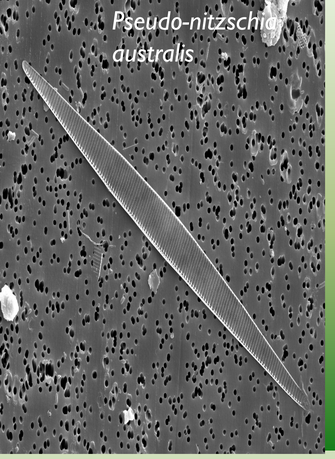


MERGING SATELLITE AND NUMERICAL MODEL DATA IN THE CALIFORNIA CURRENT TO CREATE CONTINUOUS IMAGERY AND FORECASTS OF HARMFUL ALGAL BLOOMS

Clarissa Anderson[1], Raphael Kudela[1], Mati Kahru[2], Leslie Rosenfeld[3], David Green[4], Richard Stumpf[5]

1.University of California, Santa Cruz; **2**. Scripps Institution of Oceanography
3. Central and Northern California Ocean Observing System (CeNCOOS)
4. NOAA National Weather Service; **5.** NOAA National Ocean Service

NASA Ecological Forecasting Team Meeting
7-9 May 2014, Silver Spring, MD

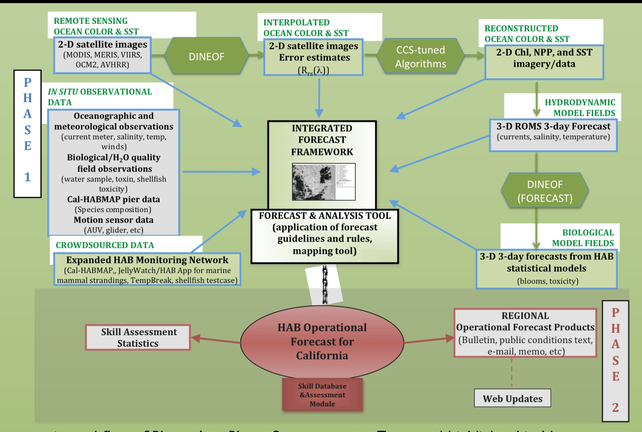
PROJECT SUMMARY

This project introduces a method for predicting the spatial distribution of harmful algal bloom (HAB) and toxin load likelihoods in the coastal region of the California Current System (CCS) using a unique blend of numerical models, ecological forecast models of target phytoplankton species (*Pseudo-nitzschia* and its neurotoxin, domoic acid), and satellite ocean color imagery. Our approach merges Earth system models and satellite observations with ecological forecasting and *in situ* observations of HABs from several field programs and networked data sources. We will generate these forecast products routinely and in a pre-transitional demonstration of operational predictions of toxic blooms for central California using available satellite data (MODISA, VIIRS, MERIS). **What we consider to be the most innovative aspect of the project is the merger of satellite data with numerical forecasts of the physical data to statistically reconstruct biogeochemical fields up to three days to then force our existing statistical models for forecasting HAB events. This the fastest and most robust method for immediately executing HAB forecasts.** We are leveraging the distributed databases established by the Central and Northern California Ocean Observing System (CeNCOOS) and Southern California Coastal Ocean Observing System (SCCOOS) for data management, interface with end-users, and communication with their many regional partners on the value of this effort. A forecasting analysis tool is currently in development to transform HAB monitoring and crowdsource data streams to usable information for an adaptive forecasting system that employs both models and citizen scientist observations for constraining prediction certainty. Importantly, this forecasting system and analysis tool will be developed in partnership with NOAA, specifically the National Ocean Service (NOS) and the National Weather Service (NWS), as a testbed for collaboration toward transitioning research results to an operational center. Transfer to operations will be accomplished by leveraging NOAA expertise and experience transitioning regional ocean models, guided by HAB research, into NWS National Center for Environmental Prediction. The project is aligned with NOAA's regional and national transition plans and coordinated efforts that issue operational beach hazard statements with integrated HAB forecasts to alert decision makers and inform managers. Such a capability will allow us to predict large-scale ecosystem changes and the associated impact on HABs that scale well beyond existing, shore-based monitoring programs, **making this approach the most cost-effective method for monitoring offshore disturbances that affect both aquaculture facilities and marine mammal populations.**

Acknowledgements: NNX13AL28G, NNX14AC42G
Fred Bahr (CeNCOOS), Steven Haddock (MBARI)

Phase I Goals

- ✔ • Apply an improved interpolation method for satellite data based on DINEOF (Data INterpolating Empirical Orthogonal Functions)
- ✔ • Demonstrate the feasibility of our HAB <u>forecasting</u> method that merges reconstructed satellite data with numerical models to create forecasts of biogeochemical properties and HABs (**PANEL 1**).
- ✔ • Couple existing HAB predictive algorithms to our improved ocean color retrievals with routine model runs of <u>nowcasts</u> (**PANEL 2**).
- • Expand HAB monitoring network to include citizen observations from **Jellywatch** and **TempBreak** fishing community (***underway***)
- • <u>Pre-operational demo of HAB forecasting</u> with end user involvement, product testing, and guidelines for automating a forecast analysis system



Diagrammatic workflow of Phase 1 to Phase 2 components. Top panel highlighted in blue represents the Phase 1 Feasibility Study, and red boxes in the bottom panel describe deliverables for a Phase 2 operational scenario.

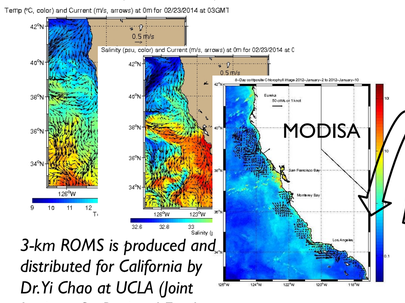
Phase II Goals

- Finalize the requirements for the Integrated Forecast Framework with end user organizations, **NOAA National Ocean Service** (Richard Stumpf) and **National Weather Service** (David Green)
- Codify routines for the forecasting analysis and mapping tool
- Establish an event-scale, rules-based approach to expert analysis of forecast products
- Establish guidelines for the skill database and assessment module
- Transfer all operations from CeNCOOS (MBARI) to NOAA NOS.

① Feasibility Demonstration #1: DINEOF and 2009 Bloom Test-Case

Hindcasting Blooms

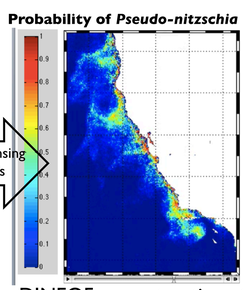
Merge output from circulation model (ROMS) with satellite data (MODISA) to run statistical HAB prediction models



3-km ROMS is produced and distributed for California by Dr.Yi Chao at UCLA (Joint Institute for Regional Earth System Science and Engineering) and the west coast office of RSS, Inc.

<u>New Improvement:</u>
Data gaps in satellite imagery are smoothed using Data Interpolating EOFs (DINEOF) before going into model runs

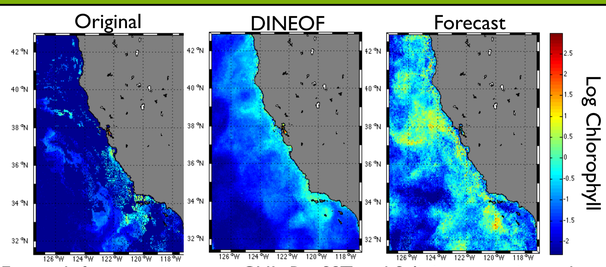
Probability of *Pseudo-nitzschia*



<u>DINEOF reconstruction at 5-day intervals</u> for 2009 to compare with published results (Anderson et al., *GRL*, 2011) for the Santa Barbara Channel. See Blue Hindcast time series at RIGHT.

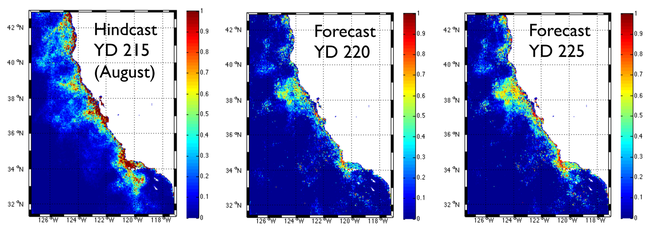
Generating Forecasts of Biogeochemical Properties using DINEOF

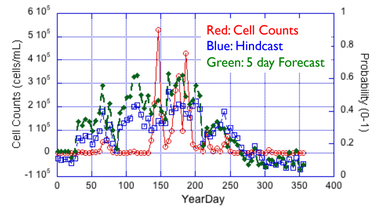
- ***<u>Predict</u>*** future R_{rs} and CHL fields by seeding DINEOF with previous 5-day interval
- Solve DINEOF using California ROMS model forecasted fields (SST, Salinity) and <u>seeded</u> MODISA R_{rs} and CHL satellite fields
  - *OR* use ROMS current trajectories to advect satellite data forward and then solve



For each forecast time-step, CHL, R_{rs}, SST, and Salinity are estimated.

Forecasting Blooms





Each 5-day interval was forecast with 6 months of historical MODISA data and compared to the hindcasts and to cell counts from Santa Barbara Channel (left).

Reasonable agreement up to 2 time-steps (10 days) forward

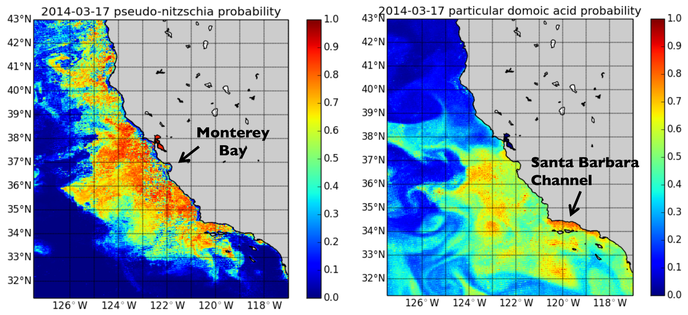
② Feasibility Demonstration #2: 2014 Domoic Acid Event

Routine Nowcast Runs

Daily predictions that merge reconstructed DINEOF fields with ROMS model output are run routinely at **CeNCOOS** and posted on their website for dissemination to a select group of test end-users.

http://www.cencoos.org/sections/conditions/blooms/habforecast/latest/

Pseudo-nitzschia & DA Predictions for March 17, 2014

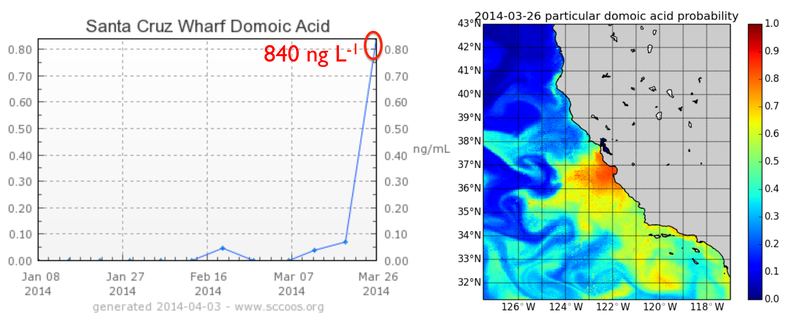


High probability of blooms all along coast

High probability of DA **offshore** and in the Santa Barbara Channel

"We have had a pulse of 5 sea lions from **Monterey Bay** with signs of DA toxicosis, also 2 adult Guadalupe fur seals which is unusual."
-Frances Gulland (U.S. Marine Mammal Commission)

DA Predictions for March 26, 2014



April 4 - CDPH Warns Consumers Not to Eat Sport-Harvested Bivalve Shellfish from Monterey or Santa Cruz Counties (*California Department of Public Health News Release*)
April 10 - CDPH Expands Warning to Include Sardines, Anchovies, Crab (*CDPH News Release*)

Take-Home

•Model predictions in the Monterey Bay were well correlated (at a week lead time) with shellfish bed closures in MB and SC Counties.

•Marine mammals may be good sentinels of the offshore onset of a DA event. We are currently compiling historical stranding data to compare with model hindcast runs. Citizen observations of mammal strandings should help us QC the forecasts of offshore DA predictions.