# HAB Forecast System for Coastal California

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Dale Robinson[4], and Richard Stumpf[5]
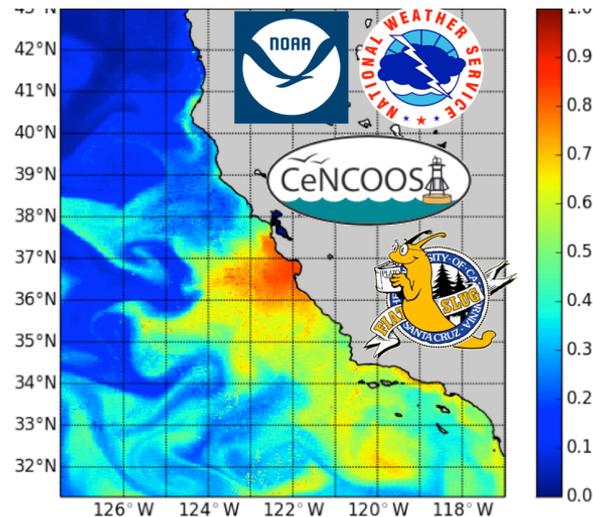
[1]University of California Santa Cruz
[2]Central & Northern California Ocean
 Observing System (CeNCOOS)

[3]UCLA JIFRESSE/RSS Inc.
[4]NOAA CoastWatch
[5]NOAA National Ocean Service

NOWCAST AND FORECAST SYSTEM FOR DOMOIC ACID EVENTS

REMOTE SENSING OCEAN COLOR & SST

2-D satellite images (MODISA, soonVIIRS)

DINEOF

INTERPOLATED OCEAN COLOR & SST

2-D satellite images Error estimates $(R_{rs}(\lambda))$

CCS-tuned Algorithms

RECONSTRUCTED OCEAN COLOR & SST

2-D Chl, Rrs $(0^+, \lambda)$ imagery

IN SITU OBSERVATIONAL DATA

Oceanographic and meteorological observations (current meter, salinity, temp, winds)
Biological/H_2O quality field observations (water sample, toxin, shellfish toxicity)
Cal-HABMAP pier data (Species composition, toxicity)
Motion sensor data (AUV, glider, etc)

CROWDSOURCED DATA

Expanded HAB Monitoring Network (HABMAP, TMMC stranding data, JellyWatch/ HAB App for marine mammal strandings,)

INTEGRATED NOWCAST & FORECAST FRAMEWORK

FORECAST & ANALYSIS TOOL (application of forecast guidelines and rules, mapping tool)

HYDRODYNAMIC MODEL FIELDS

3-D ROMS 3-day Forecast (currents, salinity, temperature)

HAB Empirical Models

BIOLOGICAL MODEL FIELDS

3-D Nowcasts of Bloom and Toxicity Probability

Advection Scheme

BIOLOGICAL MODEL FIELDS

3-D 3-day Forecasts of Bloom and Toxicity Probability

NASA Applied Sciences Program, Terrestrial Hydrology, Ocean Biology and Biogeochemistry Programs
"Ecological Forecasting for Conservation and Resource Management"
**"Remote Sensing of Water Quality"**
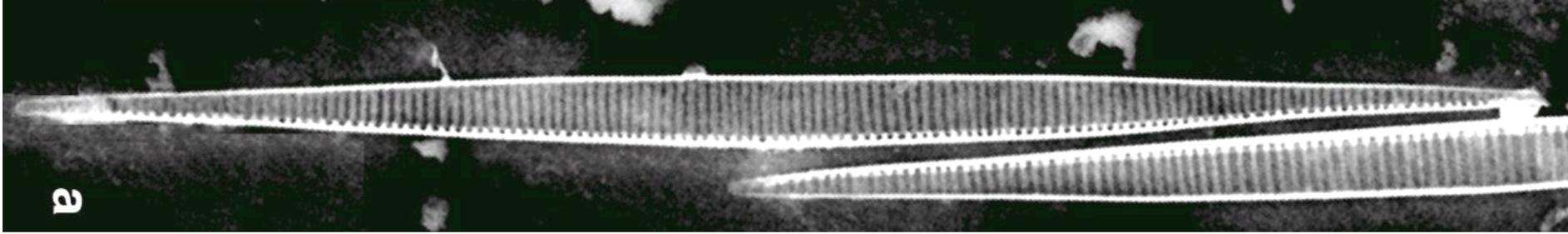
TALK OVERVIEW

- **Skill Assessment**

  - Massive Bloom of 2015

- **Technical Updates**

  - Web Portal

  - New crowdsourcing opportunity

 - Transfer to operational environment

2015 BLOOM of DOOM: May – September (and beyond)
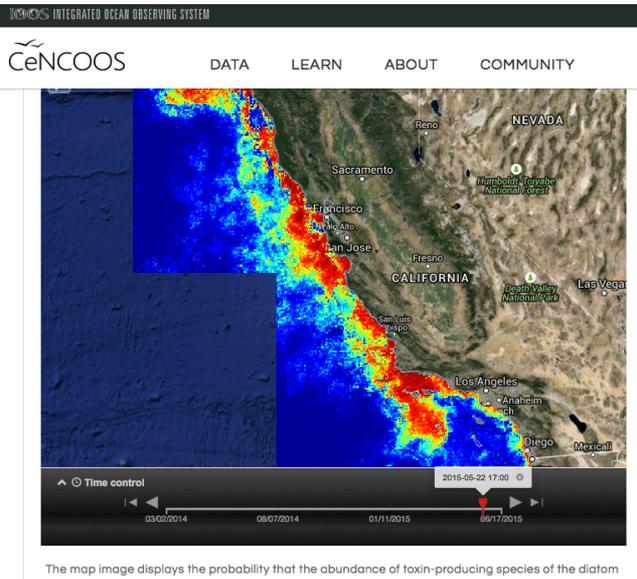
Santa Barbara to Alaska:
anchovy & sardine closures

shellfish advisories and closures

The map image displays the probability that the abundance of toxin-producing species of the diatom
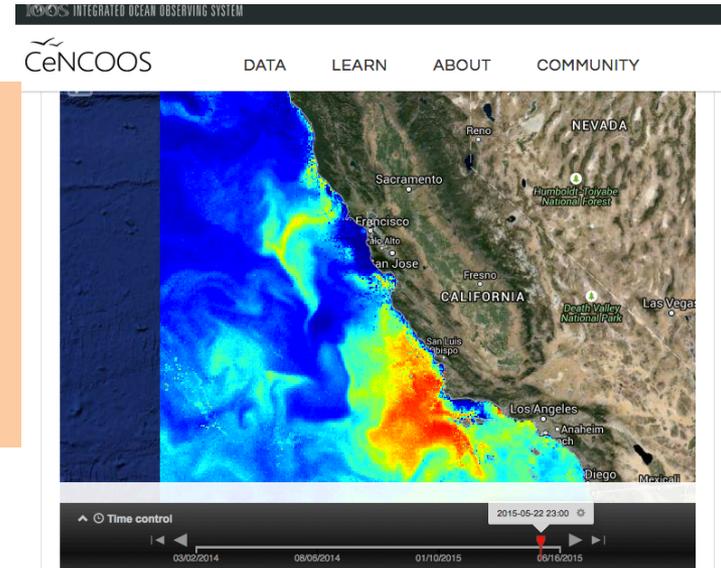
Unusual Mortality Event – includes 11 fin whales

Photo by NOAA shows one of about 30 large whales which have washed up in the Gulf of Alaska since May (and yes, those are regular-sized grizzly bears).

Dungeness Crab Closure!
Recreational and Commercial Harvests (Nov-May)

Santa Cruz Sentinel NEWS

News | Sports | Business | Entertainment | Lifestyle | Opinion | Obituaries | Place

Home | News

California's crab-season delay claims Christmas

By Aaron Kinney akinney@bayareanewsgroup.com

"The domoic acid Grinch took our Christmas crab!" said Phil DiGirolamo, owner of Phil's Fish Market, a popular spot for crab lovers in Moss Landing.

2015 – AN UNPRECEDENTED EVENT
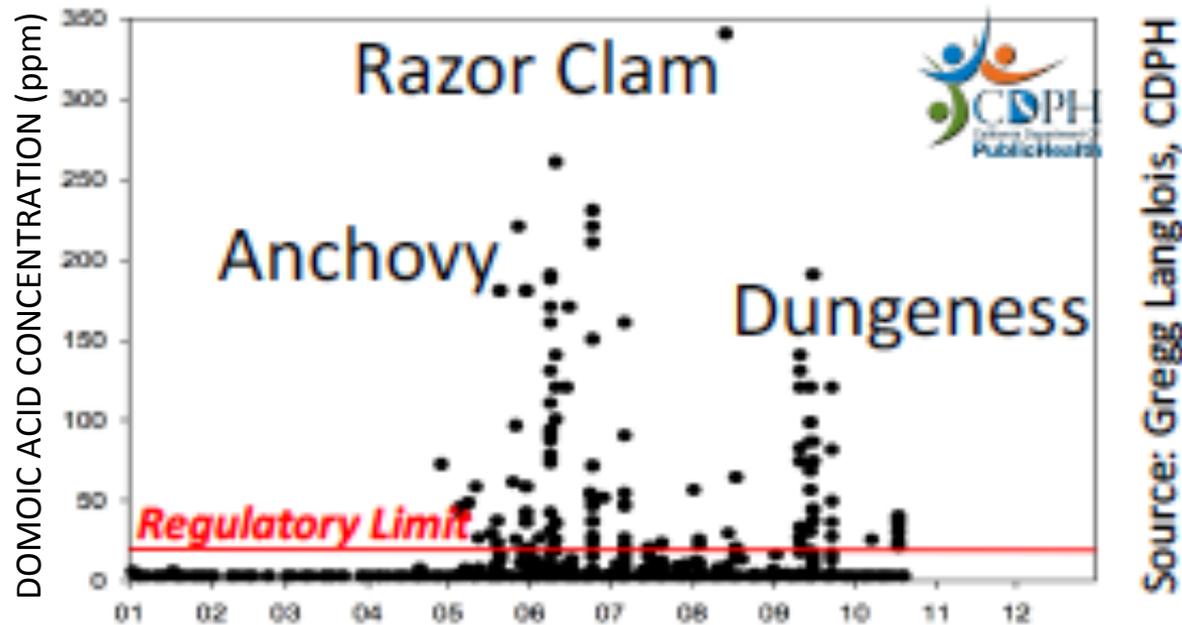
- Largest bloom ever recorded on West Coast of N. America

- DA reached new records in Dungeness, anchovy, and
  razor clams (commercial Dungeness fishery reopening next
  week for the rest of CA, except Humboldt Co.)

- Peak total concentrations > 100,000 ng/L

2015 – *Pseudo-nitzschia* – Santa Cruz WHARF
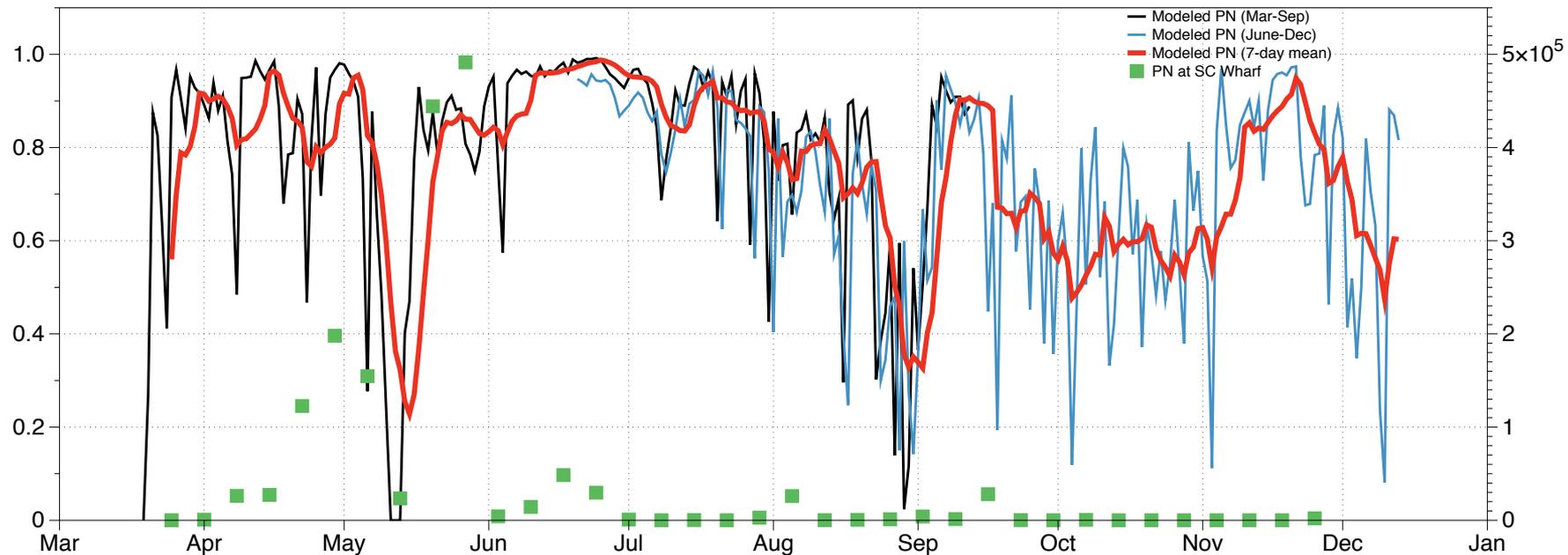
OVERALL ACCURACY = 61% (7-day mean); 43% (daily matchups)
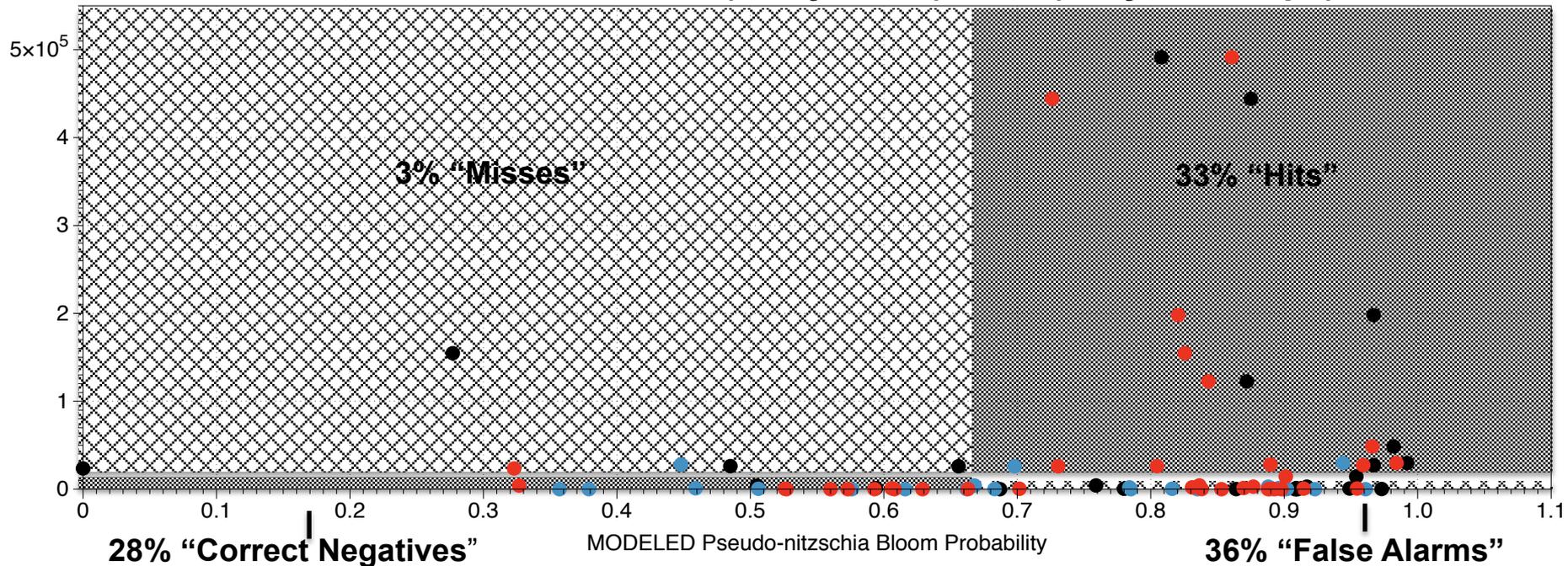
Top panel legend:
- Modeled PN (Mar-Sep)
- Modeled PN (June-Dec)
- Modeled PN (7-day mean)
- PN at SC Wharf

Top panel axes:
- Left y-axis: MODELED Pseudo-nitzschia Bloom Probability
- Right y-axis: OBSERVED Pseudo-nitzschia spp. Abundance (cells/L)
- x-axis: Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec, Jan

Bottom panel labels:
- **3% "Misses"**
- **33% "Hits"**
- **28% "Correct Negatives"**
- **36% "False Alarms"**
- y-axis: OBSERVED Pseudo-nitzschia spp. Abundance (cells/L)
- x-axis: MODELED Pseudo-nitzschia Bloom Probability

2015 – Particulate Domoic Acid – SC WHARF

Legend:
- Modeled pDA (Mar-Sep)
- Modeled pDA (June-Dec)
- Modeled pDA (7-day mean)
- pDA at SC Wharf

OVERALL ACCURACY = 73%

24% "Misses"

3% "Hits"

70% "Correct Negatives"

3% "False Alarms"

MODELED Particulate Domoic Acid Probability

MEASURED Particulate Domoic Acid (ug/L)
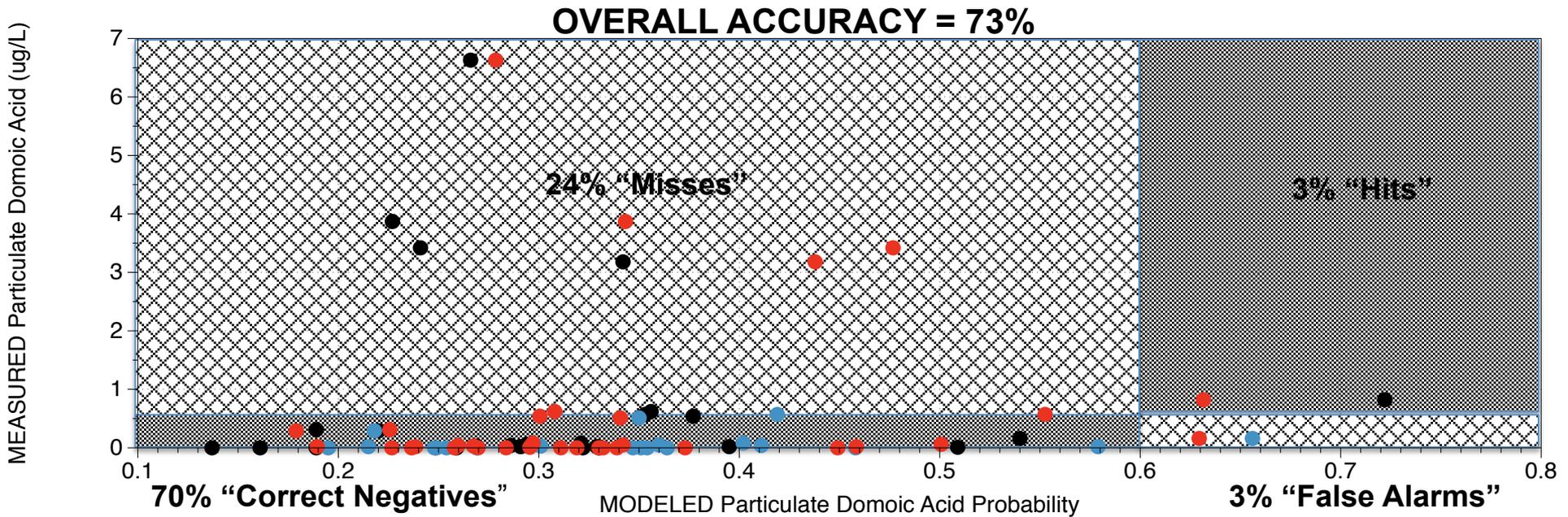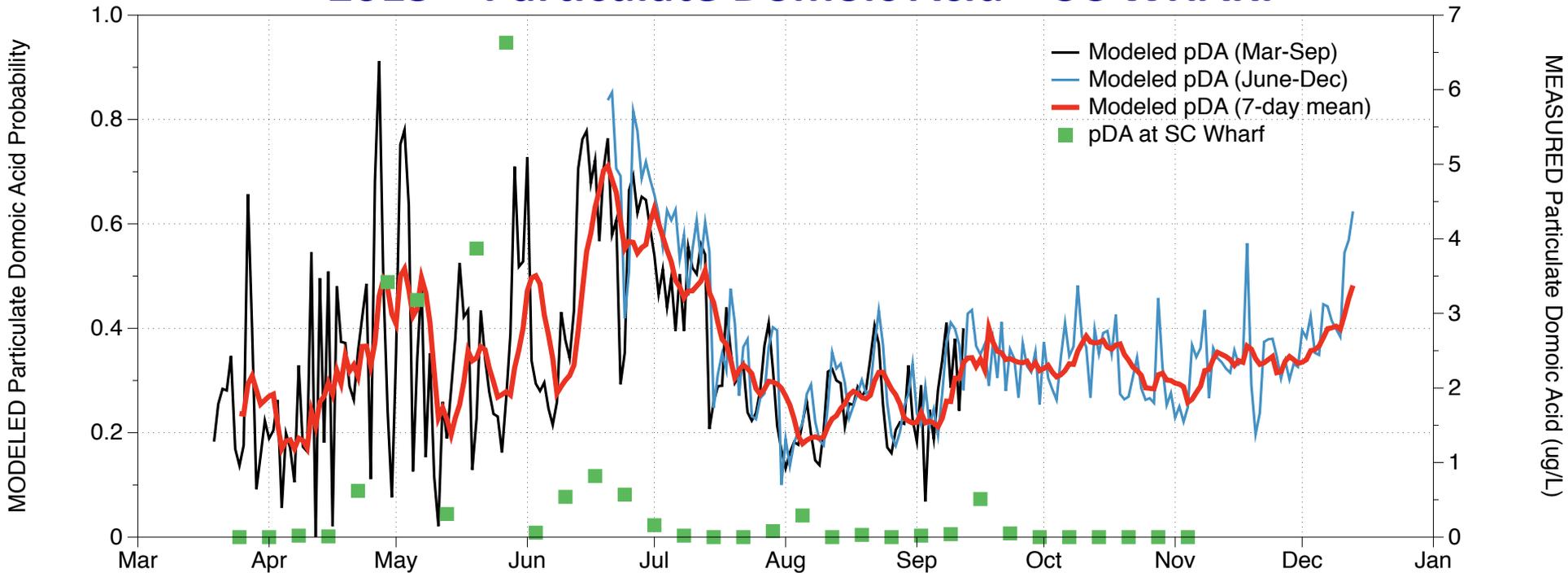
Year 1 FEASIBILITY STUDY - SKILL ASSESSMENT

The pDA model correlates well with central CA stranding peaks as early as 10 days before they occur...and with SPATT DA 9-12 days ahead


Sea Lions vs. pDA

SPATT (HP20) vs. pDA
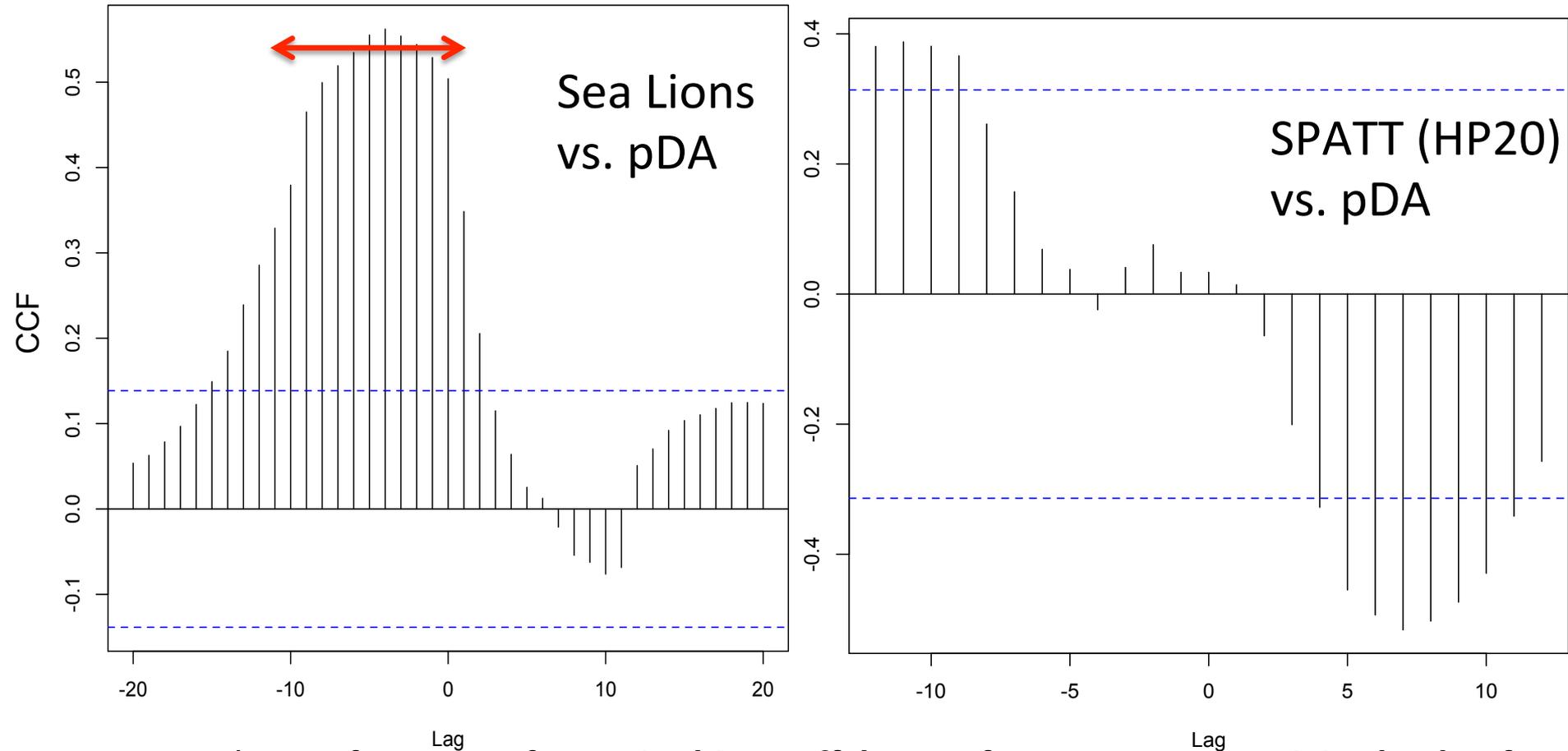
Cross correlation functions for a **pixel just offshore of Santa Cruz Municipal Wharf**. For marine mammals, the modeled time series was smoothed with a 30-day running average (low-pass filter) and neither data set was corrected with ARIMA prior to analysis since the autocorrelation function appeared stationary.

The model provides ~seasonal prediction of trophic transfer

Toxin Probability, Oct-Nov 2015

Crescent City (22-32 ppm, Jan 10)

Samoa (33 ppm Dec 30)

Trinidad (38 ppm Dec 26)

Channel Islands 460 ppm Jan 10)

Bodega Bay

Monterey Bay

SLO & SB Counties
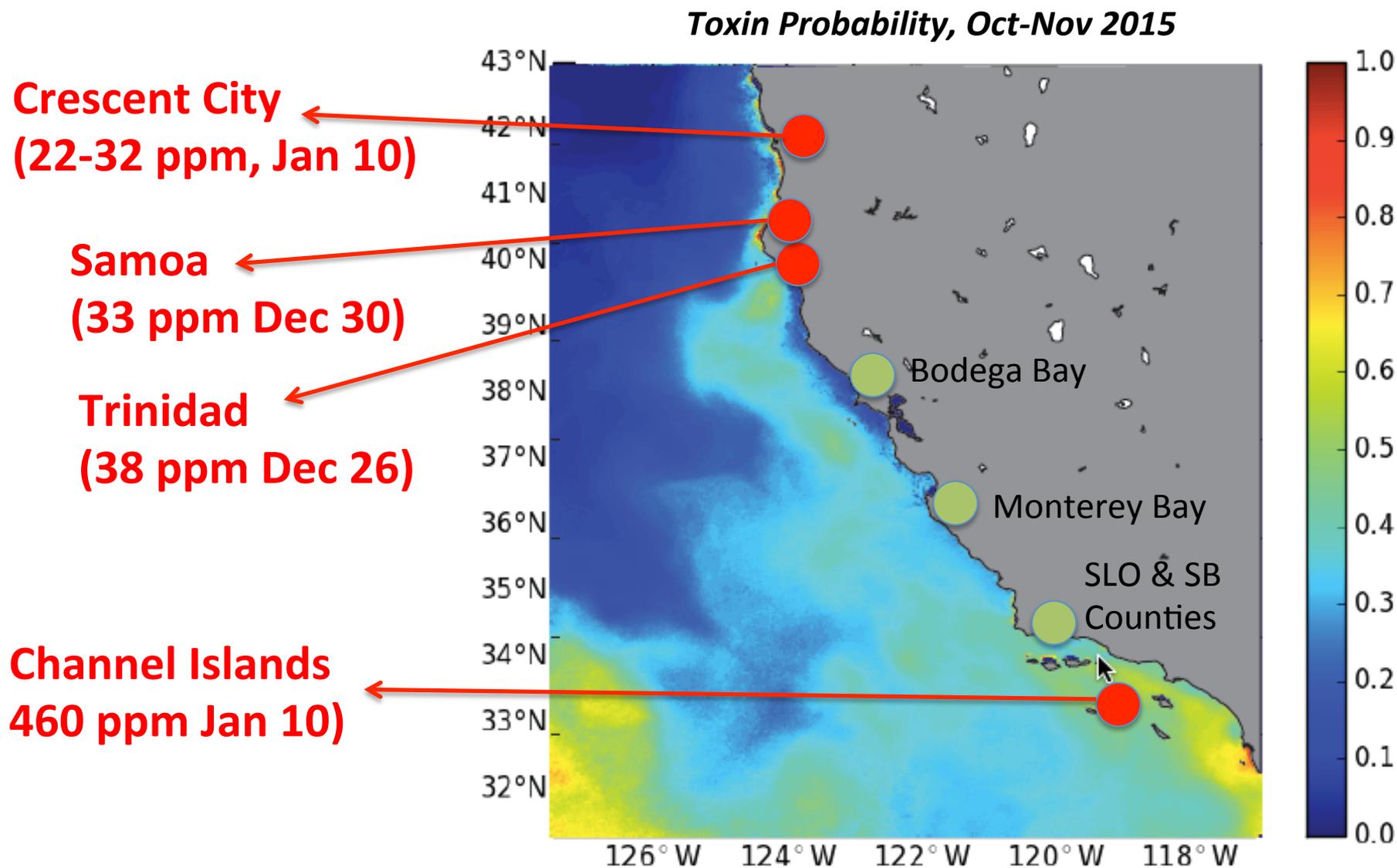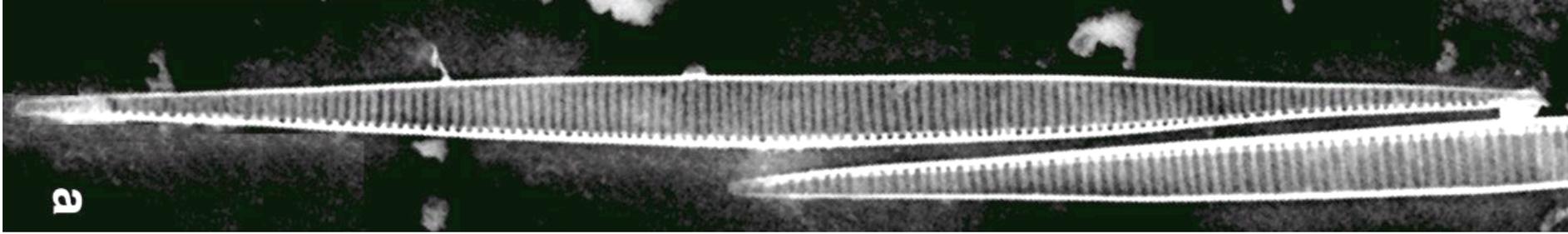
TALK OVERVIEW

- **Skill Assessment**
  - Year 1 Feasibility Study (2014)
  - Massive Bloom of 2015

- **Technical Updates**
  - Web Portal
  - New crowdsourcing opportunity
  - Transfer to operational environment

Interactive CeNCOOS Data Portal
HAB Nowcasts and Forecasts

http://www.cencoos.org/data/models/habs/previous
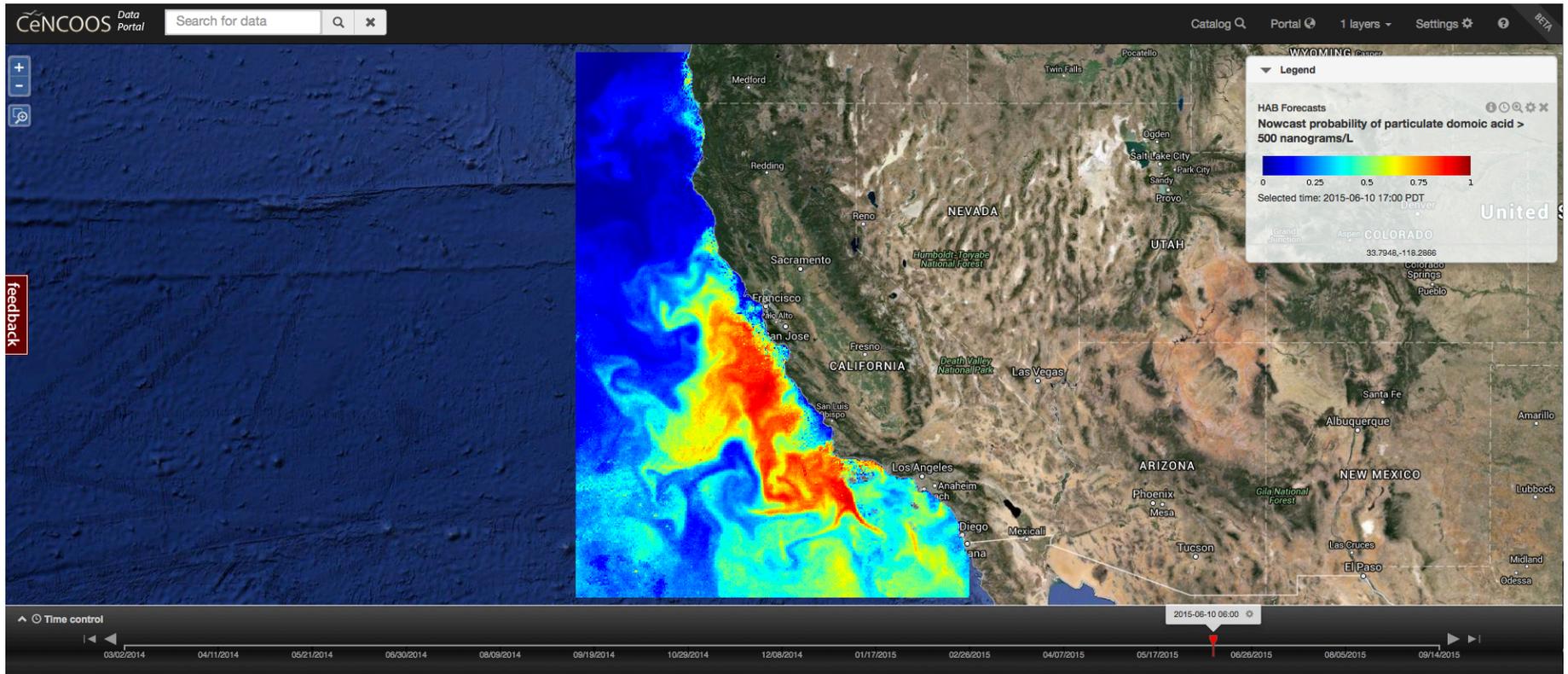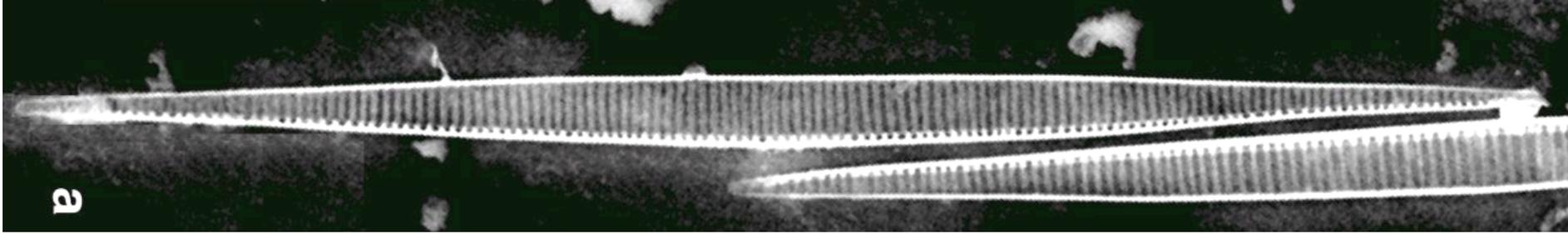
CITIZEN SCIENCE

- Ingesting marine mammals stranding datasets into data portal at CeNCOOS in collaboration with Axiom

    - <u>The Marine Mammal Center</u> – integrating full stranding datasets, with attention to DA toxicosis cases as proxy for offshore HAB events in near real-time
    - <u>BeachCOMBERS</u> data from volunteer network – nonspecific stranded/dead marine mammals & birds

CellScope
UC Berkeley

Technology

Mobile Microscopy
taking imaging to new places

Software

We develop custom software for our mobile microscopes to coordinate image collection, annotation, data management, web connection, and, for a growing number of applications, automated image analysis.

[Publications] [CellScope Explorer App]
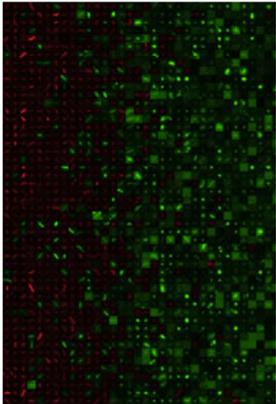
Field Studies

Together with collaborators around the world, we are testing the use of mobile microscopy to solve real-world problems in places including Vietnam, India, Thailand, Cameroon, the Ivory Coast, and Hawaii.

[Publications] [Applications]

HAB Monitoring in California
Collaboration with SCCWRP & HABMAP

OPERATIONAL HAB FORECASTING SYSTEM BY 2018/2019

MODISA TO VIIRS

REMOTE SENSING OCEAN COLOR & SST

Transition Development
CeNCOOS to NCCOS
*Final Implementation*
NOAA CoastWatch

DINEOF

RECONSTRUCTED OCEAN COLOR & SST

Transition Development
CeNCOOS to NCCOS
Final Implementation
NOAA CoastWatch

HYDRODYNAMIC MODEL FIELDS

Transition Development
RSS ROMS
Final Implementation
WCOFS at CSDL

DINEOF (FORECAST)

IN SITU **OBSERVATIONAL DATA**

Transition Development
UCSC/CeNCOOS
Final Implementation
NCCOS/NOS CO-OPS*

INTEGRATED FORECAST FRAMEWORK
FORECAST & ANALYSIS TOOL
Transition Development
UCSC/NCCOS
Final Implementation
NOS C0-OPS*

BIOLOGICAL MODEL FIELDS

Transition Development
CeNCOOS
Final Implementation
NWS WCOSS

CROWDSOURCED DATA

Transition Development
UCSC/CeNCOOS
Final Implementation
NCCOS/NOS CO-OPS*

Migrating scripts to S4 supercomputer

REGIONAL OPERATIONAL FORECAST PRODUCTS

Transition Development
CeNCOOS

Final Implementation
NOS C0-OPS*

CeNCOOS = Central and Northern California Ocean Observing System
NCCOS = National Centers for Coastal Ocean Science
CSDL = Coast Survey Development Lab
RSS = Remote Sensing Solutions, Inc.

WCOFS = West Coast Operational Forecast System
WCOSS = Weather and Climate Operational Supercomputing System
CO-OPS = Center for Operational Oceanographic Products & Services

S4: NOAA Weather Prediction Supercomputer at Univ. of Wisconsin

Prep Satellite data (CoastWatch)

Download NASA OC data

Extract Chl, 488, 555 bands and make daily composite

Collect 180 days band data

Run EOF for each band

3 netCDF3 files: Chl, r488, r555
- 180 days data
- 180 days filled data
- lat, lon, time
- land mask
- 2.5 GB each (7.5 GB total)

Downsample to ROMS resolution

netCDF4 file
- 180 days filled Chl, r488, r555
- lat, lon, time
- land mask
300 MB (150 MB compressed)

Time to run: 3 x EOFs = 2.5 – 5 hrs

Archive
Source data
DINEOF results

Collect ROMS data (CeNCOOS, S4)

netCDF4 file
- 180 days salt
- 180 days temp
- lat, lon, time
- 150 MB

Time to run
4 min / day

(CeNCOOS, S4)

Nowcast

Run models:
- Pseudo-nitzschia (Pn)
- particulate domoic acid (pda)
- cellular domoic acid (cda)

Time to run:
5 minutes

Pn, cda, pda netCDF4 files
- 180 days data
- lat, lon, time
- 100 MB each
Maps
Timeseries

Use in forecast script
(next slide)

Courtesy of CoastWatch West Coast

From Prep Satellite data
(last slide)

Forecast (CeNCOOS, S4)

Run advection model
using forecast u & v vectors

3-day ROMS forecast
- u and v currents

netCDF4 file
- 180 days filled Chl, r488, r555
- lat, lon, time
- land mask
300 MB (150 MB compressed)
From CoastWatch

Using advection model results
advect lastest filled Chl, 488, 555
forward 1, 2 & 3 days

Chl, r488, r555 .nc files
- 180 days filled data
  plus 3 advected days
- lat, lon, time
- land mask
- ROMS resolution
- 100 MB each

Run EOF on advected Chl, 488, 555
(using 180 days of filled data)

Same file as above except
- 3 advected days are filled
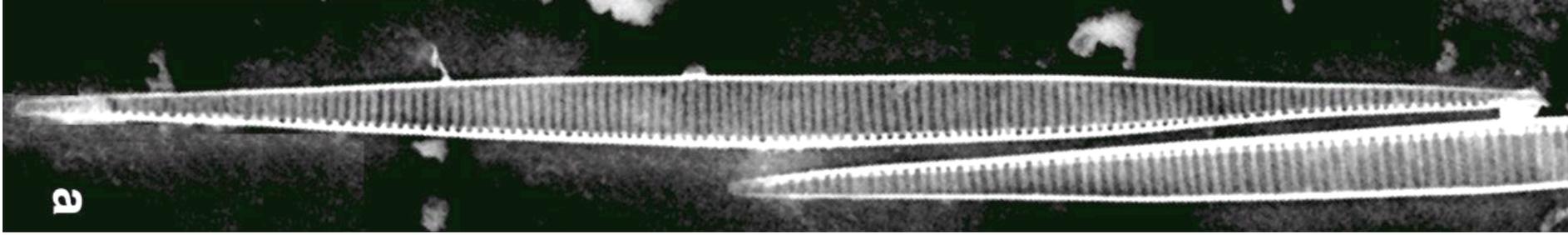
Last 180 day plus
3-day ROMS forecast
- salt,
- temp

Run pn, cda & pda models
with forecast data

Maps, timeseries

Pn, cda, pda netCDF4 files
- 3 days data
- lat, lon, time
- 2.5 MB each

Time to run total: 56 min
Adv. model: 10 min
Data advection & EOFs: 36 min
Pn, cda, pda models: 5 min

THANK YOU!

clrander@ucsc.edu

http://www.cencoos.org/data/models/habs

Upwelling Drives Abundance & Diversity

Smoothed Daily HU at 36N 122W from Jan 2014 to Nov 2015

Kendall Tau
p< 0.001
slope = 0.003

Kendall Tau
p = 0.016
slope = -0.001

Temp
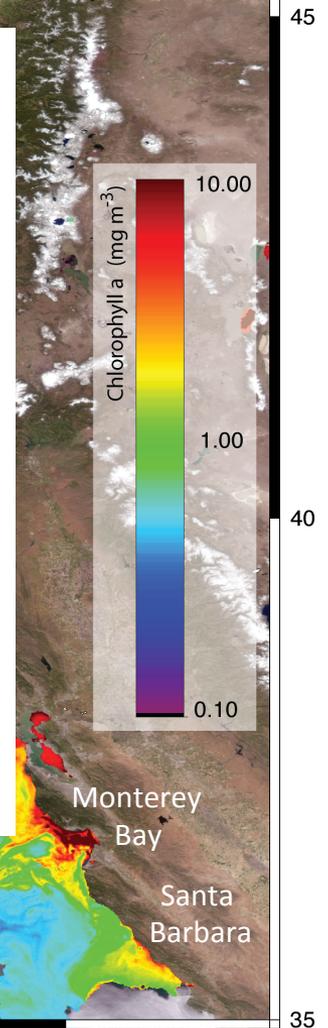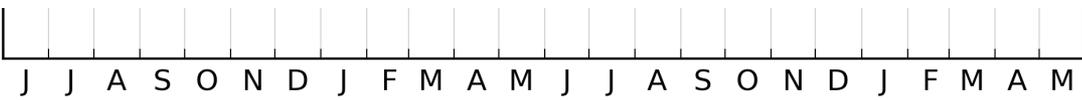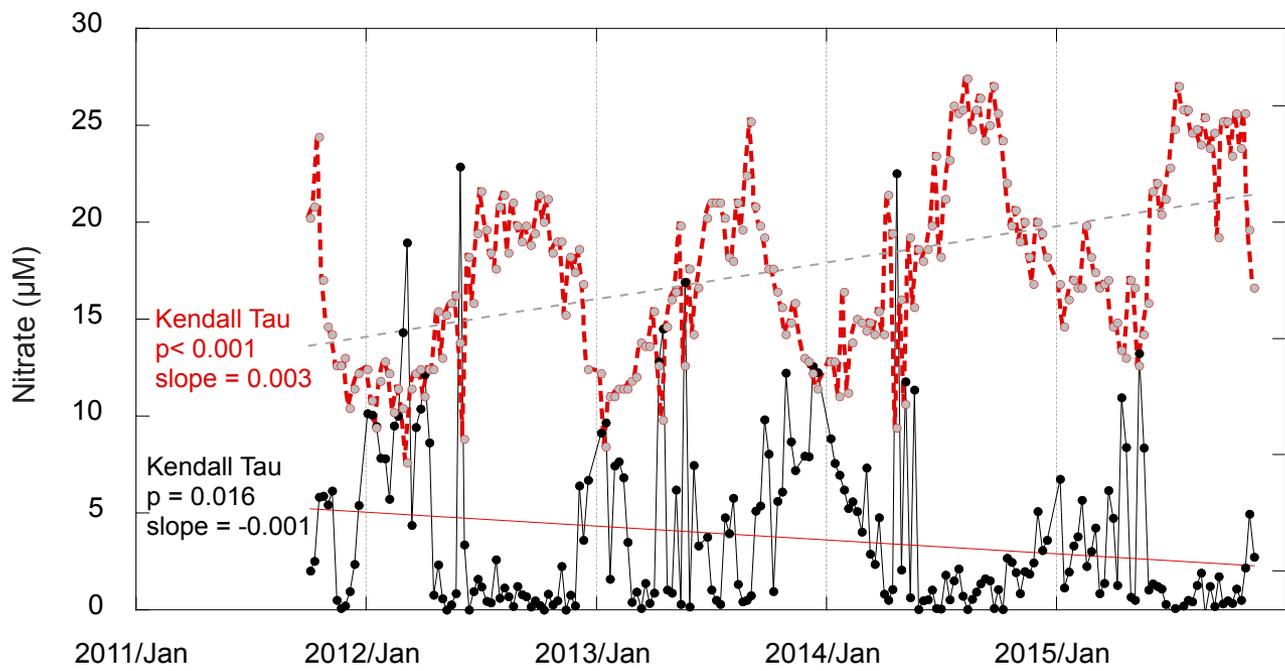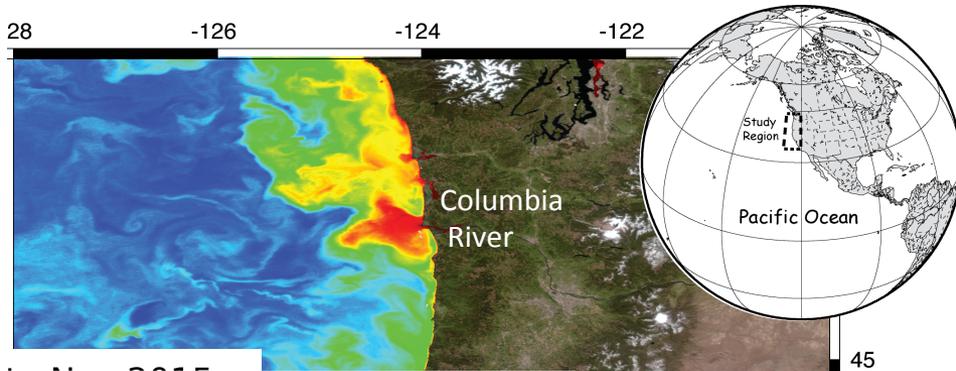
NOAA PFEL Upwelling Index

ECOHAB – *R/V Carson* Day Cruises (May 12 – June 5)
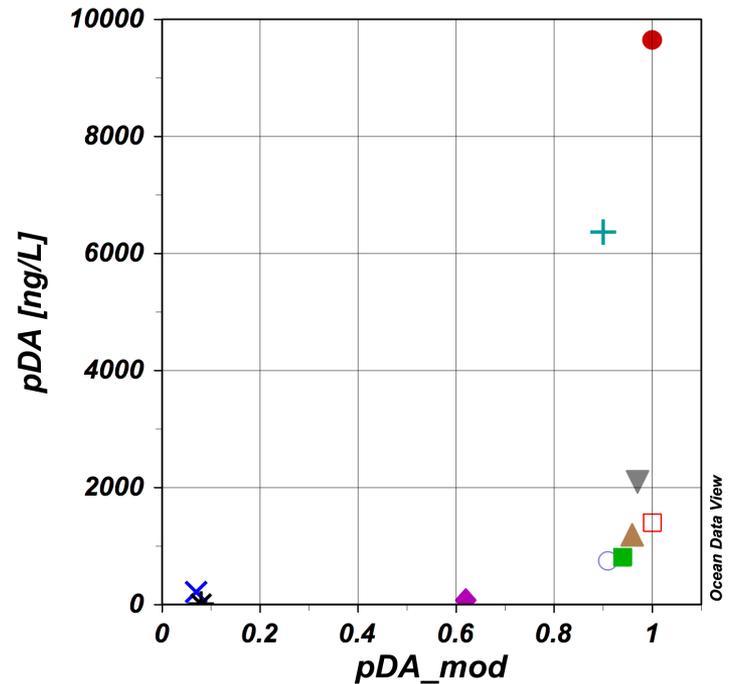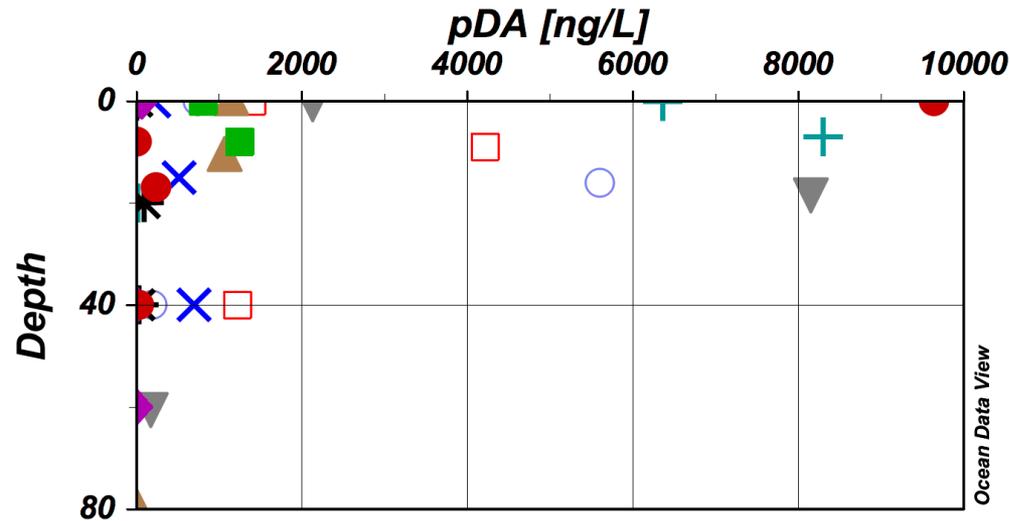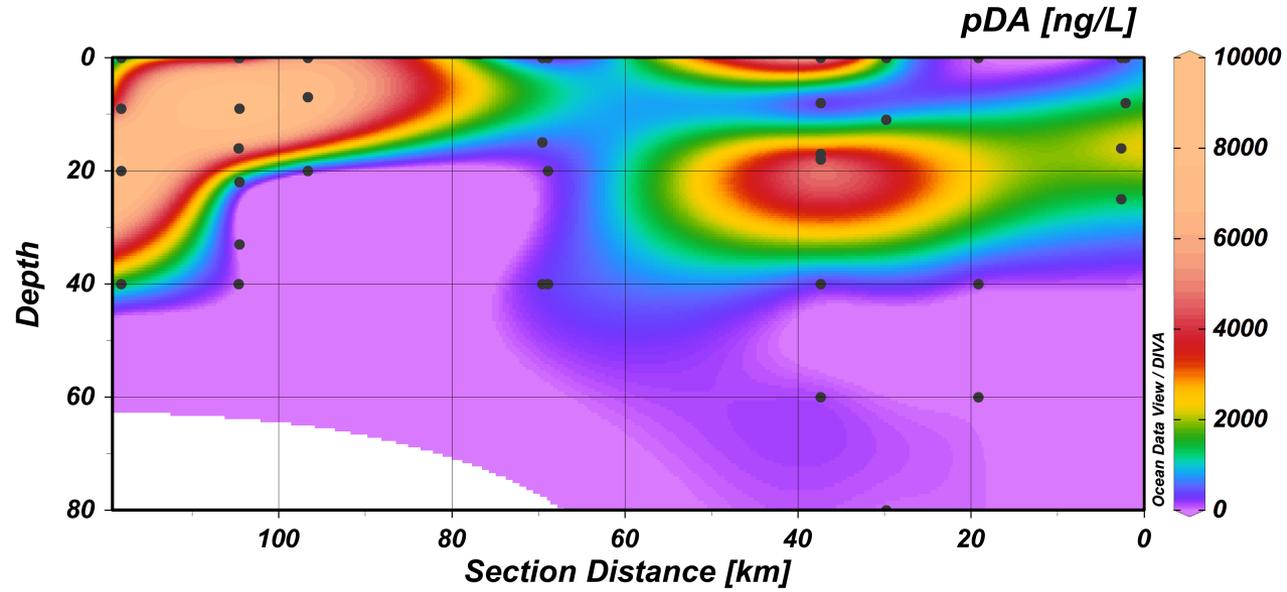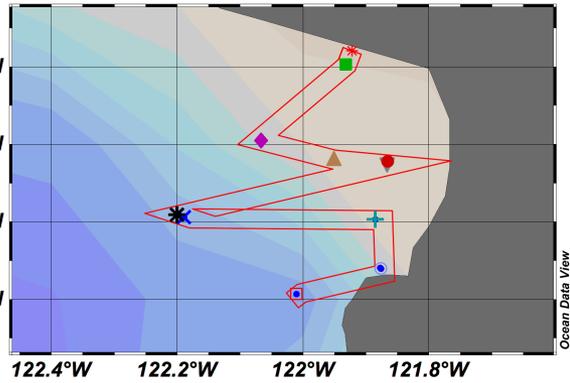
pDA FORECASTS @ SC WHARF (OCTOBER – NOVEMBER)
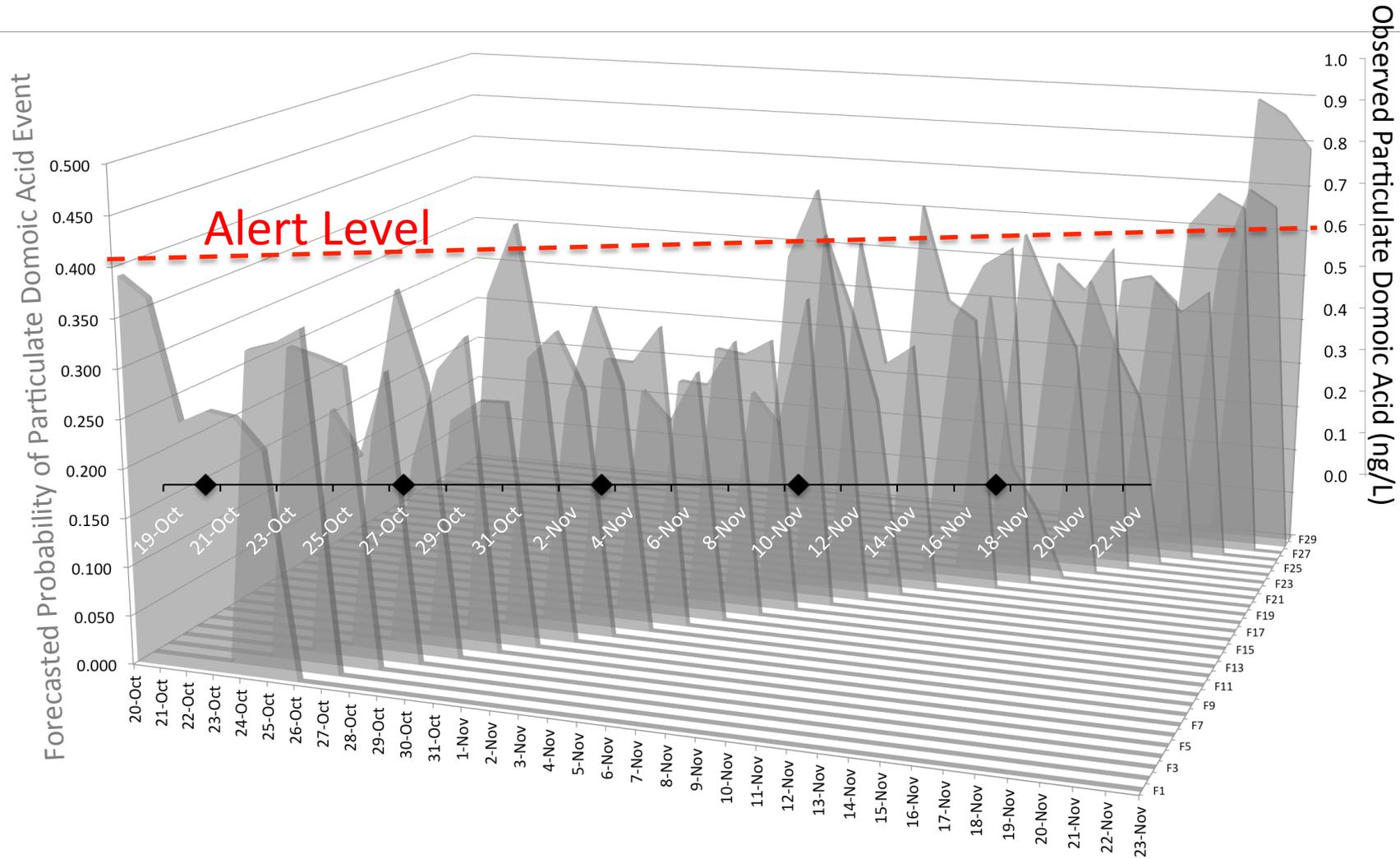
THE WARM BLOB

Bloom occurred along entire West coast simultaneously

Corresponded with Spring Transition and the coastward propagation of the Pacific Warm Anomaly ("blob")

Interaction of the blob with coastal upwelling appears to have created the DA event

Spring Transition
2015 GHRSST Anomaly
(mid-May minus mid-April)

Columbia River

San Francisco

Santa Barbara

SST Anomaly (°C)

2014-2016: From Bad to Worse? Will El Niño Save Us?

Temperature Anomalies at the M1 Mooring, Monterey Bay California

West Coast Event

**West Coast Events**

West Coast Event

No Toxicity

CA / OR Event
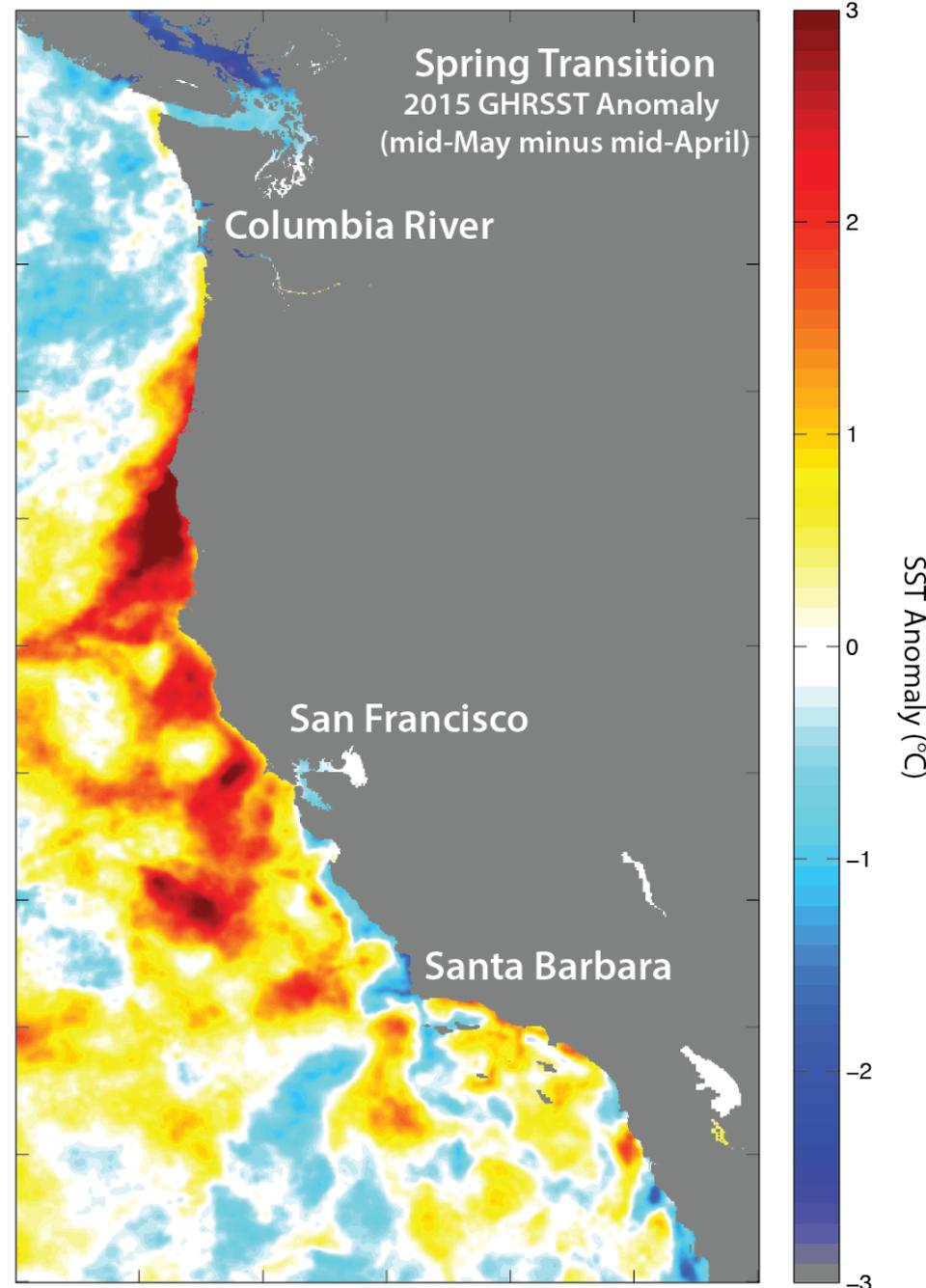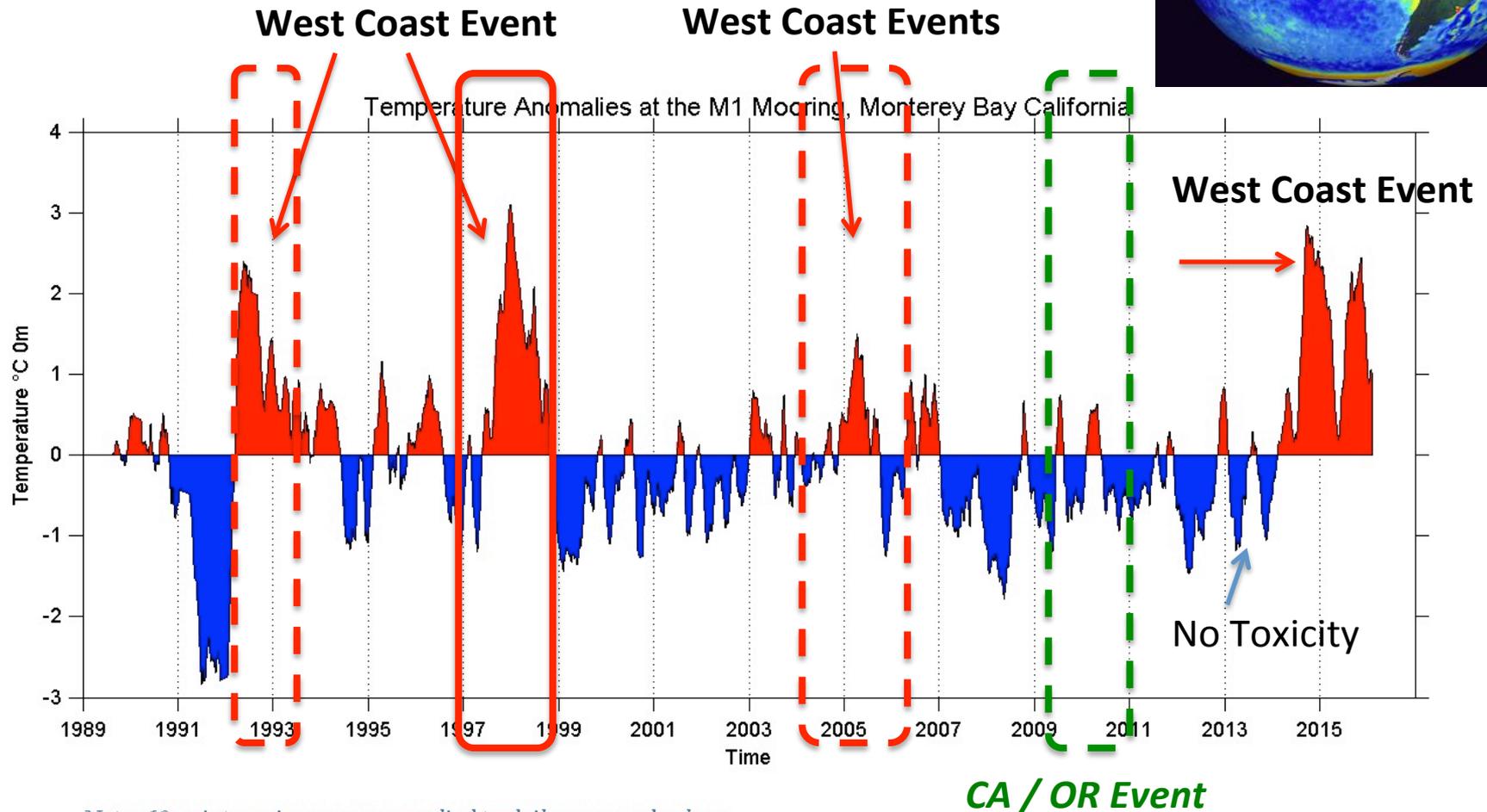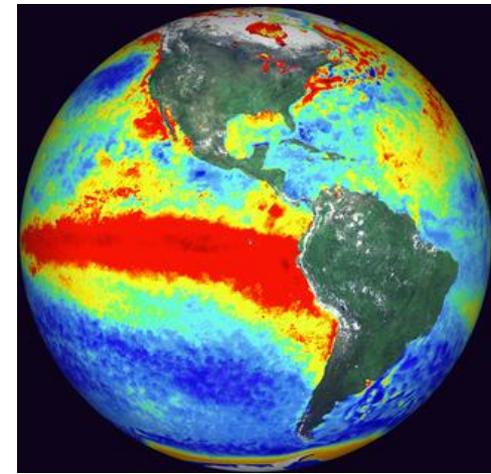
Note: 60 point moving average applied to daily averaged values.
Monterey Bay Aquarium Research Institute

Updated:10-Feb-2016

GLMs that use Rrs variables, Chlorophyll, Temperature, and Salinity *instead* of nutrient data

ROMS Simulations

Temp

Salinity

MODIS-Aqua Satellite Data

Chl, $R_{rs}(\lambda)$

Remote-Sensing HAB Model

Predicted HAB Probability
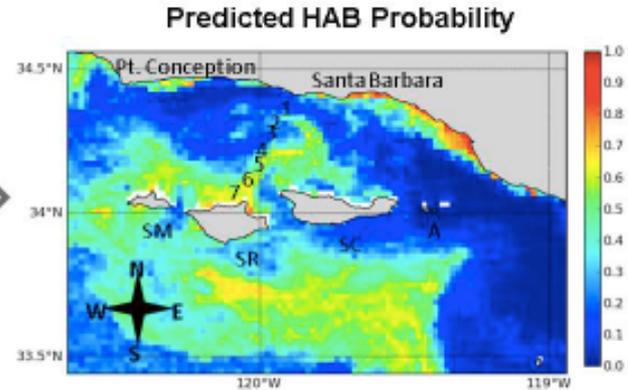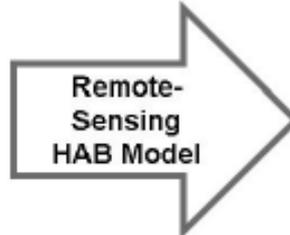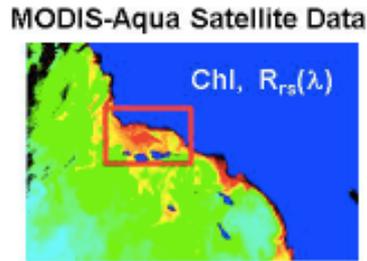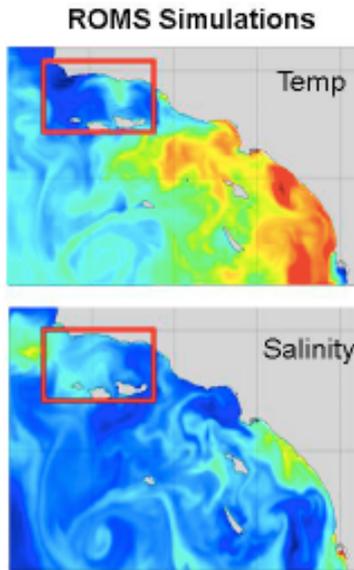
HAB Variable (Threshold)

Best-fit Logistic GLM - **RS**

$$P_{bloom} = e^{(logit)}/[e^{(logit)} + 1]$$

Pseudo-nitzschia
(10^4 cells mL^{-1})

(i)
logit = 8.54 - 10.84*[R_{rs} (510/555)] – 0.216*[Month] + 4.67*[R_{rs}(490/555)]

(ii)
logit = 5.32 – 2.87*[R_{rs} (490/555)] – 0.165*[Month]

pDA
(500 ng L^{-1})

logit = -134.3 + 0.253[Chl] + 4.0*[Sal] – 502*[R_{rs} (555)]

cDA
(10 pg cell^{-1})

logit = -90.0 - 0.35*[Temp] – 666*[R_{rs} (555)] + 2.87*[Sal]

Remote Sensing Reflectance
Salinity
Temperature
Chlorophyll

- - - - - - - - - - - -

Nitrate
Phosphate
Silicic Acid

Anderson et al. 2011, Detecting toxic diatom blooms from ocean color and a regional ocean model. Geophysical Research Letters L04603

**Year 1 FEASIBILITY STUDY - SKILL ASSESSMENT**
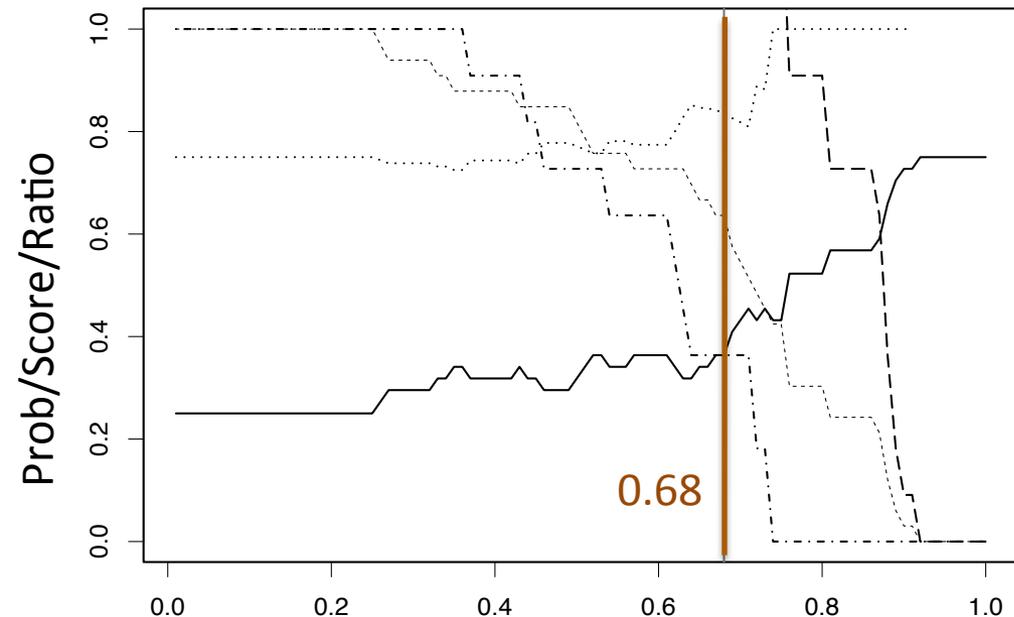
Contingency Plots to Assess Model Performance – Optimize Prob. Threshold

Pseudo-nitzschia at the SC Wharf *vs.* Nearest Model Pixel
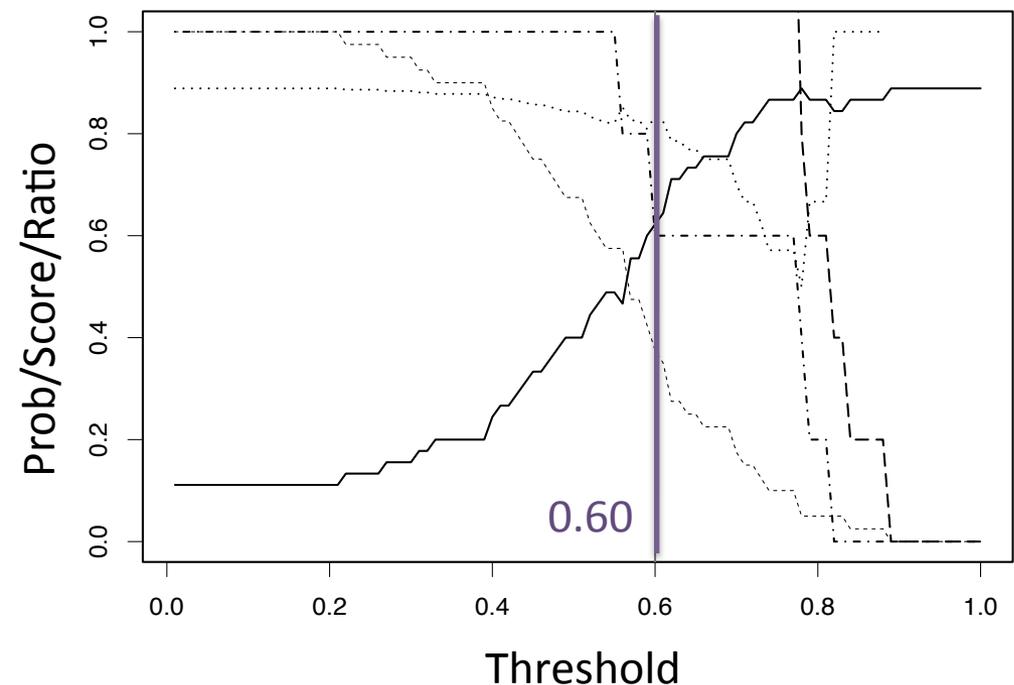
Domoic Acid at the SC Wharf *vs.* Nearest Model Pixel

Accuracy
POD
FAR
POFD
BS (bias score)

Anderson et al., revised, *Harmful Algae*
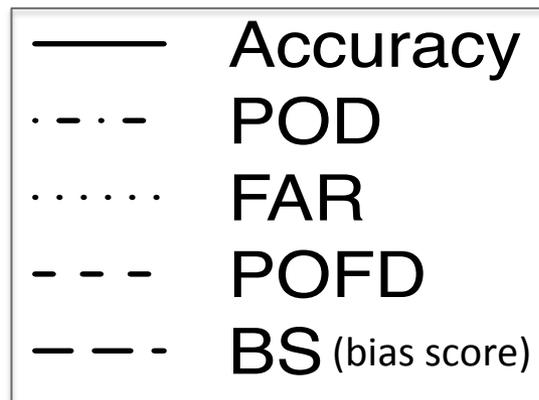
2015 BLOOM of DOOM
Dungeness Crab Closure!
Recreational and Commercial Harvests
(Nov-March)

Santa Cruz Sentinel
NEWS

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California's crab-season delay claims Christmas

By Aaron Kinney akinney@bayareanewsgroup.com

"The domoic acid Grinch took our Christmas crab!" said Phil DiGirolamo, owner of Phil's Fish Market, a popular spot for crab lovers in Moss Landing.

2014-2016: From Bad to Worse? Will El Niño Save Us?

2016-01-01 particulate domoic acid probability
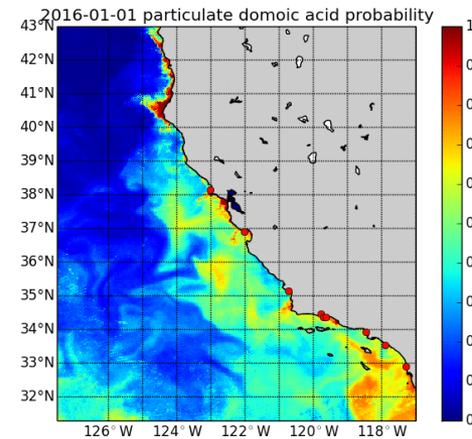
Toxins moving South to North in response to El Niño

Surface ISUS NO3 at the M1 Mooring (36.7N, -122W), Monterey Bay CA

2016 nitrate levels are again far below "normal"

NITRATE in MONTEREY BAY
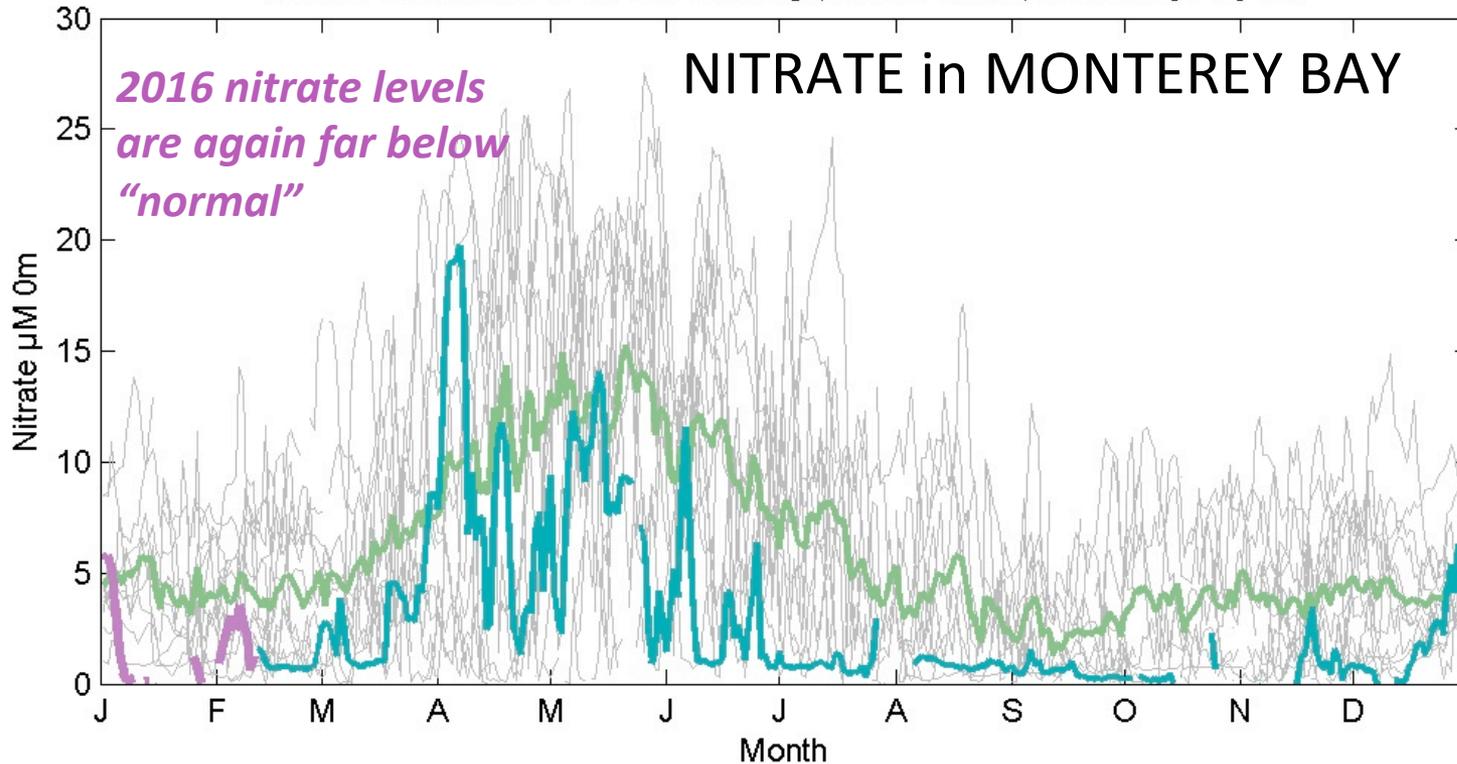
Legend:
- 2016
- 2015
- 2001-2015 Mean
- Previous Years

Climatology Minimum on 08-Mar-2010, 0.01uM; Maximum on 25-May-2013, 27.52uM
2016 YTD Minimum on Jan-15, 0.05667uM; Maximum on Jan-02, 5.78uM

Monterey Bay Aquarium Research Institute: http://www.mbari.org
Contact: reikc[at]mbari.org

Updated: Feb 10, 2016 06:58