


Research and monitoring of harmful algal blooms: Improving observations using autonomous vehicles and sensor networks.



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Challenges to Studying HABs

- High degree of environmental heterogeneity
 - High level of patchiness characteristic of many bloom events
- Many spatial and temporal scales
 - Micro- to ocean-wide spatial scale
 - Small patches v. coast-wide blooms
 - Short term temporal controls - climatological forcing
 - Nutrient uptake kinetics v. effects of sea surface warming

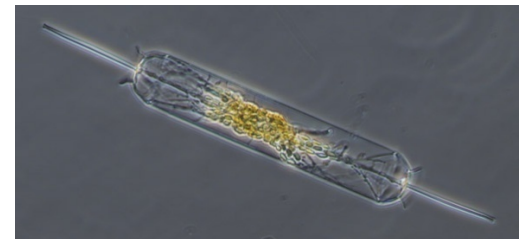
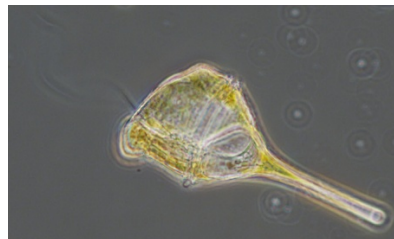
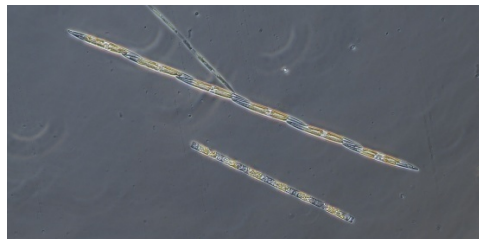
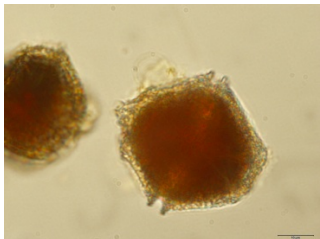


M. Godfrey

Our ability to understand the processes by which HABs develop, propagate, and dissipate has been limited by our (in)abilities to observe and model across multiple scales.

How do we observe phytoplankton?

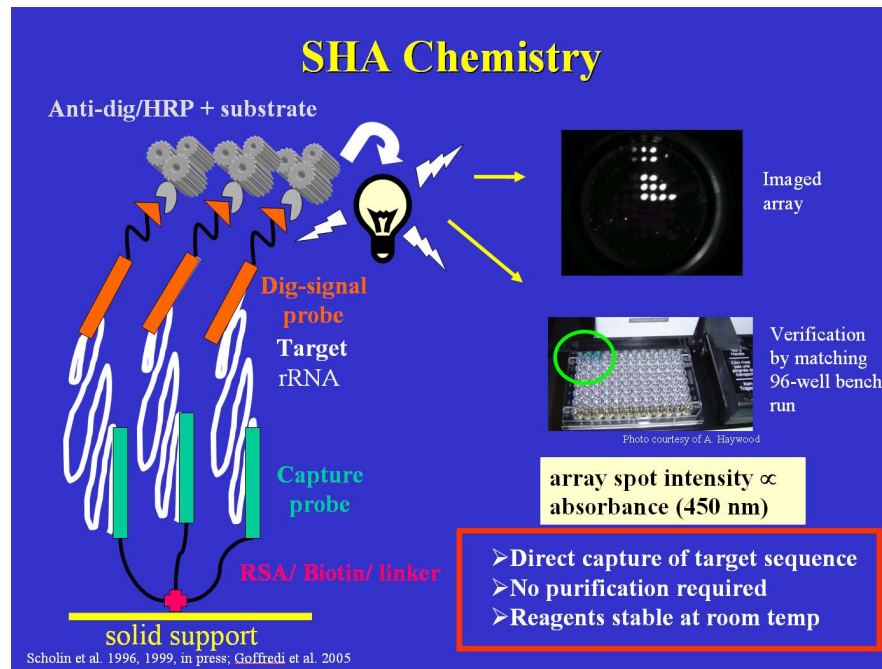
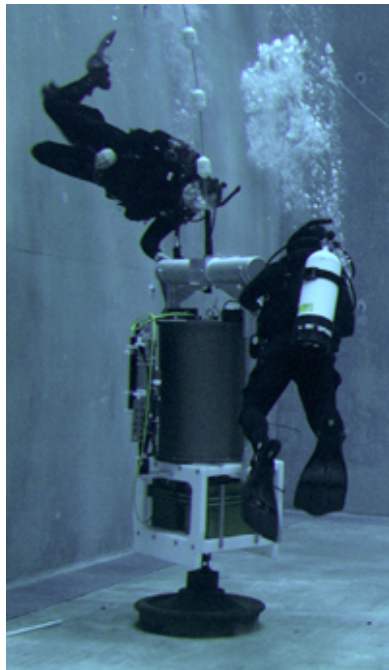
- Average phytoplankton size = 10-100 μ m
 - For scale, average human hair = 100 μ m
- We mainly use optical sensors to quantify overall phytoplankton biomass
 - Optical sensors can also differentiate large groups based on photosynthetic pigments
- *in situ* molecular sensors are being developed and deployed
 - E.g. Monterey Bay Aquarium Research Institute (MBARI) Environmental Sample Processor (ESP; PI: Scholin)



Micrographs courtesy of Caron Lab and Richard Weinberg, USC

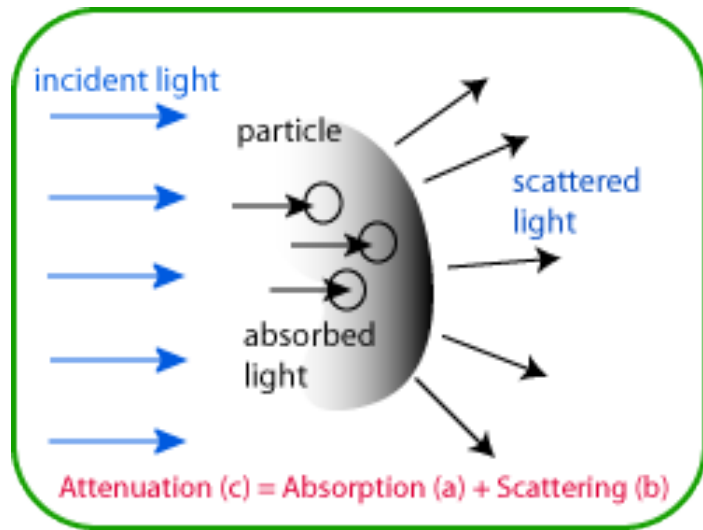
Molecular & Toxin Sensors

- Environmental Sample Processor (ESP)
 - MBARI-developed moored instrument that can really do it all
 - Uses automated, miniaturized lab procedures to quantify HAB-specific DNA and/or toxin concentrations
 - Cost of deployment & operation, and lack of commercialization has so far minimized application



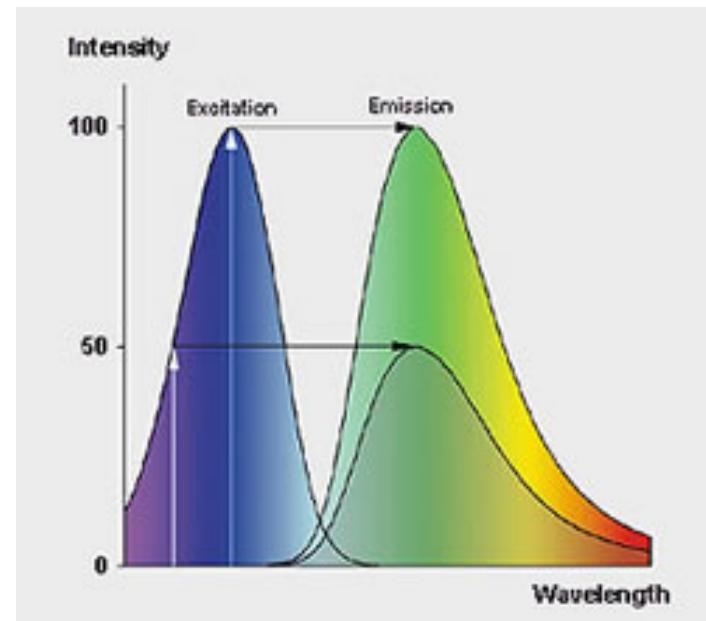
<http://www.mbari.org/esp/>

Bio-optical Sensors



- Incident light can be **absorbed** or **scattered**
 - **Absorption** varies with internal composition, e.g. photosynthetic pigments
 - **Scattering** depends on size/shape of object

- **Absorbed** light can be used in photochemistry or re-emitted at a higher wavelength
 - This re-emission is called **“fluorescence”**
 - **The plant pigment chlorophyll *a* strongly fluoresces red (given blue light)**



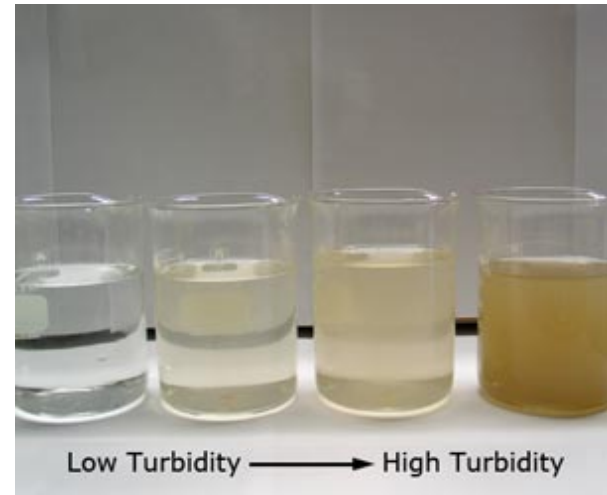
Figures courtesy of WetLabs

Scattering

- Measured as either backscattering or turbidity
- Increased turbidity or backscattering = higher particulate load in water
- Particulates could be phytoplankton or other suspended particles
 - Difficult to differentiate, need more information



Bloom of *Akashiwo sanguinea* in King Harbor, May 2010

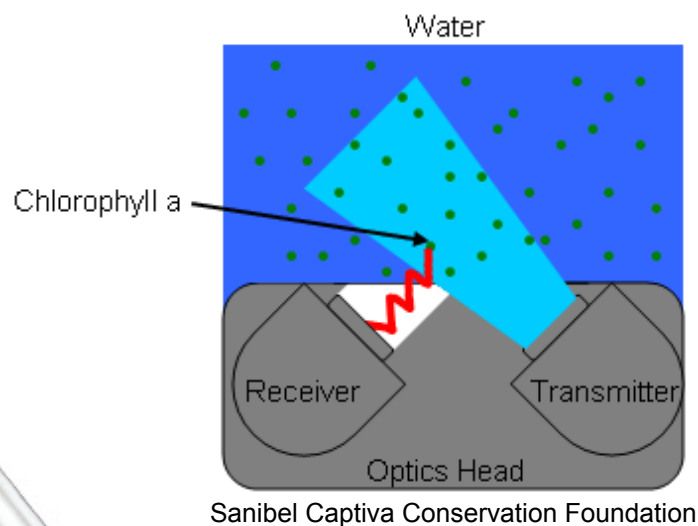
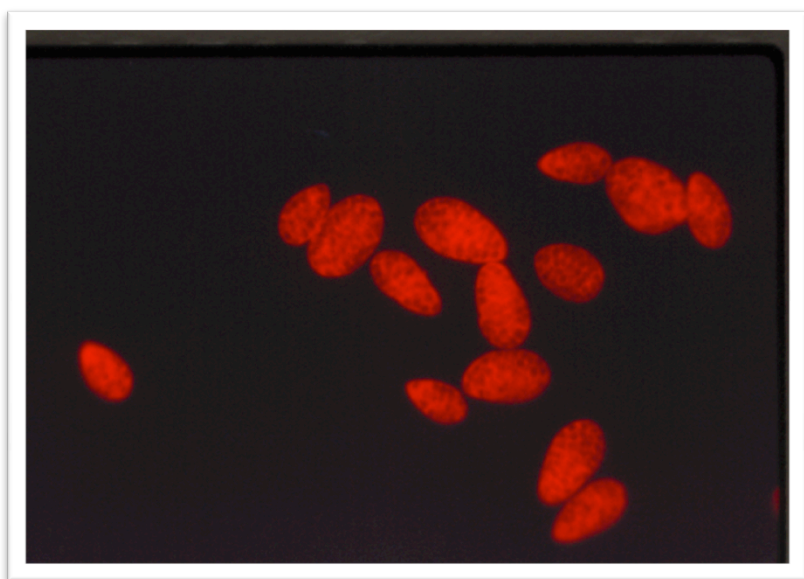


http://www.fondriest.com/science_library-hm/turbidity.htm

Fluorescence



<http://grupogima.blogspot.com>

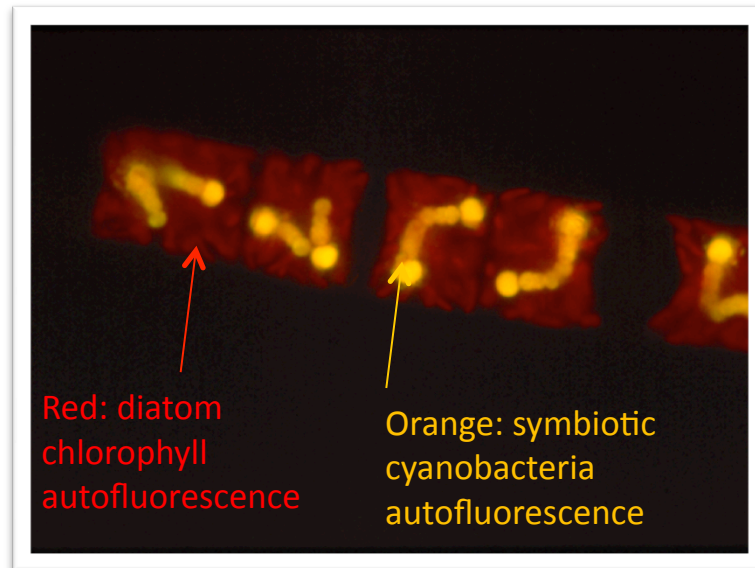
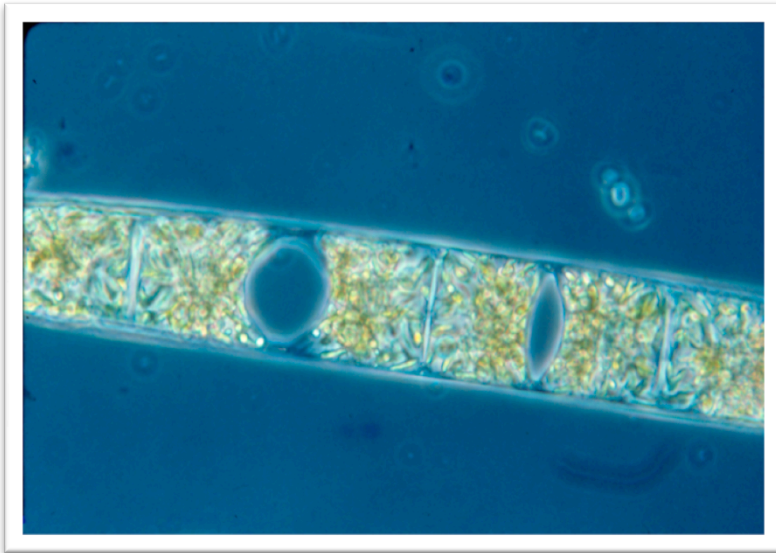


Turner Designs Cyclops Fluorometer

- Chlorophyll produces red fluorescence when illuminated with blue light
- Submersible fluorometers measure chlorophyll fluorescence as a proxy for **bulk phytoplankton biomass** in water

Fluorescence

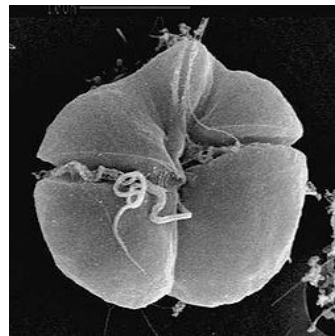
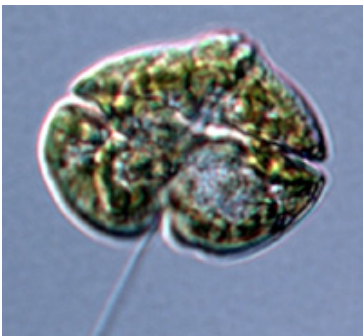
- Accessory photosynthetic pigments (e.g. carotenoids, phycobilins) have different fluorescent signatures



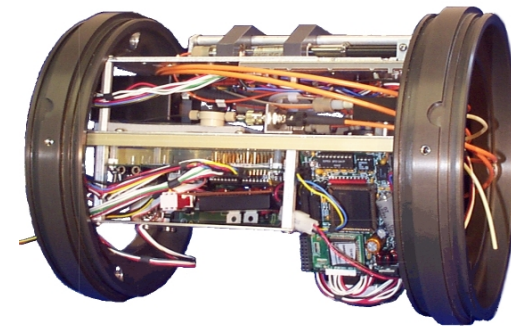
- Commercial fluorometers available to study a range of different groups

Distinguishing different groups of phytoplankton

- Differential fluorescence and absorption of photosynthetic pigments helps identify groups of phytoplankton
- Dinoflagellate *Karenia brevis* poses ecological and human health risks along Gulf coast of FL
 - Mote Marine Laboratory has developed optical sensor that identifies *K. brevis* in natural system using its unique absorption signature



K. brevis, micrographs from FL Fish & Wildlife Conservation Commission



"BreveBuster"

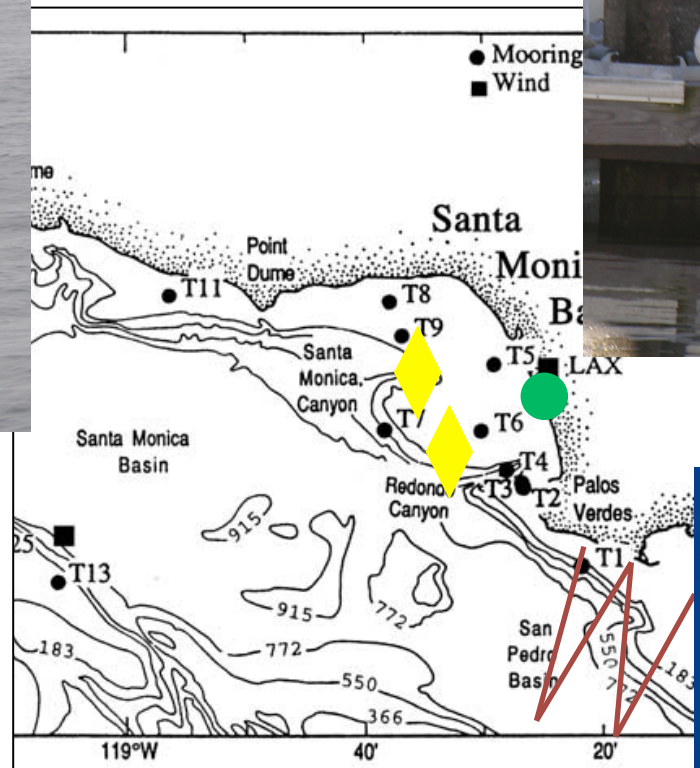
<http://coolgate.mote.org/socool/breve-def.html>

Other Parameters we Measure

- Dissolved Oxygen
 - DO varies naturally with photosynthesis, respiration, air-sea interactions
 - Large-scale algal blooms can remove DO from water, resulting in mortality of fish and invertebrates
- Temperature, Salinity
 - Warming temperatures often favor increased growth
 - Temp & Sal control seawater density, which affects stratification and mixing of waters
- Physical conditions
 - Currents, tidal forcing can concentrate or disperse populations

Multiscale sensing of HABs

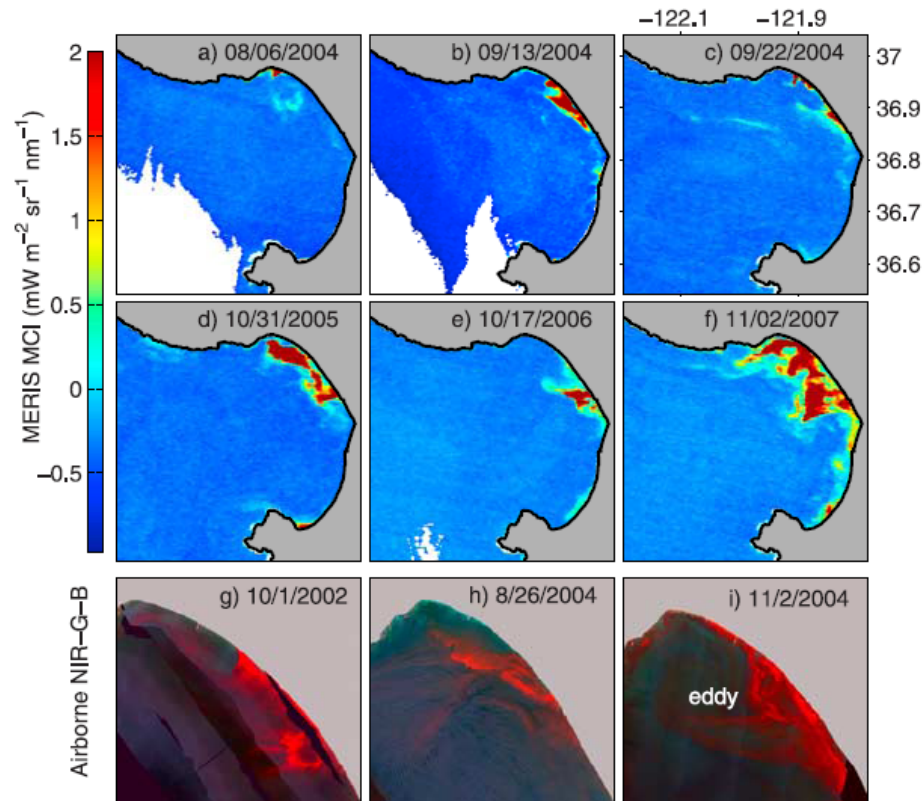
- Static & mobile systems allow for high temporal and spatial resolution of bloom events



Southern California Bight, from Hickey et al.

Tools and Approaches for HAB Research - Nearshore

- Near-shore systems play role in seeding and incubation of HAB populations



Propagation of an *Akashiwo sanguinea* bloom in Monterey Bay (Ryan et al, 2008)

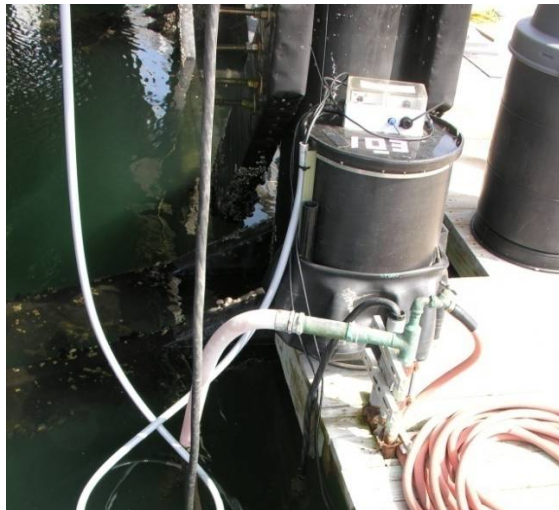
- Near-shore Southern CA systems: prone to red tides & strongly experience their effects



Tools and Approaches for HAB Research - Nearshore

- Nearshore dock-based systems
 - Provide easily accessible data on environmental conditions
 - Relatively inexpensive, high sampling frequencies
 - Easy access - augment with human-mediated sampling
- Dock-based stations in King Harbor, Marina del Rey, CA

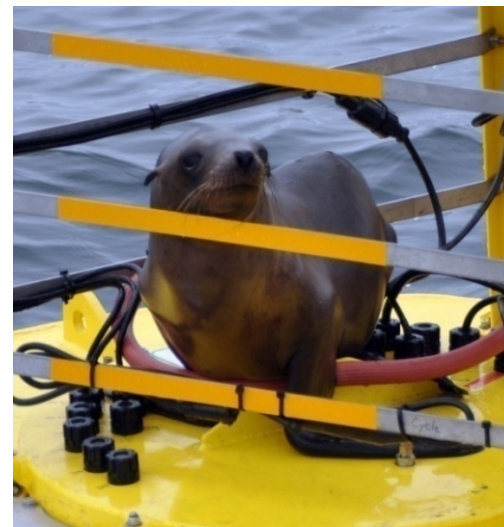
Buoy-integrated
Hydrolab DS5
sensors in King
Harbor



WetLabs WQM ready for deployment in MDR

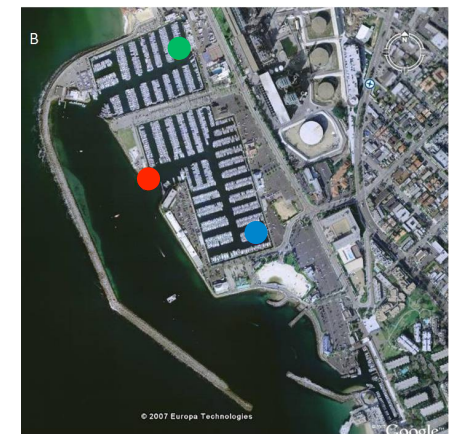
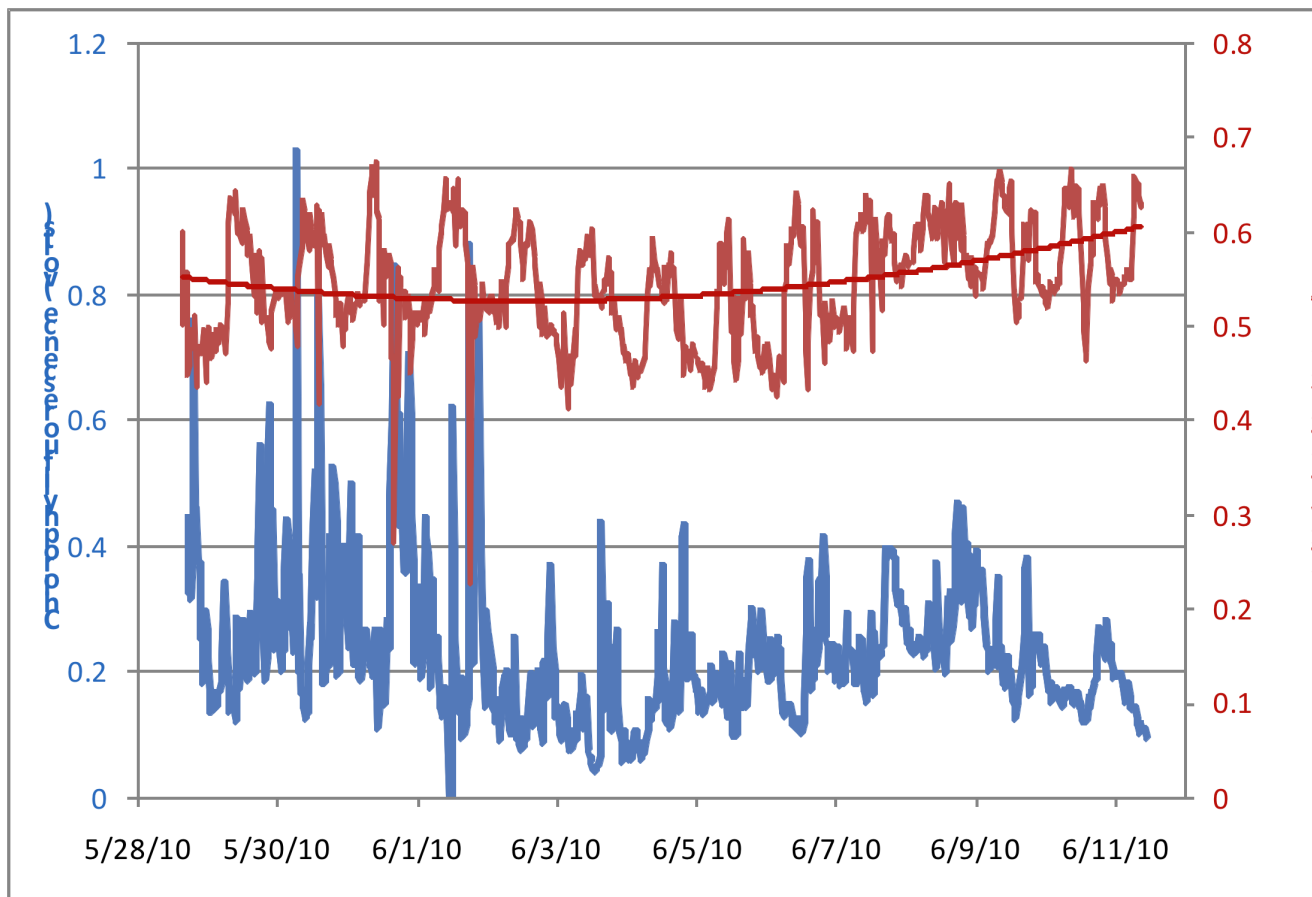
Tools and Approaches for HAB Research – Continental Shelf

- Offshore Oceanographic Buoys
 - Provide connectivity with outer ocean
 - High temporal frequency at single point
 - Power and telemetry, biofouling more problematic offshore
- 2 Moored buoys in Santa Monica Bay



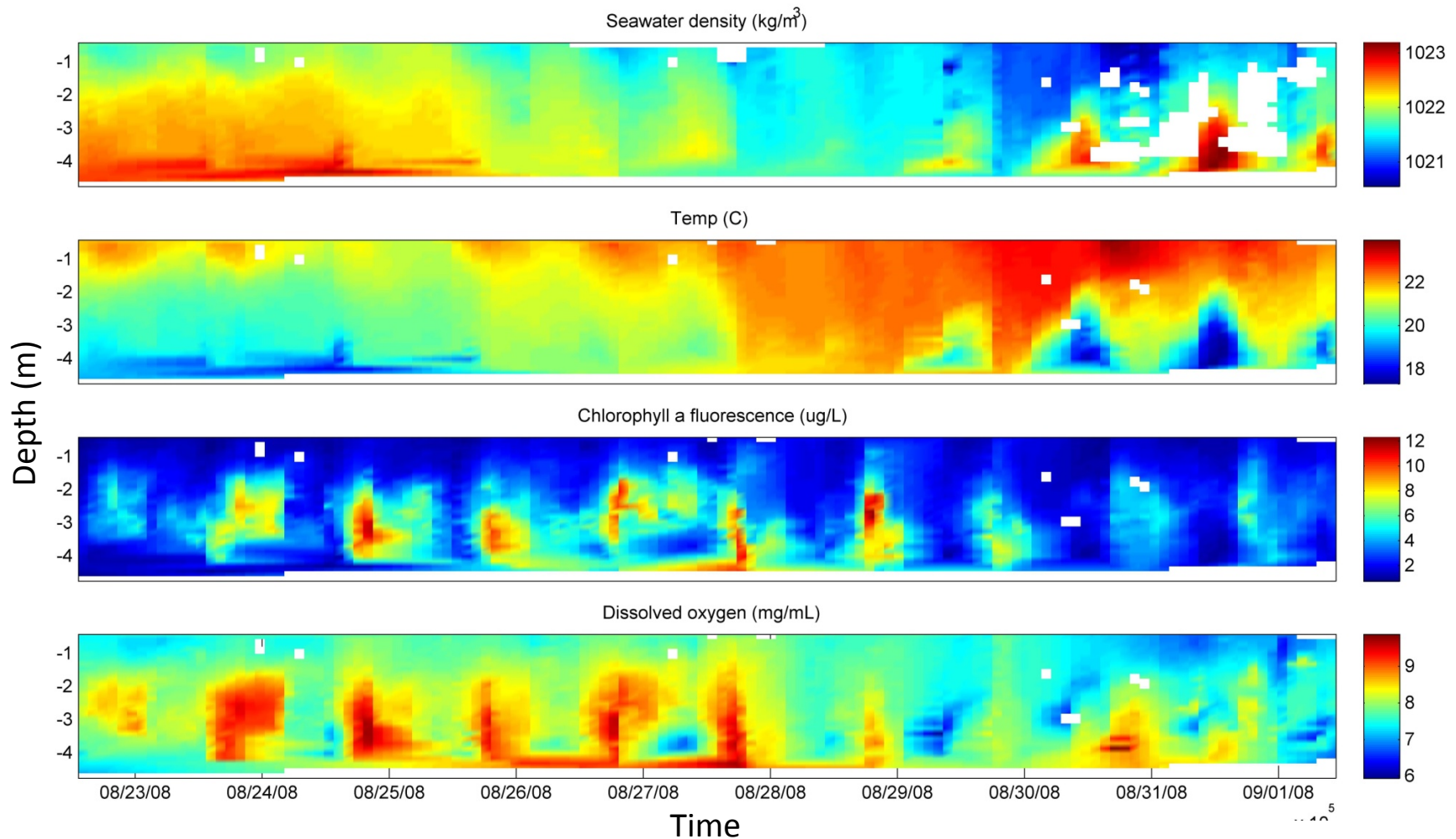
Temporal sensing of HABs

- High frequency resolution of bloom events in King Harbor, Redondo Beach
- Early Alert triggers sampling of emerging events



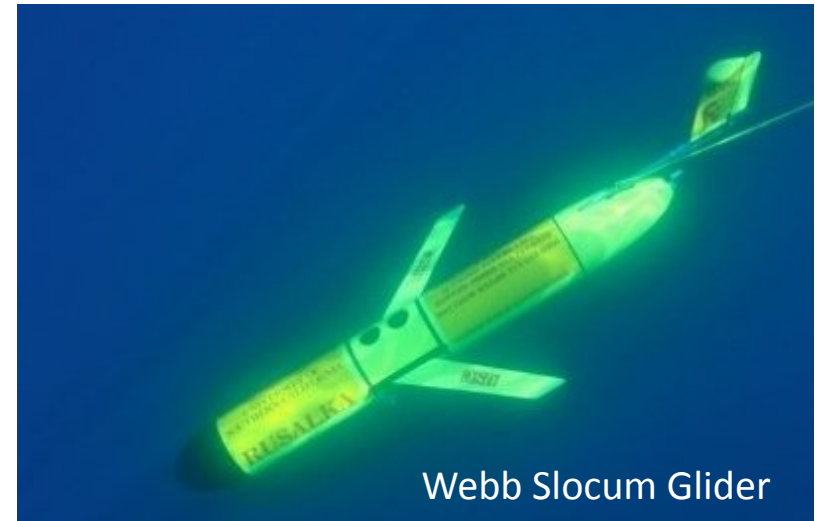
Temporal sensing of HABs in 3D

- Interrogation of underlying forcing processes



Tools and Approaches for HAB Research

- **Mobile platforms**
 - Exploit multiple spatial scales over limited time (8 hours – few weeks)
 - Vertical profiling capabilities
 - Flexible sensor payload
 - Power-limited



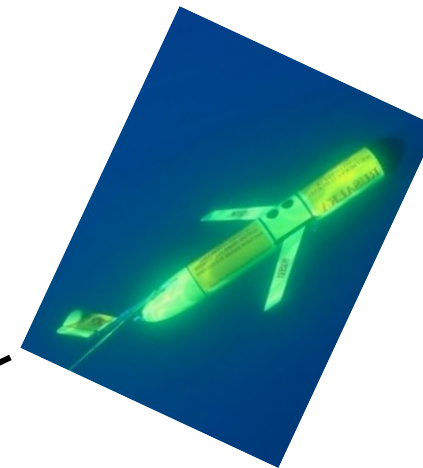
Case Study – Glider application to emerging HAB



- Southern California: Spring upwelling events stimulate diatom blooms
 - Members of genus *Pseudonitzschia* produce neurotoxin domoic acid (DA)
- Slocum Glider
 - Efficient buoyancy-controlled diving
 - CTD + Optics package allow for robust, timely measurements
 - Chlorophyll fluorescence, backscattering



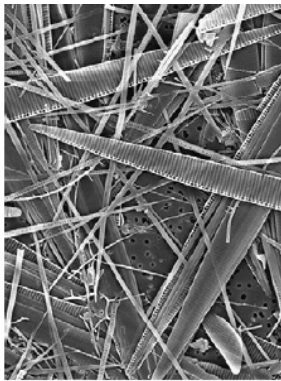
Diving: negatively buoyant



Surfacing: positively buoyant

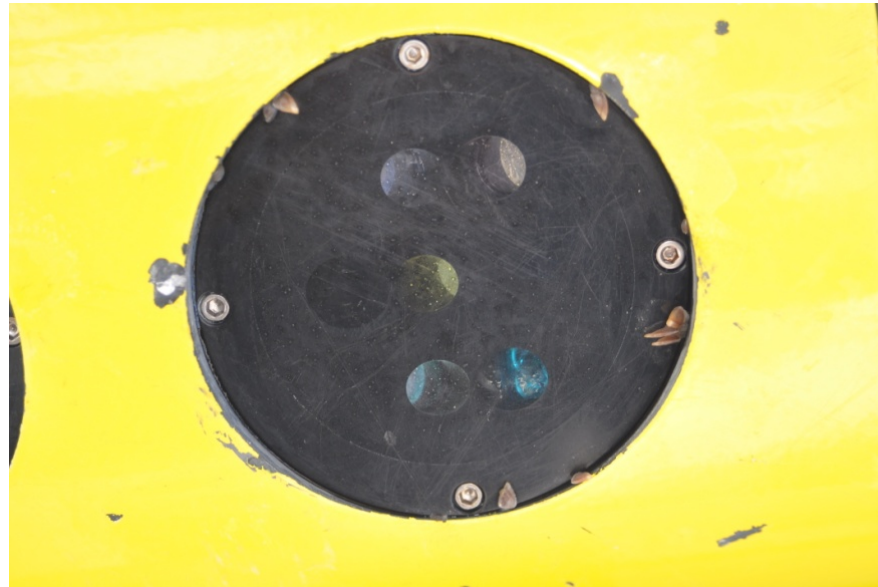
Case Study – Glider profiling of emerging HAB

- Spring 2009 – early reports of marine mammal strandings
- Low *Pseudonitzschia* sp. abundances, DA concentrations in pier-based samples

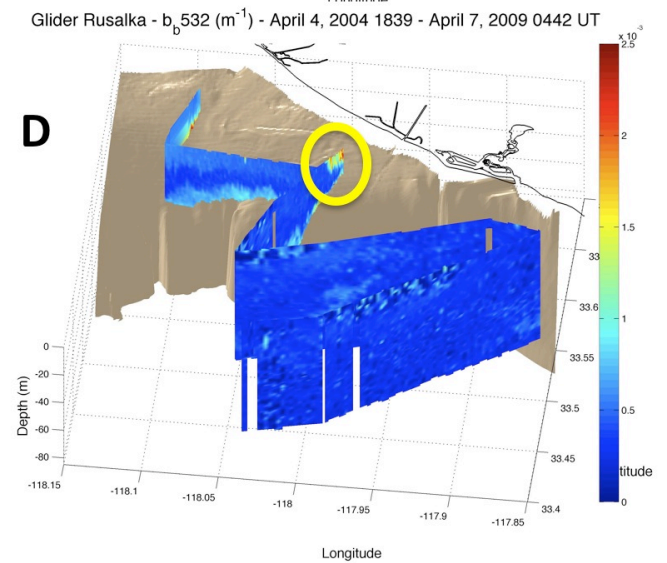
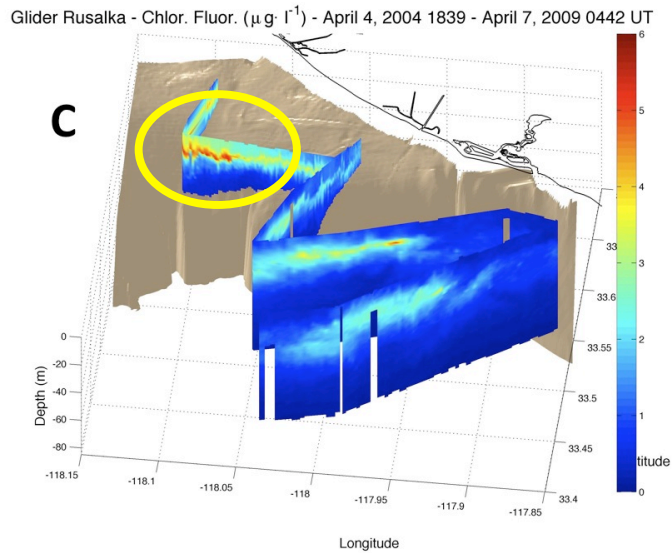
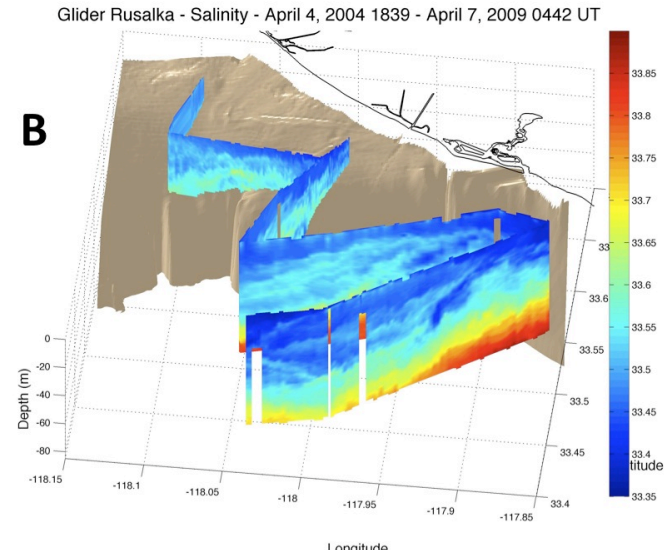
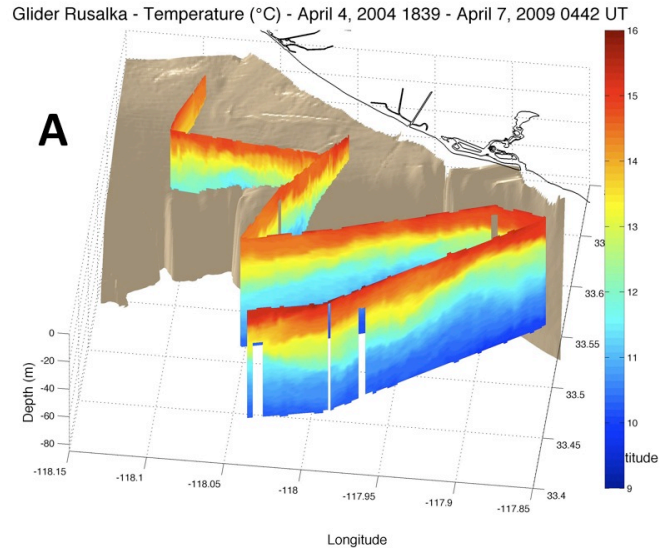


Case Study – Glider profiling of emerging HAB

- Lab tests showed *Pseudonitzschia* population to be highly toxic
- Barnacles collected from 3-week glider deployment had significant concentrations of domoic acid too!

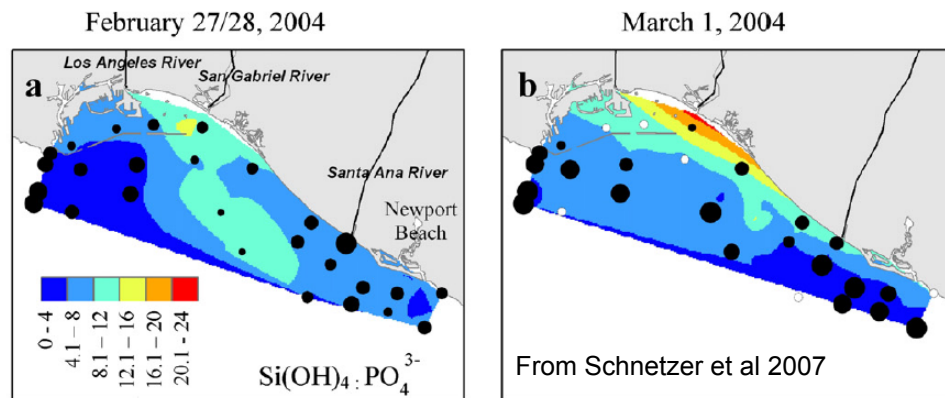


Case Study – Glider profiling of emerging HAB



Continuing Work

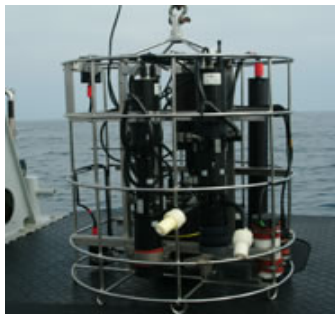
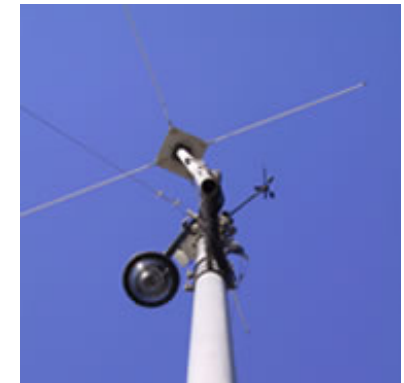
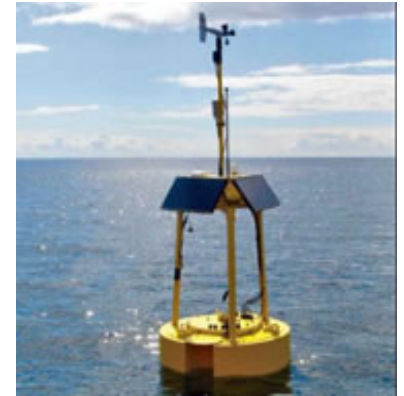
- Incorporation of monitoring data into predictive models of HABs in Southern California
- Bight 08/10: Nutrient budget + HABs
- Deployment of new, single-person deployable AUV for coastal/inshore waters
- Getting the public involved...



The USC Center for Integrated Networked Aquatic Platforms

CINAPS [sin-aps]

- Bridging the gap between technology, communication, and the scientific exploration of aquatic ecosystems.
- **Collaborative** research effort between Marine Biology, Computer Science and Oceanography at USC
- Scientific questions regarding the formation, propagation and prediction of **Harmful Algal Blooms (HABs)**.



cinaps.usc.edu

The screenshot shows a web browser window displaying the website cinaps.usc.edu/king_harbor.html. The browser's address bar and tabs are visible at the top. The website header features the CINAPS logo and the title "Center for Integrated Networked Aquatic Platforms". A navigation menu includes links for Home, Projects, Platforms, Photo & Video, Sites & Data, People, Partners, Outreach, and Publications.

On the left side, a text block describes two instruments located at Harbor Patrol that monitor water quality parameters at depths of approximately 1.25 and 3.71 meters below the surface at 15-minute intervals. These instruments are part of the larger Center for Embedded Networked Sensing project. Below this text is a small satellite map of the Harbor Patrol area.

On the right side, a text block explains that water quality instruments located off a dock in the King Harbor Marina in Redondo Beach collect oceanographic and water quality data, utilized for the Center for Embedded Networked Sensing project. Below this text is a section titled "King Harbor Dock" containing three line charts:

- Temperature (°C)**: Shows data for Shallow (red) and Deep (blue) locations. Both show a minimum of 16.28 and a maximum of 18.32, with an average of 17.36.
- Salinity (PSU)**: Shows data for Shallow (red) and Deep (blue) locations. Both show a minimum of 34.32 and a maximum of 34.58, with an average of 34.45.
- Unlabeled Chart**: Shows a third data series (blue) with a minimum of 30.00.

The bottom of the screenshot shows the Windows taskbar with various application icons and the system tray displaying the time as 8:09 AM on 1/31/2011.

- Information on SoCal HABs, links to datastreams

Participatory Sensing – HAB Watch

- Collaboration with UCLA Center for Embedded Networked Sensing (CENS)
- Submission of geo-coded HAB pictures through cell phones

The screenshot displays the HAB Watch website in a Mozilla Firefox browser. The main content area features a map of the Los Angeles region with a blue circle highlighting a sighting location near Santa Monica. A detailed view of this sighting is shown in a pop-up window, featuring a photograph of a sandy beach with green, filamentous algae. Below the photo, the following information is displayed:

2009	
Jan	1 2 3
Feb	
Mar	1
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	
Description	
Tags	
Rating	
4	

Below the pop-up window, a calendar for 2009 shows the number of sightings per day. The data is as follows:

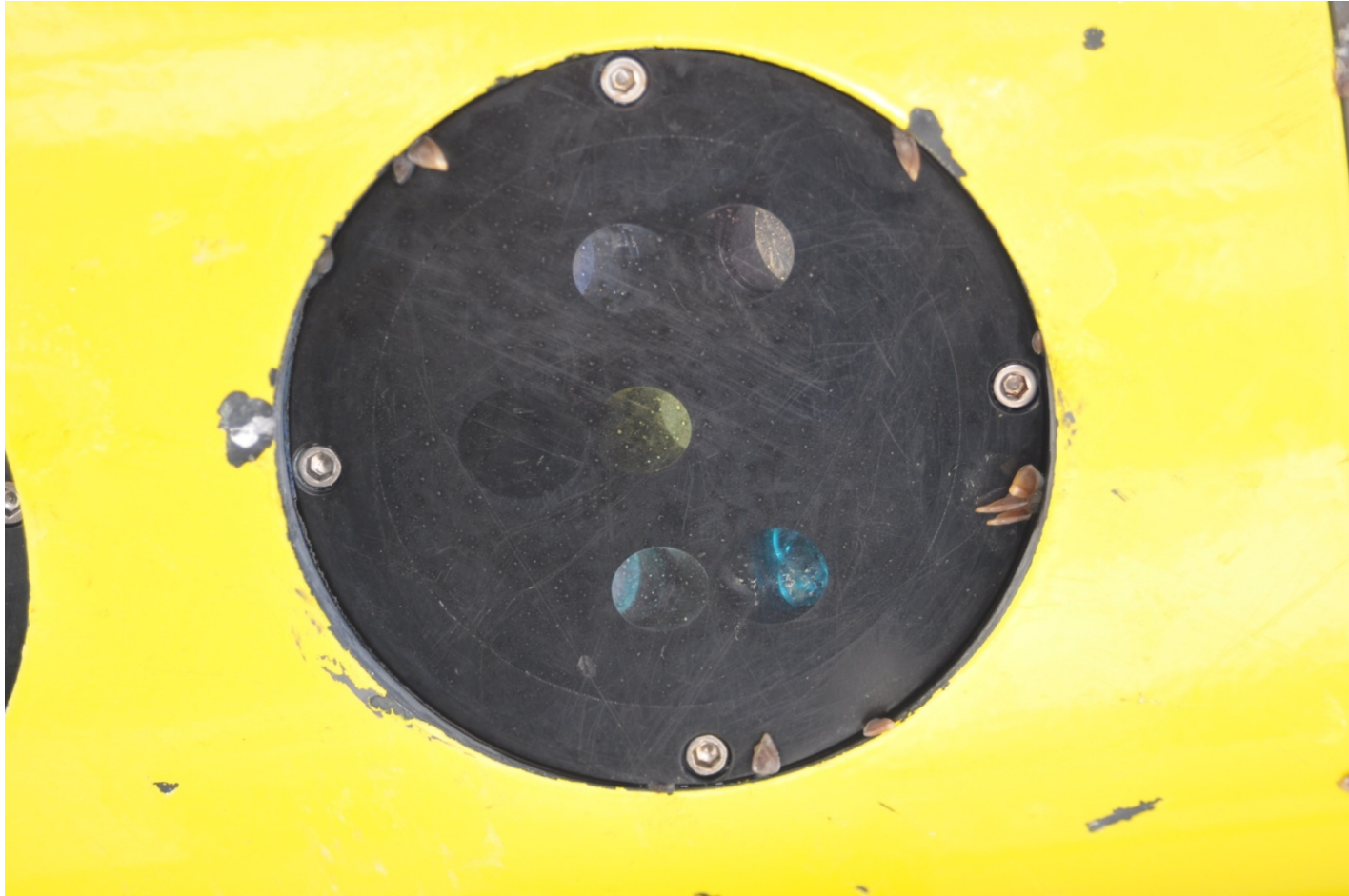
2009	
Jan	
Feb	
Mar	1
Apr	
May	
1	2
30	1
1	2

A micrograph showing a dense population of small, round, brownish cells, likely yeast or a similar microorganism, on a light-colored background. The cells are distributed throughout the field of view. The text "Thank you!" is overlaid in the center.

Thank you!

Questions?

Barnacles on glider



Had high levels of DA

Acknowledgements

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National Science Foundation



Center for Embedded Networked Sensing



NOAA (MERHAB)



USC SeaGrant



Brown Family Foundation

Questions?