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

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Challenges to Studying HABs

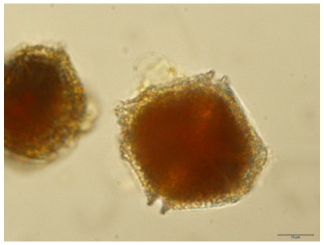
- High degree of environmental heterogeneity
  - High level of patchiness characteristic of many bloom events
- Many spatial and temporal scales
  - Micro- to ocean-wide spatial scale
    - Small patches v. coast-wide blooms
  - Short term temporal controls - climatological forcing
    - Nutrient uptake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

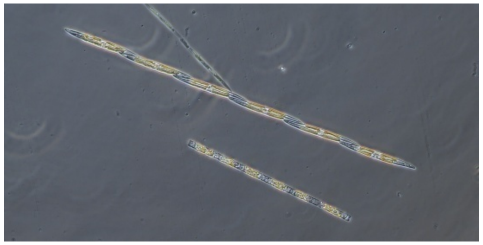
M. Godfrey

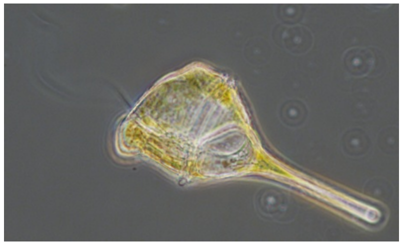
Our ability to understand the processes by which HABs develop, propagate, and dissipate has been limited by our (in) abilities to observe and model across multiple scales.

How do we observe phytoplankton?

- Average phytoplankton size = 10-100µm
  - For scale, average human hair = 100µm
- 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)



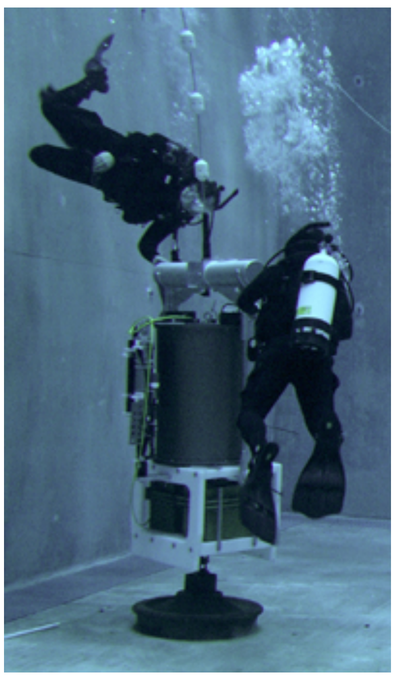


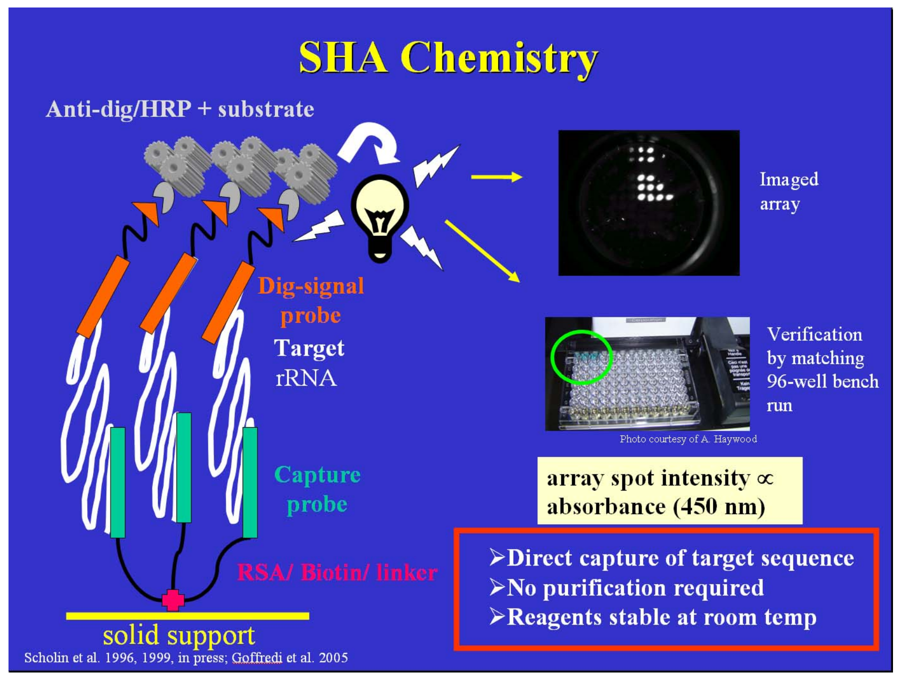


Micrographs courtesy of Caron Lab and Richard Weinberg, USC

Molecular & Toxin Sensors

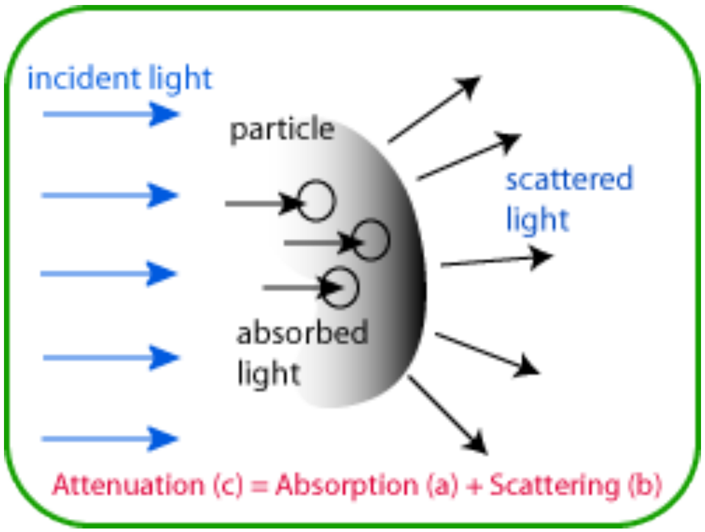
- Environmental Sample Processor (ESP)
  - MBARI-developed moored instrument that can really do it all
  - Uses automated, miniaturized lab procedures to quantify HAB-specific DNA and/or toxin concentrations
  - Cost of deployment & operation, and lack of commercialization has so far minimized application





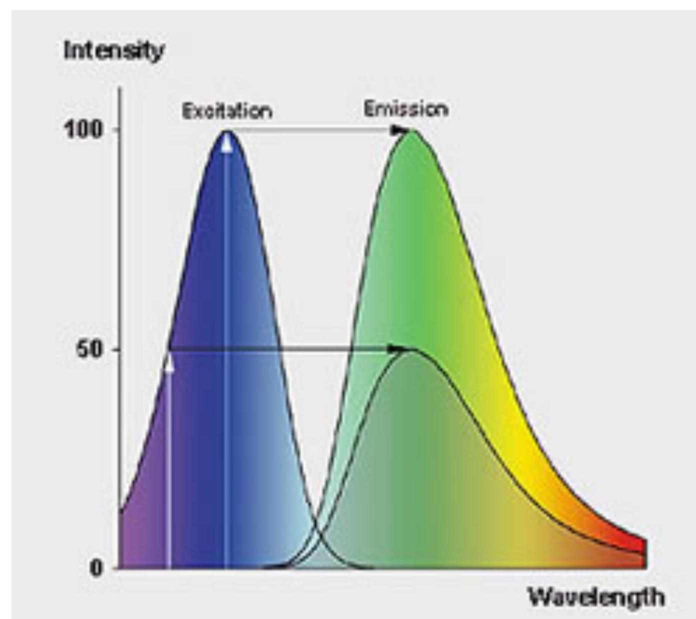
http://www.mbari.org/esp/

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)**

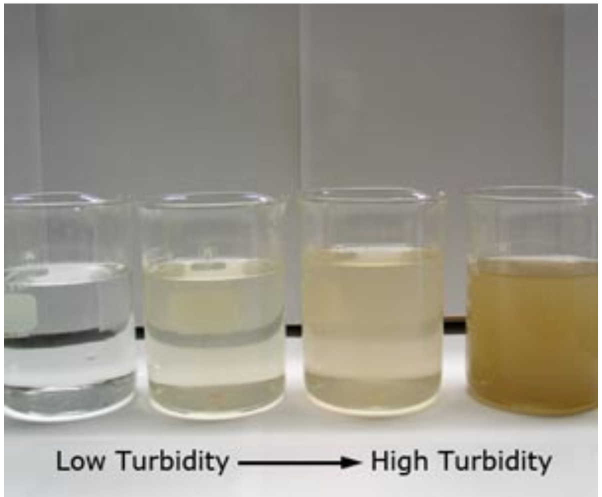


Figures courtesy of WetLabs

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

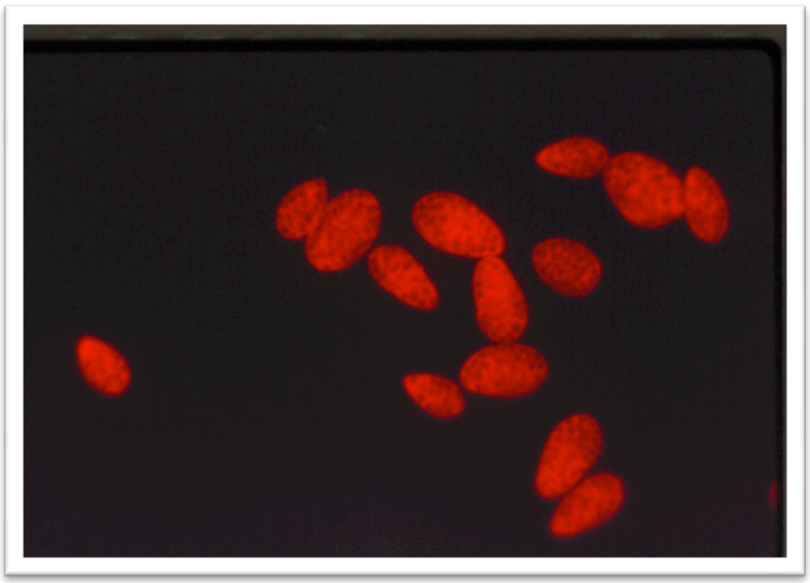
Bloom of *Akashiwo sanguinea* in King Harbor, May 2010



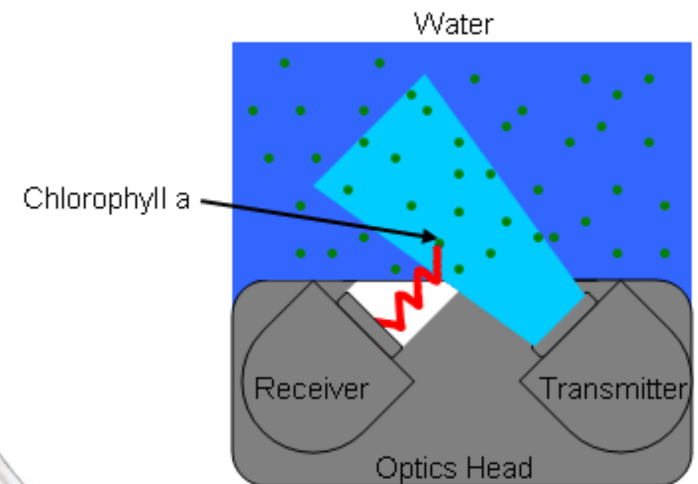
http://www.fondriest.com/science_library-htm/turbidity.htm

Fluorescence

http://grupogima.blogspot.com



Turner Designs Cyclops Fluorometer

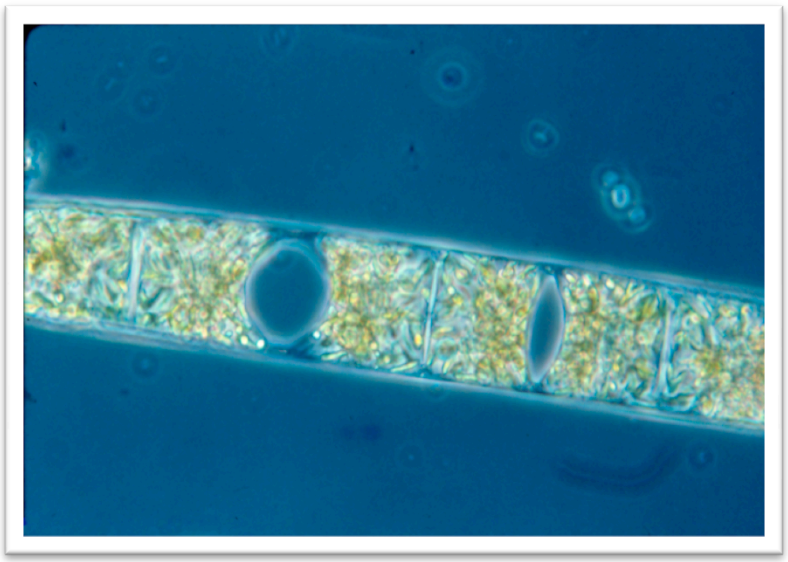


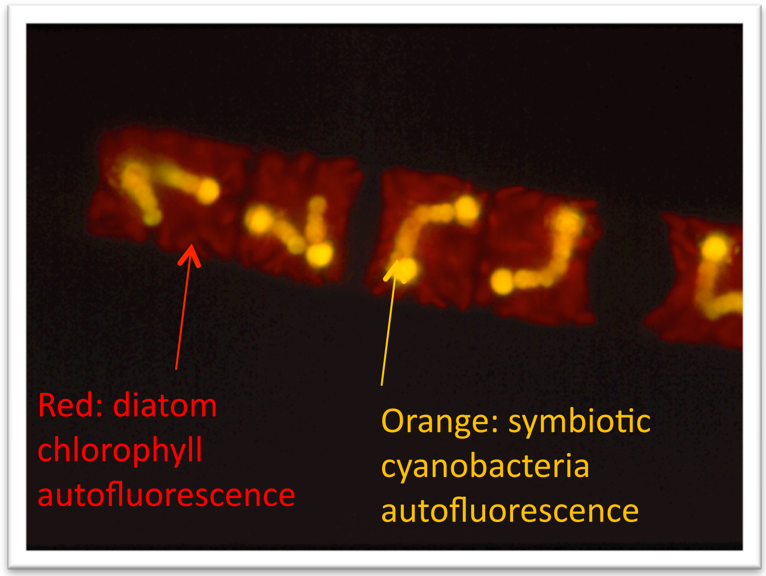
Sanibel Captiva Conservation Foundation

- 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

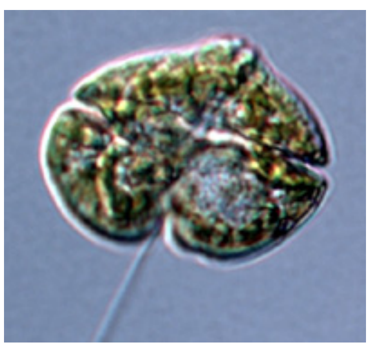
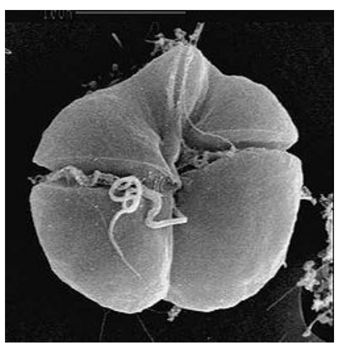




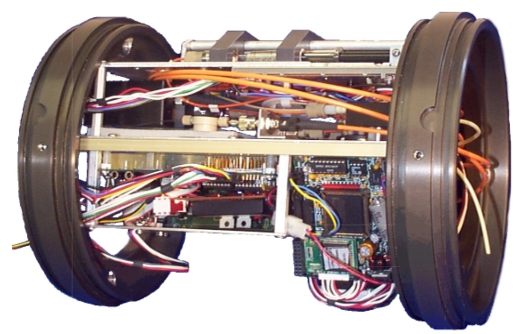
- Commercial fluorometers available to study a range of different groups

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



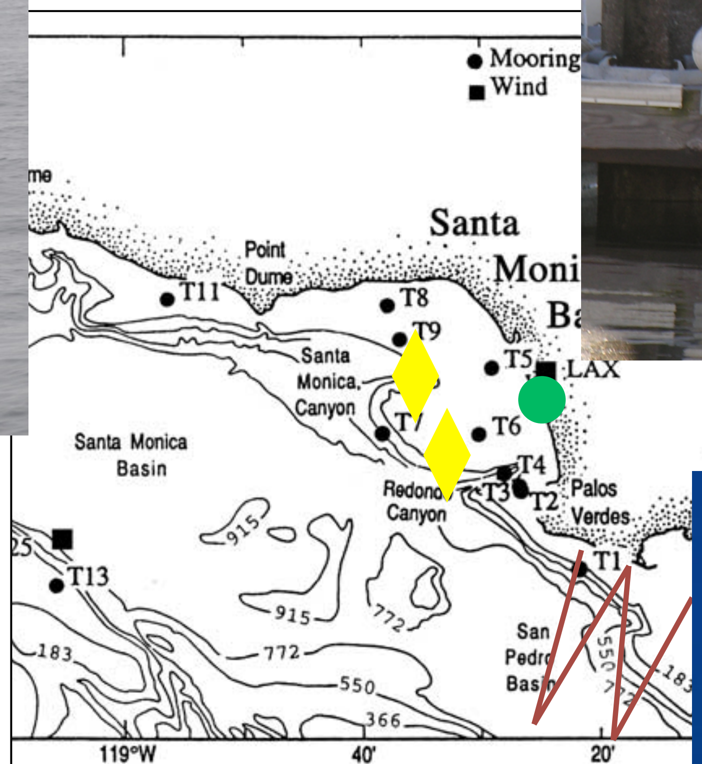
“BreveBuster”
http://coolgate.mote.org/socool/breve-def.html

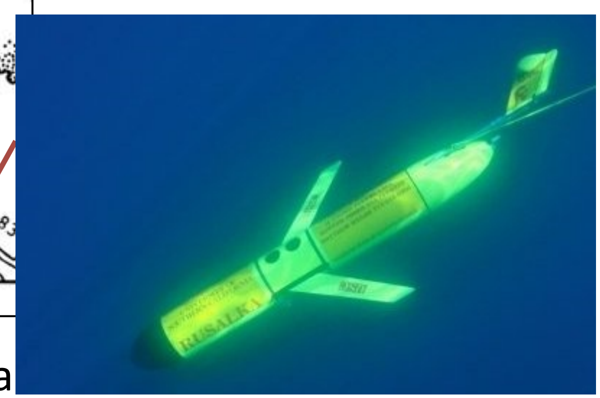
Other Parameters we Measure

- 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

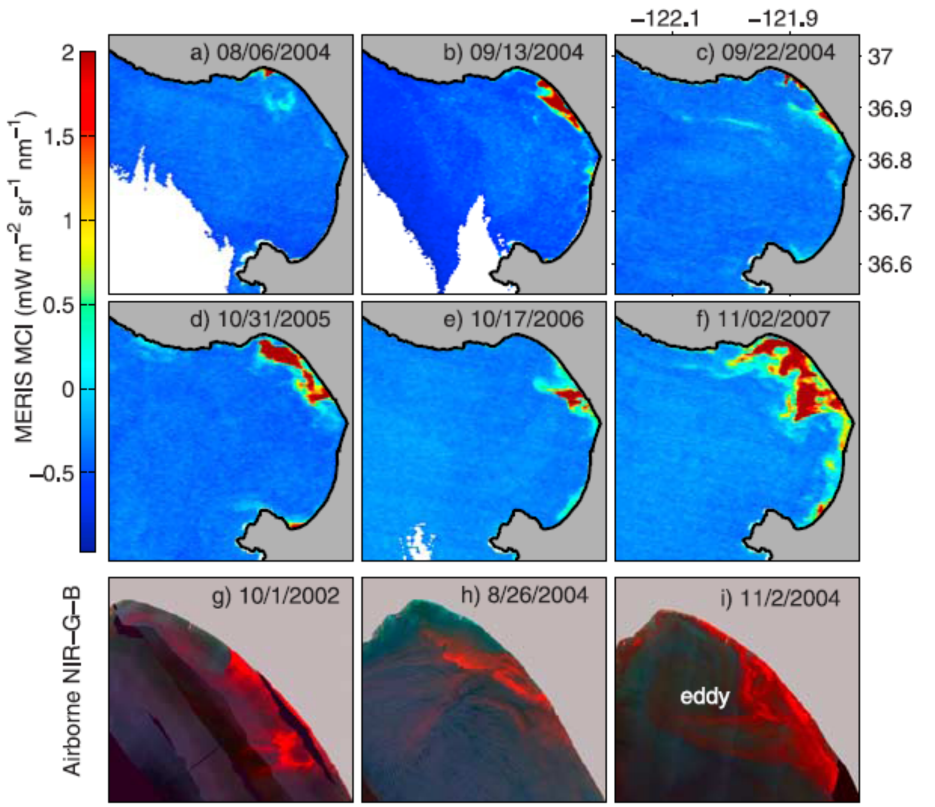




Southern California Bight, from Hickey et a

Tools and Approaches for HAB Research - Nearshore

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



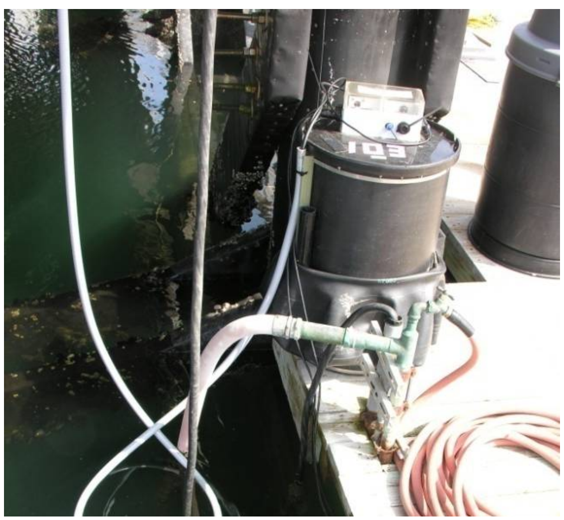
Propagation of an *Akashiwo sanguinea* bloom in Monterey Bay (Ryan et al, 2008)

- 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

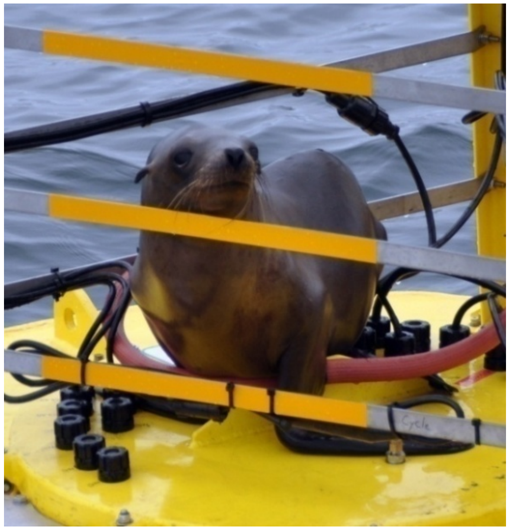
Buoy-integrated Hydrolab DS5 sensors in King Harbor



WetLabs WQM ready for deployment in MDR

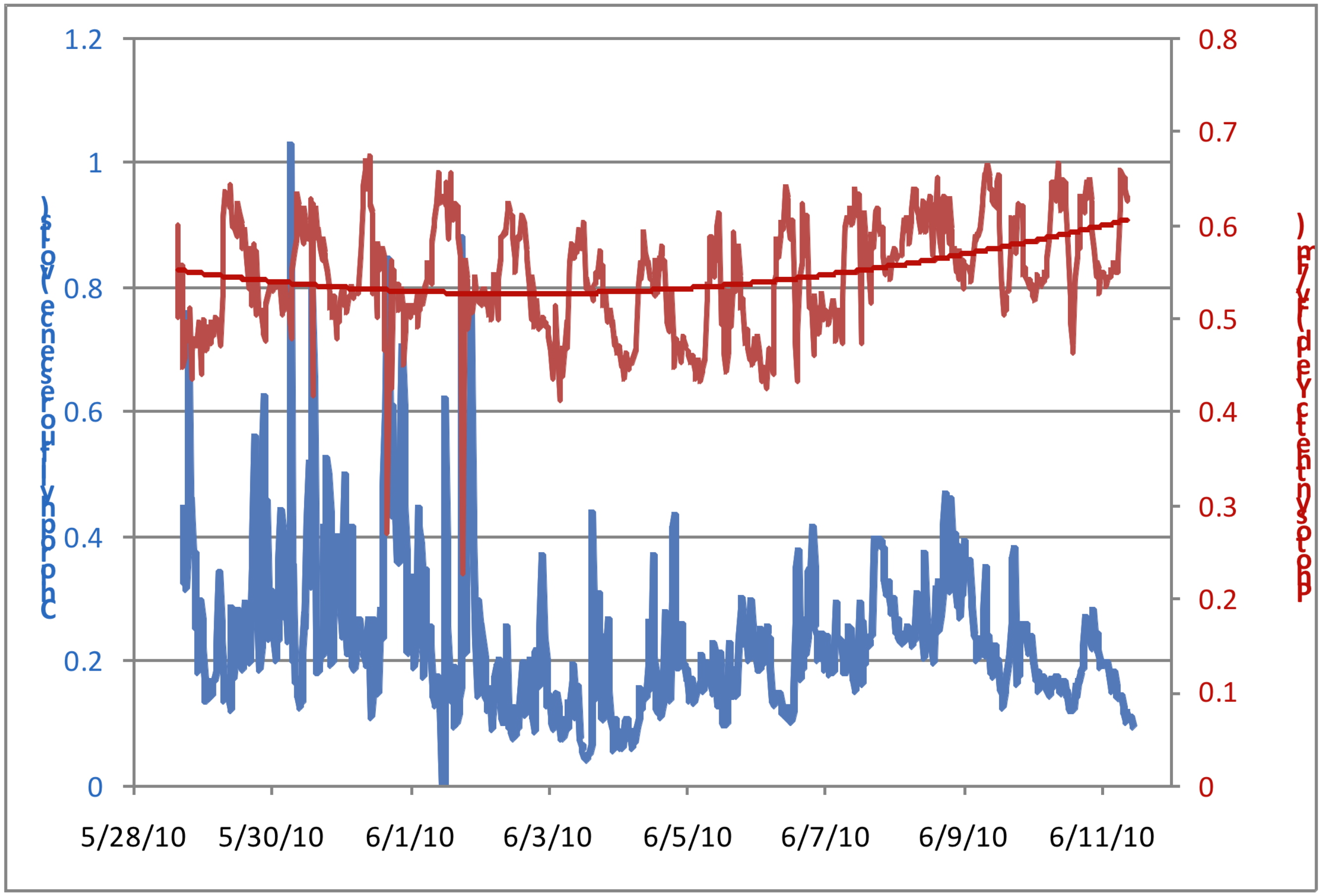
Tools and Approaches for HAB Research – Continental Shelf

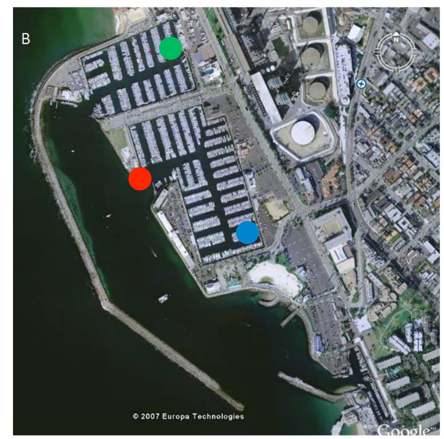
- Offshore Oceanographic Buoys
  - Provide connectivity with outer ocean
  - High temporal frequency at single point
  - Power and telemetry, biofouling more problematic offshore
- 2 Moored buoys in Santa Monica Bay

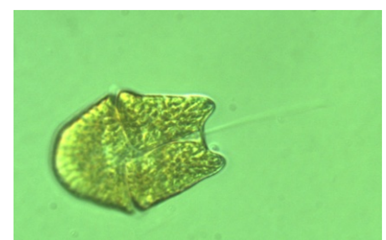


Temporal sensing of HABs

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



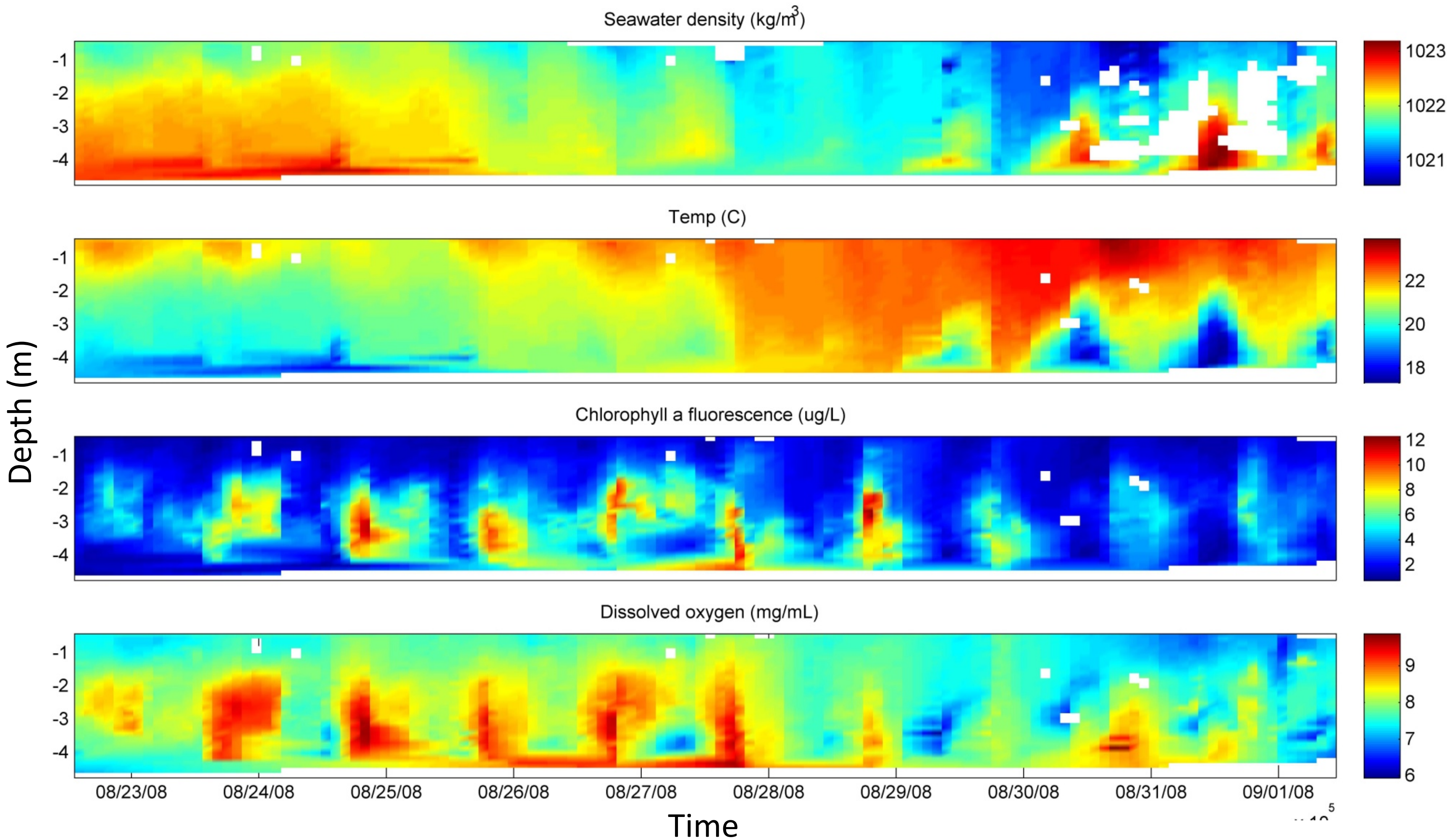




Akashiwo sanguinea

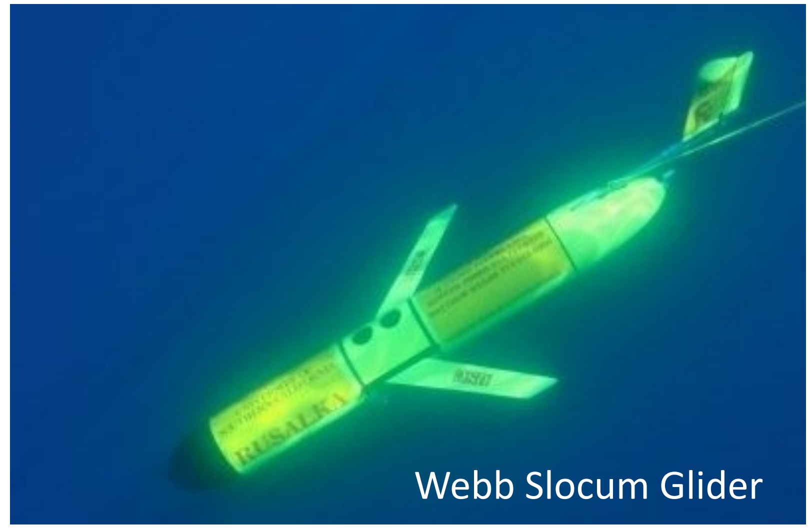
Temporal sensing of HABs in 3D

- 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

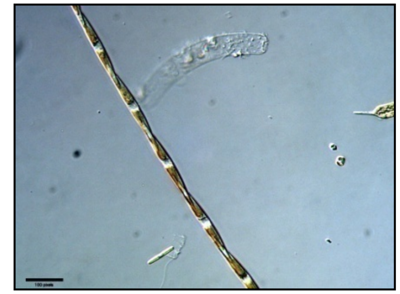


Webb Slocum Glider

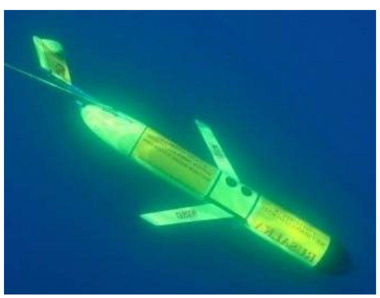
USC/OceanScience QBoat

YSI EcoMapper

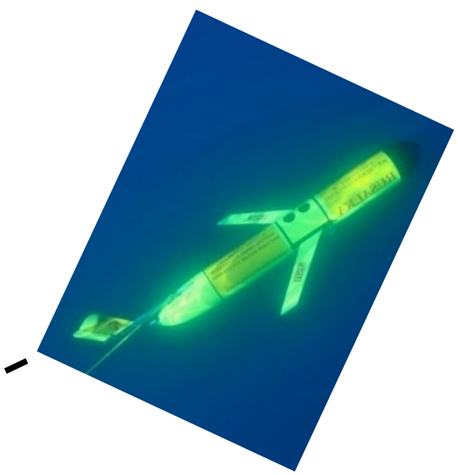
Case Study – Glider application to emerging HAB



- 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



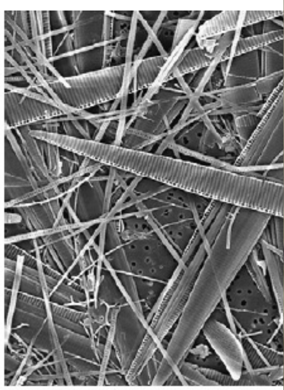
Diving: negatively buoyant



Surfacing: positively buoyant

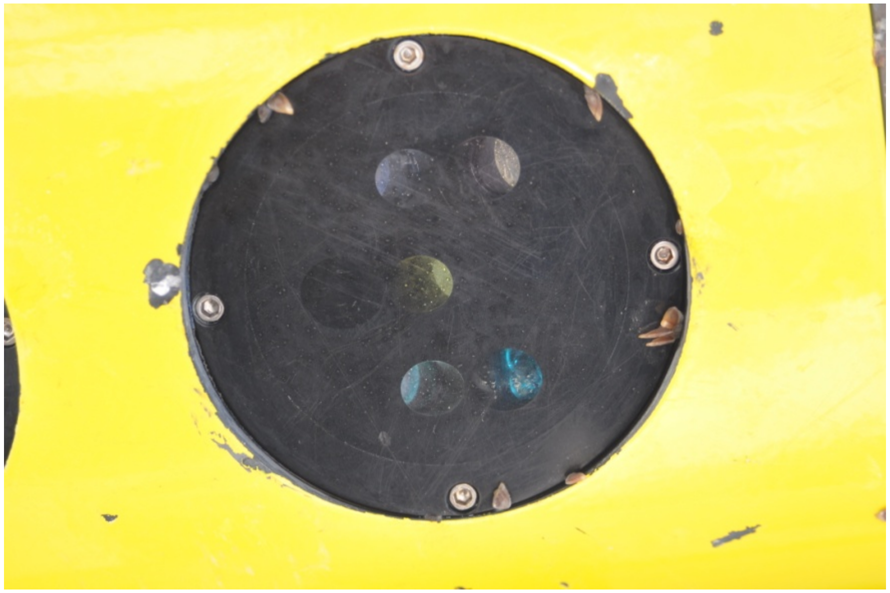
Case Study – Glider profiling of emerging HAB

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

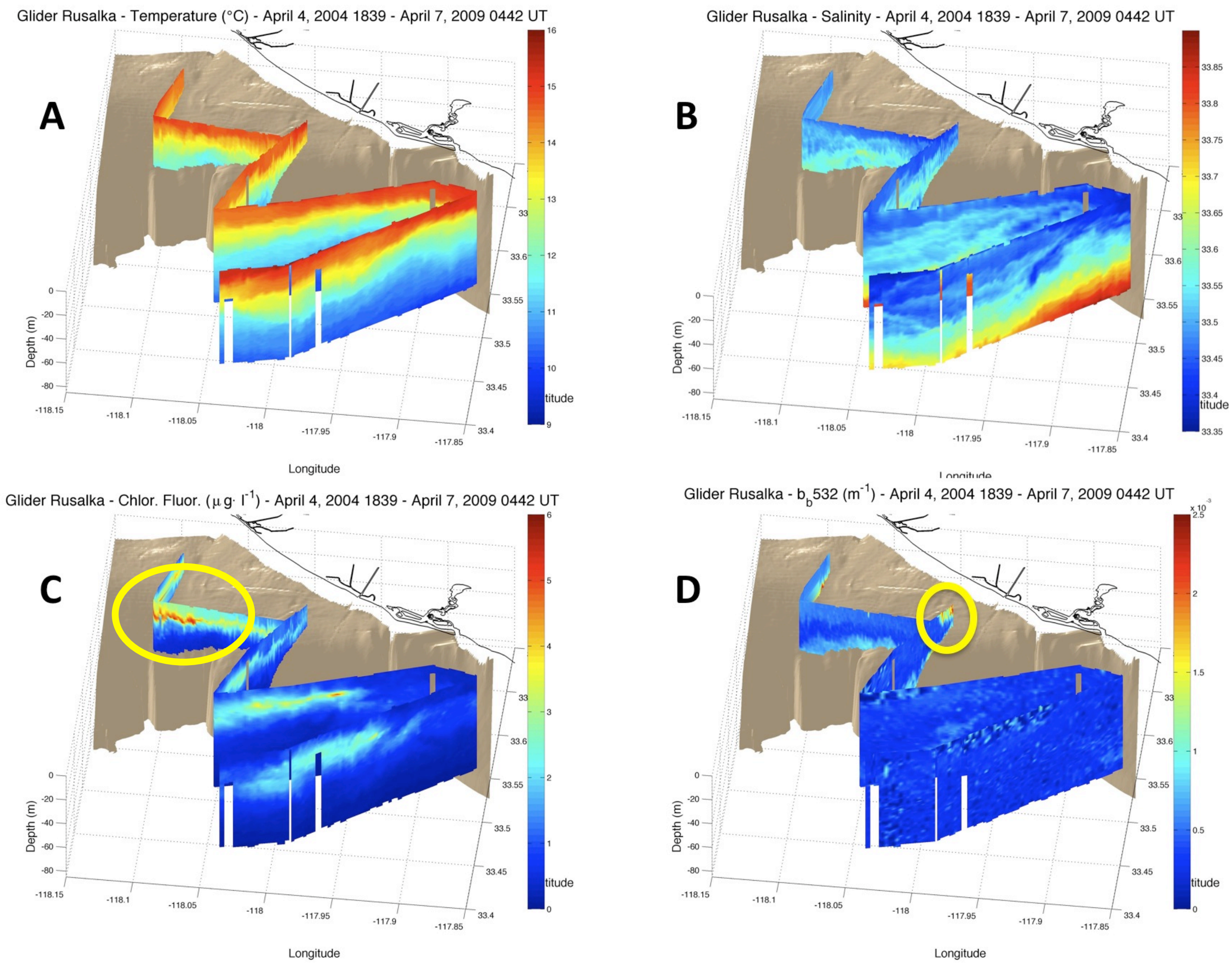


Case Study – Glider profiling of emerging HAB

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

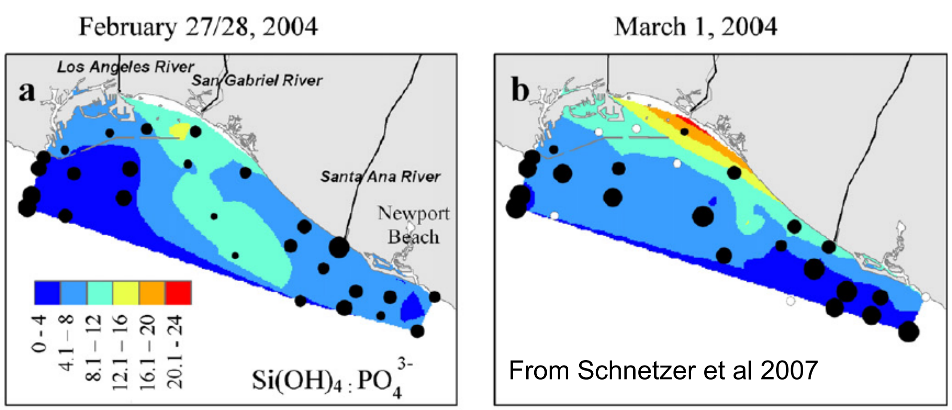


Case Study – Glider profiling of emerging HAB



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...

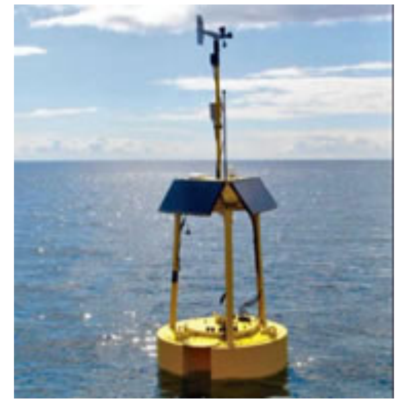


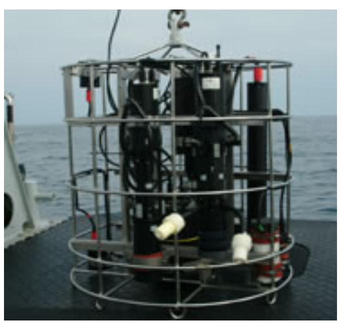
From Schnetzer et al 2007

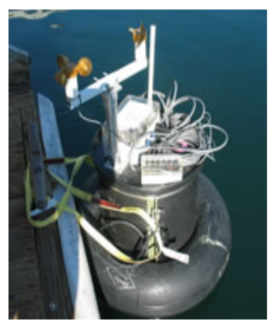
The USC Center for Integrated Networked Aquatic PlatformS

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).**







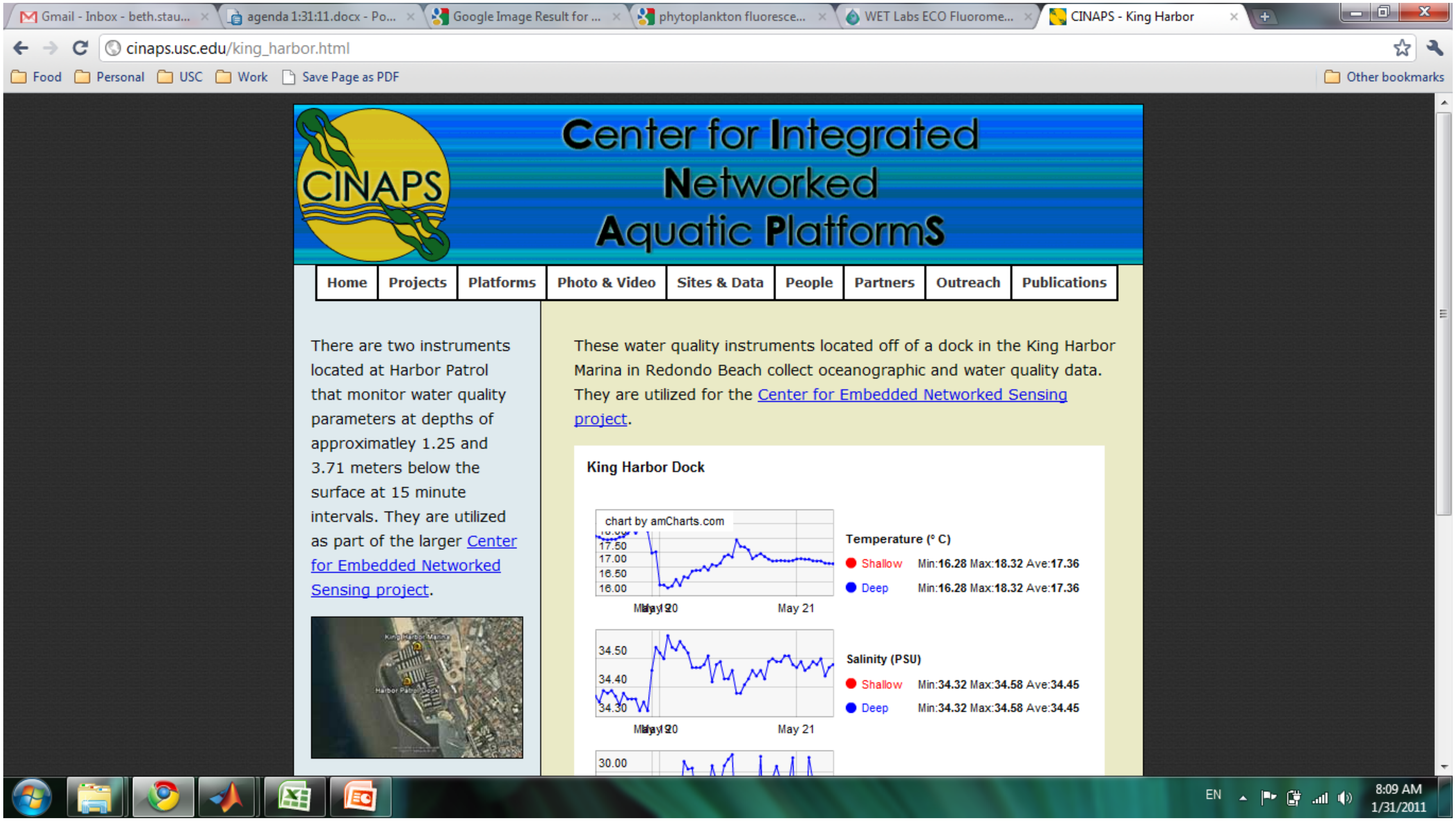
USC

CARON LAB
Protistan Aquatic Microbial Ecology

usCLAB

ROBOTIC EMBEDDED SYSTEMS LABORATORY
USC

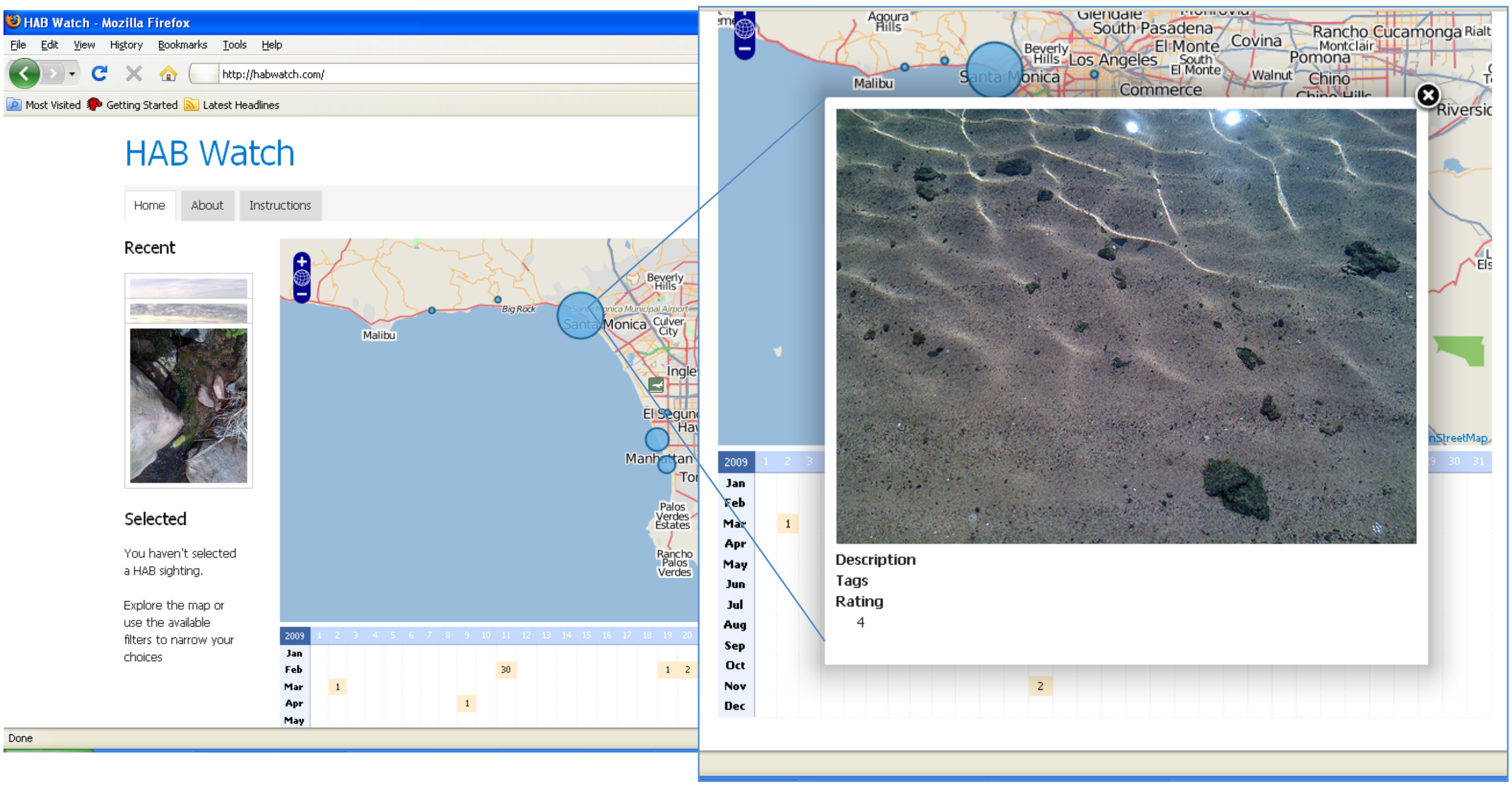
cinaps.usc.edu

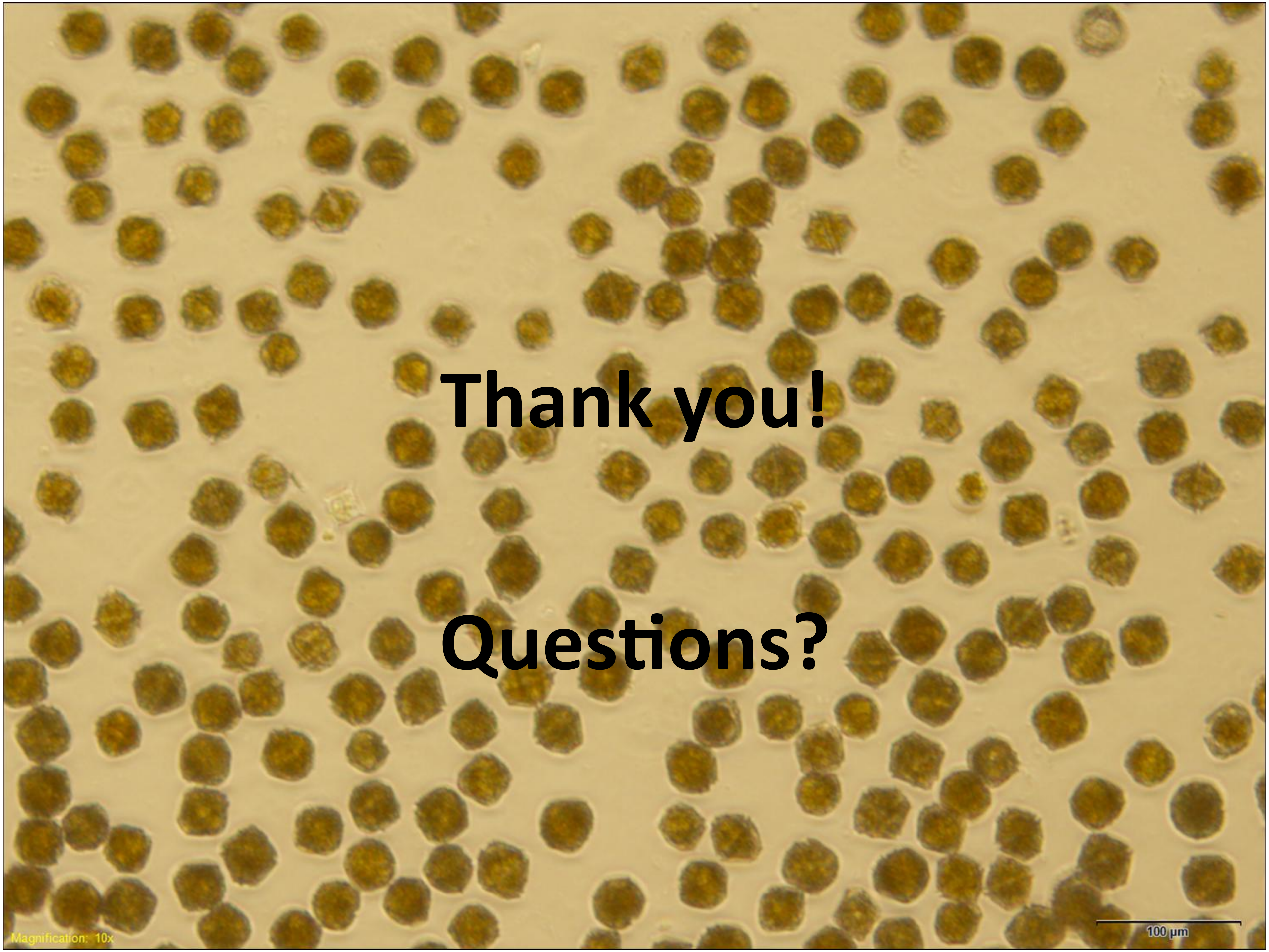


- Information on SoCal HABs, links to datastreams

Participatory Sensing – HAB Watch

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

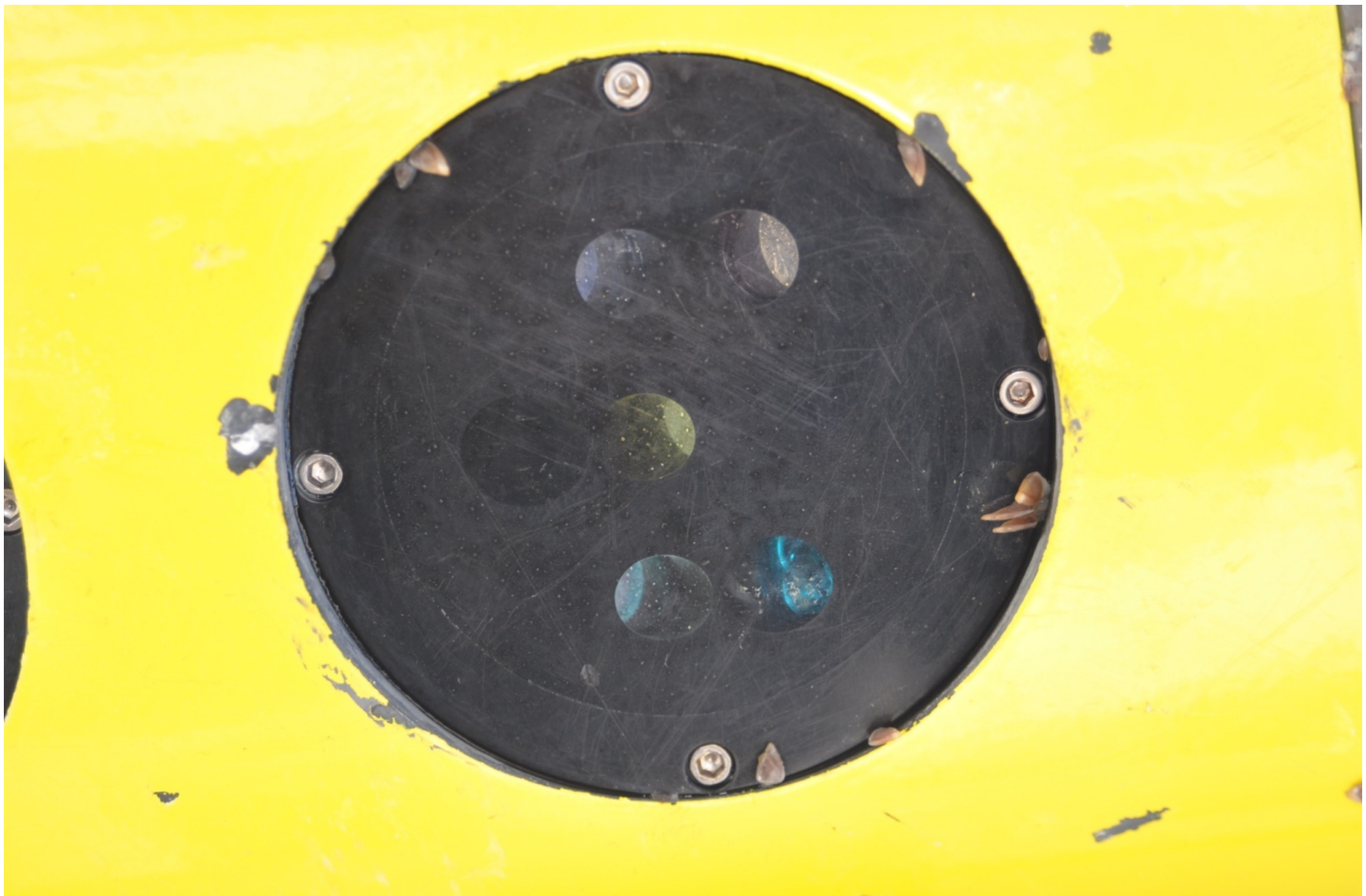




Thank you!

Questions?

Barnacles on glider



Had high levels of DA

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Center for Embedded Networked Sensing

NOAA (MERHAB)

USC SeaGrant

Brown Family Foundation

Questions?