Advances in Monitoring and Forecasting Harmful Algal Blooms Through a Combination of Remote Sensing, Models and Other Tools Across the U.S.

Shelly Tomlinson
East Coast Node Manager

NOAA's National Centers for Coastal Ocean Science

Collaboration with entire NCCOS HAB forecast branch and external partners

SCIENCE SERVING COASTAL COMMUNITIES

What is a harmful bloom?

"The salient criterion to use in defining whether a "harmful" species is in bloom and the distinctive feature of such blooms lie not in the level of abundance, but whether its occurrence has harmful consequences."

-Ted Smayda, 1997 L&O

Mission

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The HAB Forecasting Branch (HAB-F) delivers near real-time forecasting products for predicting the intensity/severity, location, and the health risk HABs pose in the Great Lakes and coastal regions of the U.S.

- *Developing a monitoring and forecasting system which is **national in scope**.*
- *Individual forecasting products are **regional** and require an understanding of the drivers for specific HAB species including weather, oceanographic and environmental conditions, all of which vary greatly by location.*
- *HAB forecasting products are delivered **locally** and serve as decision-support tools to provide early warning of regional blooms for local coastal resource managers, public health officials and researchers.*

*Current HAB Forecasts CANNOT detect blooms at cell concentrations associated with regulatory limits in shellfish

HAB Forecasting History

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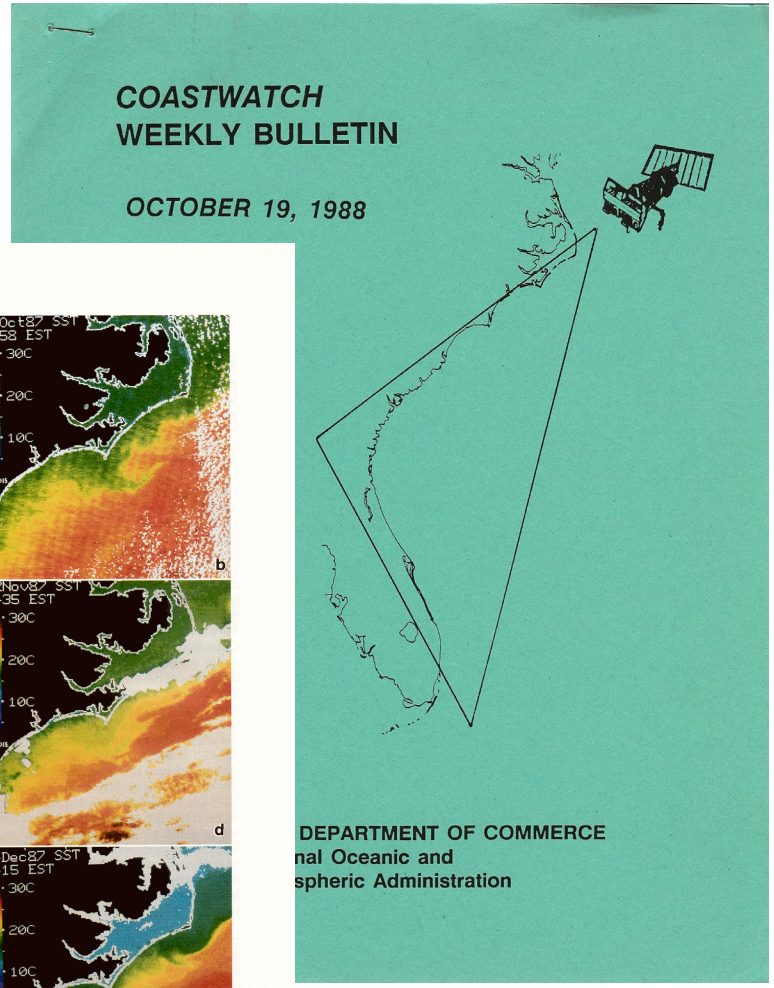
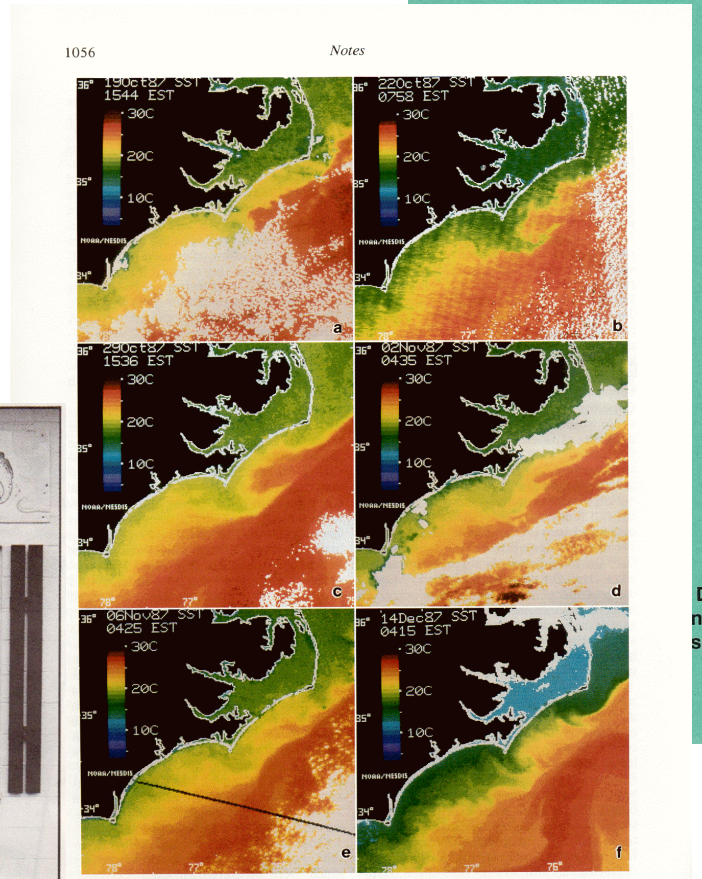
- October 31 1987: A *Karenia brevis* (*Ptychodiscus brevis* at that time) bloom made landfall in Beaufort NC. NOAA National Marine Fisheries (NMFS) (Dr. Patricia Tester) helps identify first occurrence in North Carolina
- November 1987: NOAA's Satellite Service (NESDIS) provides SST used to determine the source of bloom in North Carolina
- Winter 1987-1988: Winds and satellite data determine source of HAB from FL straits and Gulf Stream transport
- Summer 1988-1989: NOAA CoastWatch program was established and began supplying operational satellite imagery





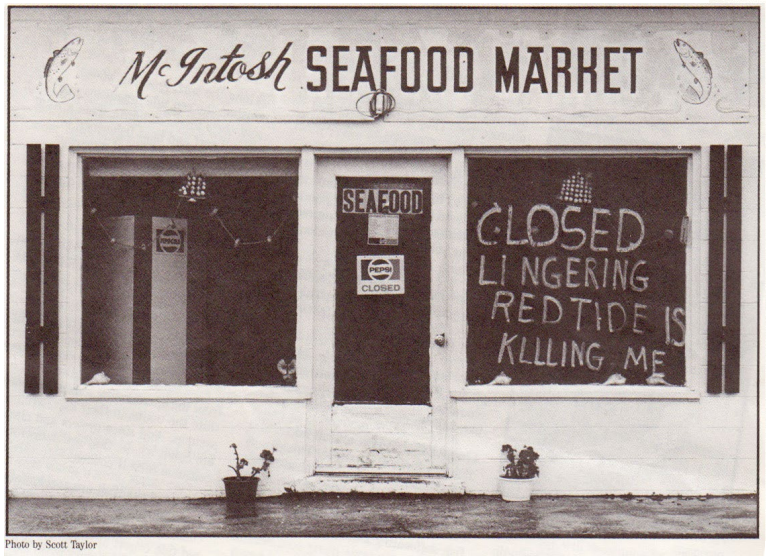


Photo: Scott Taylor, for UNC Sea Grant, February 1988

Tester, et al., 1991. *Limnology and Oceanography*

Forecasting Components

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There are typically 3 components of HAB forecasting products…

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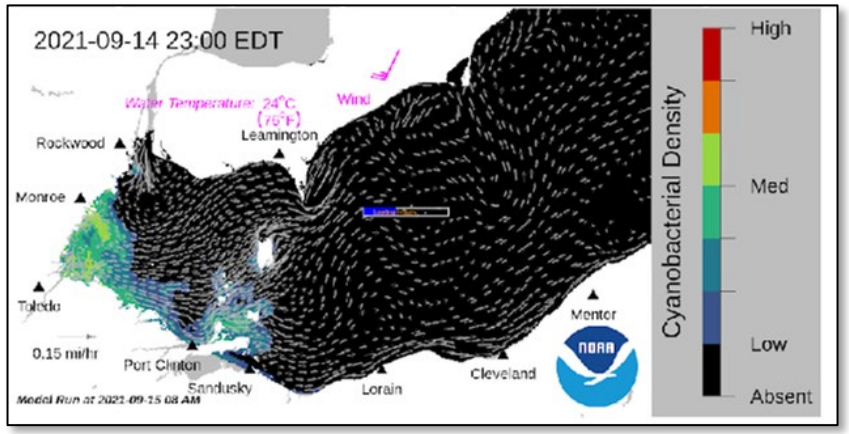
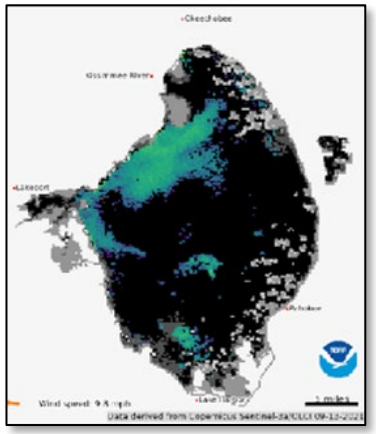
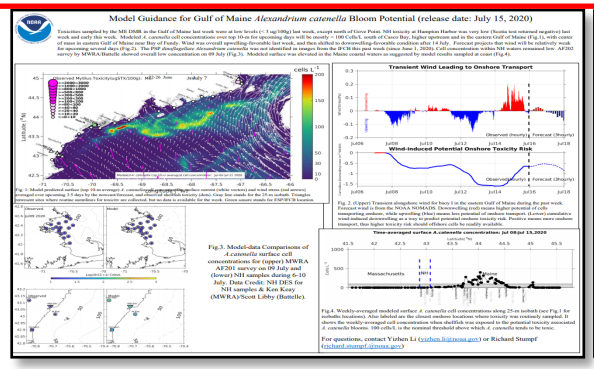


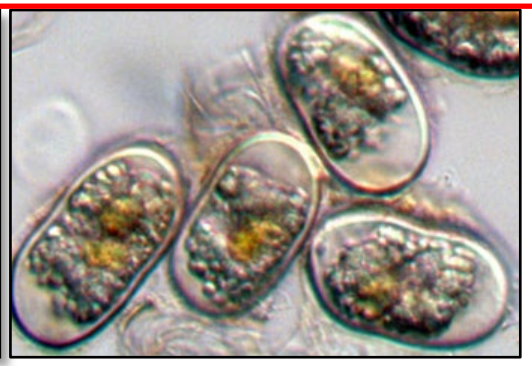
Lake Erie Operational HAB Forecast



Lake O Image Product

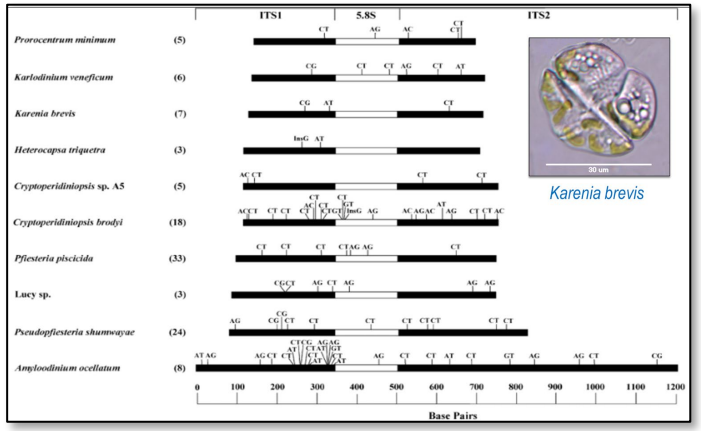


Gulf of Maine Forecast Dashboard



Alexandrium cysts

2) Modeling: In addition to hydrodynamic models to forecast likely transport of HABs (*e.g.* in western Lake Erie) specific numerical and ecological models have been developed.



Molecular Methods for HAB detection

3) *In Situ* & Laboratory Validation Products: Remotely sensed products and models need to be validated with field samples. The lab portion of HAB-F uses cutting edge protocols to determine phytoplankton assemblages & toxins in water samples.

Gulf Coast: *Karenia brevis* “red tide”, NSP public health, tourism, fishing, seafood industry

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NOAA Chris Holland

Eve Edelheit for The Washington Post)

Exceeded 20 years of HAB forecasting along the Gulf Coast

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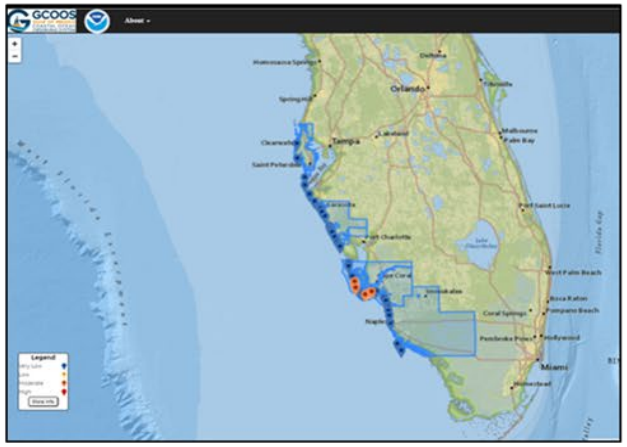
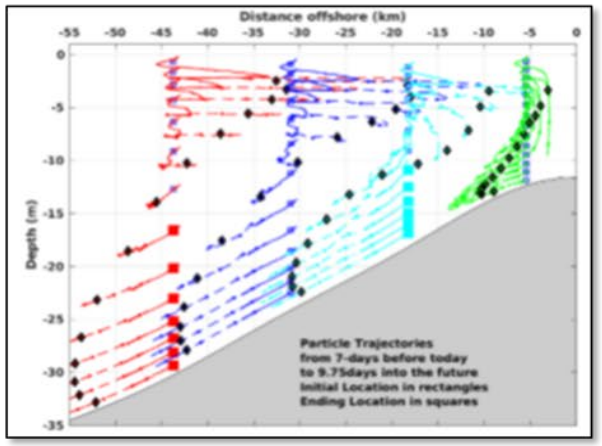
Improvements: 2022 higher resolution respiratory irritation forecasts

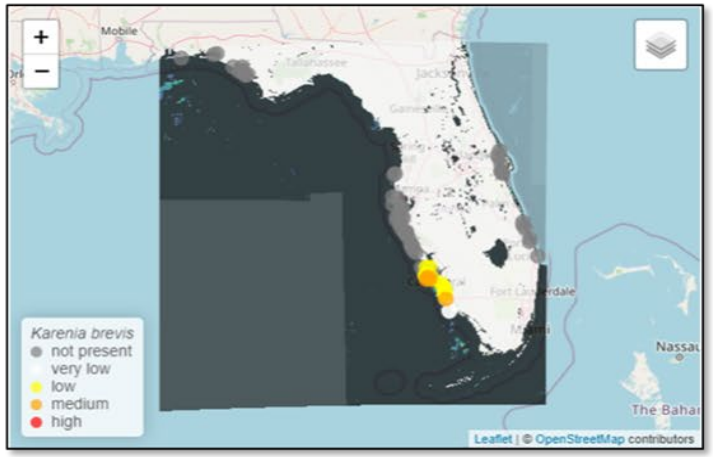
- Respiratory forecast at individual beaches throughout the day combined with improved satellite detection of *K. brevis* blooms through fluorescence algorithm
- Combined with intensification forecast based on cell concentration and upwelling favorable winds
- NSP producer: Cannot predict bloom at shellfish regulatory limit of 5000 cells/L



Respiratory Forecast
Potential respiratory irritation over the next two days



Intensification Forecast
Likelihood that a bloom will develop or change



Satellite Imagery
Real-time imagery from the Ocean Land Color Imager (OLCI) showing bloom location and extent.

GCOOS GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM

Satellite-derived products for algal bloom monitoring

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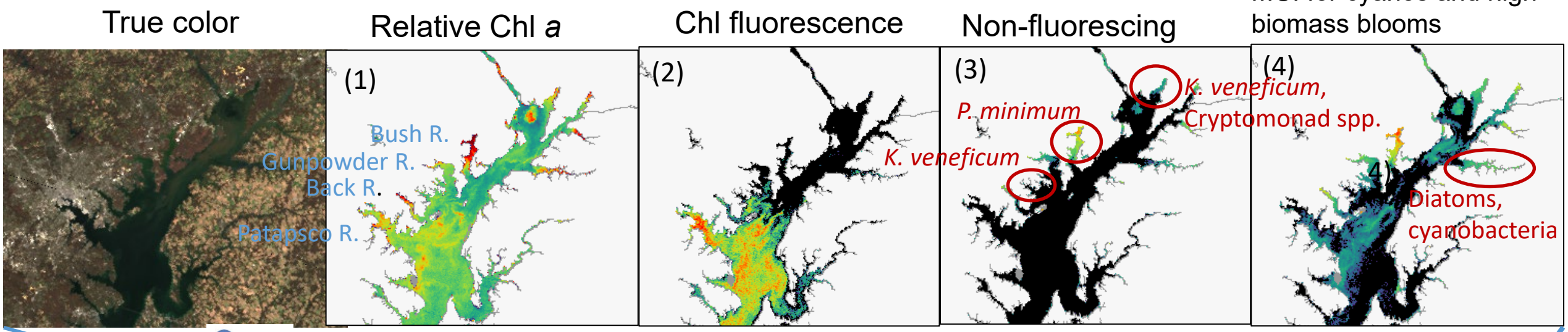
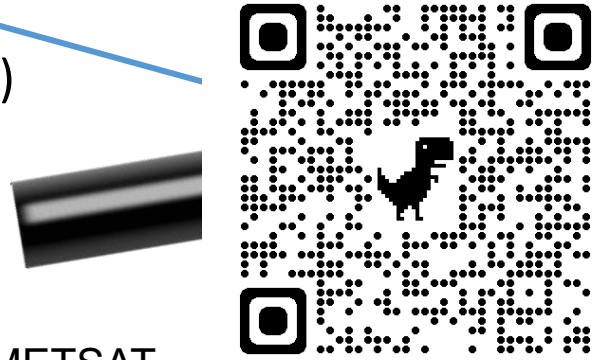


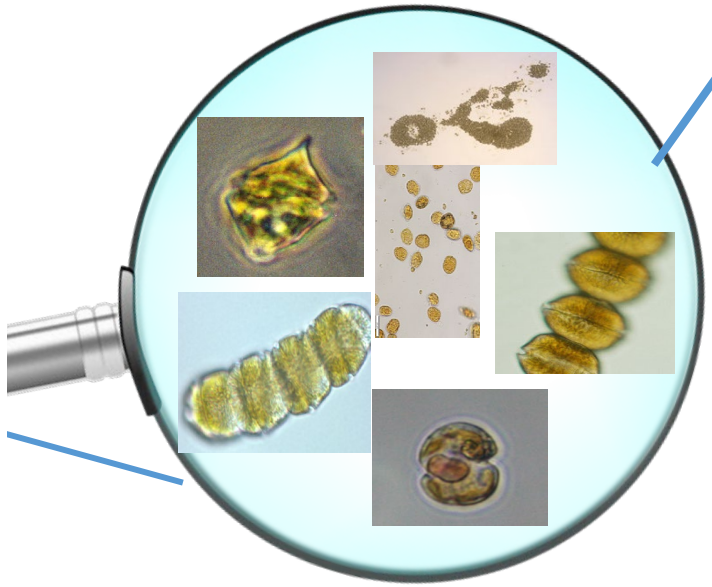
EUMETSAT esa

Nov 18, 2016

Developing and providing OLCI from Sentinel for bloom monitoring in Maryland and Virginia routinely since 2016

(1) Red-Edge Chl (RE10) (Wynne et al, 2022) – 2024 added switch to low chl waters (OC4)
(2) Red Band Difference (RBD) (Amin et al., 2009)
(3) Cyanobacteria Index (Wynne et al., 2008)
(4) Maximum Chlorophyll Index (MCI)
(Gower et al., 2008, 2010)





Imagery derived from Copernicus Sentinel data from EUMETSAT

Working towards higher resolution products - Spatial

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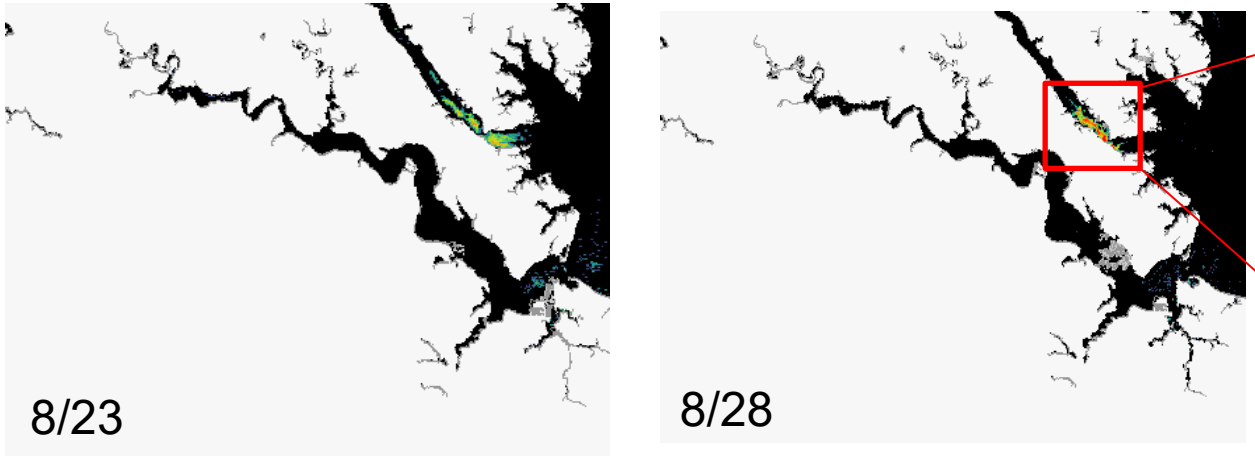
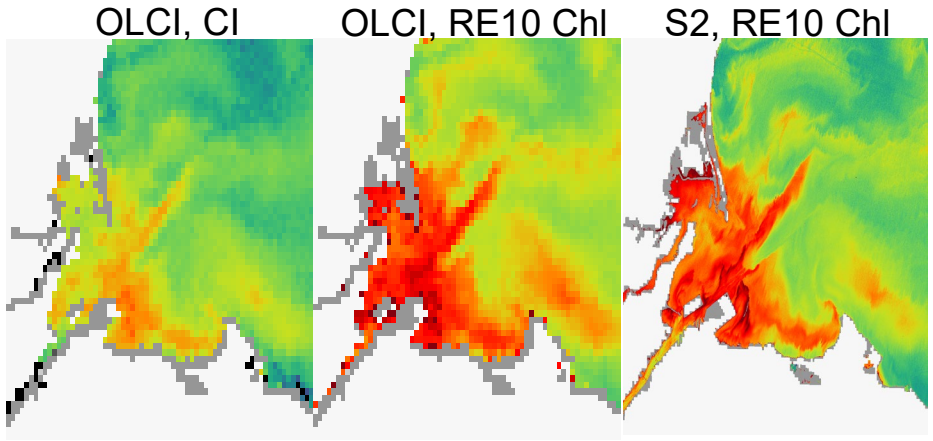
Sentinel 3 Fluorescence algorithm (RBD) from EUMETSAT processed at NCCOS, 300 m every day



Sentinel 2 provides 20 m imagery every 5 days

False color image from EO Browser at European Space Agency (ESA)
https://apps.sentinel-hub.com/eo-browser/

*Resulted in NCCOS Event Response funds to support additional sampling



Lake Erie Microcystis bloom on 9/5/2024

The Future: Geostationary, Hyperspectral

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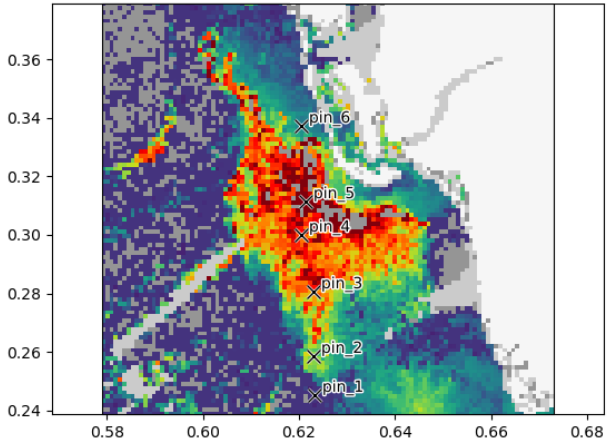
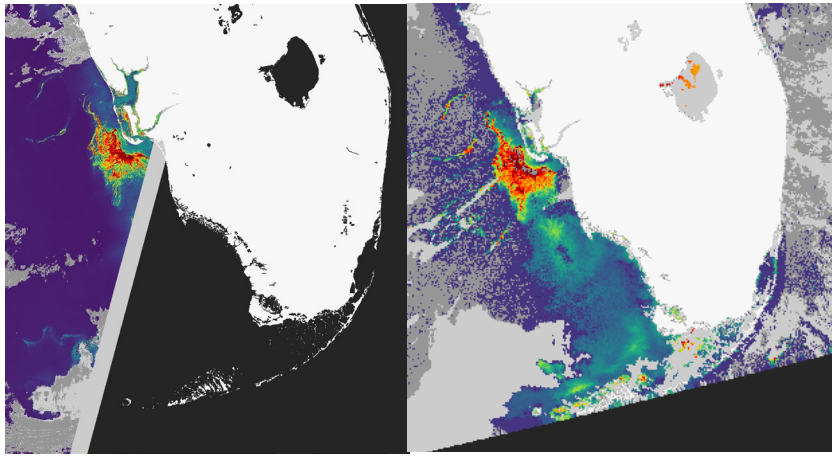
Improvements with Geostationary and Hyperspectral satellite imagery (PACE, GLIMR and GeoXO)

- Ability to monitor bloom patchiness and movement throughout the day
- Better bloom detection around clouds/glint
- Better phytoplankton community separation
- Better estimate of biomass
- Increased resolution at the coasts



RE10 Chl OLCI (left) and PACE (right)



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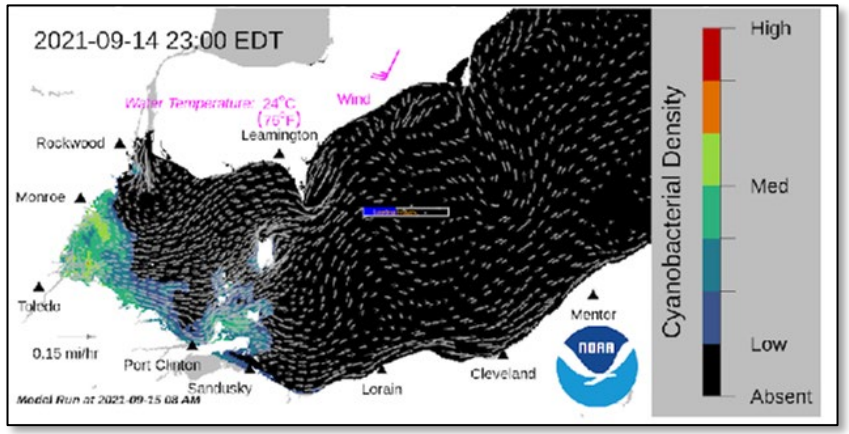

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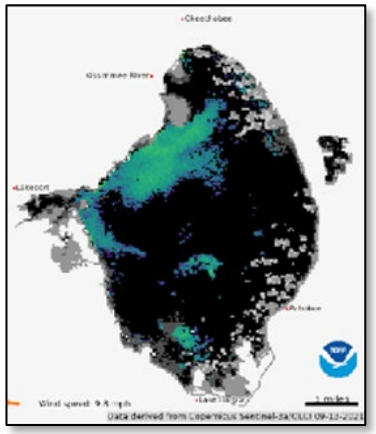

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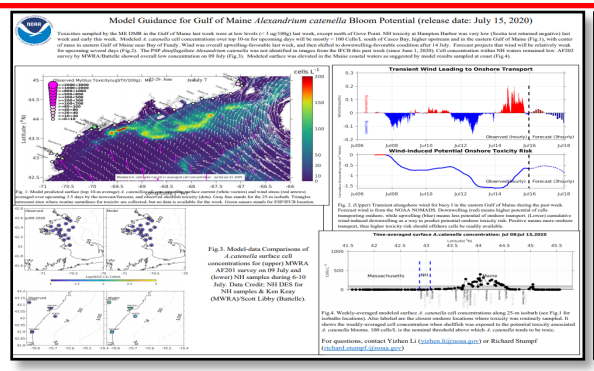
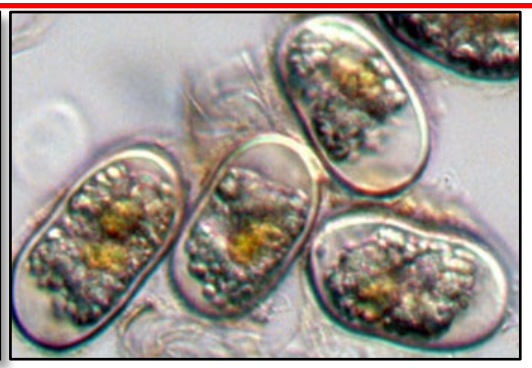


Gulf of Maine Forecast Dashboard



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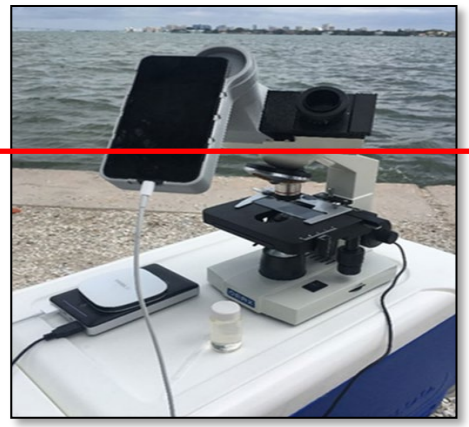

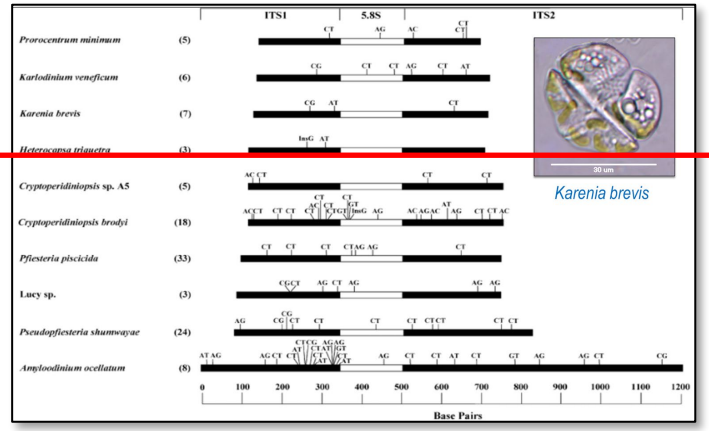

Karenia brevis

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Lake Erie: Cyanobacteria, drinking water, recreation, dog/livestock deaths

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2017 Lake Erie NOAA/GLERL credit Zachary Haslick Aerial Associates Photography
https://www.flickr.com/photos/noaa_glerl/36546206512/in/photostream/

Lake Erie – Cyanobacteria blooms

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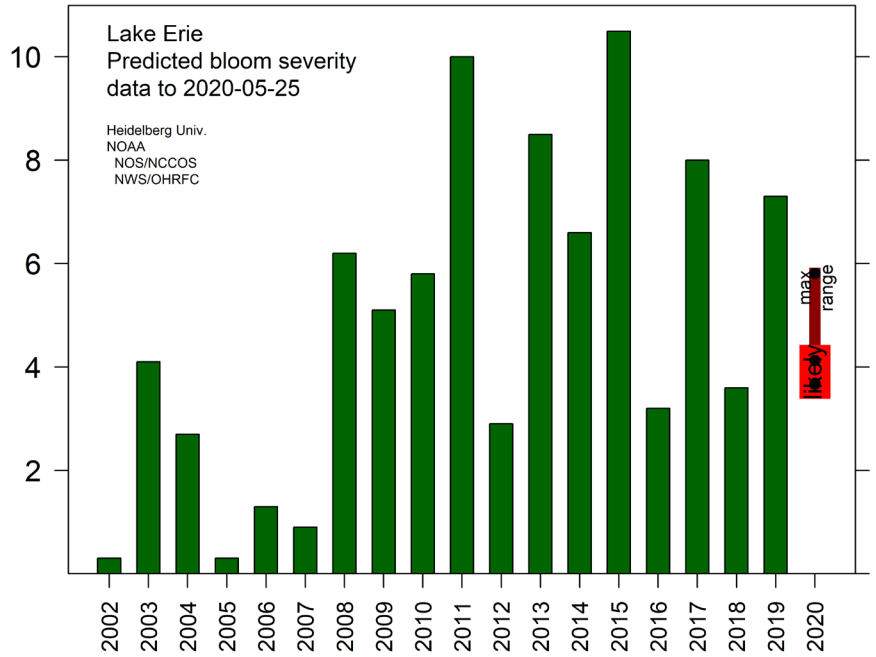
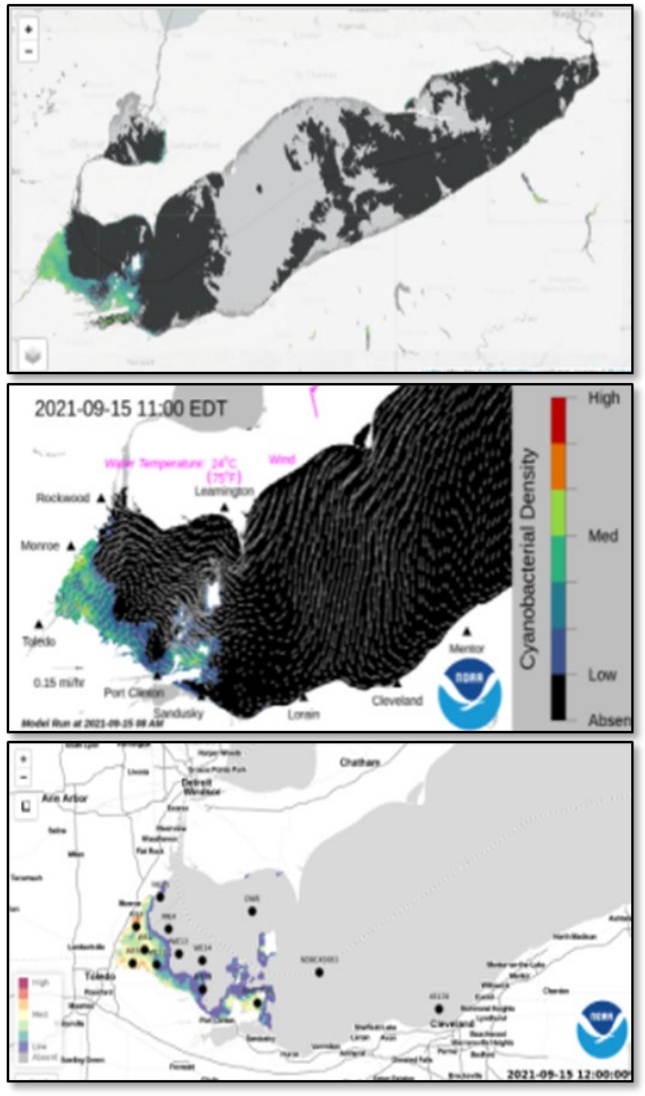
1) Weekly nowcast/forecast: an early warning system for active/current bloom events – became Operational in 2017

2) Added seasonal forecast: an outlook of bloom severity for the upcoming bloom season;





Observed Bloom Position: Current bloom location and extent

Forecasted Bloom Position: Forecasted bloom location and extent

Vertical Mixing Forecast: Forecast of potential mixing to determine likelihood of scum

GLERL Great Lakes Environmental Research Laboratory

National Center for Water Quality Research HEIDELBERG UNIVERSITY

Chesapeake Bay – Aquaculture, water quality

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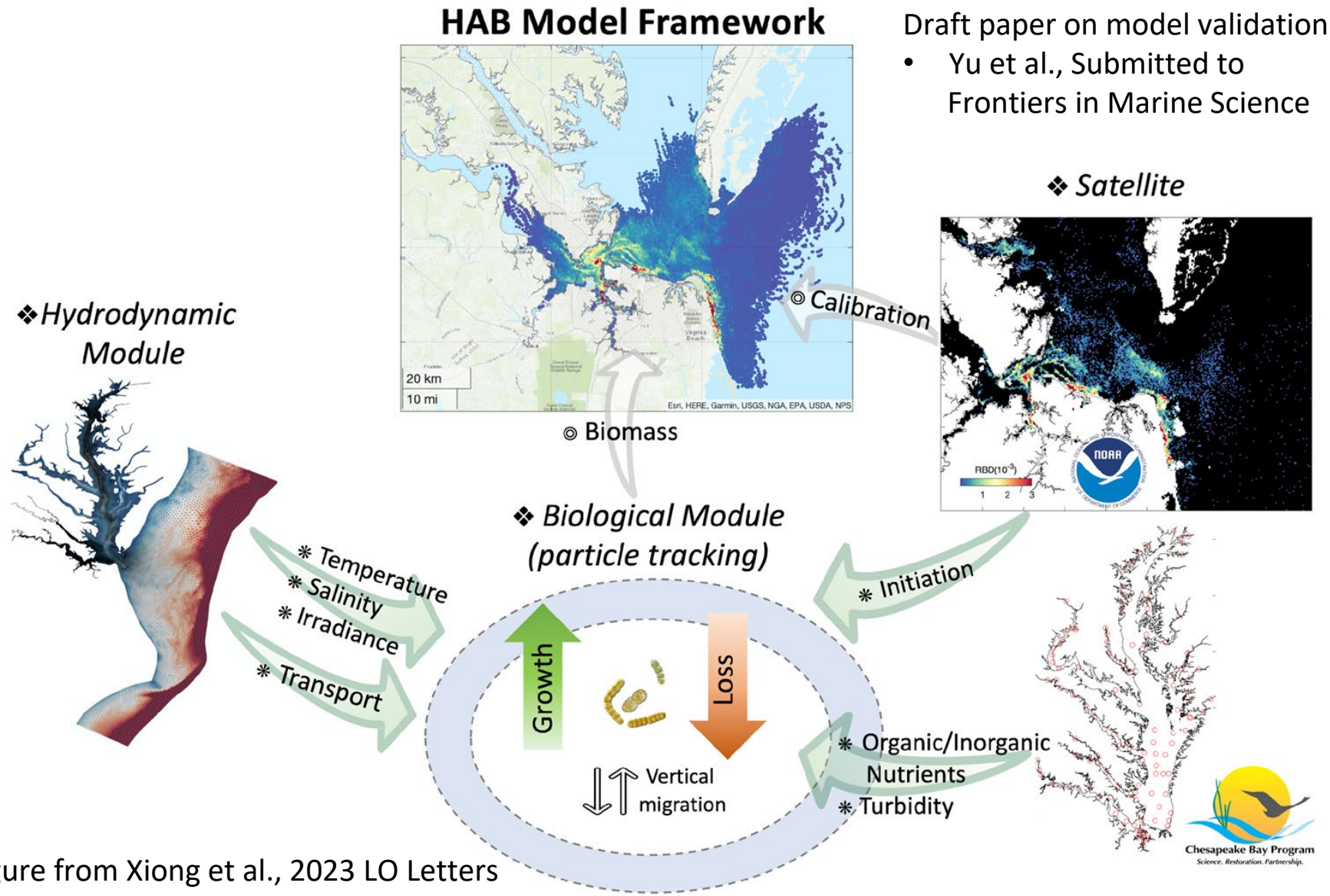

Figure from Xiong et al., 2023 LO Letters

Draft paper on model validation

- Yu et al., Submitted to Frontiers in Marine Science

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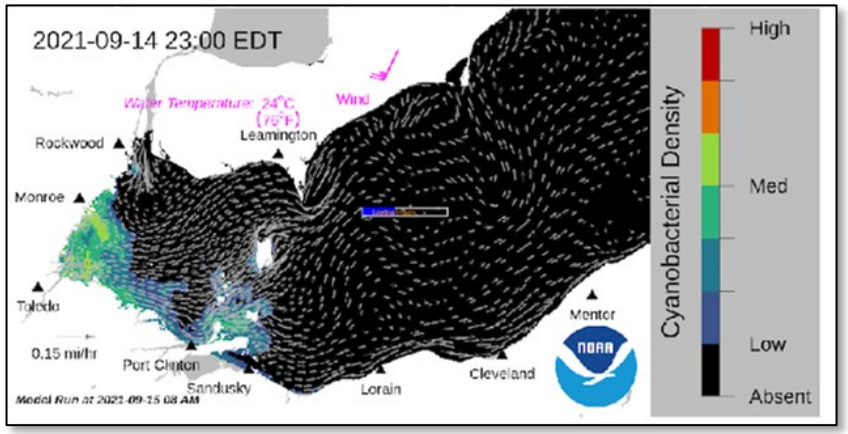

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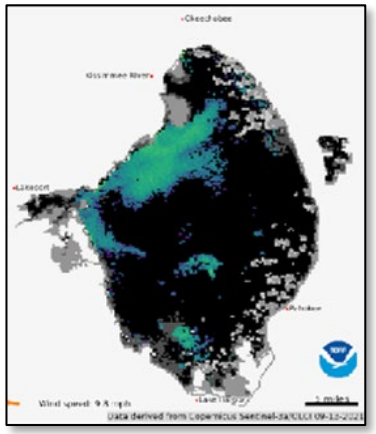

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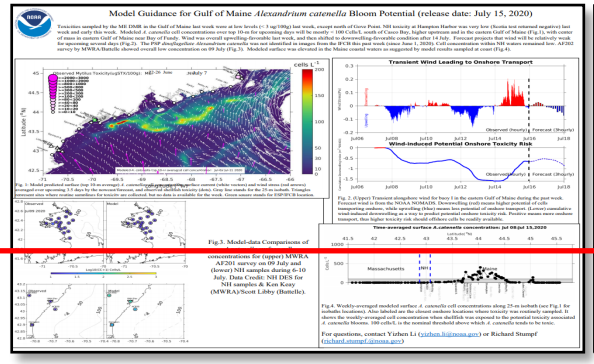
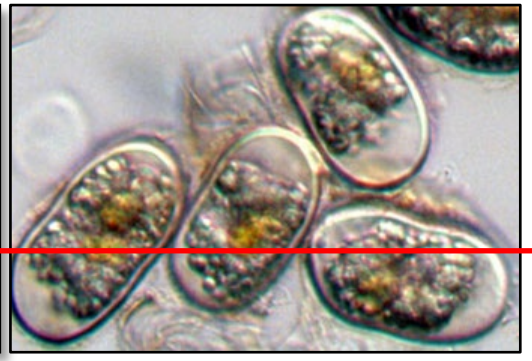


Gulf of Maine Forecast Dashboard



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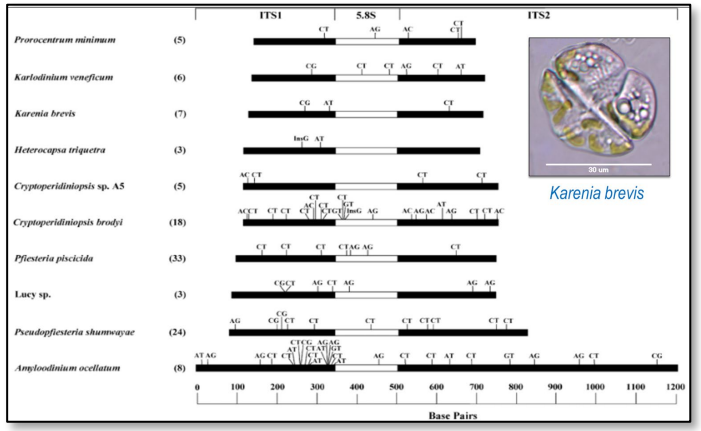

Molecular Methods for HAB detection

Foundations of a National HAB Observing Network (NHABON)

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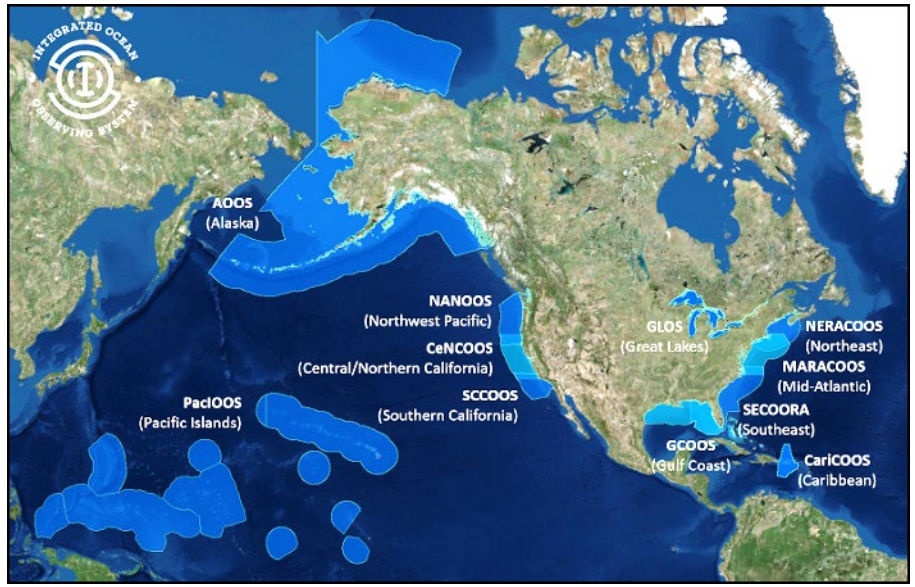
- Provides sustained observations for HAB detection, early warning, and forecasting
- Supports state, tribal, and national missions to understand, predict, mitigate, and manage HABs
- Provides ability to detect known & emerging species
- Flexible, scalable, and tailored to regional needs
- Builds on:
  - NOAA's prior & continuing investments in research, technology, forecasting
  - NOAA *Framework for a National HAB Observing Network*
  - IOOS Ass. *Implementation Strategy*
  - NOAA/IOOS' support of regional ocean & coastal observing systems



Slide courtesy of Quay Dortch, NCCOS/CRP

Summary

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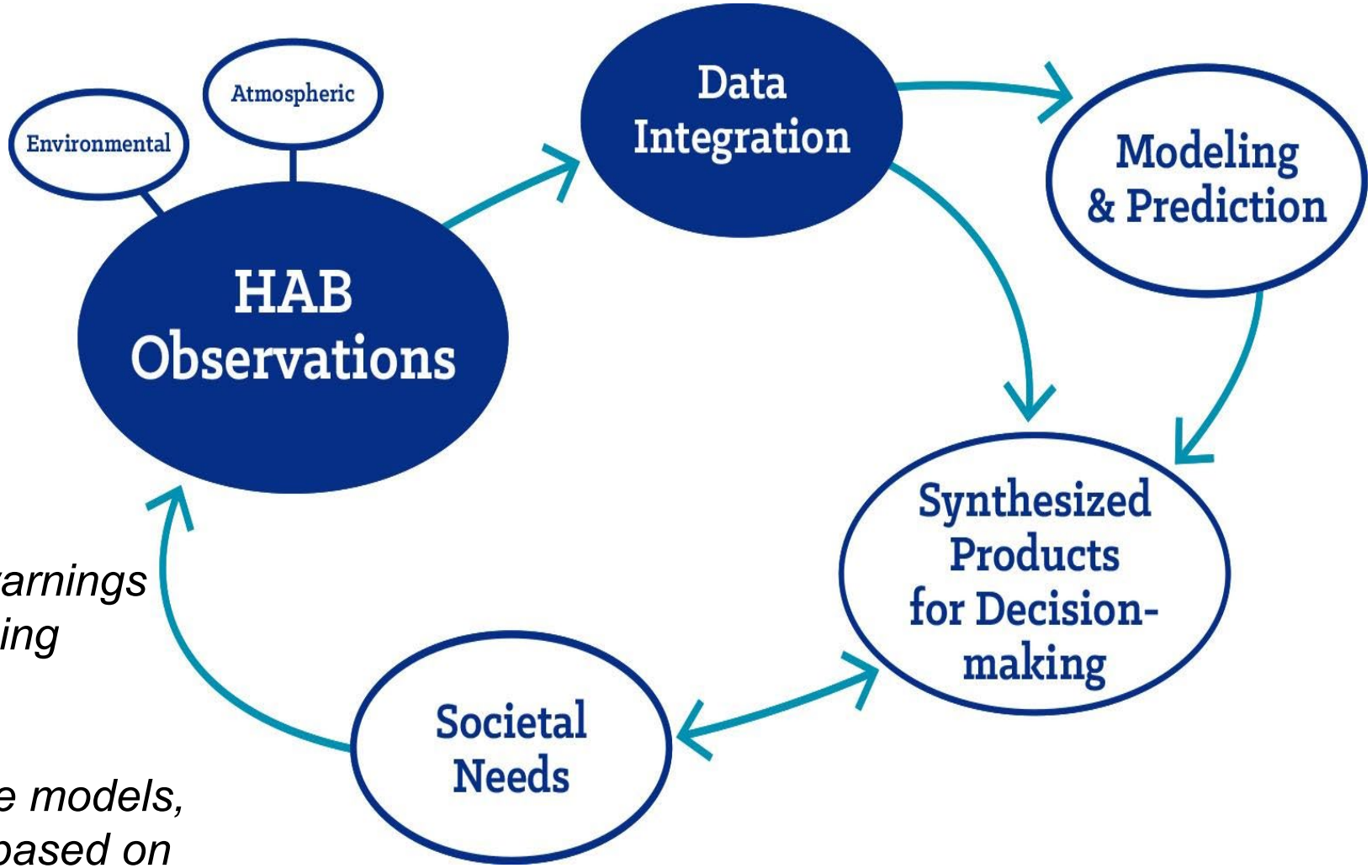

HAB observations support early warnings and forecasts that are key to keeping communities safe.

It is an iterative process to improve models, observing, and forecast products based on latest technology and research.

Slide courtesy of Quay Dortch, NCCOS/CRP

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Thank You!

Questions?

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Michelle.Tomlinson@noaa.gov