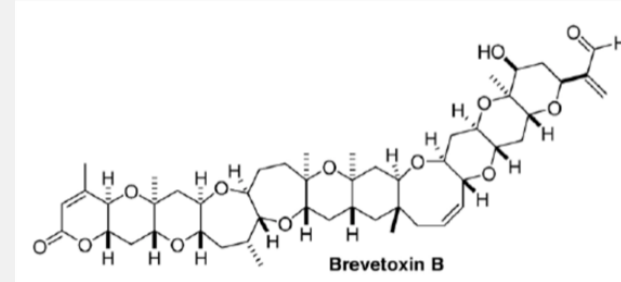


Overview of Coupled Model and Remote Sensing Tools for Understanding HABs

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



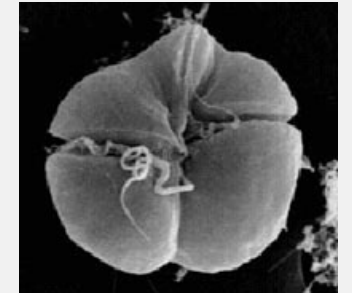
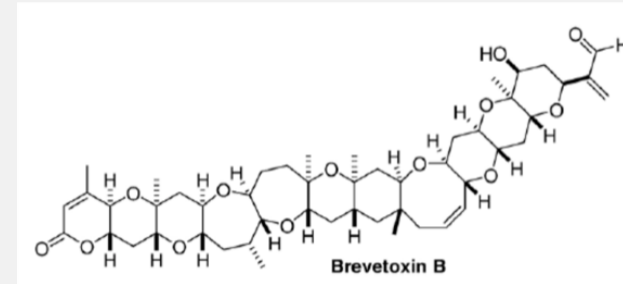
Credit: WHOI <https://www.whoi.edu/redtide/human-health/neurotoxic-shellfish-poisoning>

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)



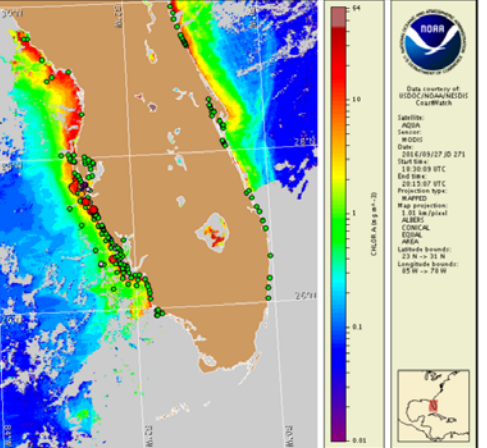
Gulf of Mexico Harmful Algal Bloom Bulletin
 Region: Southwest Florida
 Thursday, 29 September 2016
 NOAA National Ocean Service
 NOAA Satellite and Information Service
 NOAA National Weather Service
 Last bulletin: Monday, September 26, 2016

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; bay regions: 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; 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



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>

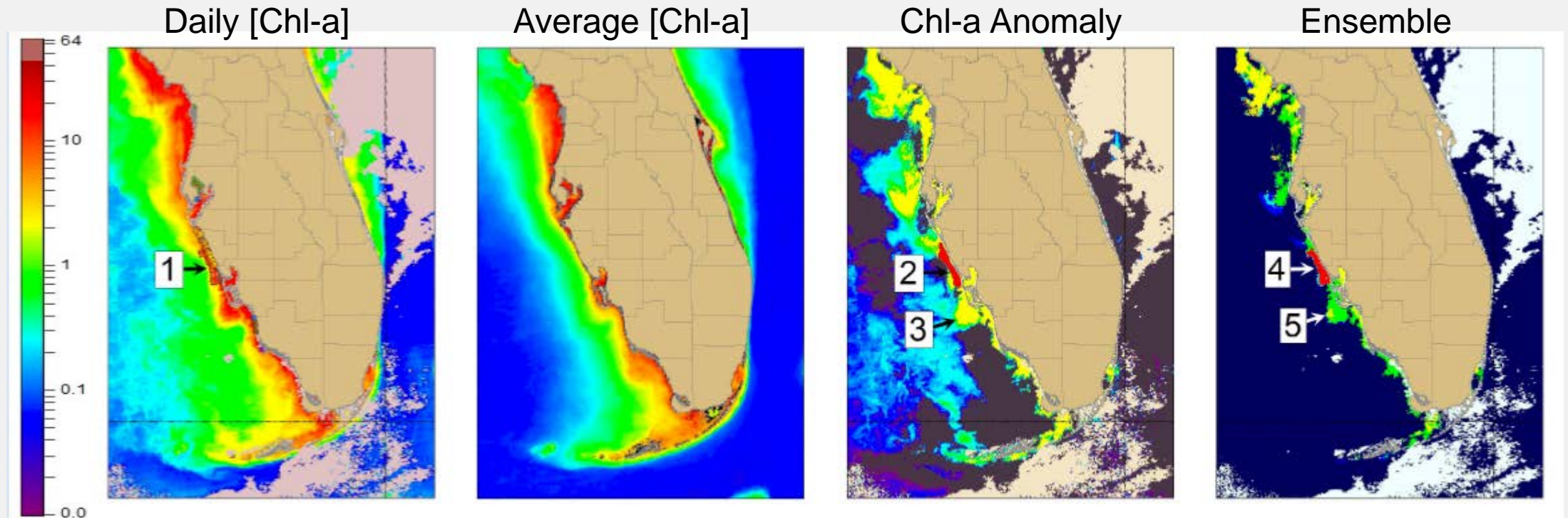
To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit at: <http://tidesandcurrents.noaa.gov/hab/bulletins.html>

- *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

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

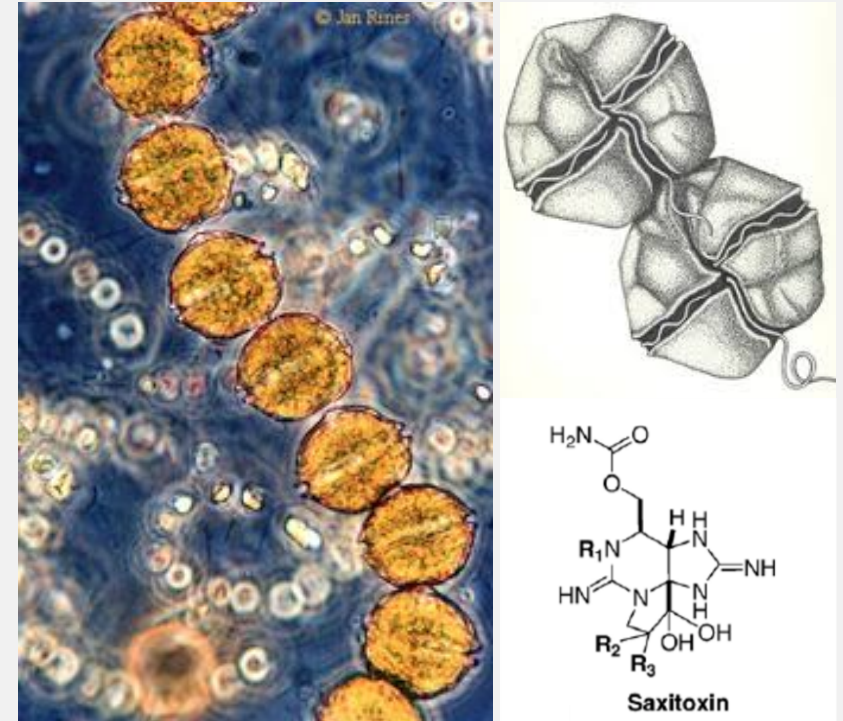


Image Credit: Left: Jan Rines (U. of Rhode Island) <http://oceandatacenter.ucsc.edu>; Right: Karina Cardozo (Cardozo et al., 2007)

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

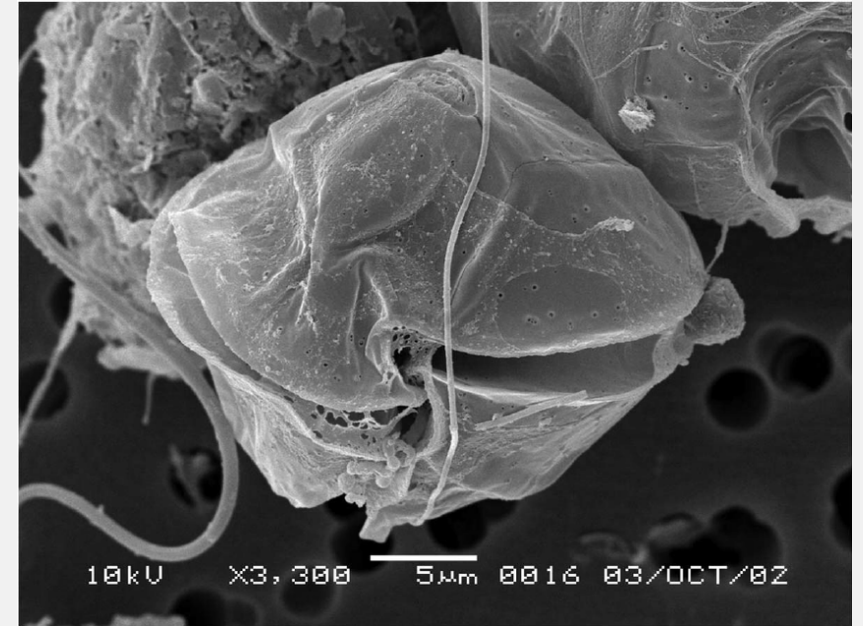


Image Credit: (L to R) NCCOS, Martin et al., 2007

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

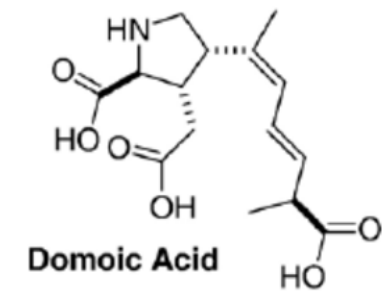
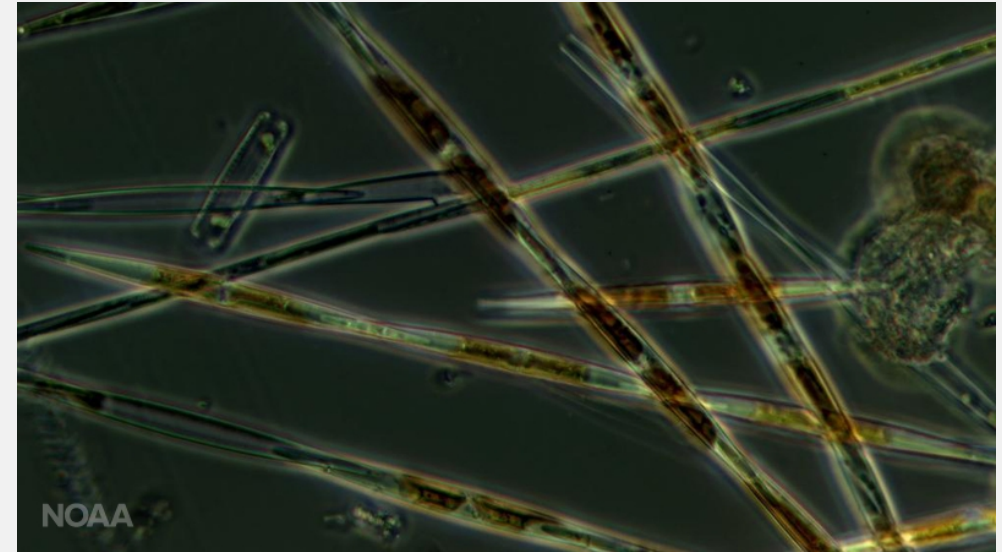
An aerial photograph of a coastal region. The top half shows a large body of water with a prominent blue-green hue, likely indicating a harmful algal bloom. The bottom half shows a dense grid of agricultural fields in various shades of green and brown. A semi-transparent white box is overlaid on the water area, containing text.

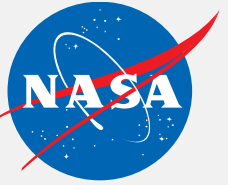
California Harmful Algae Risk Mapping (C-HARM) System

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





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