

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/>

The screenshot shows the ARSET website with the following details:

- Header:** NASA ARSET Applied Remote Sensing Training, Earth Sciences Division, Applied Sciences, ASP Water Resources.
- Search Bar:** Search this site.
- Navigation:** Home, About, Trainings.
- Course Title:** Introduction to Remote Sensing of Harmful Algal Blooms.
- Image:** A satellite image showing a large area of greenish-blue water, indicating a harmful algal bloom.
- Dates:** Tuesday, September 5, 2017 to Tuesday, September 26, 2017.
- Times:** 11:00–12:00 and 21:00–22:00 EDT (UTC-4).
- Description:** Harmful algal blooms (HABs) can have a negative impact on the ecosystem and human health. Satellite remote sensing is able to collect data frequently and over a large area to identify impaired water quality from HABs. This data can inform decision-makers on where best to put their resources for taking water samples, determine what toxins are in the water, whether they need to change or move drinking water intakes, and whether a fishery needs to be closed. Remote sensing data enables individuals and organizations to have more flexible plans for water sampling. It also leads to a more efficient and appropriate allocation of resources for protecting human health.
- Water Resources:** Online Trainings, In-Person Trainings, Applications.
- Upcoming Training:** 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.
- Water:**
- 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

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 screenshot shows a Google Form titled "Introduction to Remote Sensing of HABs". The form has a background image of a coastal area with green water and land. It includes fields for "Email Address" and "Name", both marked as required. A question at the bottom asks if rising temperatures increase the incidence of harmful algal blooms.

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 *

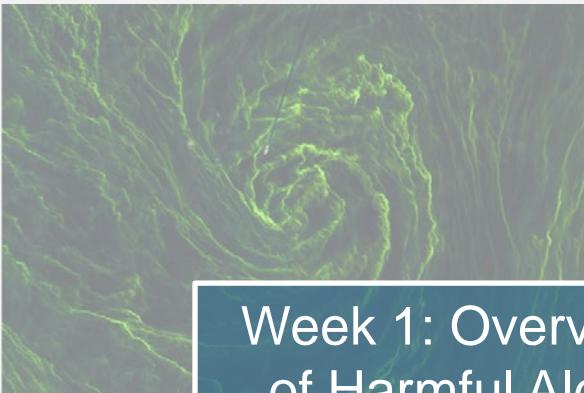
Your answer

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

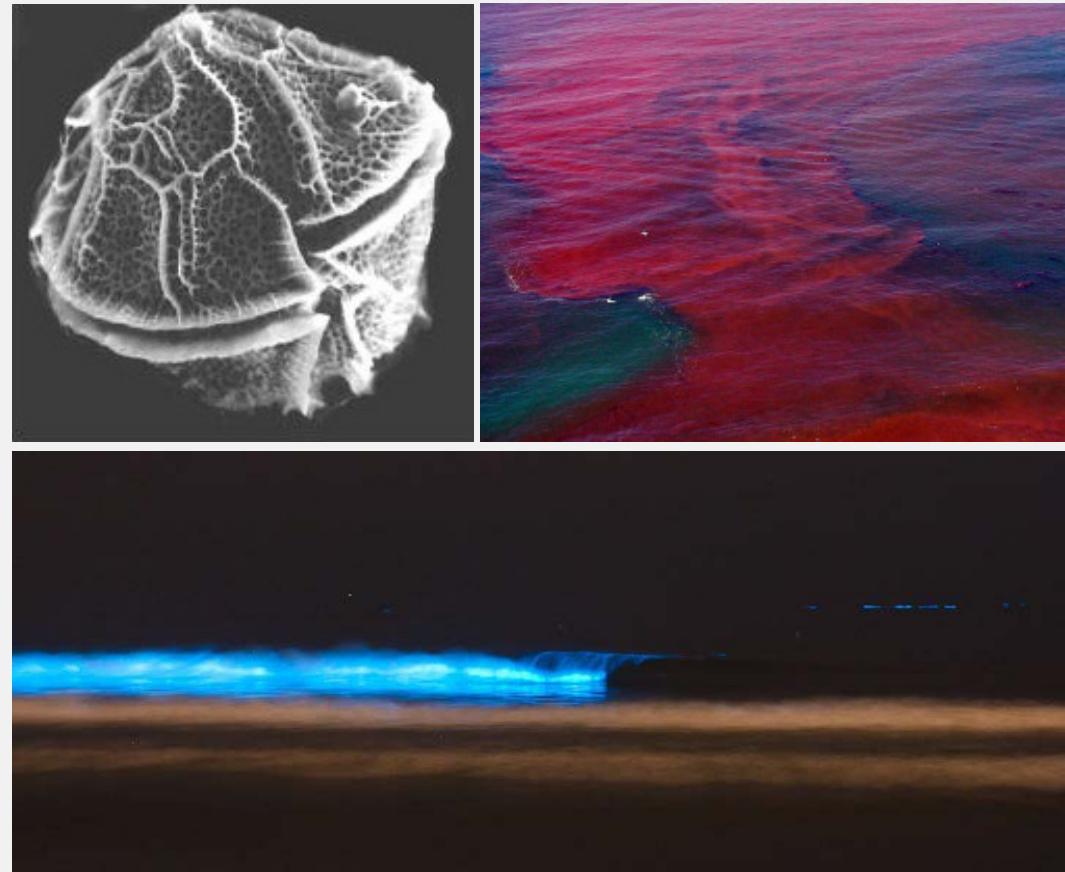
Week 3: HABs in
the Coastal
Environment



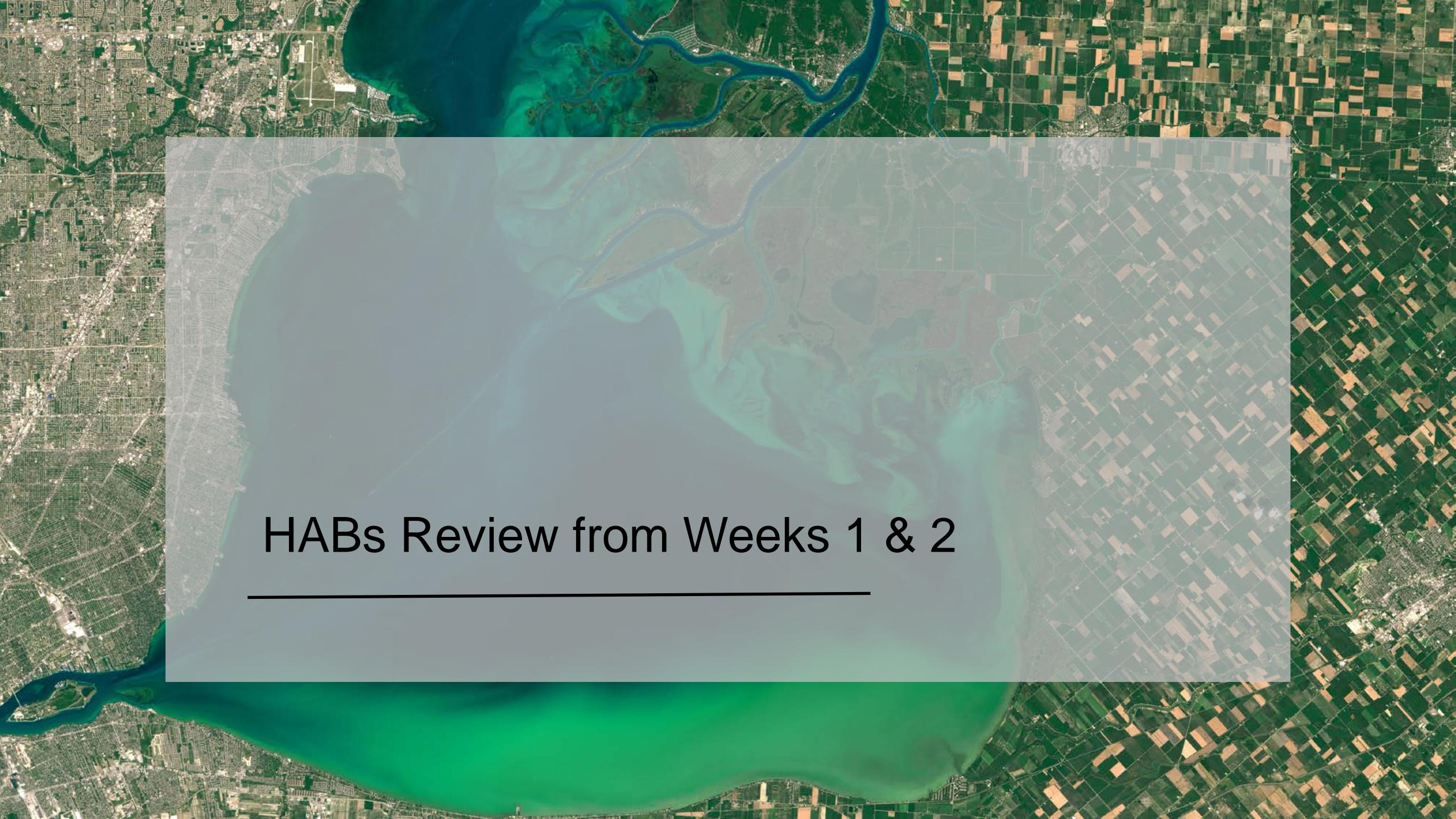
Week 4: Large Scale
Monitoring

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 Kuylestierna, Kai Schumann, Kevin Baird

The background image is a high-resolution aerial satellite photograph of Lake Erie. The lake's surface is a vibrant turquoise color, with darker greenish-blue patches indicating deeper water or phytoplankton blooms. The surrounding land is a patchwork of agricultural fields, some in green and others in brown, suggesting different crops or fallow land. Urban areas are visible as clusters of buildings and roads along the lake's edge, particularly on the western shore. A thin white rectangular box is overlaid on the image, containing the title text.

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.”

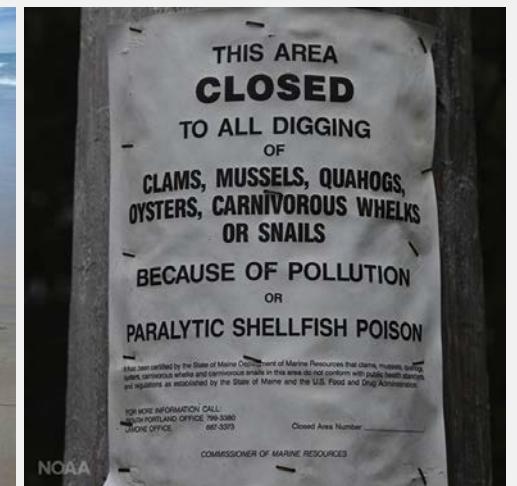
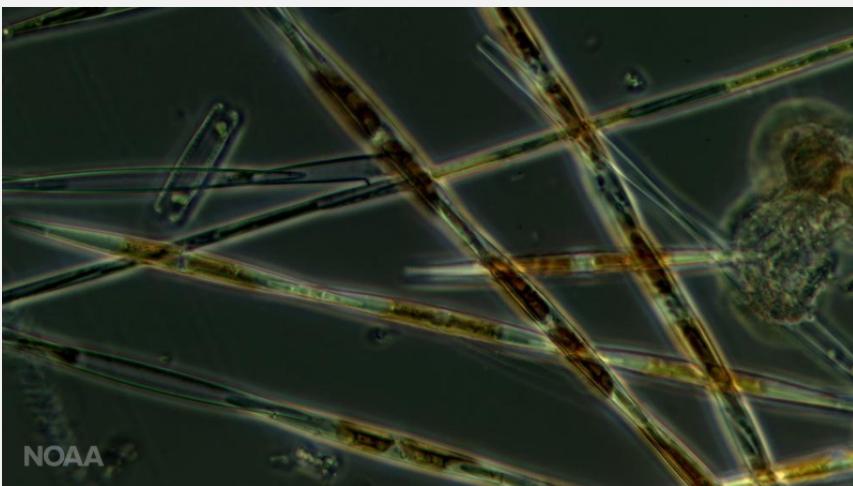


Image credit: <http://www.noaa.gov/what-is-harmful-algal-bloom>

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

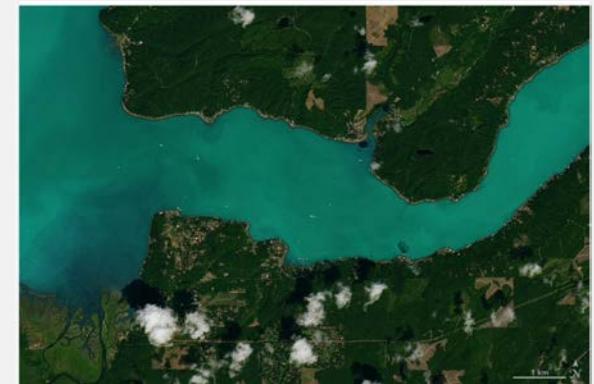
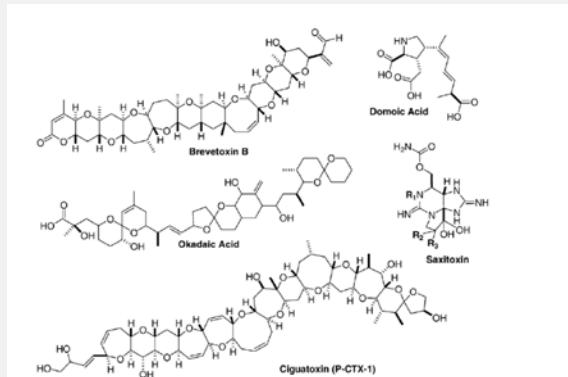


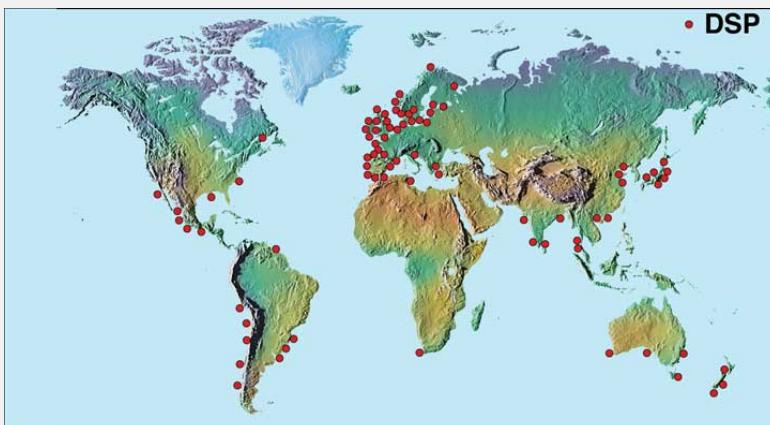
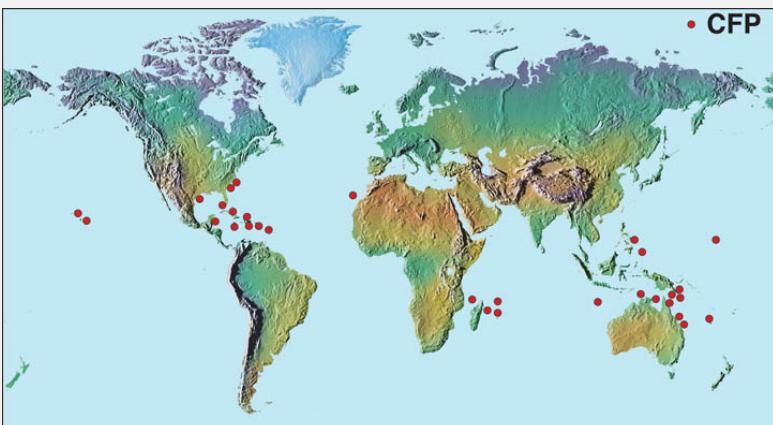
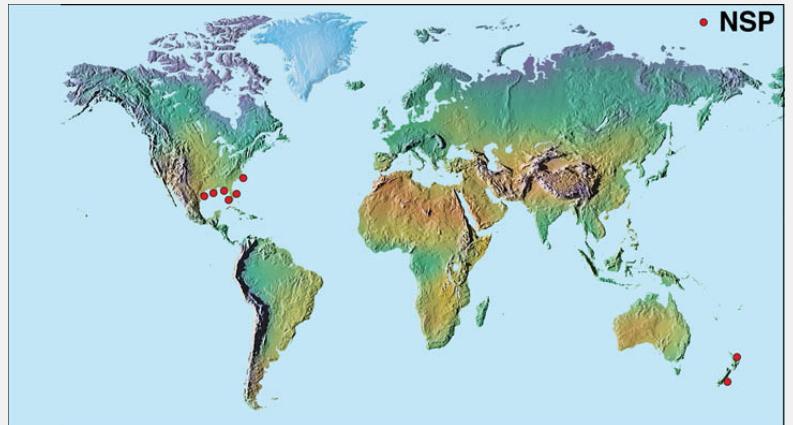
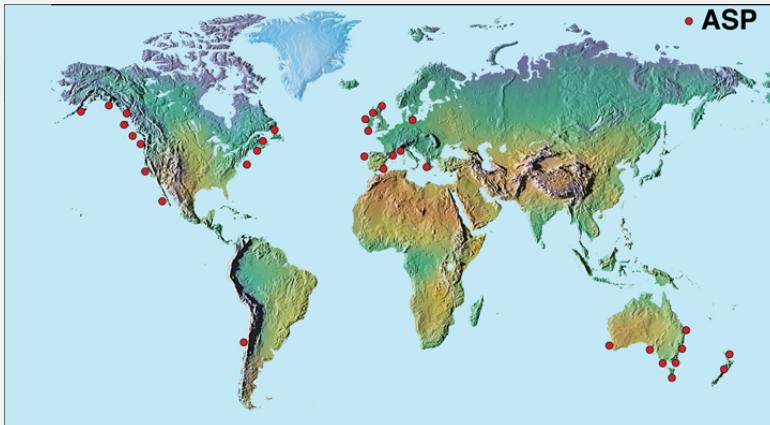
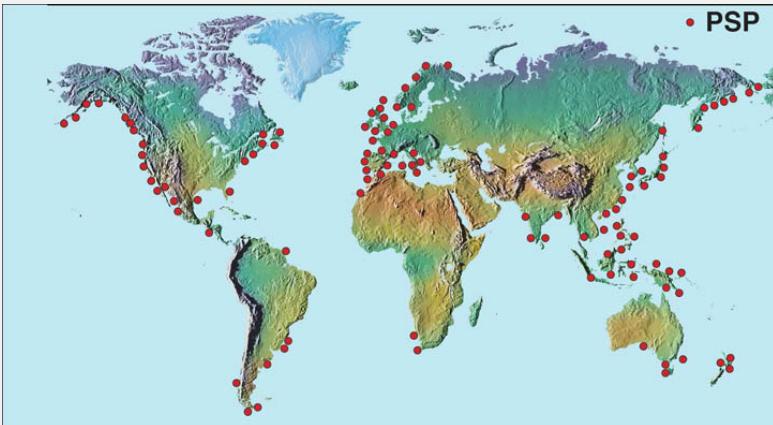
Photo Credits (clockwise from top left) Karina Cardozo (Cardozo et al., 2007); NASA Earth Observatory; NOAA Northwest Fisheries Science Center; Linda Preskitt

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

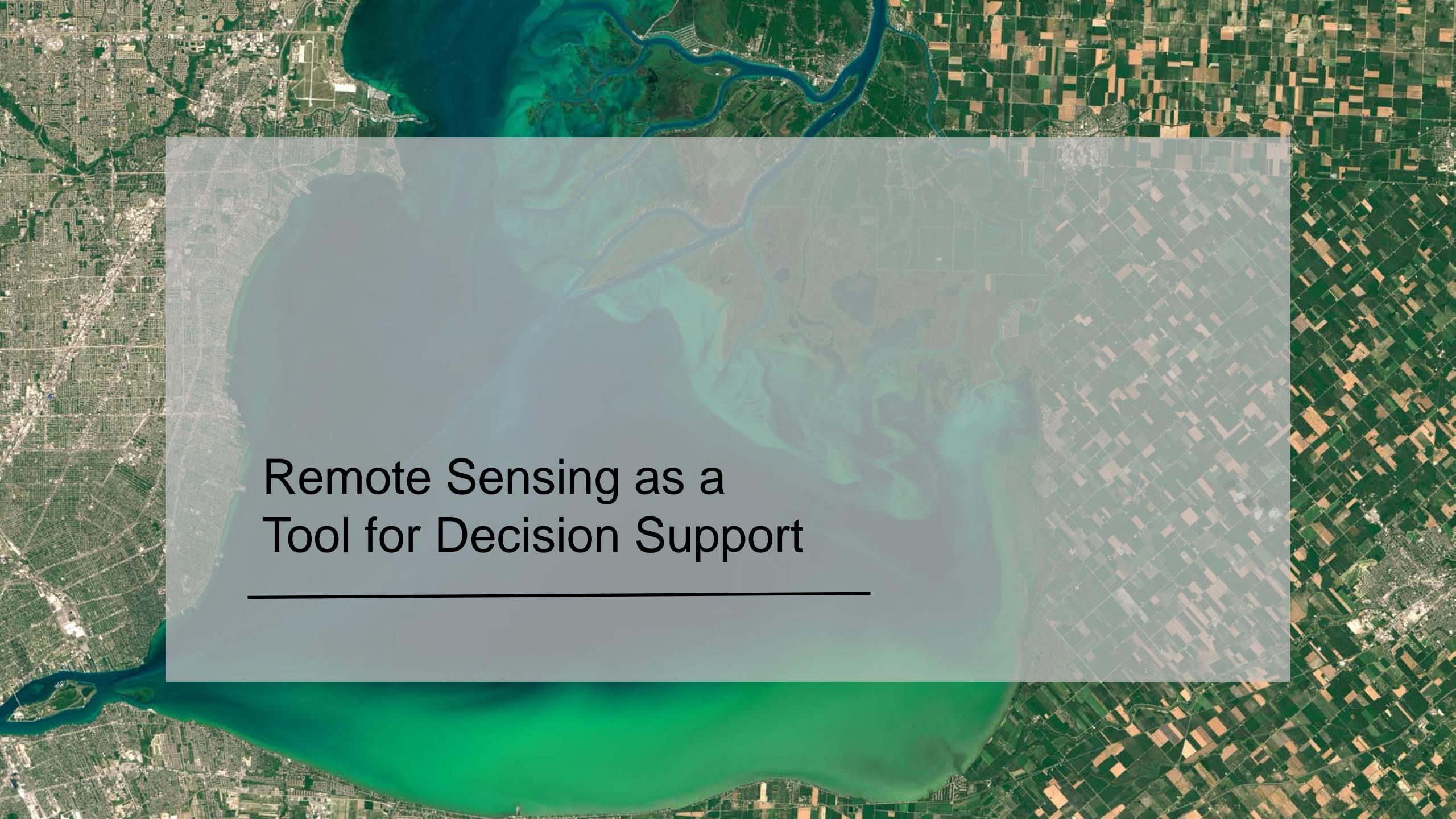


PSP - Paralytic Shellfish Poisoning
ASP - Amnesic Shellfish Poisoning
NSP - Neurotoxic Shellfish Poisoning
CFP - Ciguatera Fish Poisoning
DSP - Diarrheic Shellfish Poisoning

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

Main Take-Away for the Webinar Series...

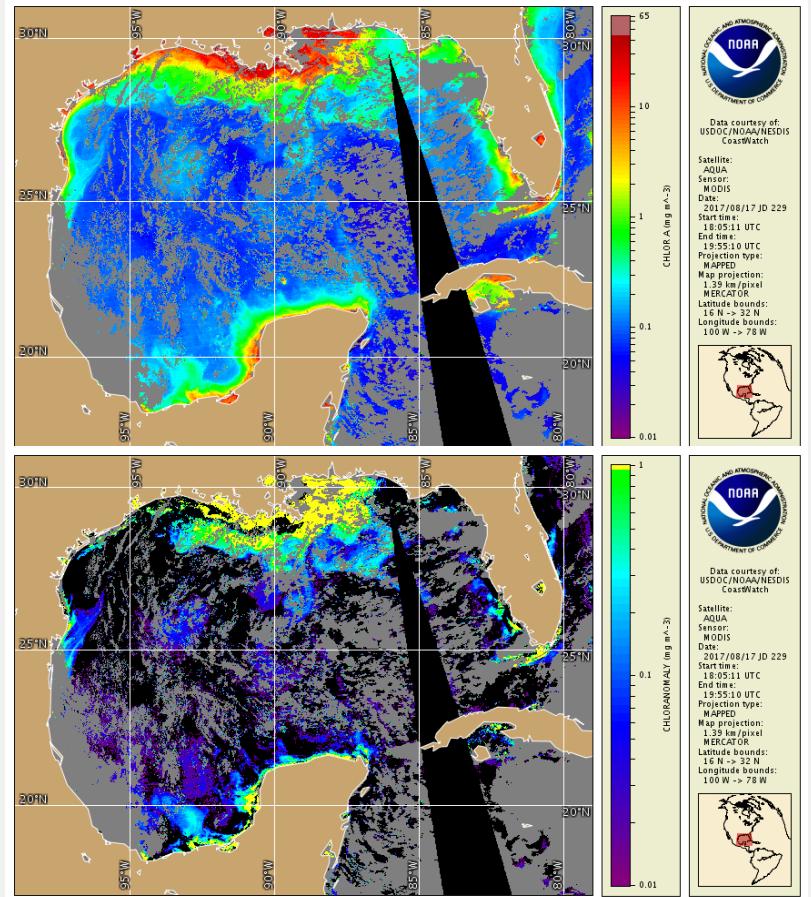
- Remote sensing imagery is a tool to aid in the monitoring and forecasting of HAB events to understand impacts to the ecosystem and/or human health
- Remote sensing imagery does not replace sampling on-the-ground
- Imagery, with associated algorithms and ecosystem models, informs adaptive sampling approaches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

The background image is a high-resolution aerial satellite photograph of a coastal region. It shows a large, dark blue-green body of water on the left, which meets a lighter green area representing land. A winding river or coastal inlet cuts through the land, with its banks showing signs of erosion or sedimentation. To the right, there is a patchwork of agricultural fields in various shades of green and brown, indicating different crops or soil types. In the far distance, a city with a grid-like street pattern is visible along the coast.

Remote Sensing as a Tool for Decision Support

Parameters Relevant for HAB Detection

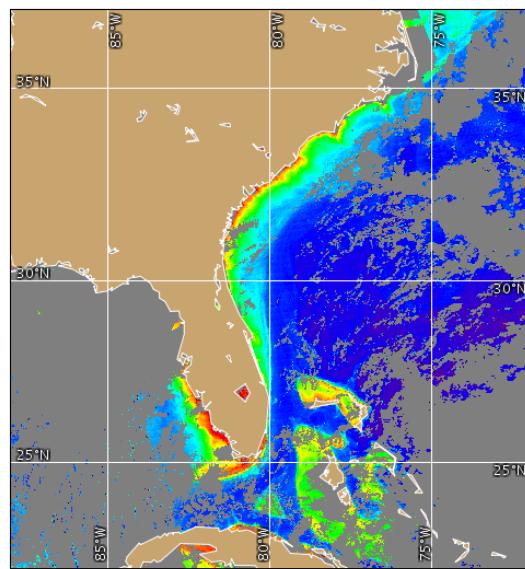
- The following parameters, available from remote sensing observations, are commonly used to detect the presence of an algal bloom
 - Chlorophyll-a Concentration (Chl-a)
 - Chlorophyll-a Concentration Anomalies
 - Taxon-Specific Bio-optical Properties
 - Sea Surface Temperature (SST) and other environmental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



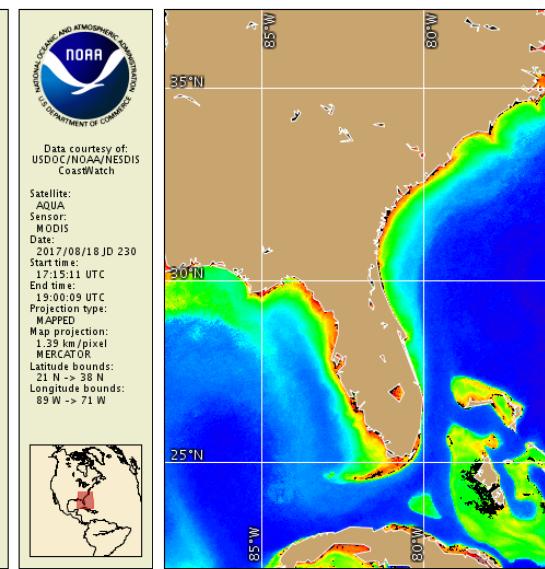
Parameters Relevant for HAB Detection

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

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

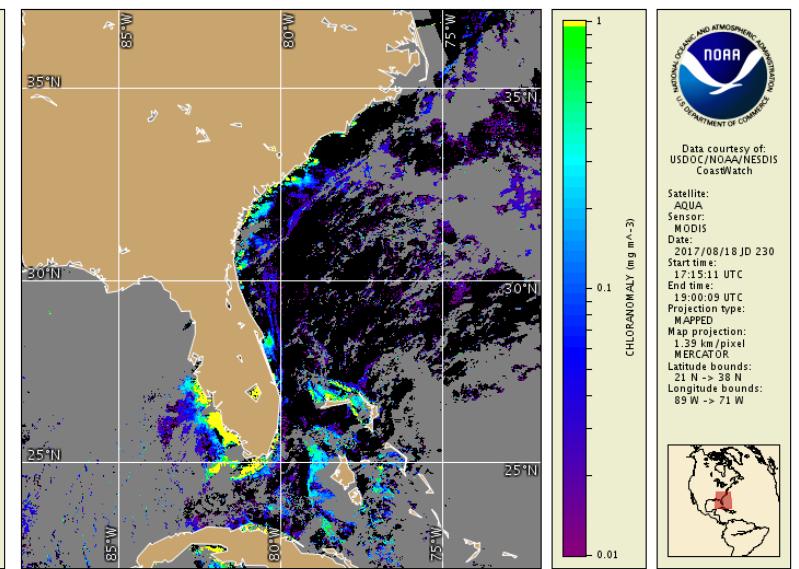


Chl-a Concentration



Chl-a Concentration
Bimonthly Mean

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



Chl-a Anomaly

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

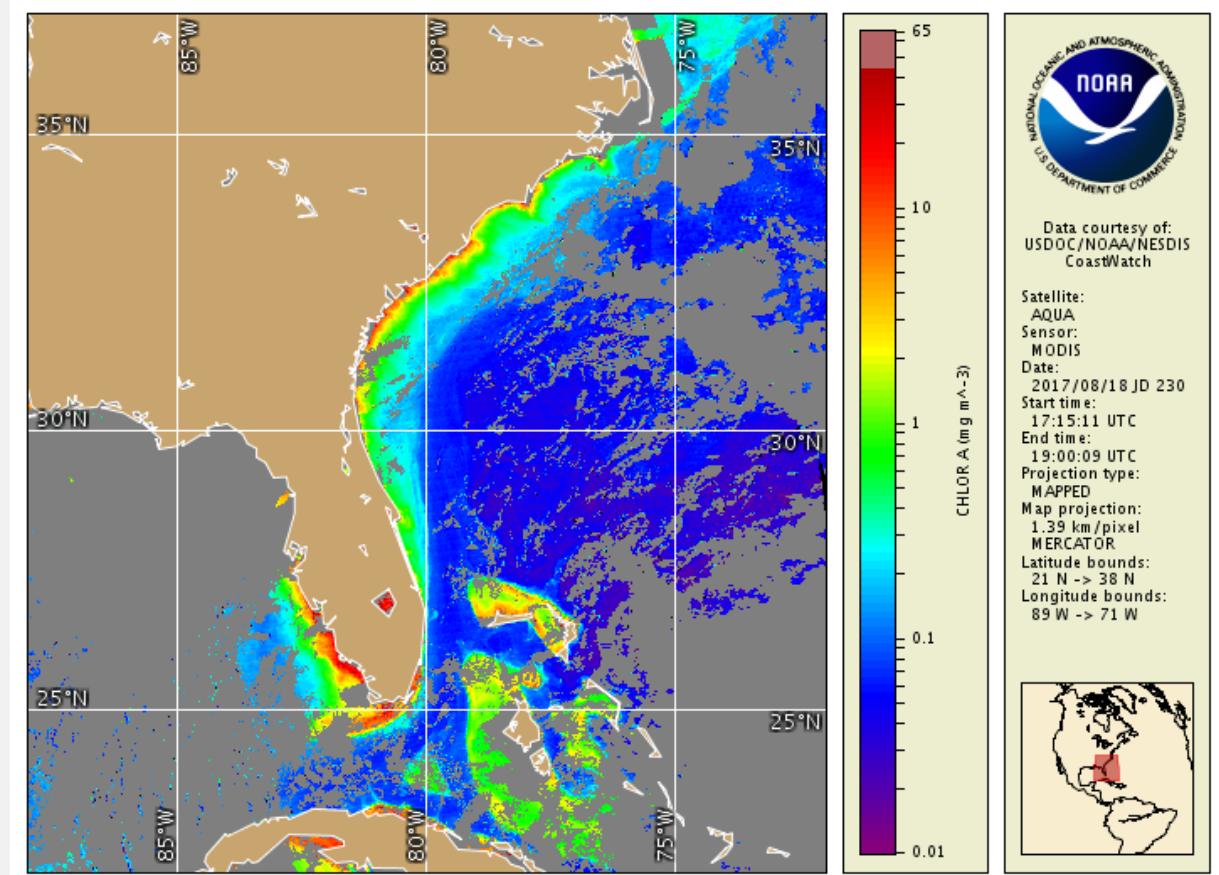
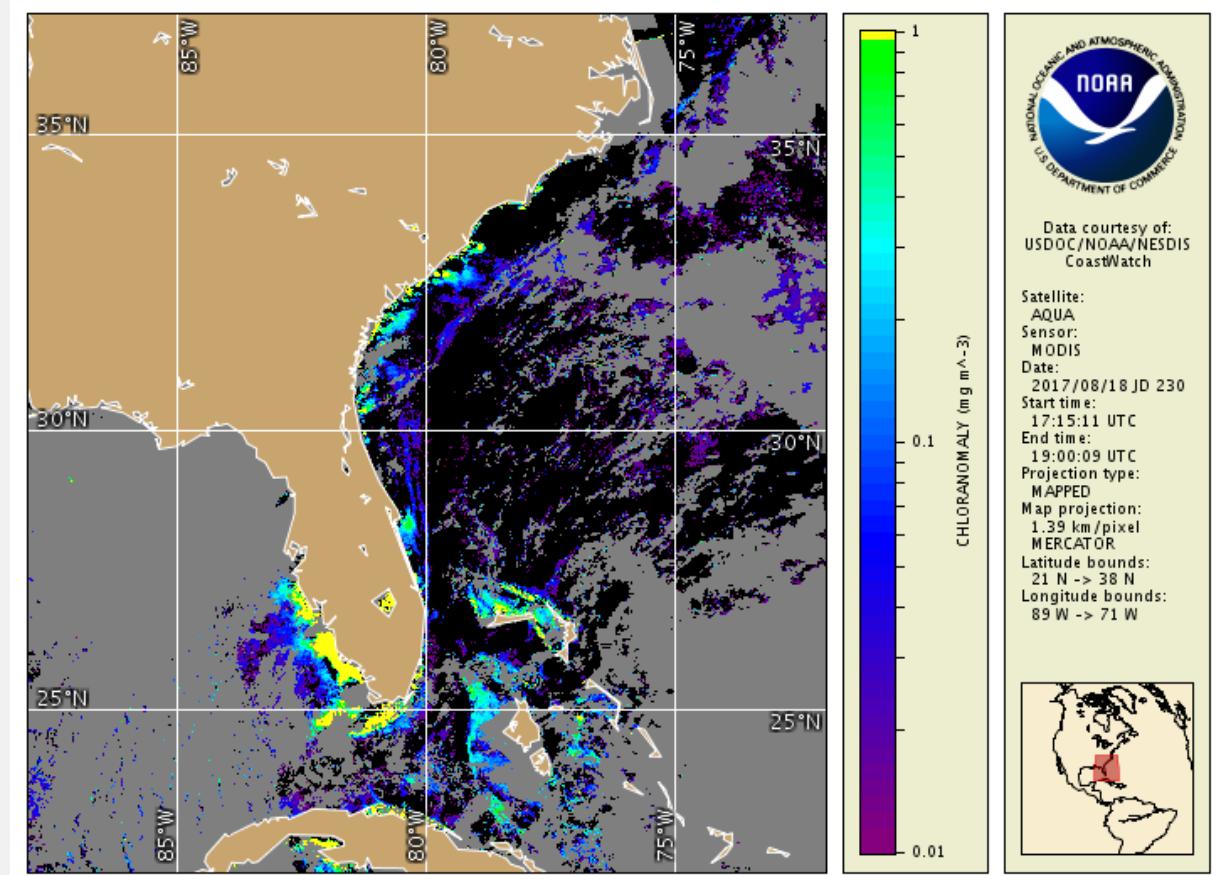


Image Credit: http://www.ospo.noaa.gov/Products/ocean/color/swir_chla_daily.html

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 shows the GIOVANNI Data Discovery interface version 4.23. At the top, there are links for EARTHDATA, Data Discovery, DAACs, Community, and Science Disciplines. A banner at the top right indicates a MODIS OPeNDAP server continuing problem. The main area is titled "Select Plot" and includes sections for "Select Date Range (UTC)" (with date and time input fields), "Select Region (Bounding Box or Shape)" (with a map and coordinate input fields), and "Select Variables". The "Variables" section is expanded, showing two categories: "Disciplines" and "Measurements". Under "Disciplines", options include Aerosols (174), Atmospheric Chemistry (66), Atmospheric Dynamics (356), Cryosphere (15), Hydrology (996), Ocean Biology (44), Oceanography (48), and Water and Energy Cycle (1060). Under "Measurements", options include 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, there are buttons for Help, Reset, Feedback, and Plot Data.

Understanding the Chlorophyll-a Anomaly

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

The screenshot shows the GIOVANNI interface with several sections highlighted:

- Analysis and Plot Selection:** A red box highlights the "Select Plot" section at the top, which includes options for Maps, Comparisons, Vertical, Time Series (selected as Hovmoller, Longitude-Averaged), and Miscellaneous.
- 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 00:00 to 2017-06-30 23:59. 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 in the "Select Variables" section, which shows 11 matching variables out of 1679. The keyword entered is "Chlorophyll".

Select Plot

Maps: Select... Comparisons: Select... Vertical: Select... Time Series: Hovmoller, Longitude-Averaged Miscellaneous: Select...

Select Date Range (UTC)
YYYY-MM HH:mm
2010 - 01 - 01 00 : 00 to 2017 - 06 - 30 23 : 59

Select Region (Bounding Box or Shape)
Format: West, South, East, North
-86.6602,24.8145,-80.332,31.4941

Select Variables

Disciplines
 Ocean Biology (10)
 Oceanography (9)

Measurements
 Chlorophyll (11)
 Organic Carbon (3)
 Phytoplankton (6)

Platform / Instrument

Spatial Resolutions

Temporal Resolutions

Wavelengths

Portal

Number of matching Variables: 11 of 1679 Total Variable(s) included in Plot: 1

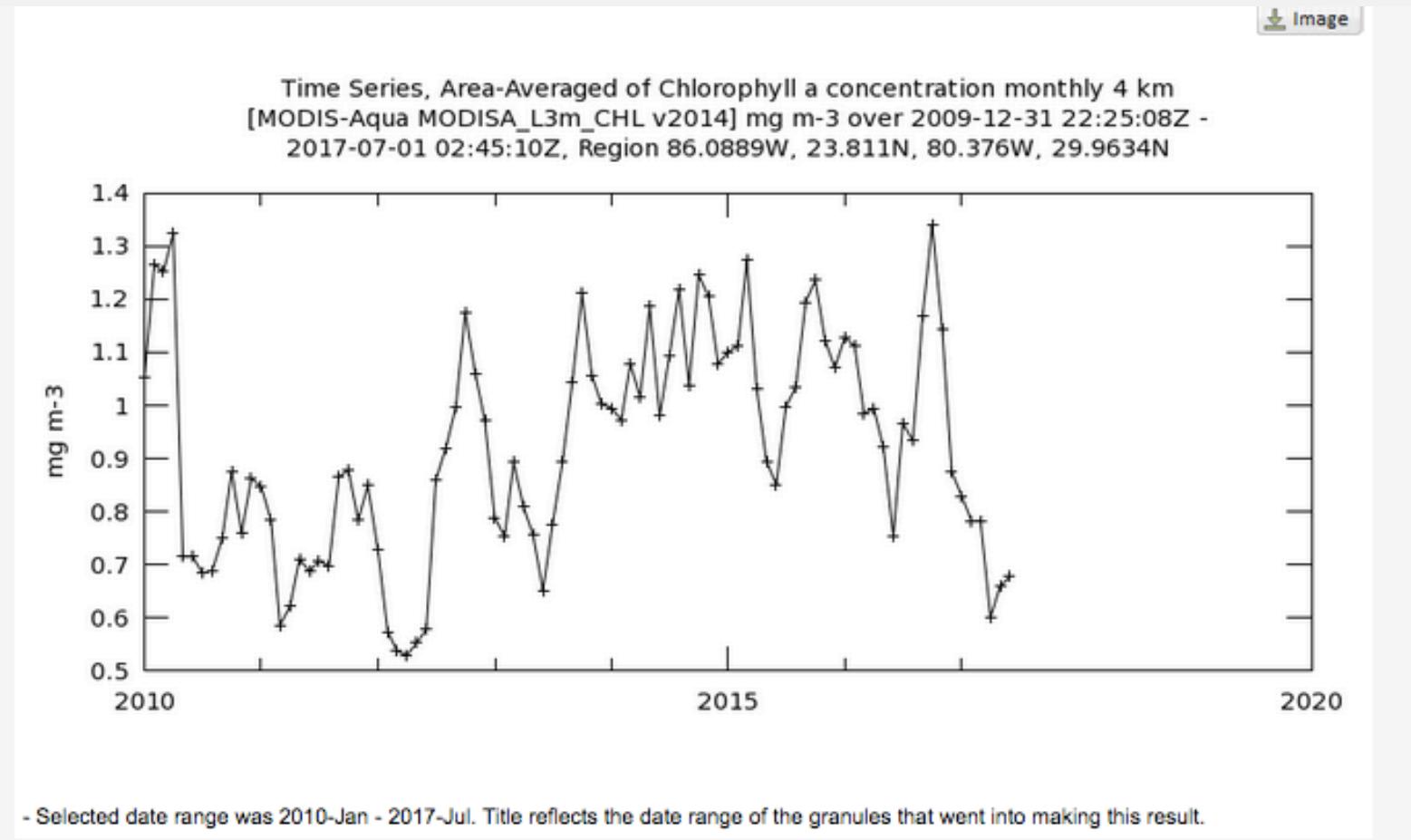
Keyword: Chlorophyll Search Clear

Variable	Source	Temp.Res.	Spat.Res.	Begin Date	End Date
Chlorophyll a Concentration (OCTS_L3m_CHL_v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30
Assimilated Total Chlorophyll (NOBM_DAY_vR2014)	NOBM	Daily	0.667 x 1.25 °	1998-01-01	2012-12-31
Assimilated To		Monthly	0.667 x 1.25 °	1998-01-01	2012-12-31
Normalized flu	Ac	Monthly	4 km	2002-07-04	2017-06-30
Chlorophyll a concentration (MODISA_L3m_CHL_v2014)	MODIS-Ac	Monthly	4 km	2002-07-04	2017-06-30
Chlorophyll a Concentration (SeaWiFS_L3m_CHL_v2014)	SeaWiFS	Monthly	9 km	1997-09-04	2010-12-11
Chlorophyll Concentration, OC3 Algorithm (OCTS_L3m_CHL_v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30
Concentration of Particulate Organic Carbon (OCTS_L3m_POC_v2014)	OCTS	Monthly	9 km	1996-11-01	1997-06-30
Concentration of Particulate Organic Carbon (MODISA_L3m_POC_v2014)	MODIS-Ac	Monthly	4 km	2002-07-04	2017-06-30
Absorption coefficient due to phytoplankton (aph) at 443 nm (SeaWiFS_L3m_IOP_v2014)					

Help Reset Feedback Plot Data

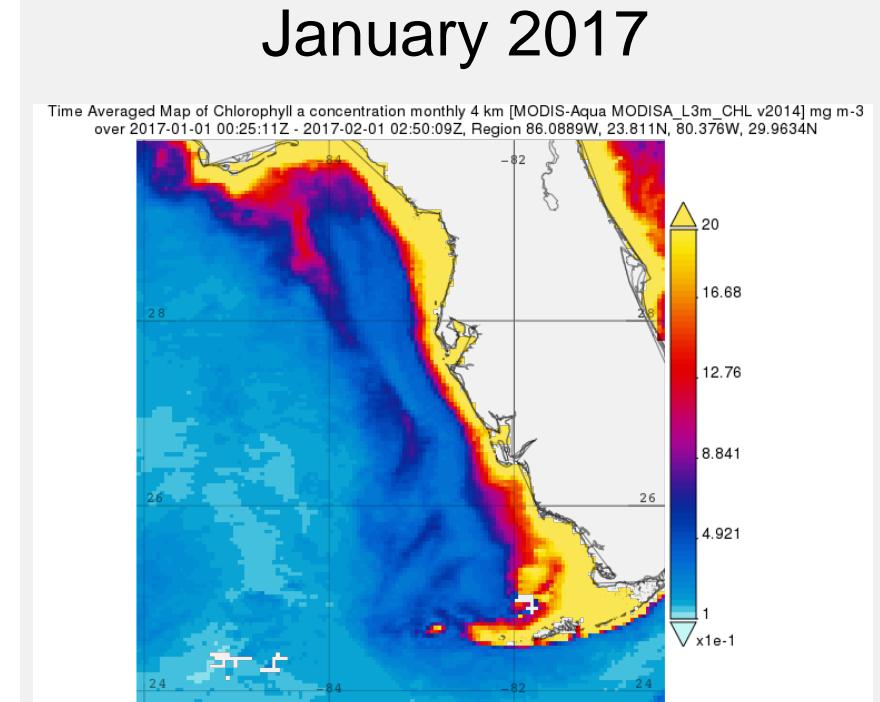
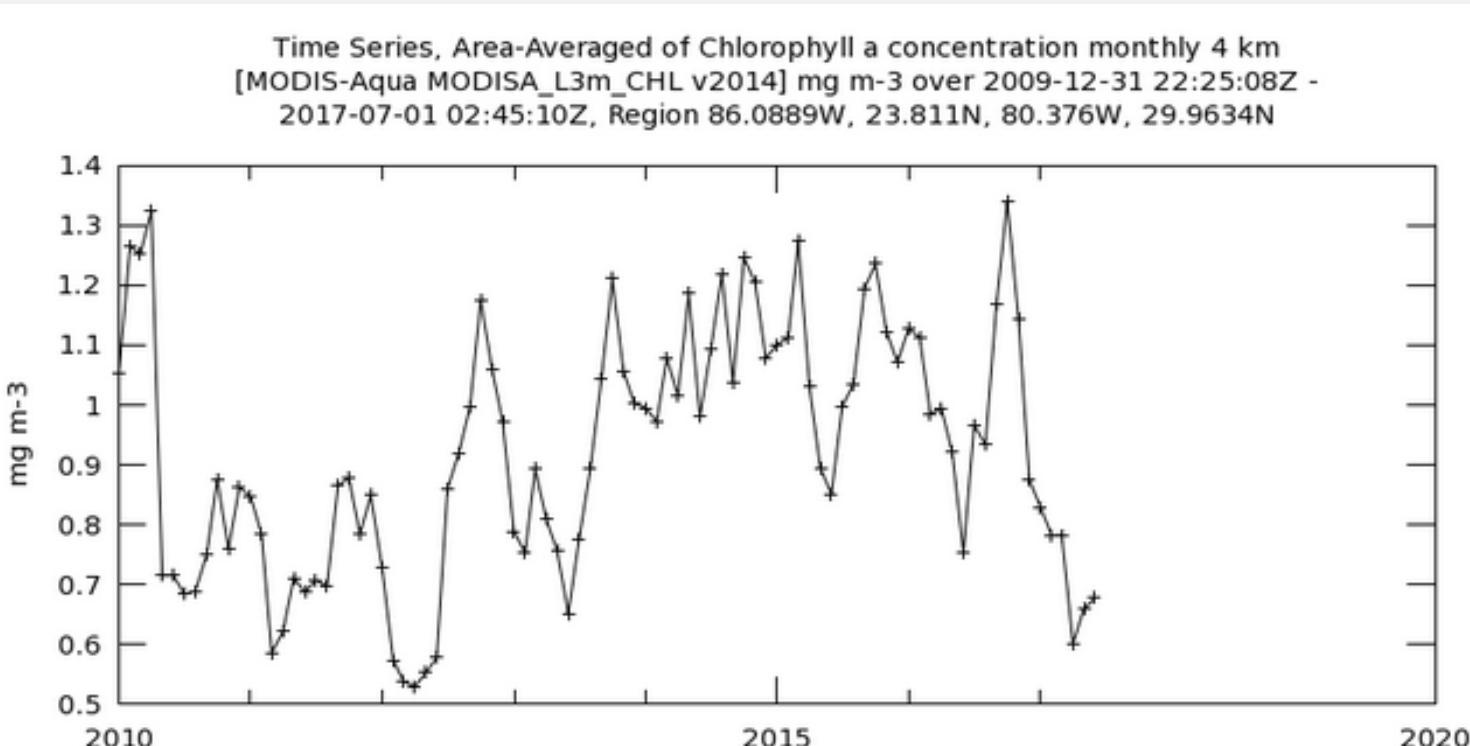
Giovanni Can Be Used to Visualize Chl-a Anomalies Globally

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



Giovanni: Chlorophyll Concentration in the Gulf of Mexico

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



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

Taxon-Specific Bio-Optical Properties

Case Studies

- *Karenia brevis*
 - large phytoplankton with distinctive optical backscattering characteristics
- *Microcystis aeruginosa*
 - cells contain gas filled vesicles that cause the organism to float to the surface during blooms, forming surface scums

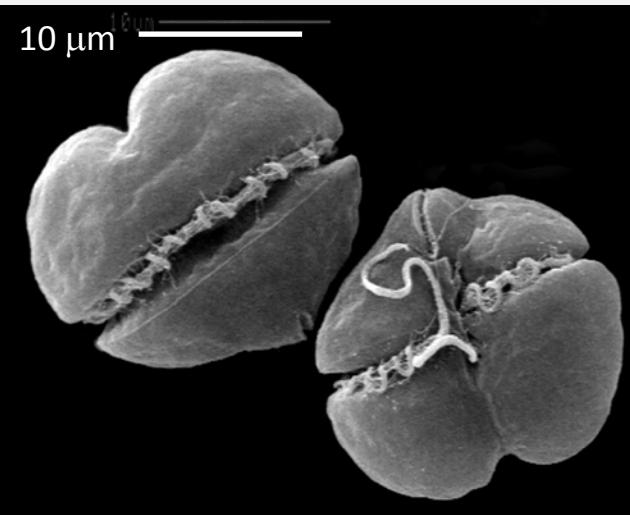
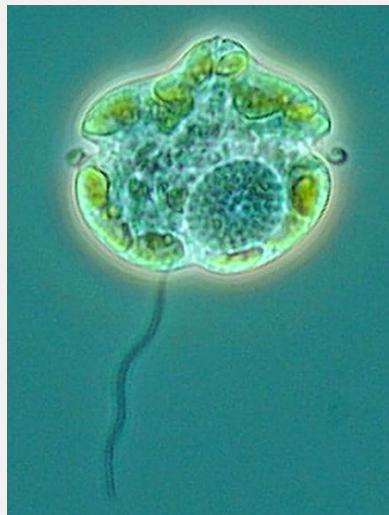


Photo Credit: Florida Fish and Wildlife Conservation Commission

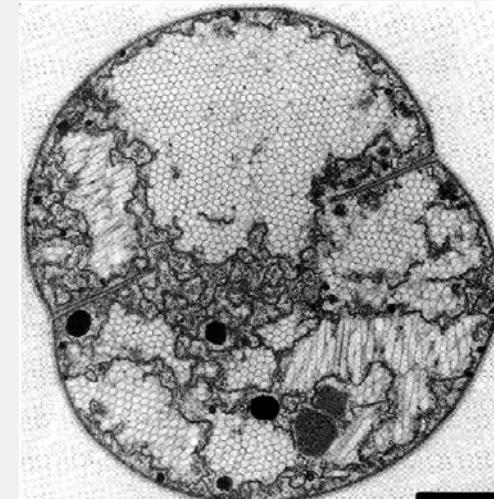
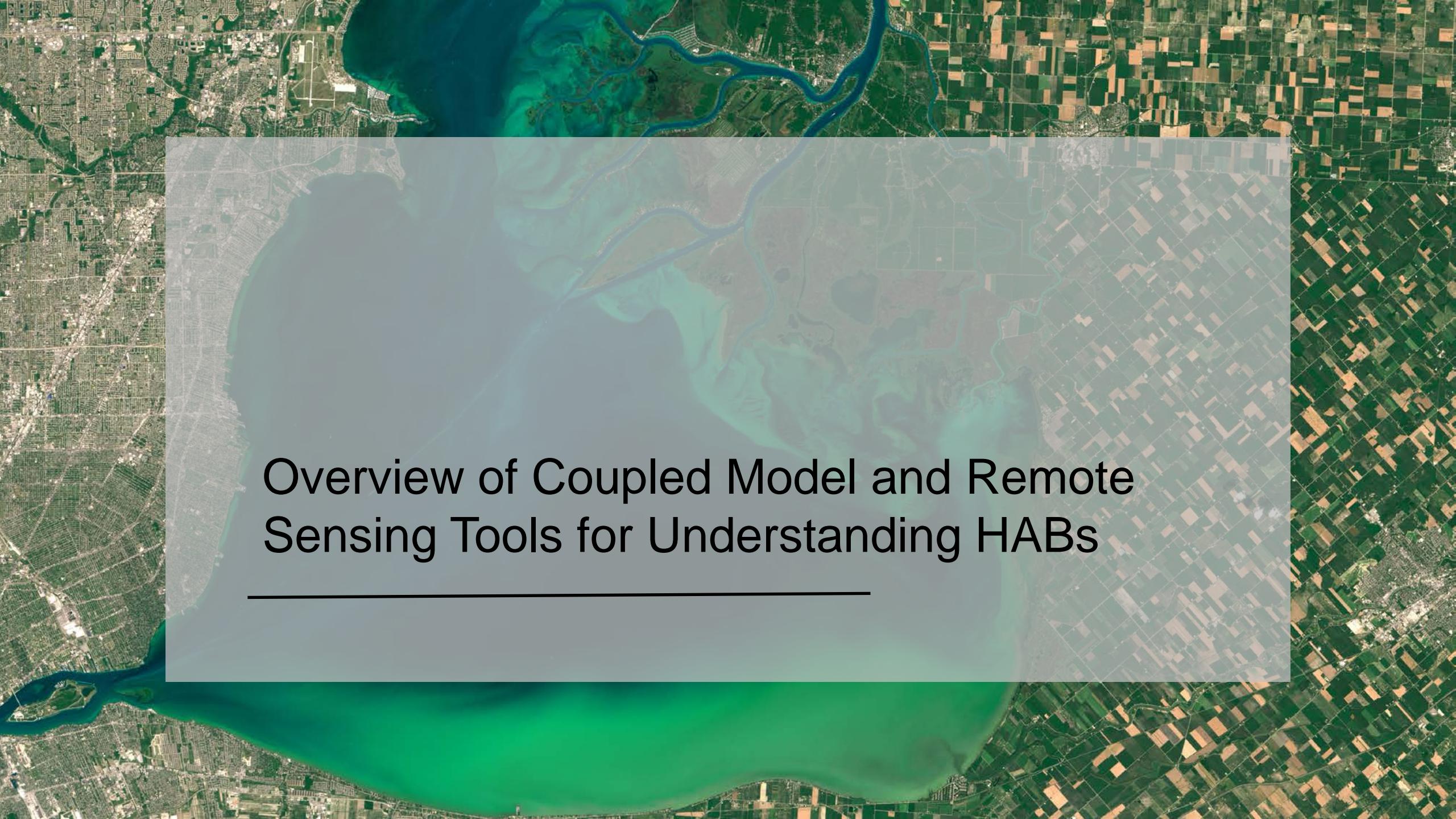


Photo Credit: H.S. Pankratz

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>

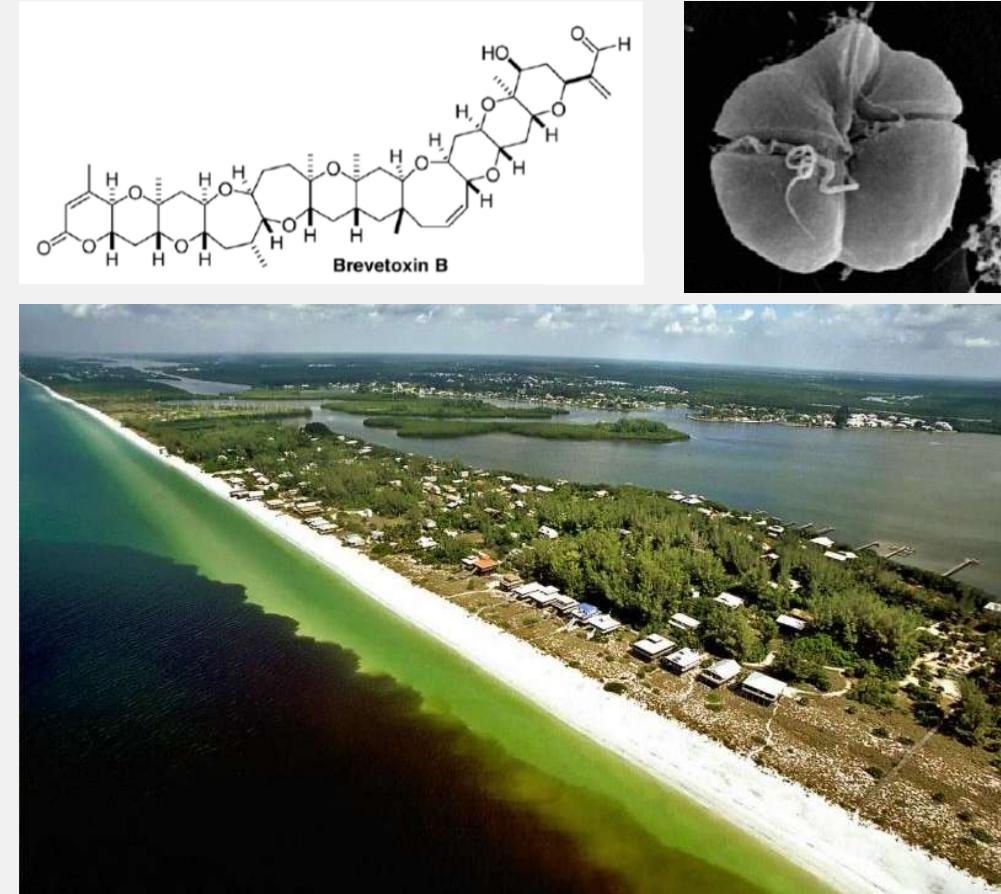
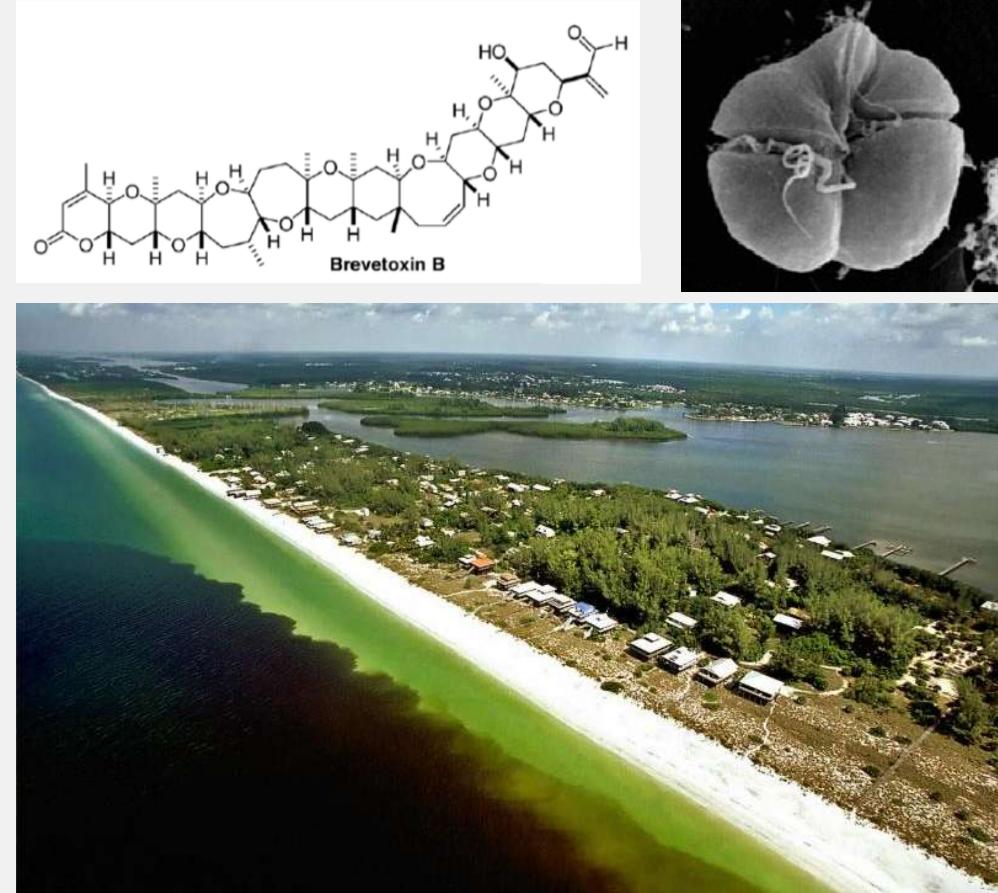


Photo Credit (Clockwise from Top): Karina Cardozo (Cardozo et al., 2007); John Dutton; P. Schmidt, Charlotte Sun Times

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

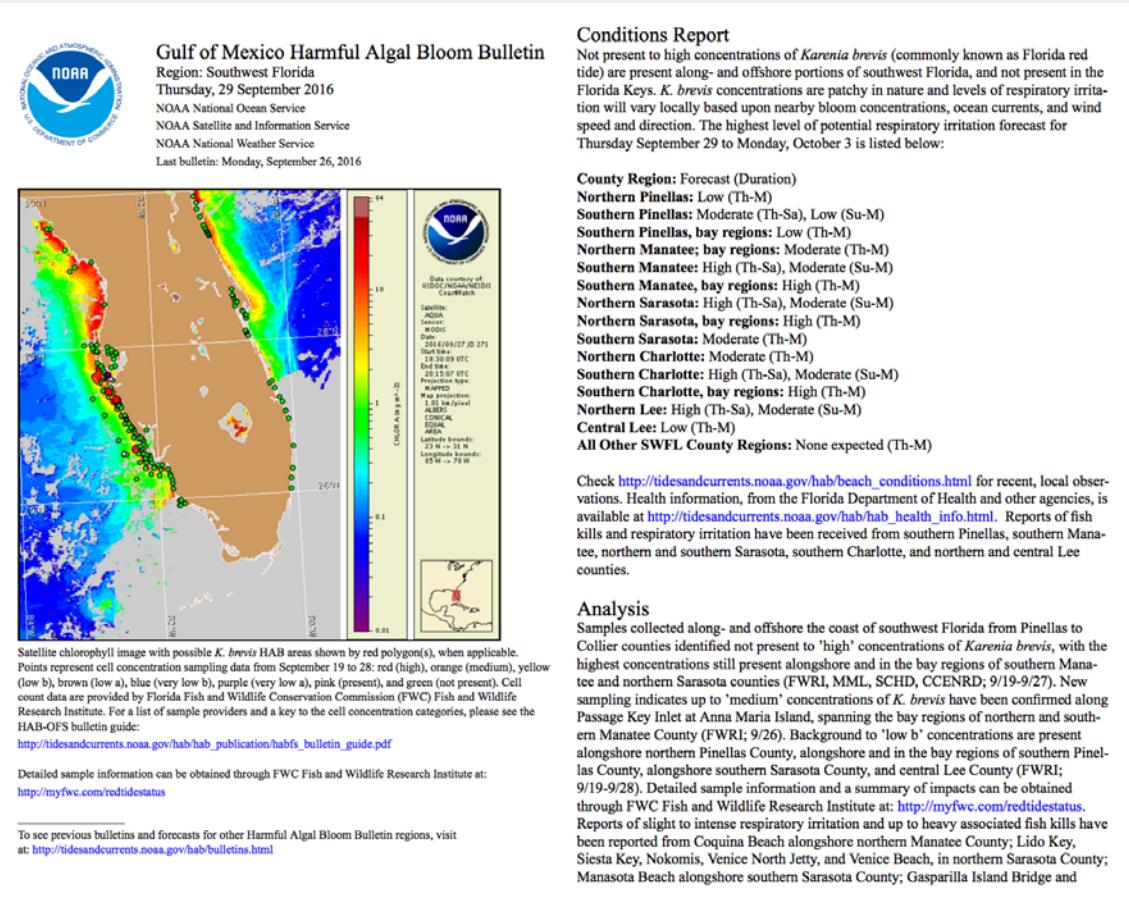


Credit: WHOI <https://www.whoi.edu/redtide/human-health/neurotoxic-shellfish-poisoning>

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)



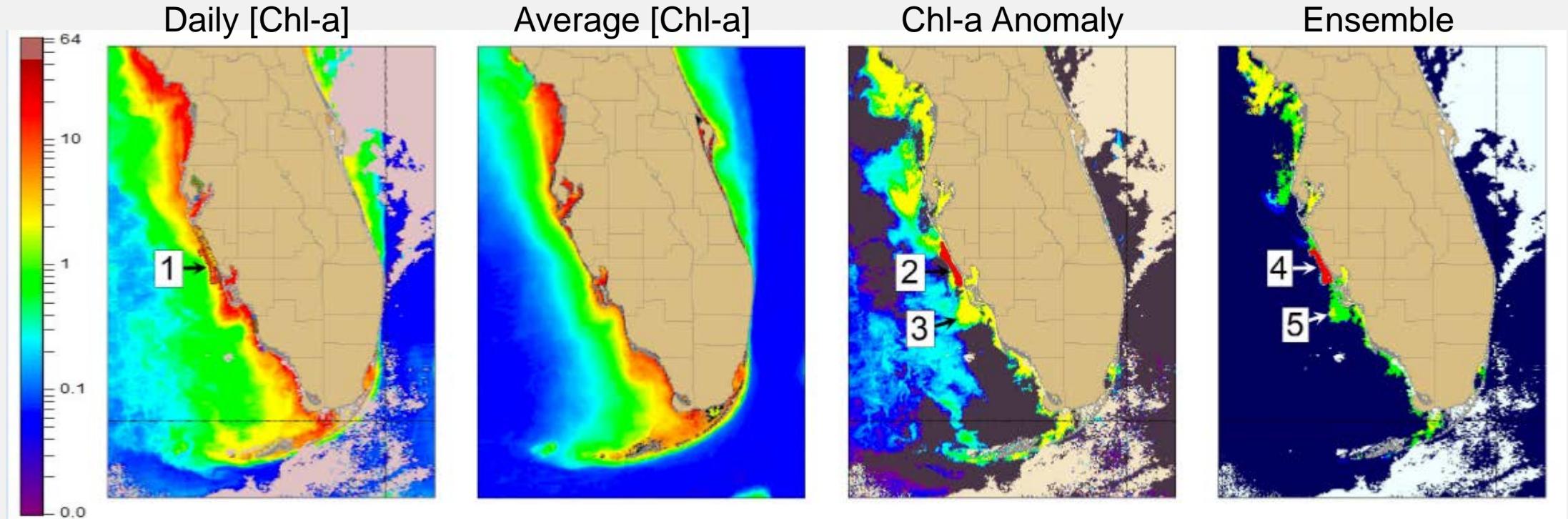
- *Karenia brevis* forms patchy blooms and the impact can vary by location
- To build its forecast, the NOAA HAB Bulletin combines:
 - ocean satellite imagery
 - field observations
 - models
 - public health reports
 - ocean buoy data

<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

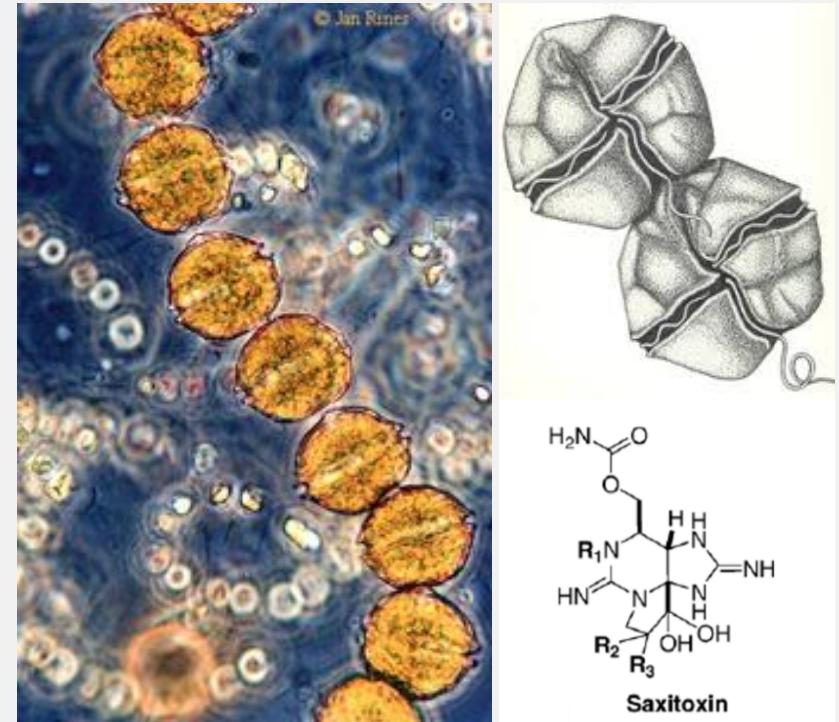


Image Credit: Left: Jan Rines (U. of Rhode Island)
<http://oceandatacenter.ucsc.edu>; Right: Karina Cardozo
(Cardozo et al., 2007)

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

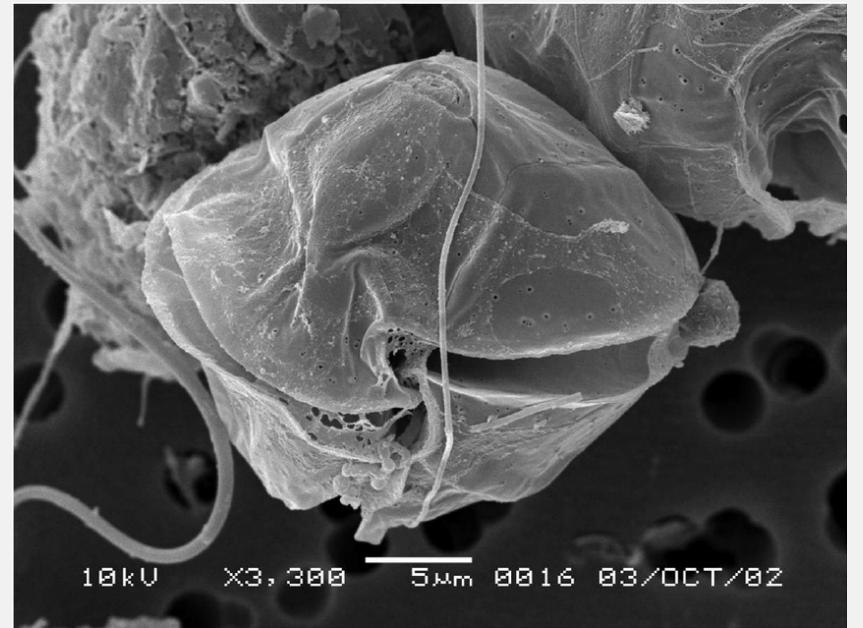
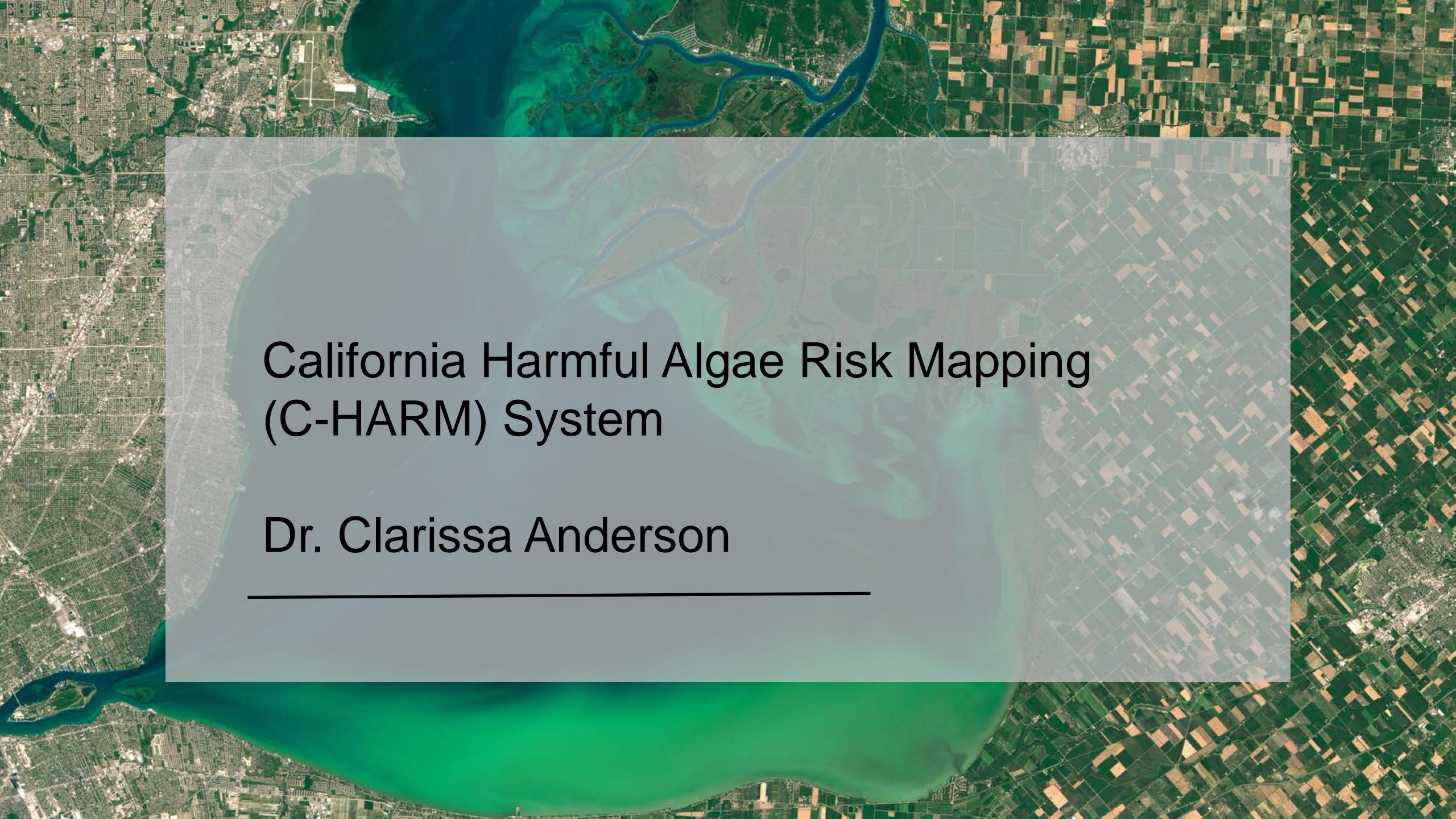


Image Credit: (L to R) NCCOS, Martin et al., 2007

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

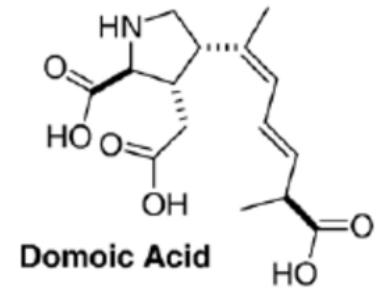
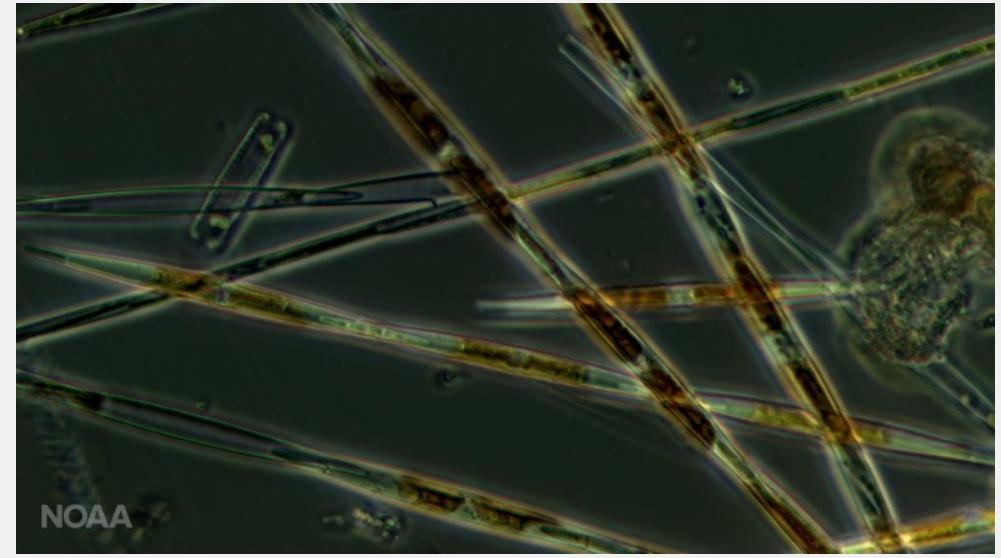
The background of the slide is a high-resolution aerial satellite image of a coastal region. It shows a mix of urban areas with dense building clusters, agricultural land with various field patterns, and a large body of water. A prominent river or channel flows through the center of the image, connecting the land to the water. The water appears in shades of blue and green, suggesting depth or algae concentration.

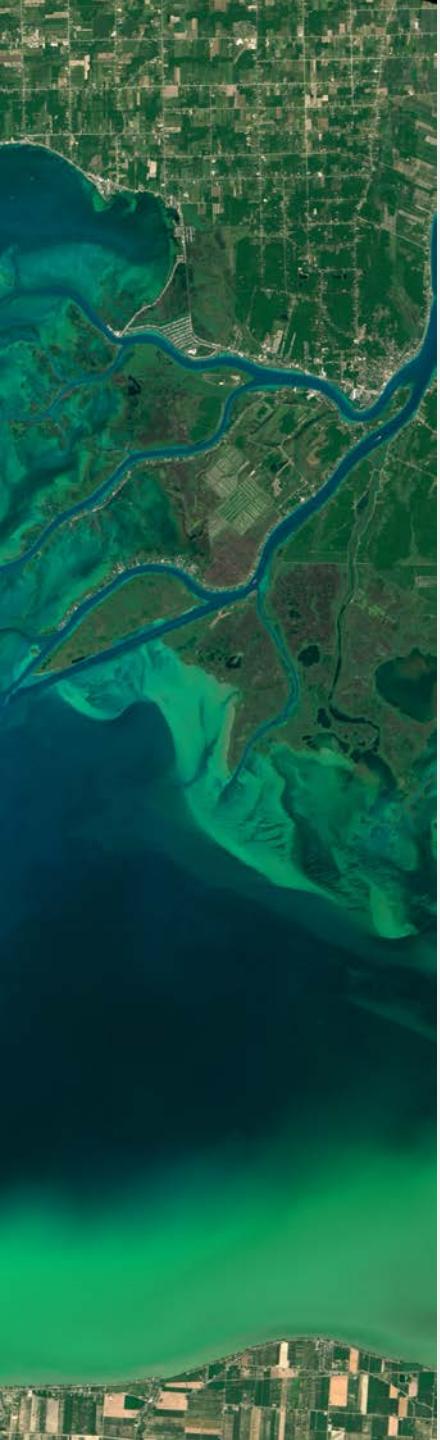
California Harmful Algae Risk Mapping (C-HARM) System

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





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Thank you!

Next Week:

Large-Scale Monitoring Using Remote Sensing and Citizen Science