

# The California Harmful Algae Risk Mapping (C-HARM) System: *Harmful algal bloom warning system for fisheries and ecosystem management*

IOOS | Integrated Ocean Observing System

Search

CeNCOOS

DATA

LEARN

ABOUT

COMMUNITY

C-HARM Model

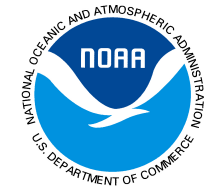
Home > Data > Technologies > Models

LATEST CONDITIONS

FORECAST CONDITIONS

PREVIOUS CONDITIONS

Clarissa Anderson<sup>1</sup>, Raphael Kudela<sup>2</sup>, Fred Bahr<sup>3</sup>, Dave Anderson<sup>3</sup>,  
Yi Chao<sup>4</sup>, Dale Robinson<sup>5</sup>, and Richard Stumpf<sup>6</sup>



<sup>1</sup>Southern California Coastal Ocean Observing System (SCCOOS)

<sup>2</sup>University of California, Santa Cruz

<sup>3</sup>Central & Northern California Ocean Observing System (CeNCOOS)

<sup>4</sup>UCLA JIFRESSE/RSS Inc.

<sup>5</sup>NOAA CoastWatch

<sup>6</sup>NOAA National Ocean Service

**PICES-2016  
OMNI Hotel  
San Diego, CA**

# Need for A Predictive Capability

- Domoic Acid from the diatom *Pseudo-nitzschia* is a serious health and ecosystem risk– and is identified as the leading HAB issue on the US West Coast. *Lewitus et al. 2012*

*(apologies for not being here yesterday!)*

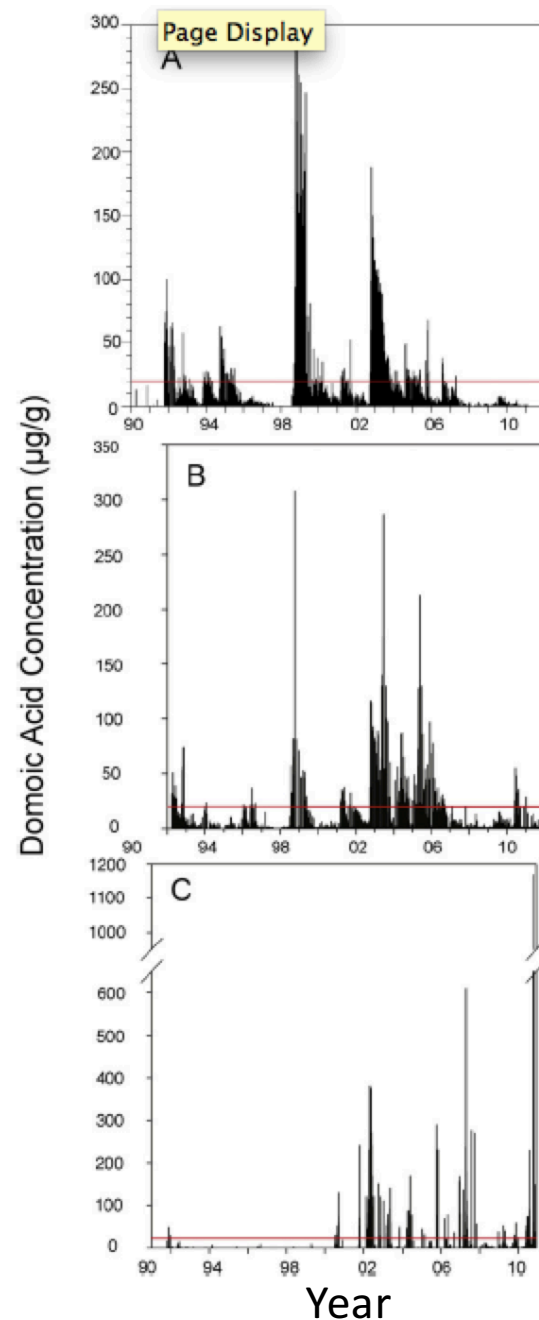
- While not always linked to water quality, there is evidence that toxicity responds to anthropogenic nutrients  
*Anderson et al. 2008; Howard et al. 2007; Kudela et al. 2008; Kudela et al. 2010*

- Despite the wealth of research programs that directly and indirectly interface with HAB issues in California, **there is no predictive capability for HAB events**



## INITIAL BASELINE FOR DECISION MAKING

- Monitoring in real-time at low spatial resolution
- Relies primarily on the presence of toxin in shellfish and fixed quarantine periods



# Empirical Habitat Models

Lane et al. (2009)

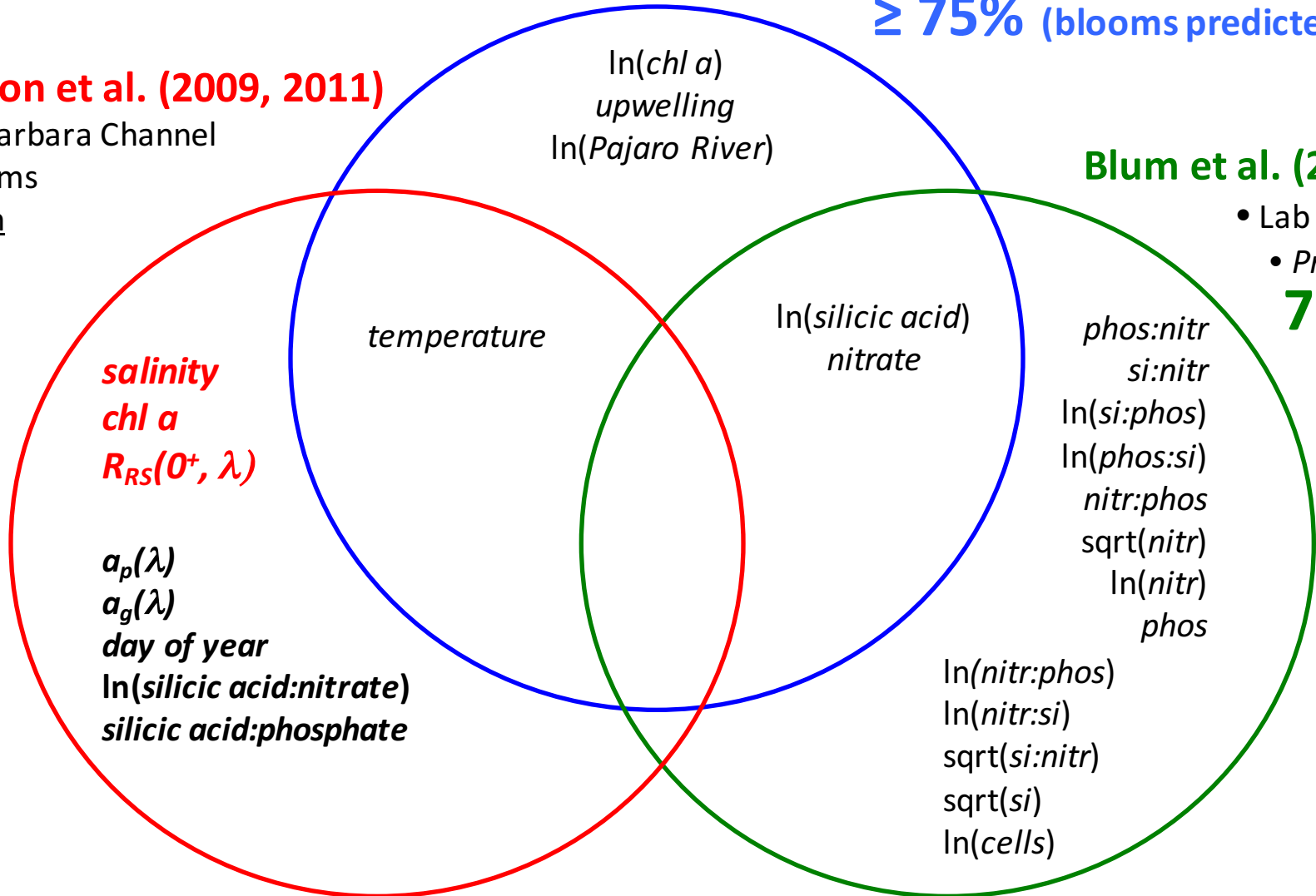
- Monterey Bay; toxigenic *Pn* blooms

≥ 75% (blooms predicted)

Anderson et al. (2009, 2011)

- Santa Barbara Channel
- *Pn* blooms
- *Pn* toxin

75%

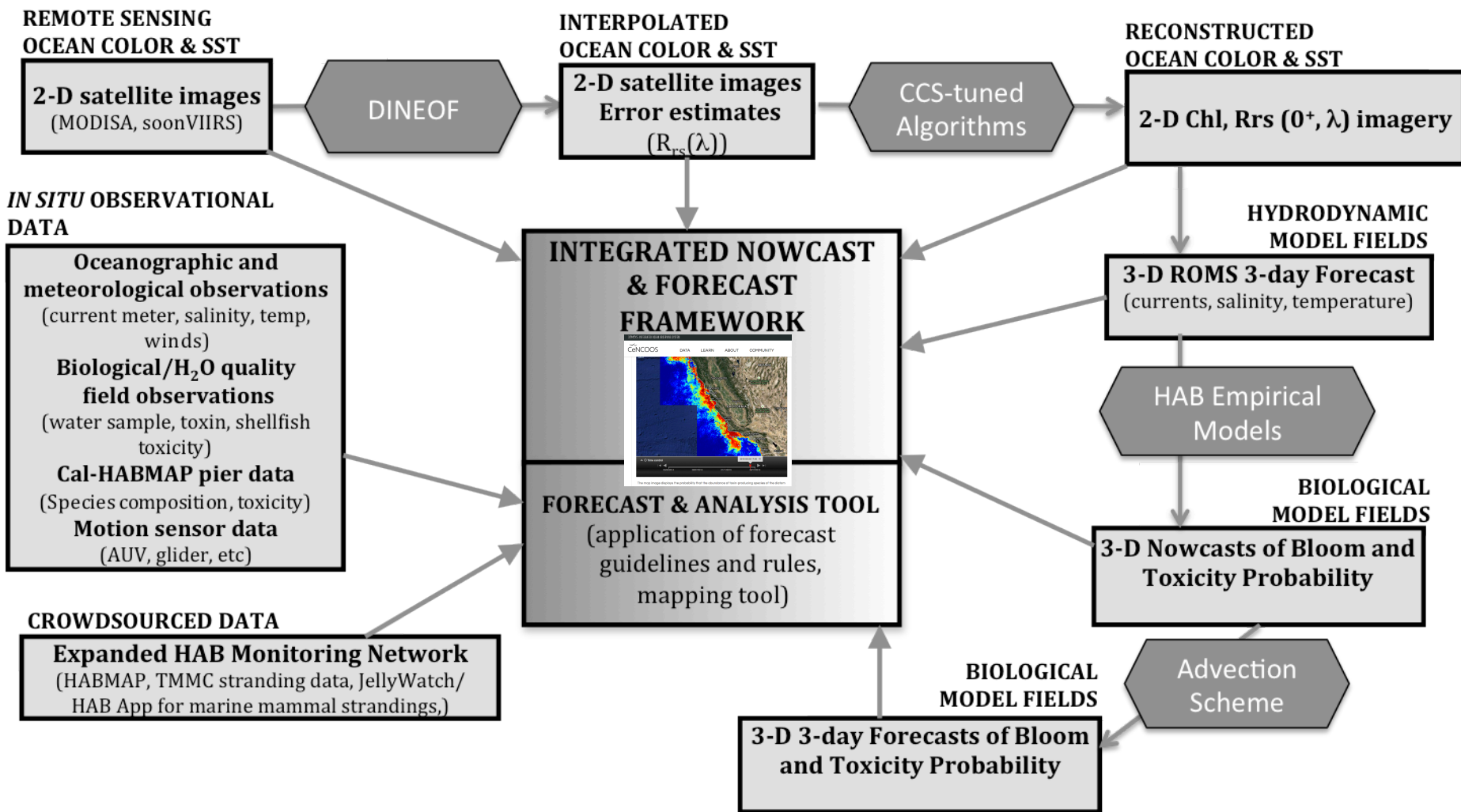


Blum et al. (2006)

- Lab + field
- *Pn* toxin

77%

# C-HARM SYSTEM FOR *PN* BLOOMS & DOMOIC ACID EVENTS



NASA Applied Sciences Program, Terrestrial Hydrology, Ocean Biology and Biogeochemistry Programs  
 “Ecological Forecasting for Conservation and Resource Management”  
 “Remote Sensing of Water Quality”

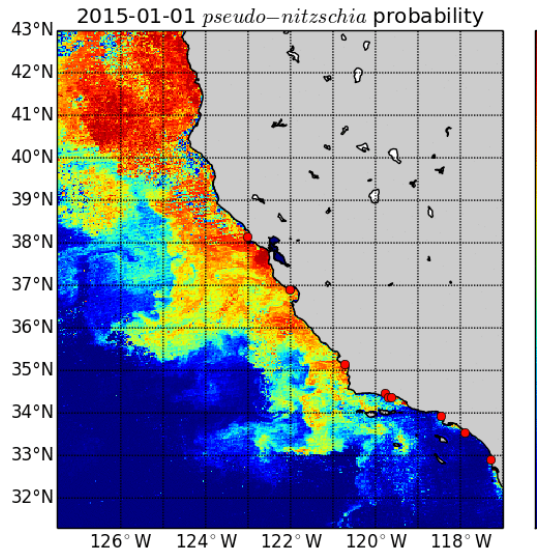


# Interactive CeNCOOS Data Portal

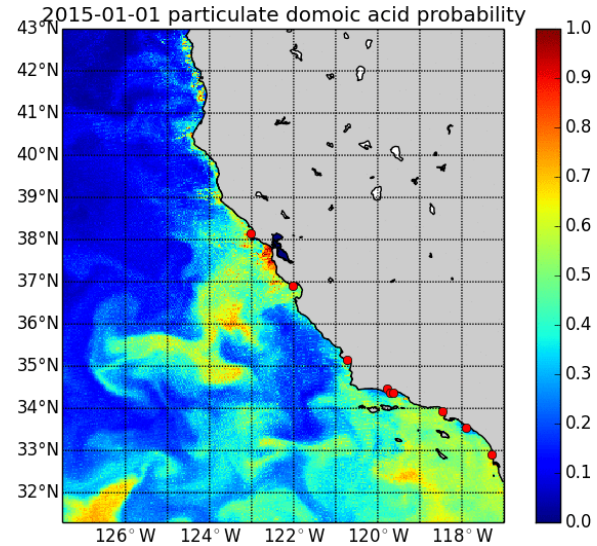
## C-HARM Nowcasts and 3-day Forecasts

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

Probability  
Maps

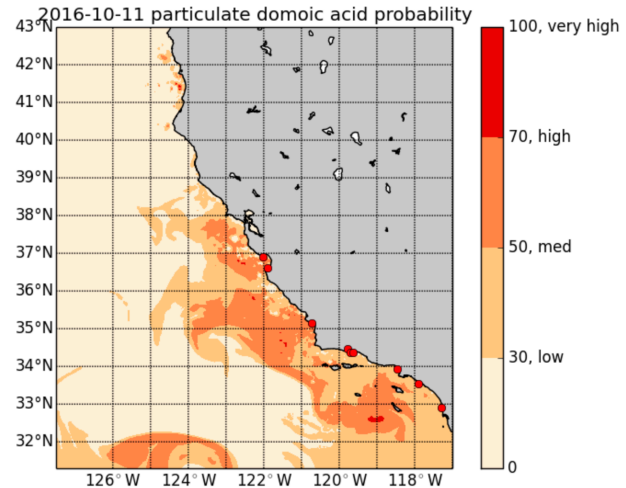
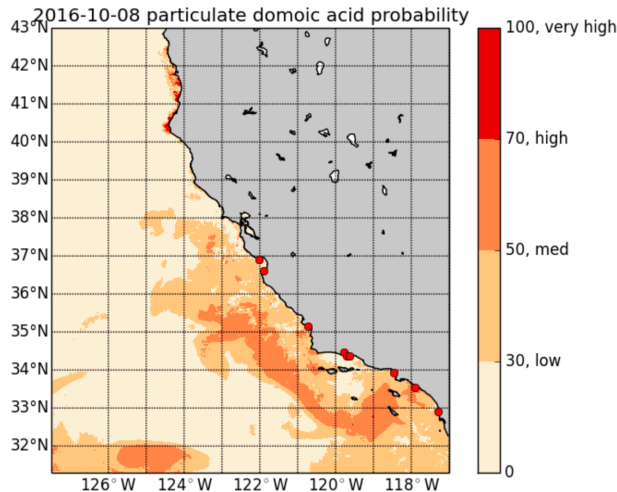


Particulate Domoic Acid Nowcast



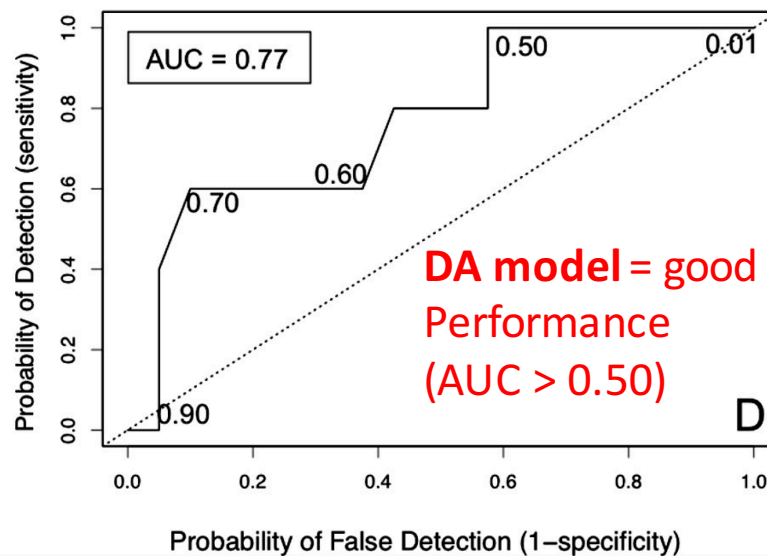
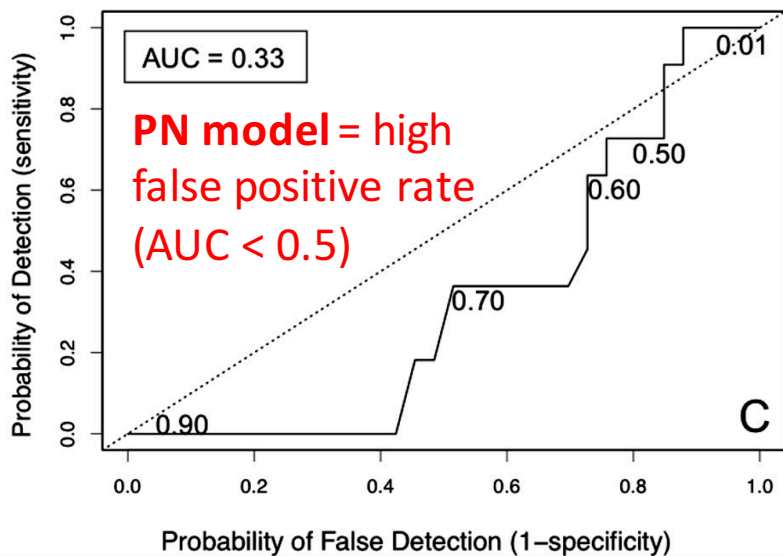
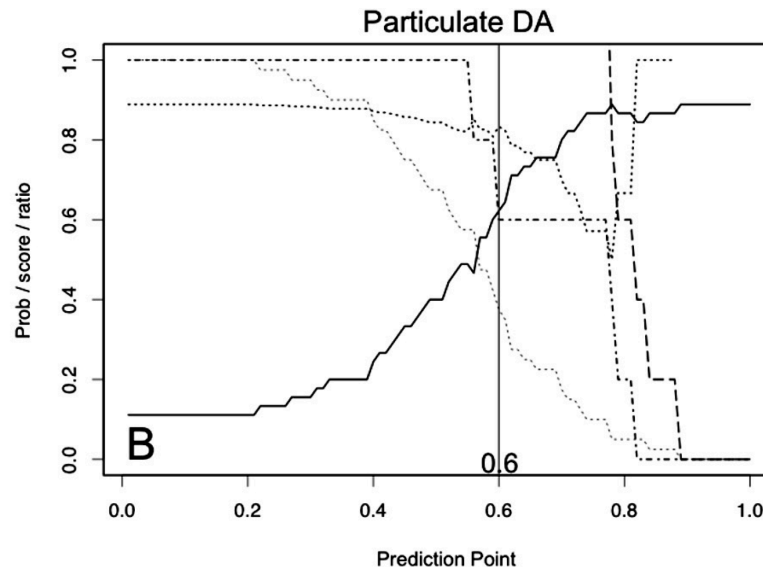
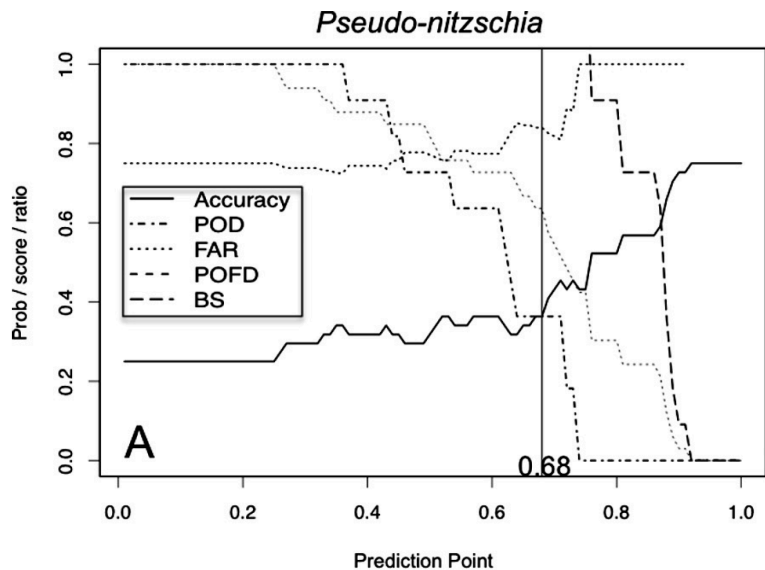
Particulate Domoic Acid Forecast

Risk Maps



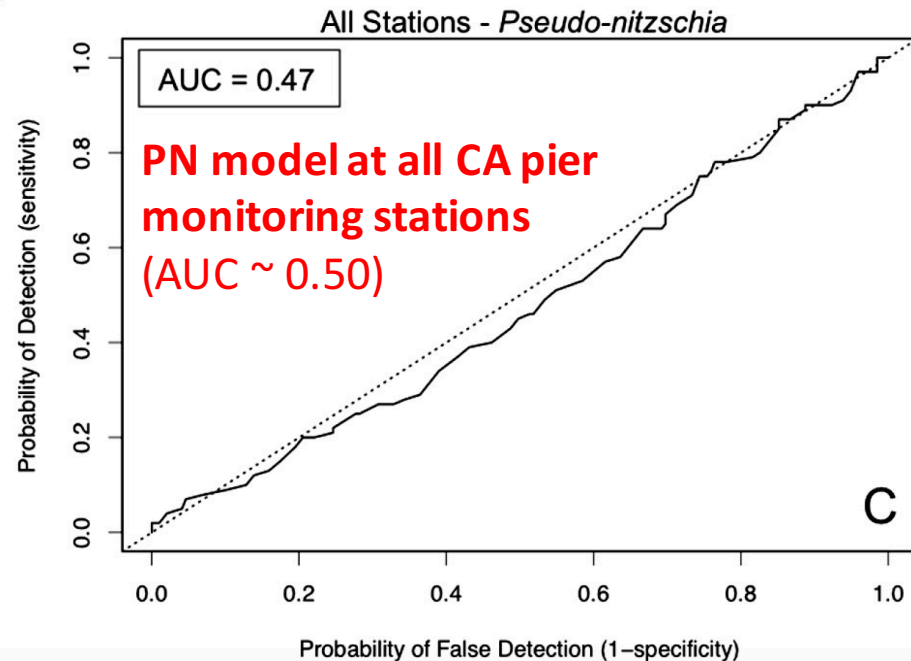
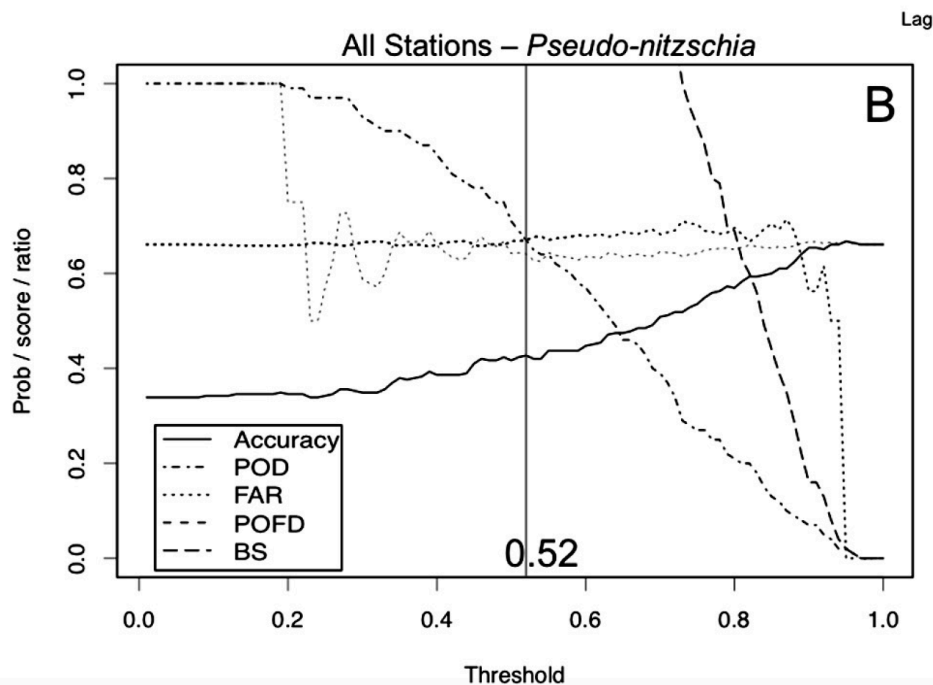
# 2014 FEASIBILITY STUDY - SKILL ASSESSMENT

Contingency Plots to Assess Model Performance - Optimize Prob. Threshold



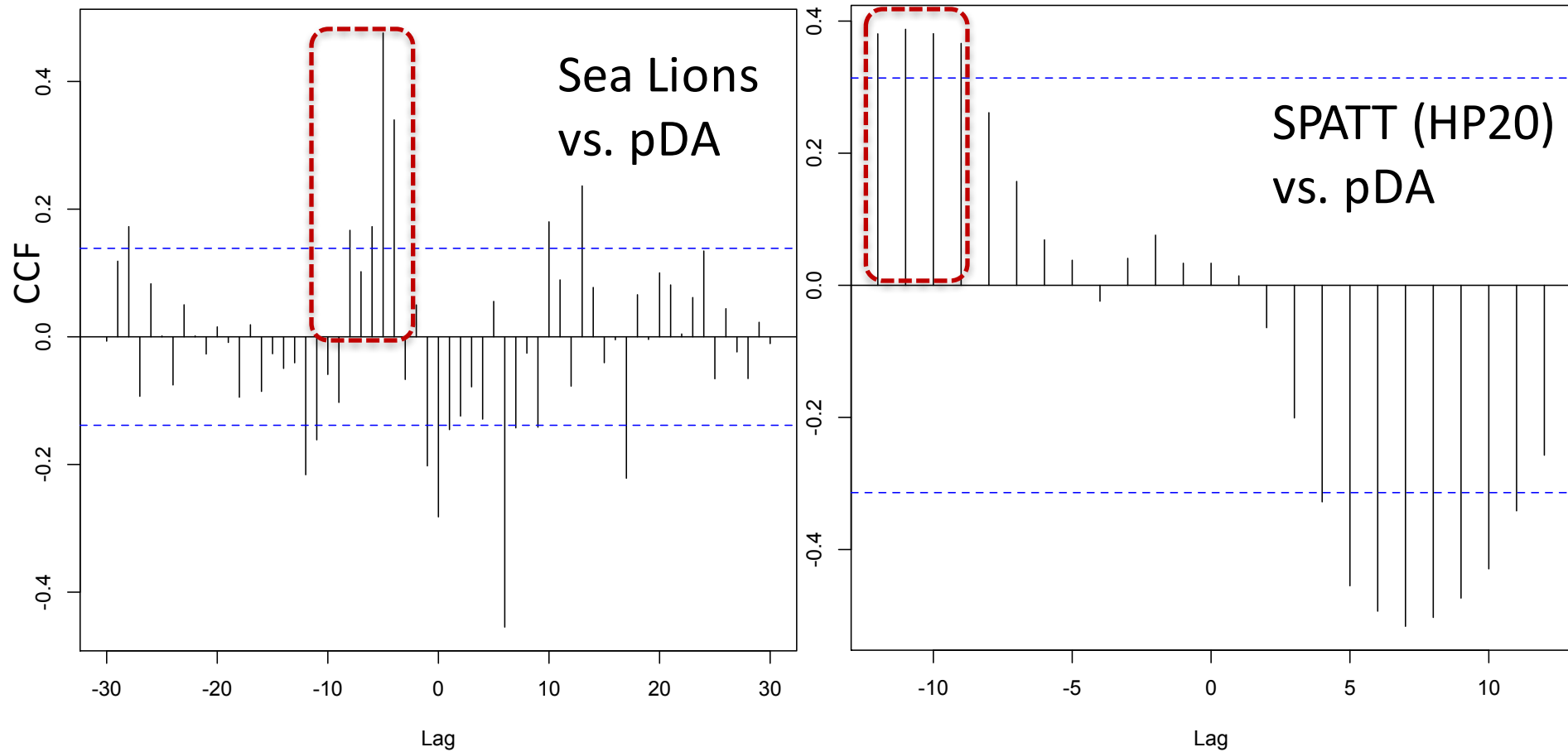
# 2014 FEASIBILITY STUDY - SKILL ASSESSMENT

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# 2014 FEASIBILITY STUDY - SKILL ASSESSMENT

The pDA model correlates well with central CA stranding peaks as early as 7 days before they occur...and with SPATT DA 9-12 days ahead



Cross correlation functions for the nearest **pixel corresponding with Santa Cruz Municipal Wharf**. ARIMA was applied to time series prior to analysis to account for non-stationarity.



RESEARCH LETTER

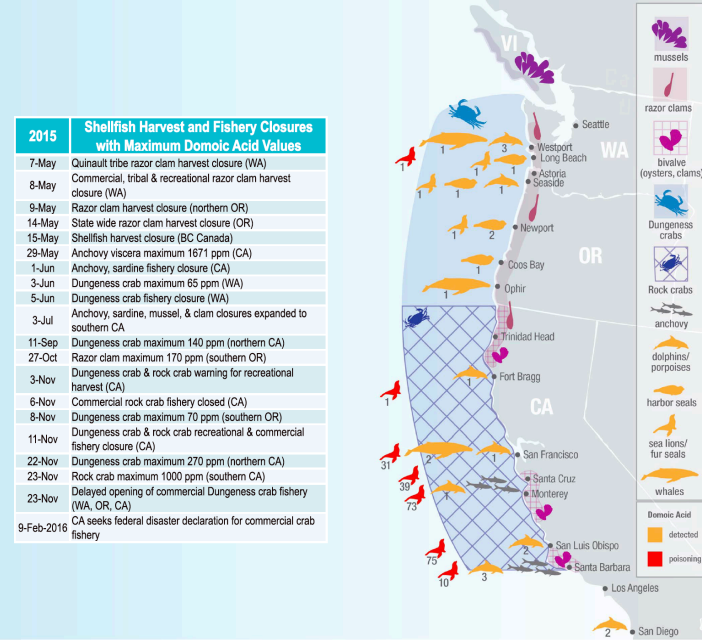
10.1002/2016GL070023

Special Section:

Midlatitude Marine Heatwaves: Forcing and Impacts

An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

Ryan M. McCabe<sup>1</sup>, Barbara M. Hickey<sup>2</sup>, Raphael M. Kudela<sup>3</sup>, Kathi A. Lefebvre<sup>4</sup>, Nicolaus G. Adams<sup>4</sup>, Brian D. Bill<sup>4</sup>, Frances M. D. Gulland<sup>5</sup>, Richard E. Thomson<sup>6</sup>, William P. Cochlan<sup>7</sup>, and Vera L. Trainer<sup>4</sup>

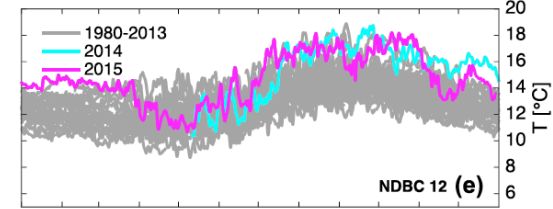
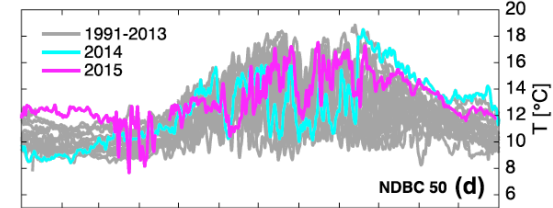
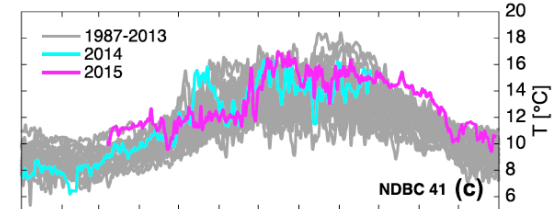
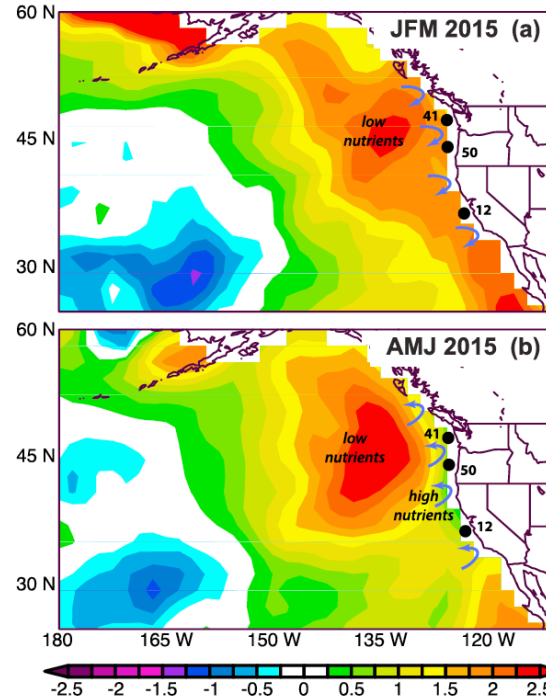


Important Ecosystem Impacts in CA in 2015-2016:

- 1) Marine mammal UME
- 2) Dungeness & Rock Crab fishery closed for entire season at many sites (\$48.7M in direct losses)

Conditions leading to this *Pseudo-nitzschia* bloom were outside the statistical envelope for C-HARM

Good test case!



Month: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec





## RESEARCH LETTER

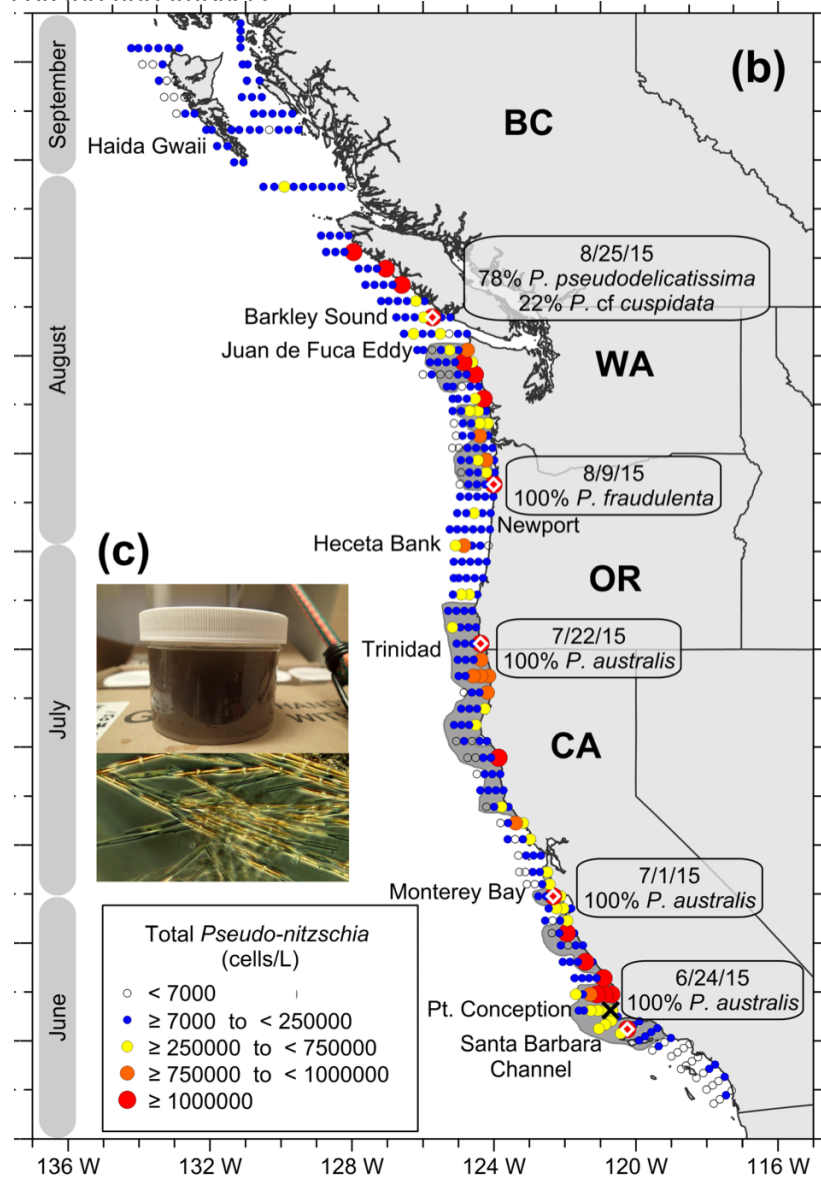
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# An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

### Special Section:

Midlatitude Marine Heatwaves: Forcing and Impacts

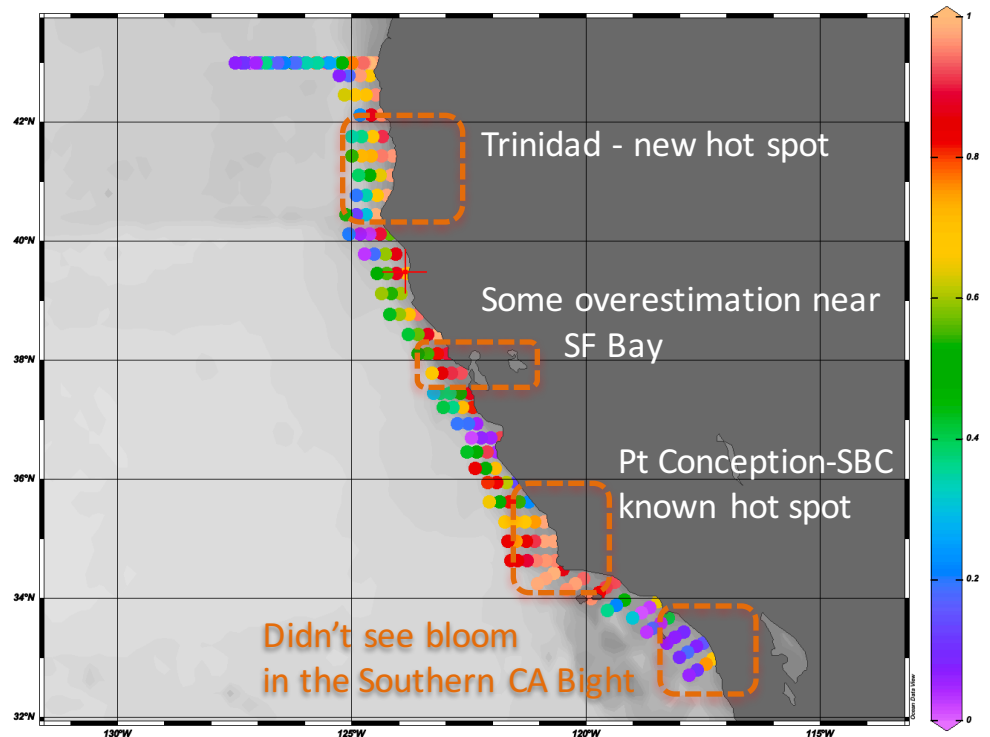
Ryan M. McCabe<sup>1</sup>, Barbara M. Hickey<sup>2</sup>, Raphael M. Kudela<sup>3</sup>, Kathi A. Lefebvre<sup>4</sup>, Nicolaus G. Adams<sup>4</sup>, Brian D. Bill<sup>4</sup>, Frances M. D. Gulland<sup>5</sup>, Richard E. Thomson<sup>6</sup>, William P. Cochlan<sup>7</sup>, and Vera L. Trainer<sup>4</sup>



*R/V Shimada* NMFS Cruise-of-Opportunity

## C-HARM ESTIMATES AT CRUISE STATIONS

Likelihood of a *Pseudo-nitzschia* bloom







## RESEARCH LETTER

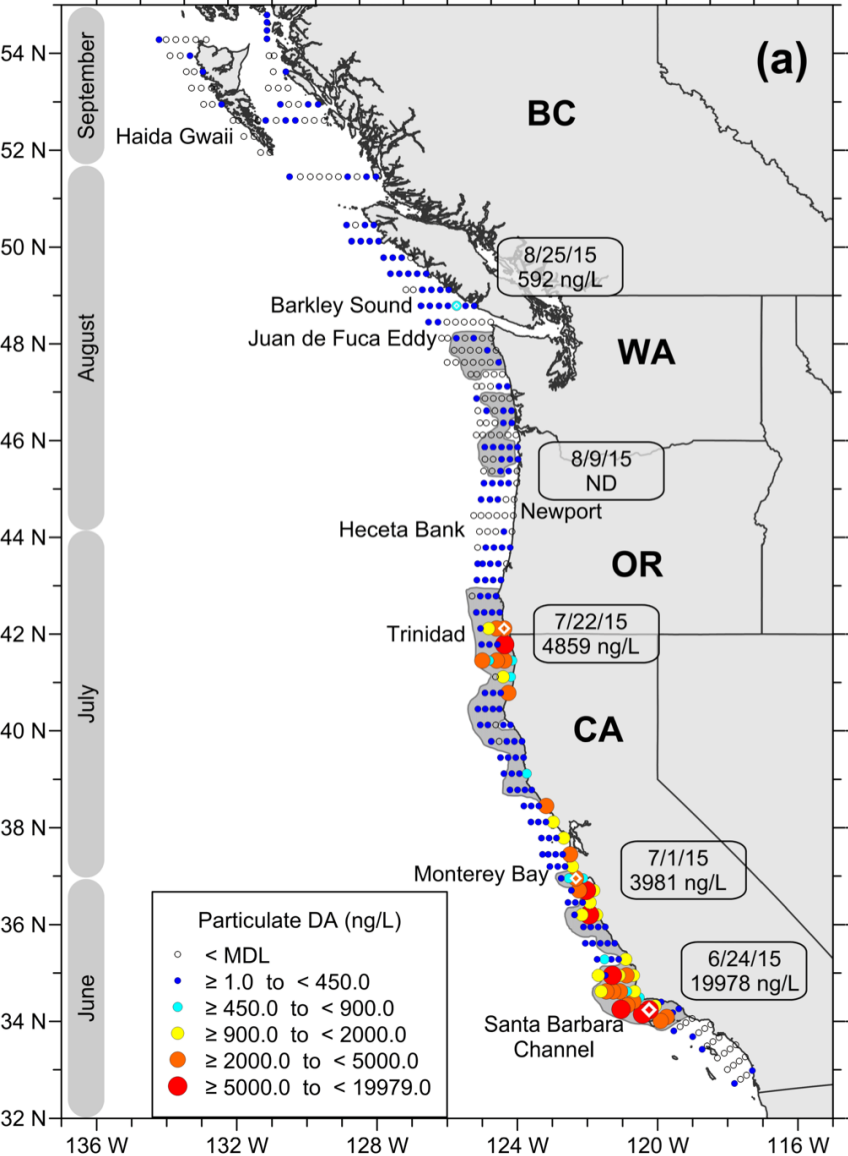
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# An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

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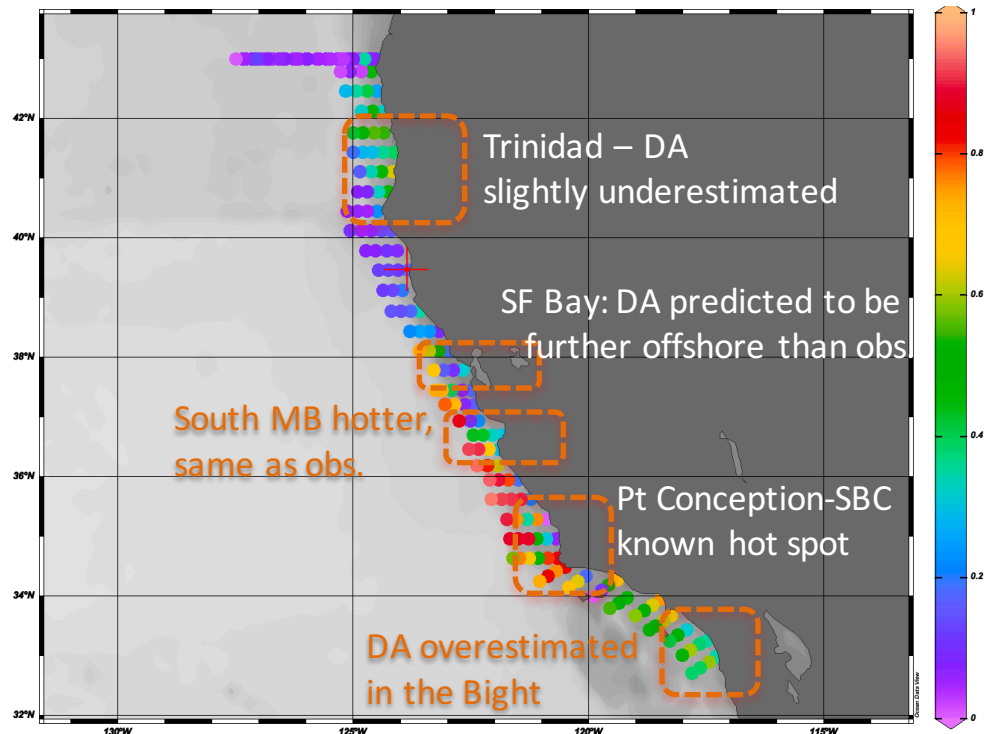


*R/V Shimada* NMFS Cruise-of-Opportunity

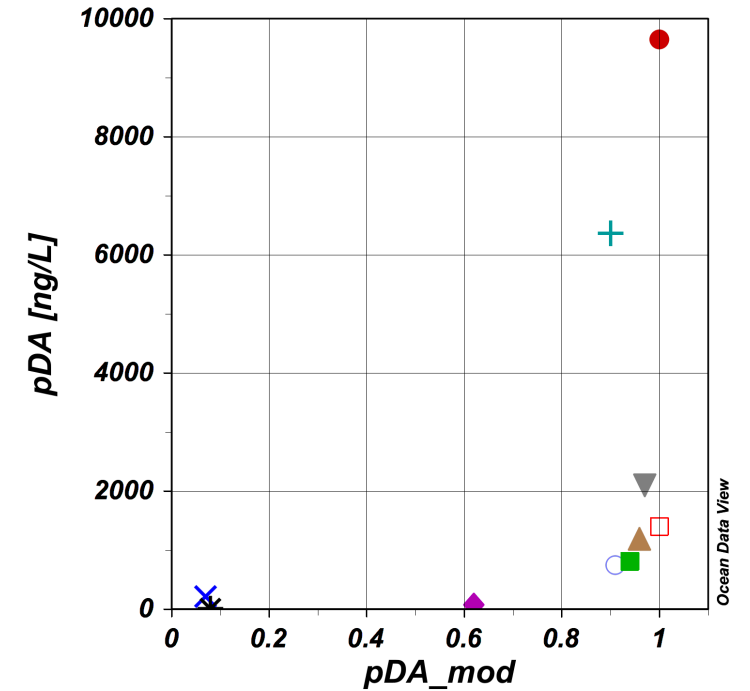
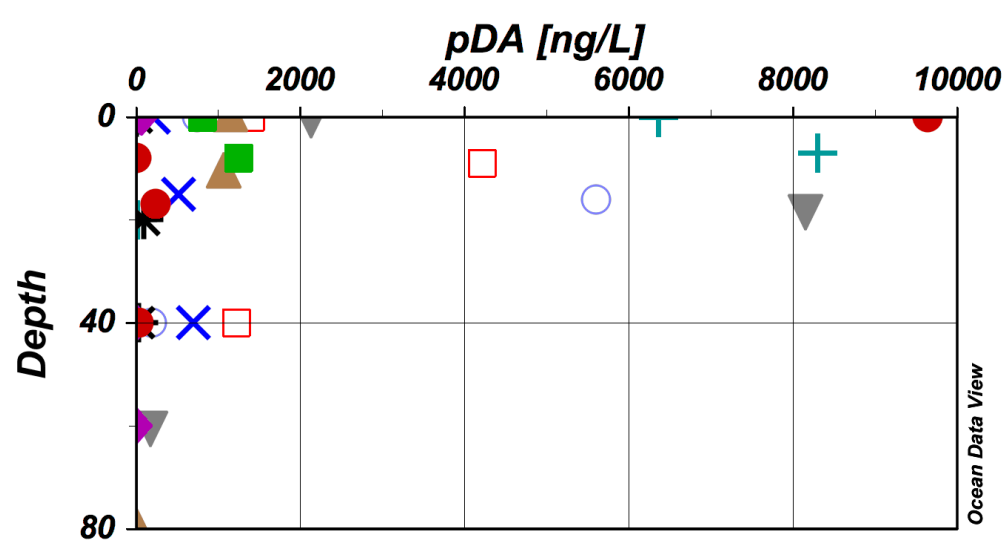
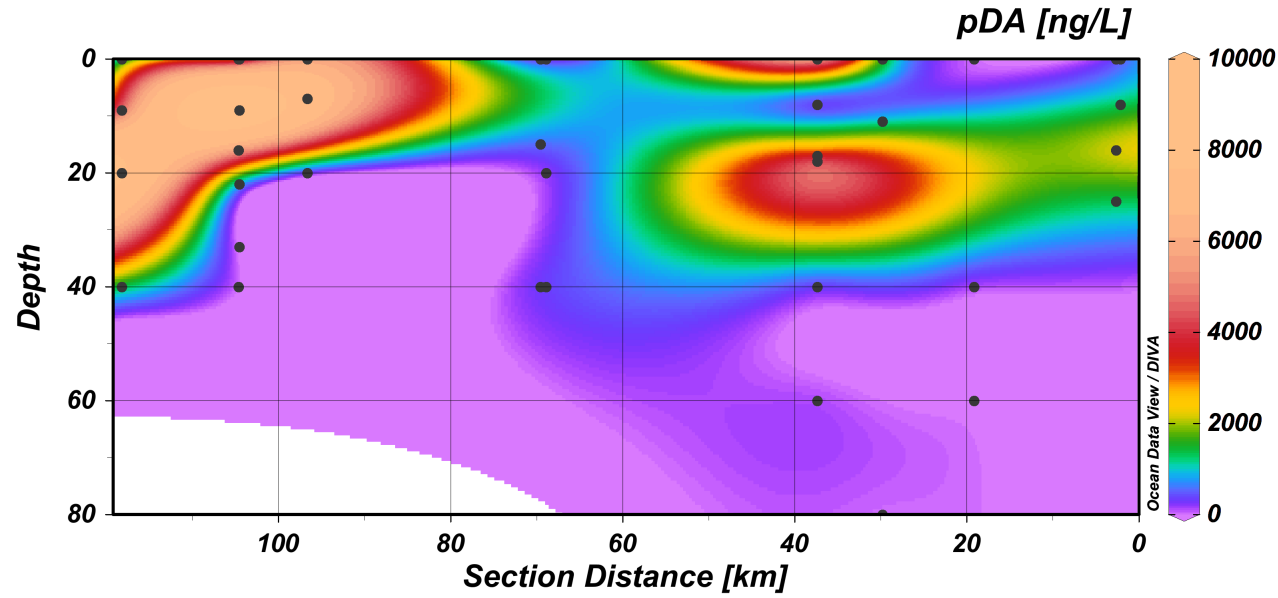
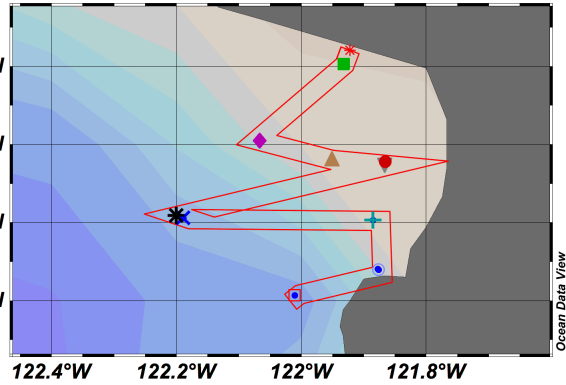
## C-HARM ESTIMATES AT CRUISE STATIONS

Likelihood of elevated DA Levels

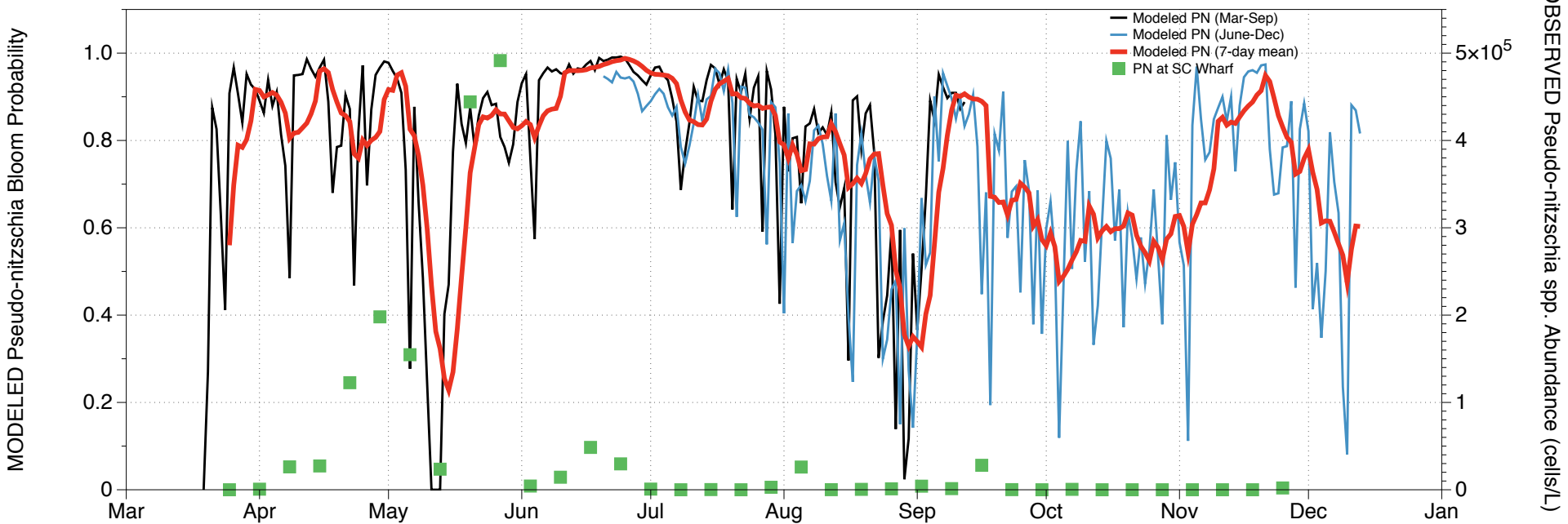
71% Accuracy, 20% False Positives



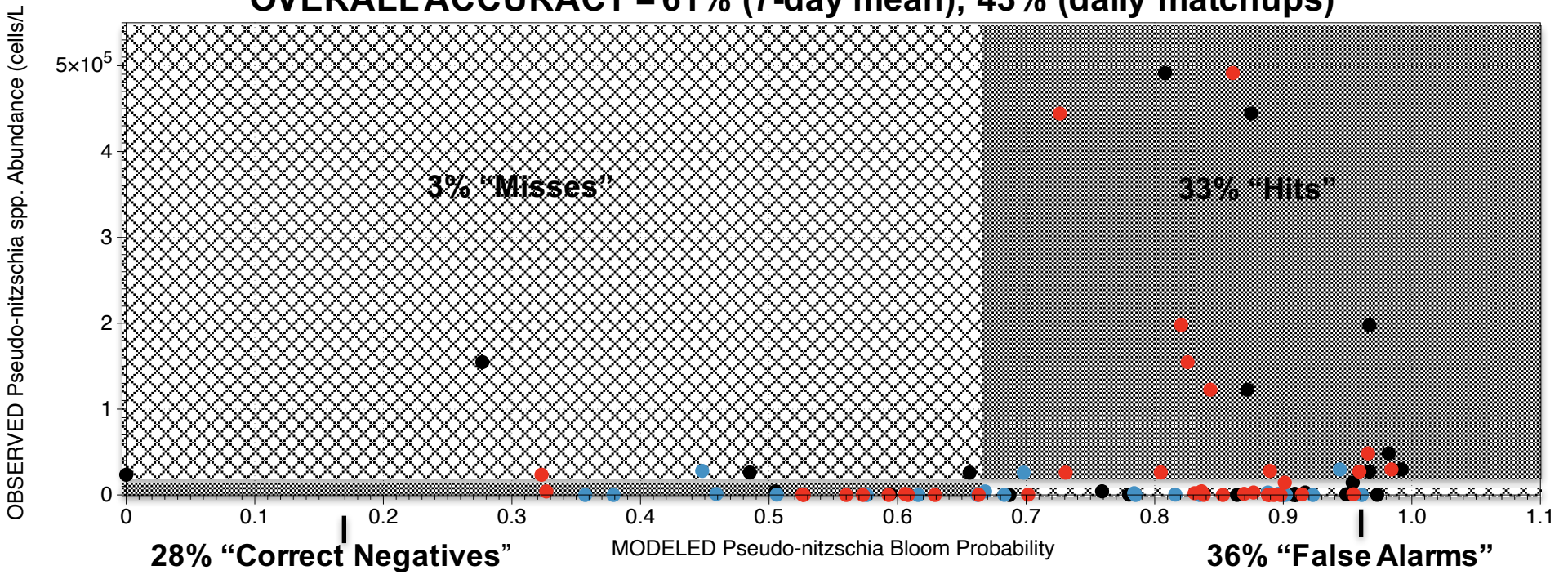
# ECO HAB – R/V Carson Day Cruises (May 12 – June 5)



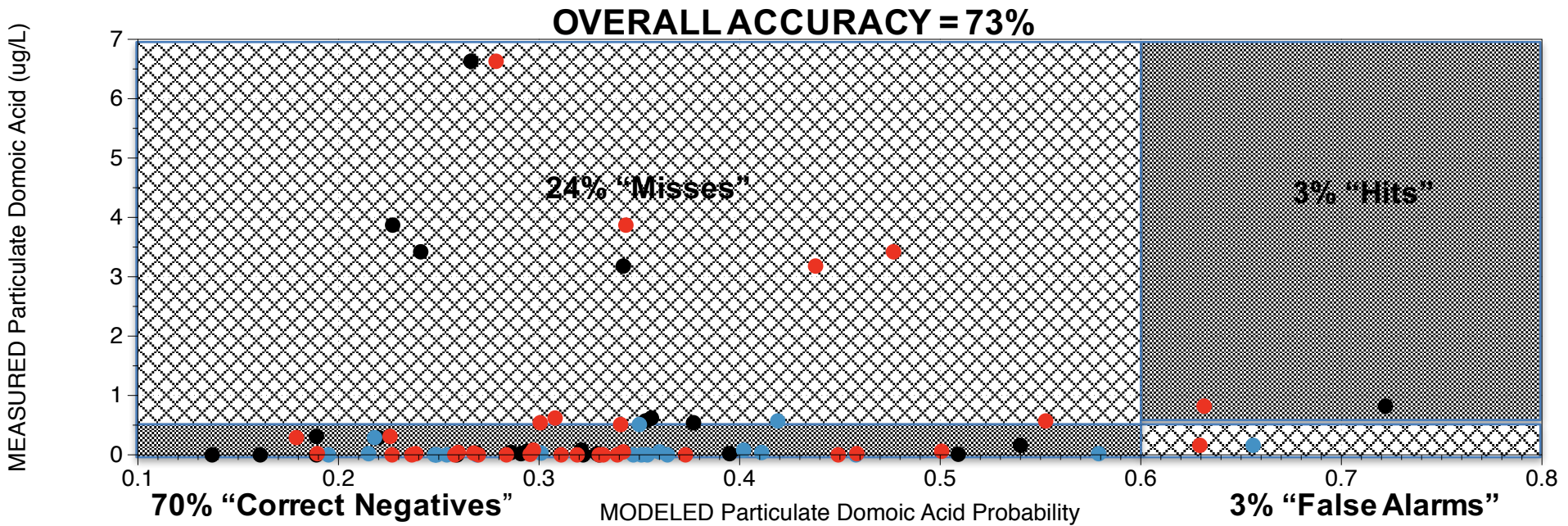
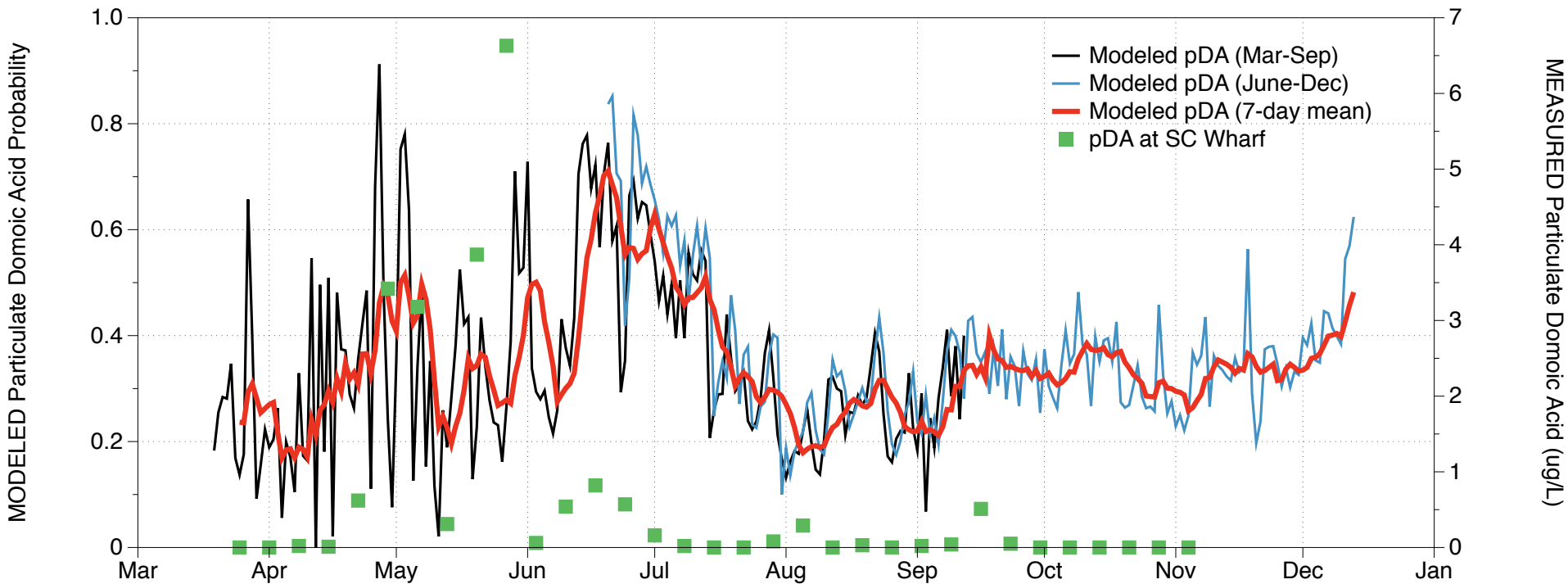
# 2015 – *Pseudo-nitzschia* – Santa Cruz WHARF



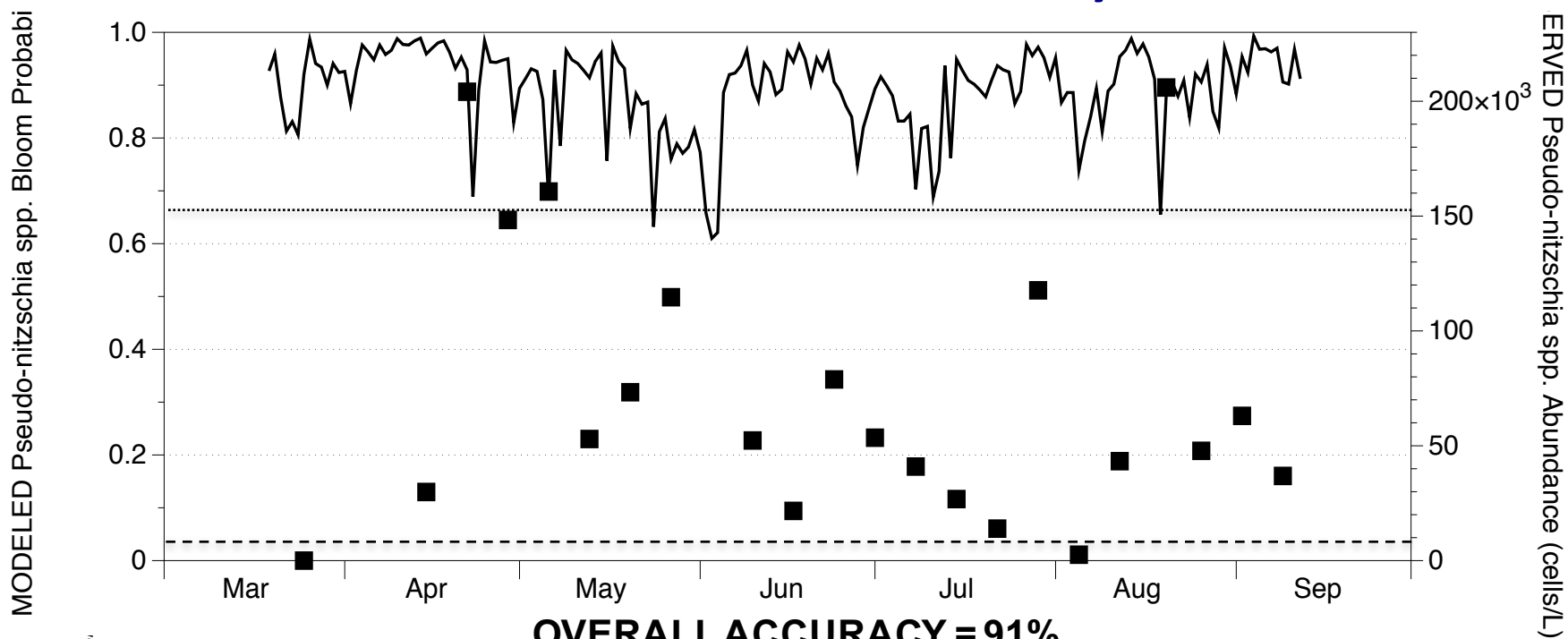
**OVERALL ACCURACY = 61% (7-day mean); 43% (daily matchups)**



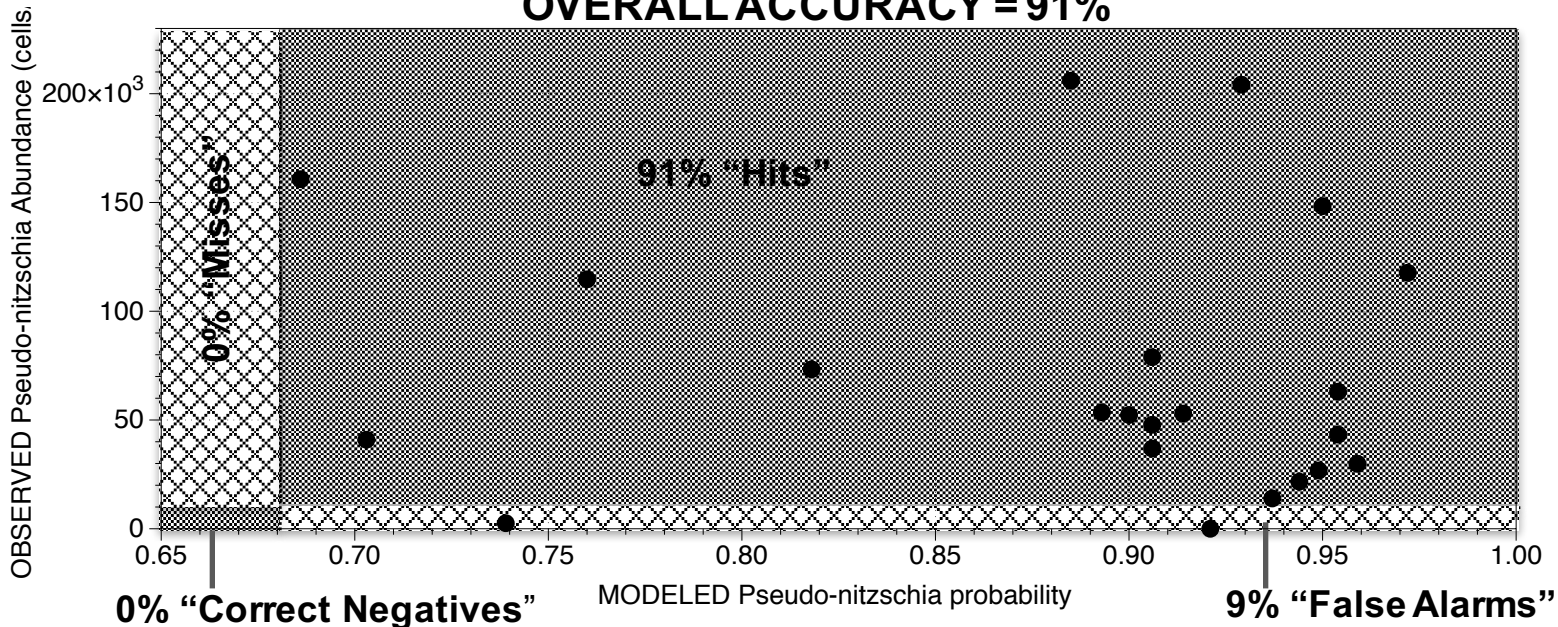
# 2015 – Particulate Domoic Acid – SC WHARF



# 2015 – *Pseudo-nitzschia* – Monterey WHARF

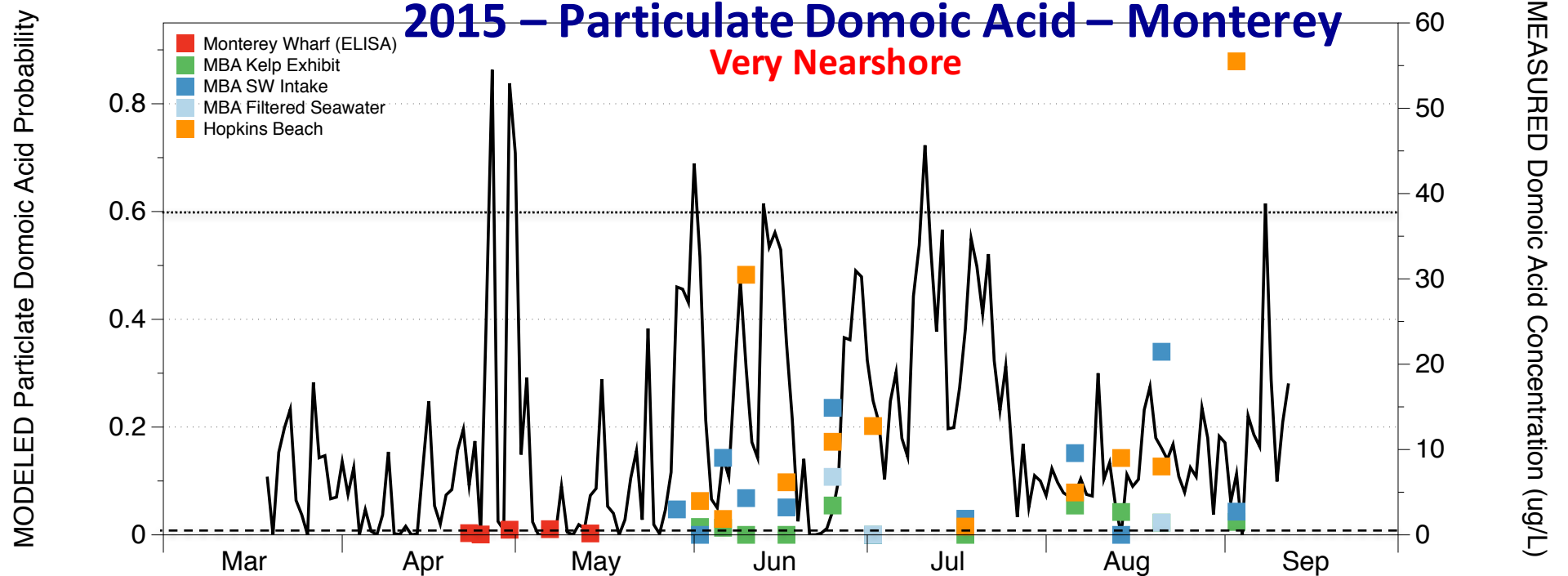


**OVERALL ACCURACY = 91%**

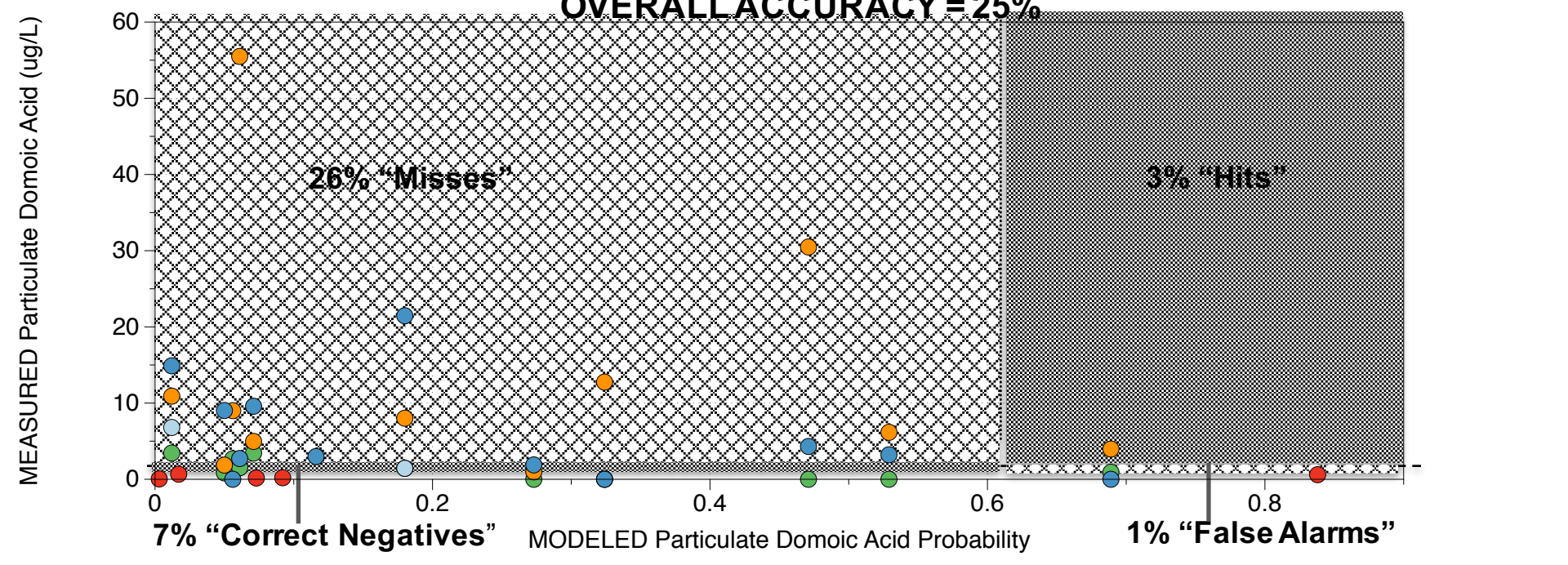


# 2015 – Particulate Domoic Acid – Monterey

Very Nearshore



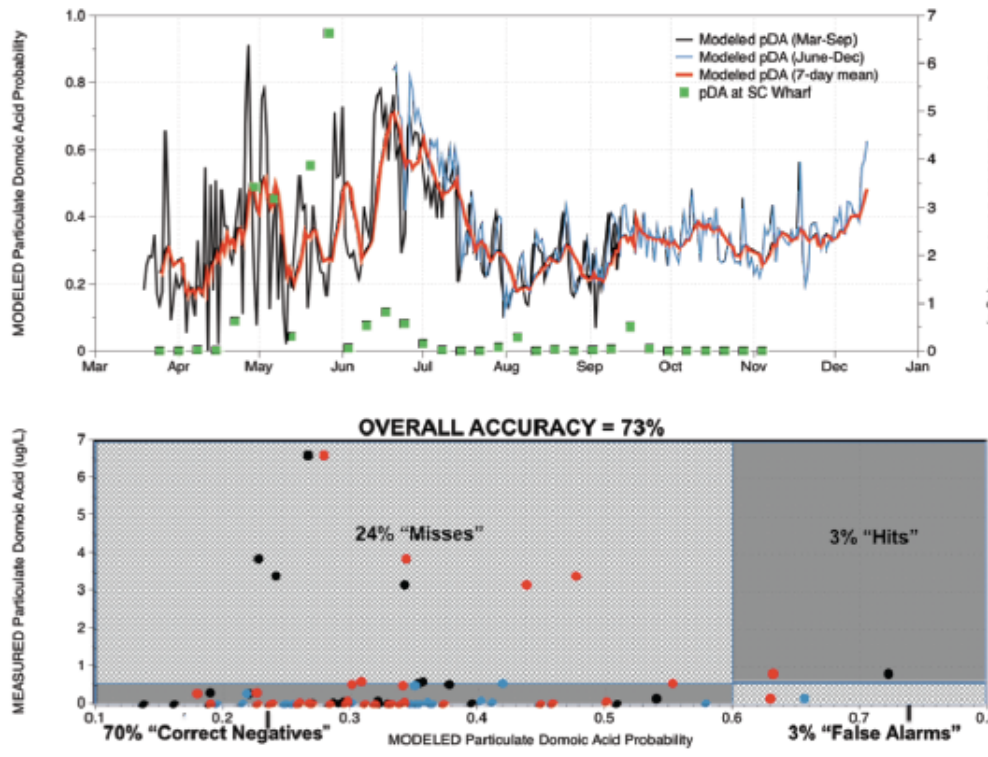
## OVERALL ACCURACY = 25%



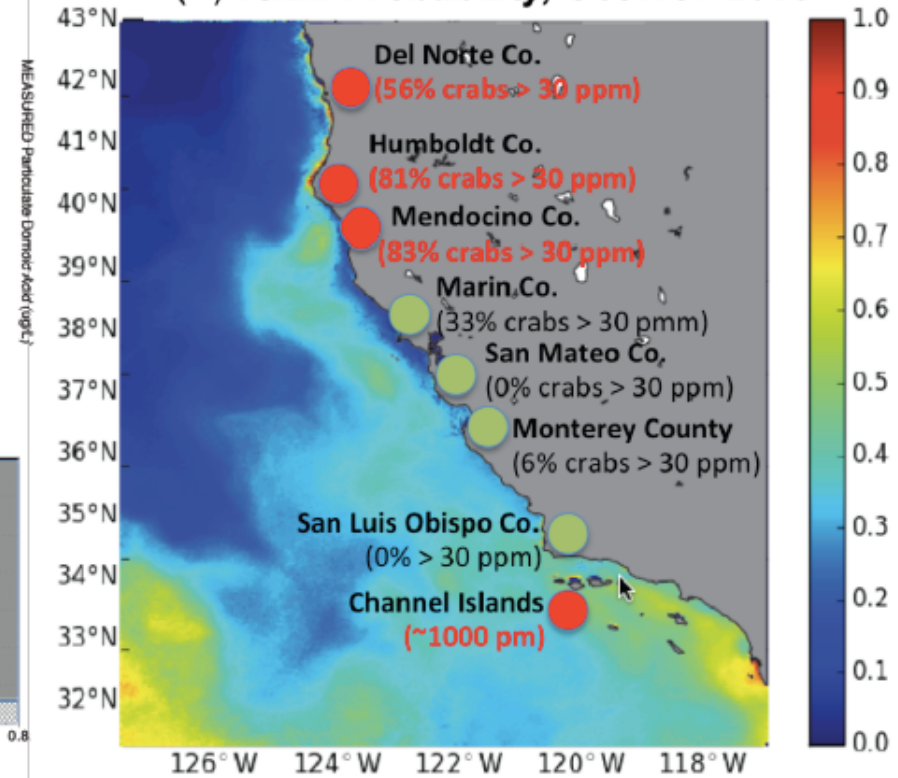


# 2015 – Dungeness crab closures match climatological model

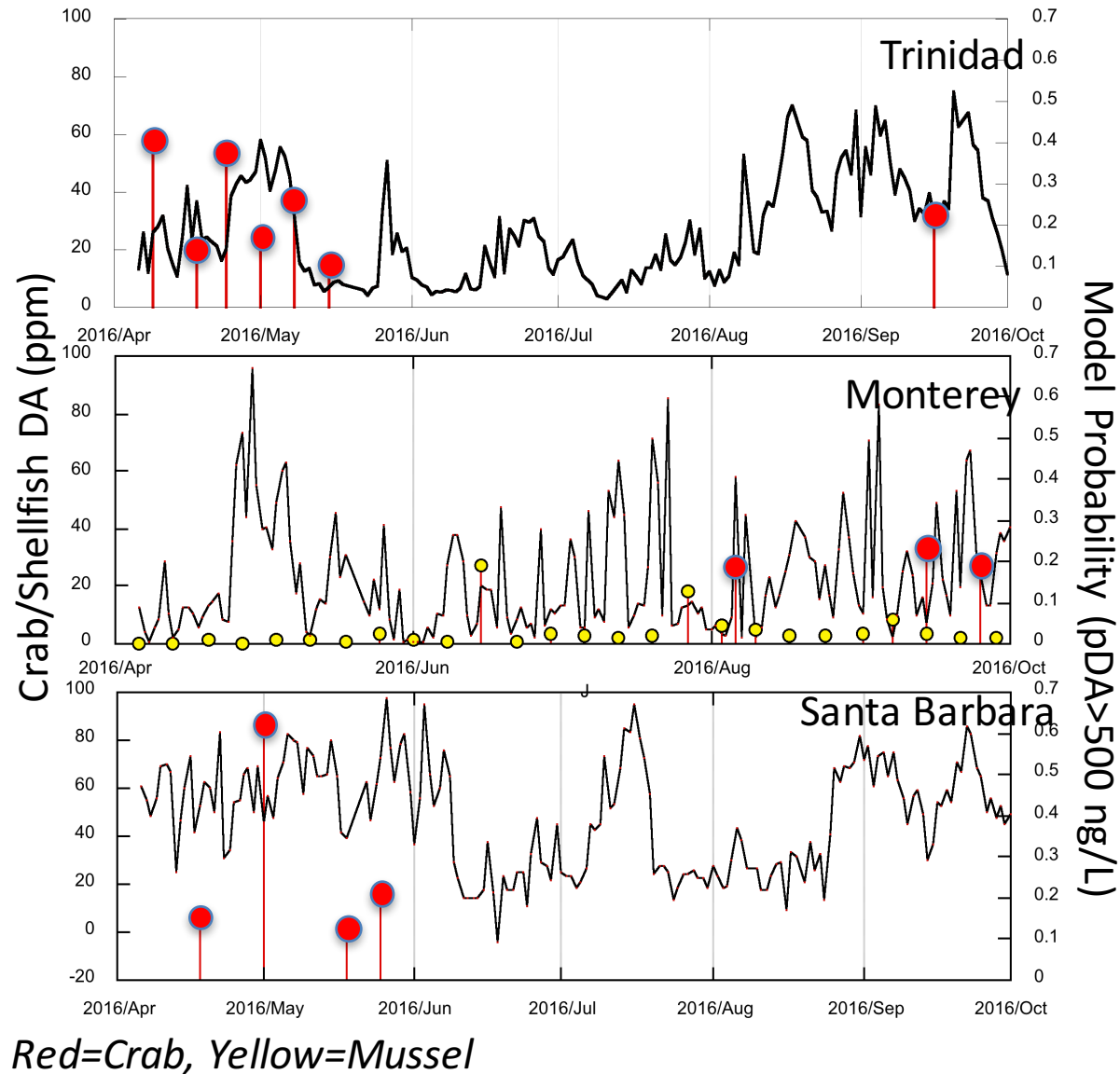
(A) Santa Cruz Wharf – Skill Assessment



(B) Toxin Probability, Oct-Nov 2015

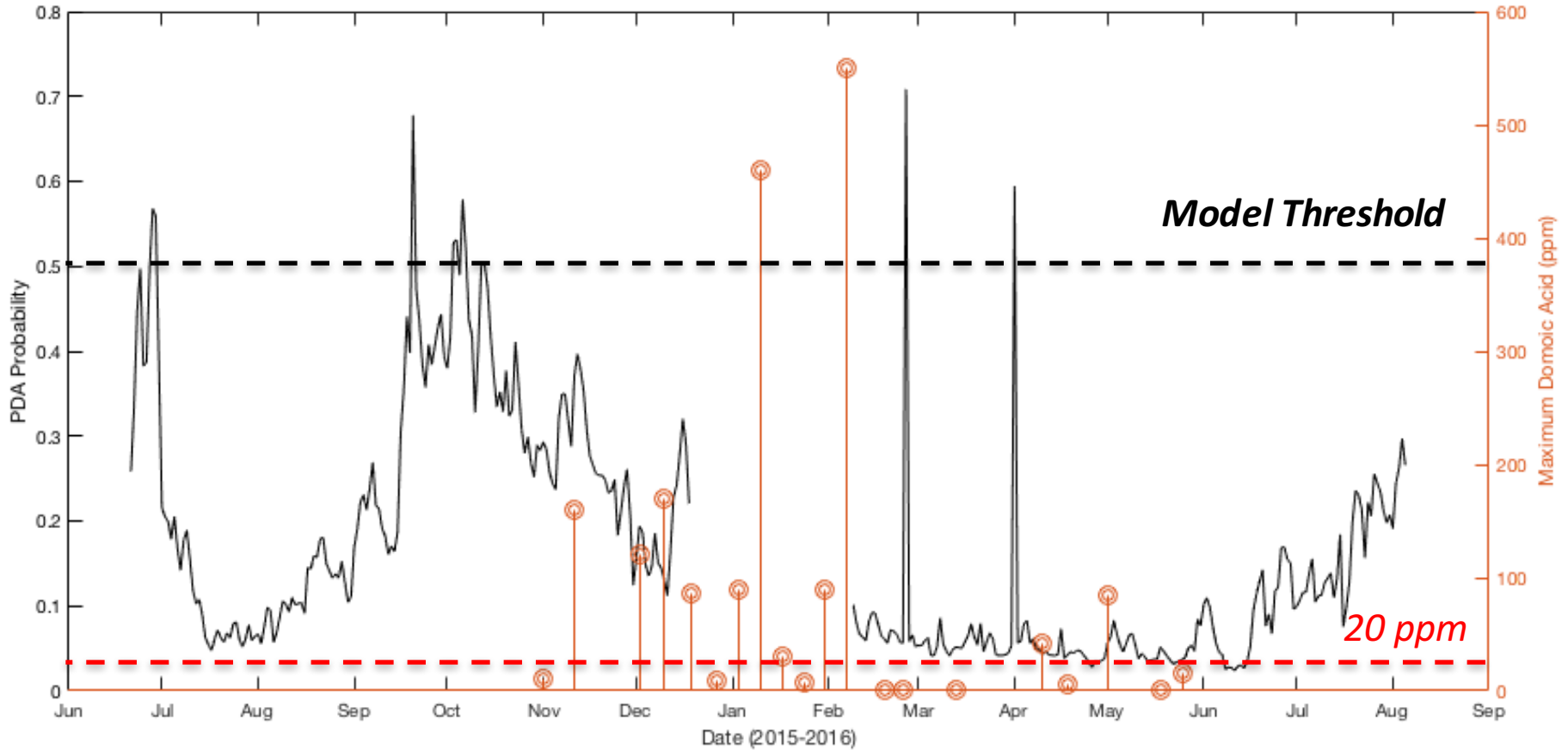


# 2016 – Crab/Shellfish toxicity tracks nearshore model



# PDA Model Tracks Crab Toxicity

## *Santa Barbara Block 710, CDFW Crab DA*

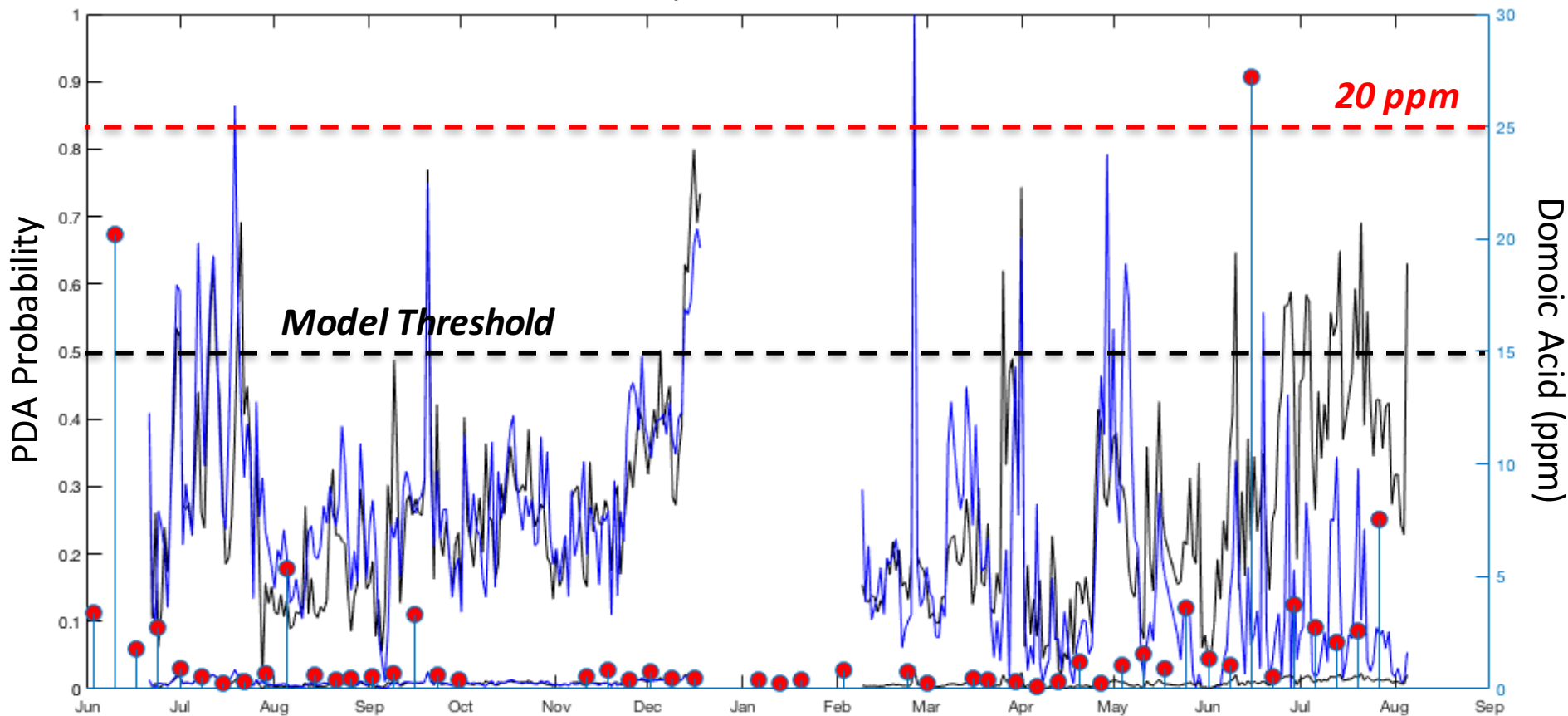


*The water-column model leads crab toxicity by about one month*

# Monterey Bay Model vs. Mussels

Santa Cruz Wharf: Blue

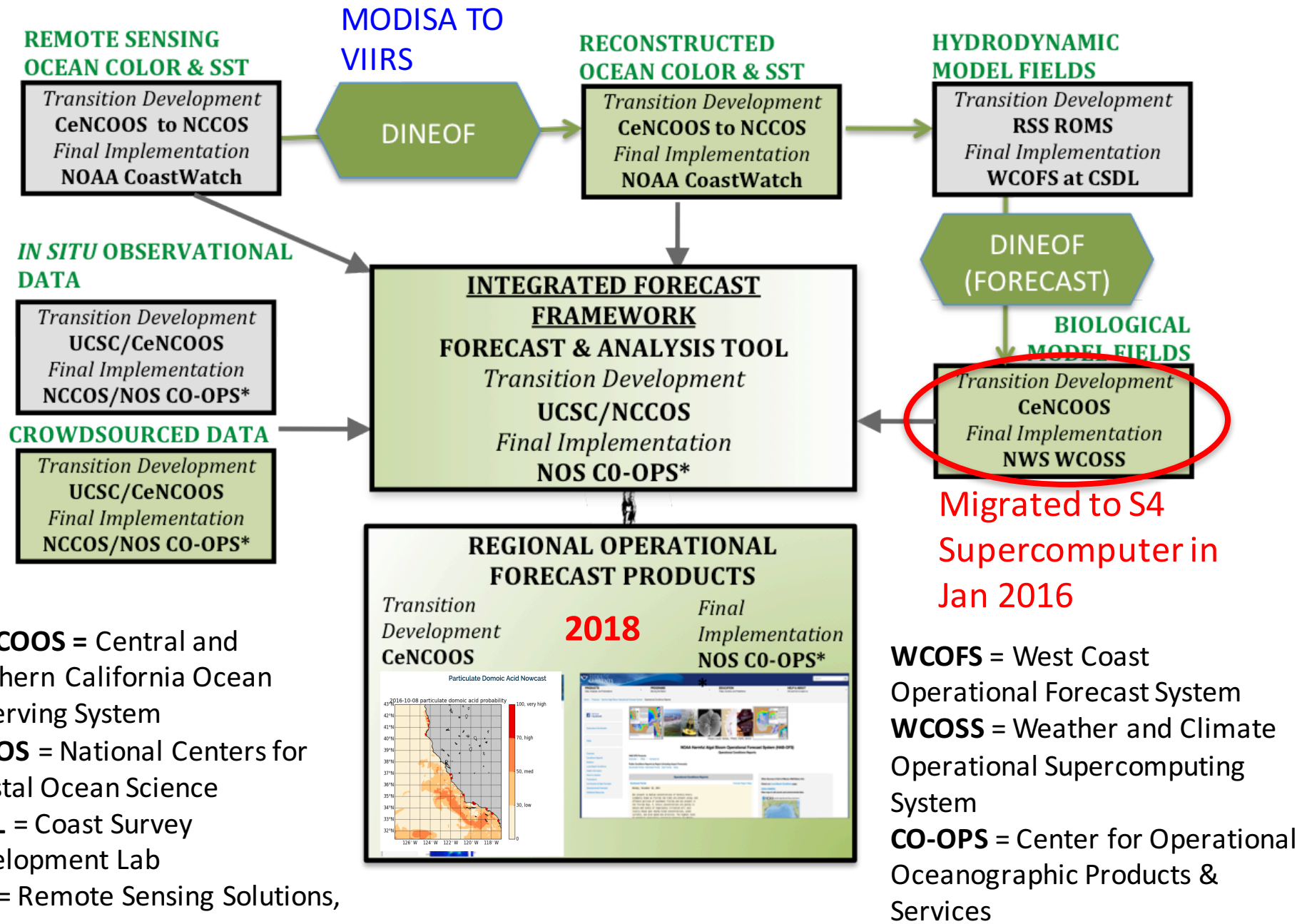
Monterey Commercial Wharf: Black



**Monterey and Santa Cruz diverge in 2016**

SCW = 2 ppm  
Monterey = 70 ppm

# OPERATIONAL HAB FORECASTING SYSTEM BY 2018/2019



**CeNCOOS** = Central and Northern California Ocean Observing System

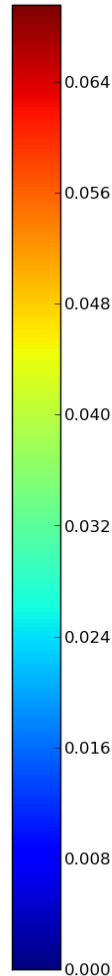
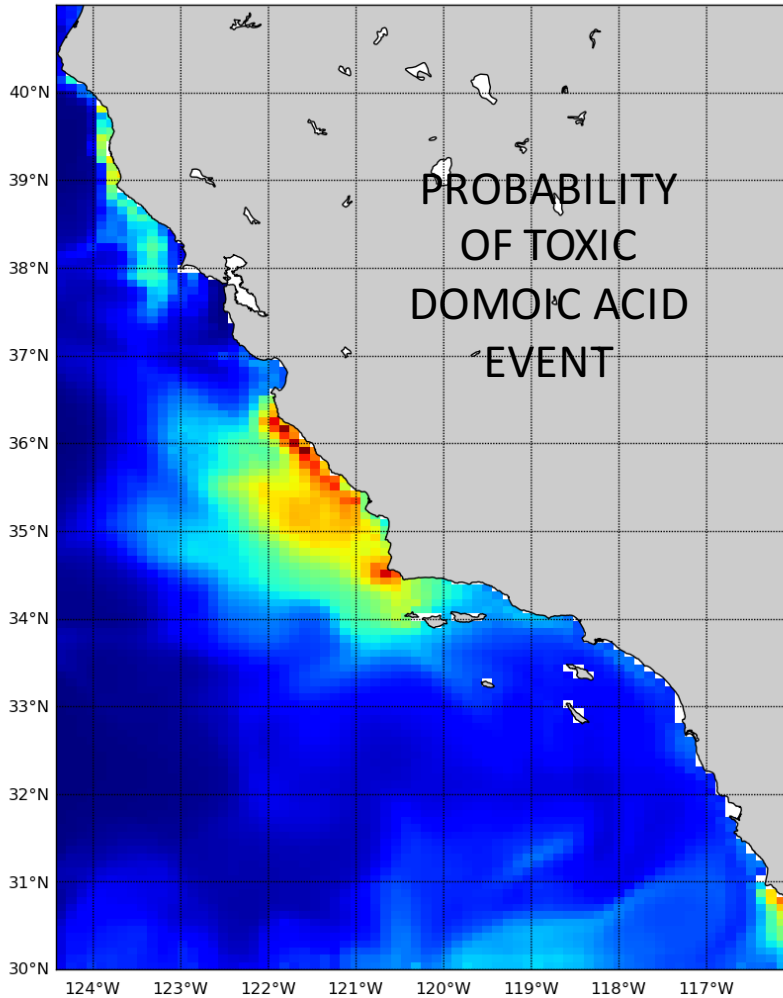
**NCCOS** = National Centers for Coastal Ocean Science

**CSDL** = Coast Survey Development Lab

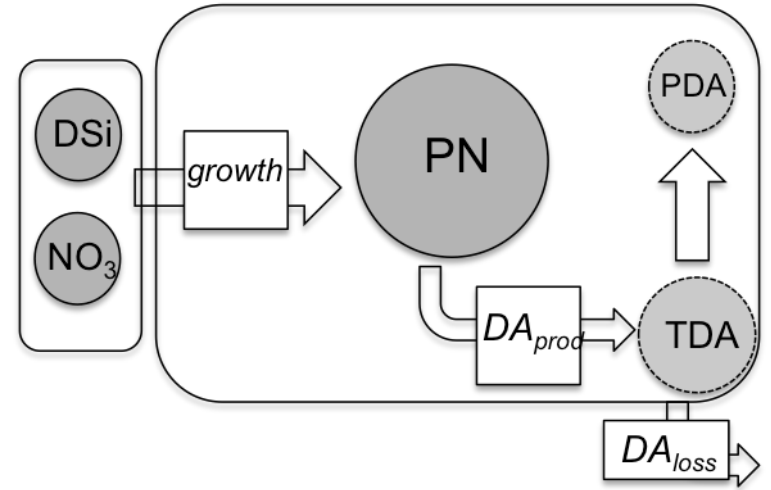
**RSS** = Remote Sensing Solutions, Inc.

# Predicting toxin production from first principles

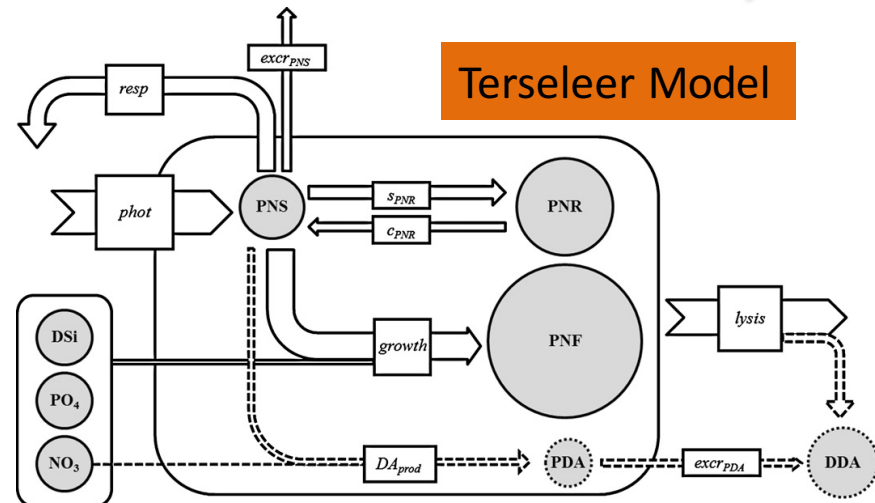
*collaboration with Chris Edwards and Raphe Kudela*



Our Model

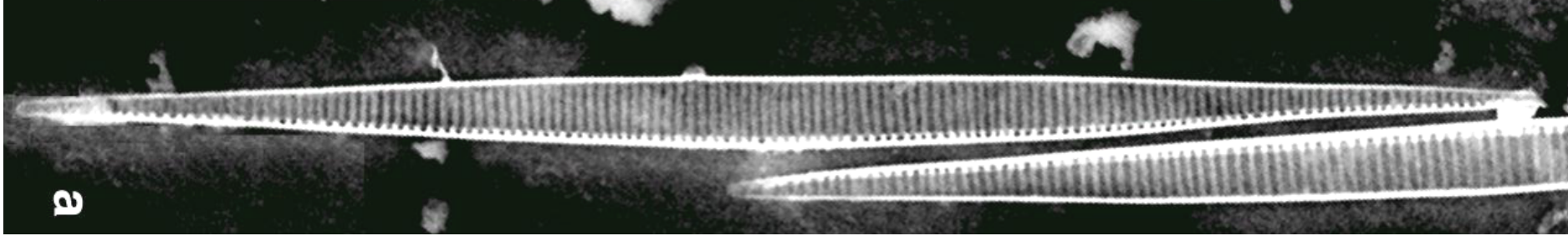


Terseleer Model



**END GOAL:** Create realistic simulations of DA events in coastal California - Is more model complexity really better?





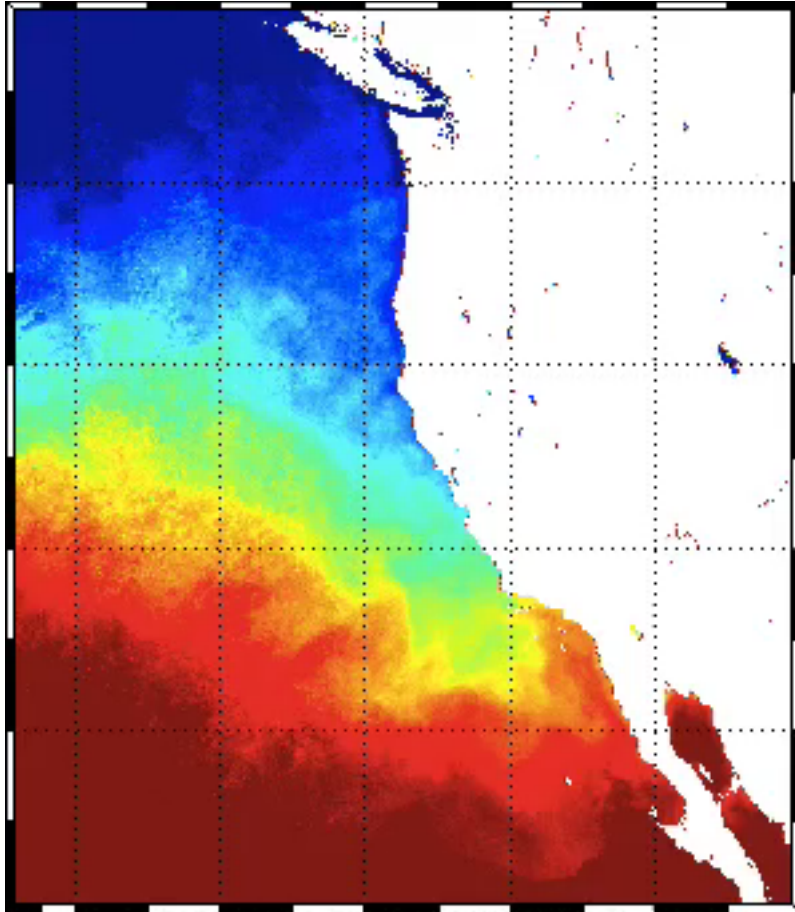
**THANK YOU!**

[clrander@ucsd.edu](mailto:clrander@ucsd.edu)

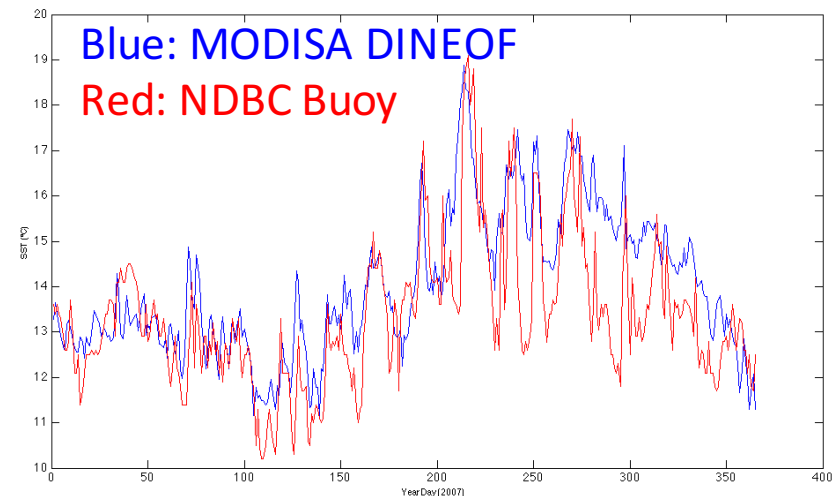
<http://www.cencoos.org/data/models/habs>

# Data Interpolating of EOFs (DINEOF)

- Statistical reconstruction of satellite data solving spatial and temporal EOFs simultaneously (Beckers & Rixen, 2003)
- Can use covariance-matrices to solve for multiple linked datasets
- SST:  $R^2=0.9$ , RMSE  $< 1^\circ\text{C}$ , as good as Pathfinder AVHRR but daily!



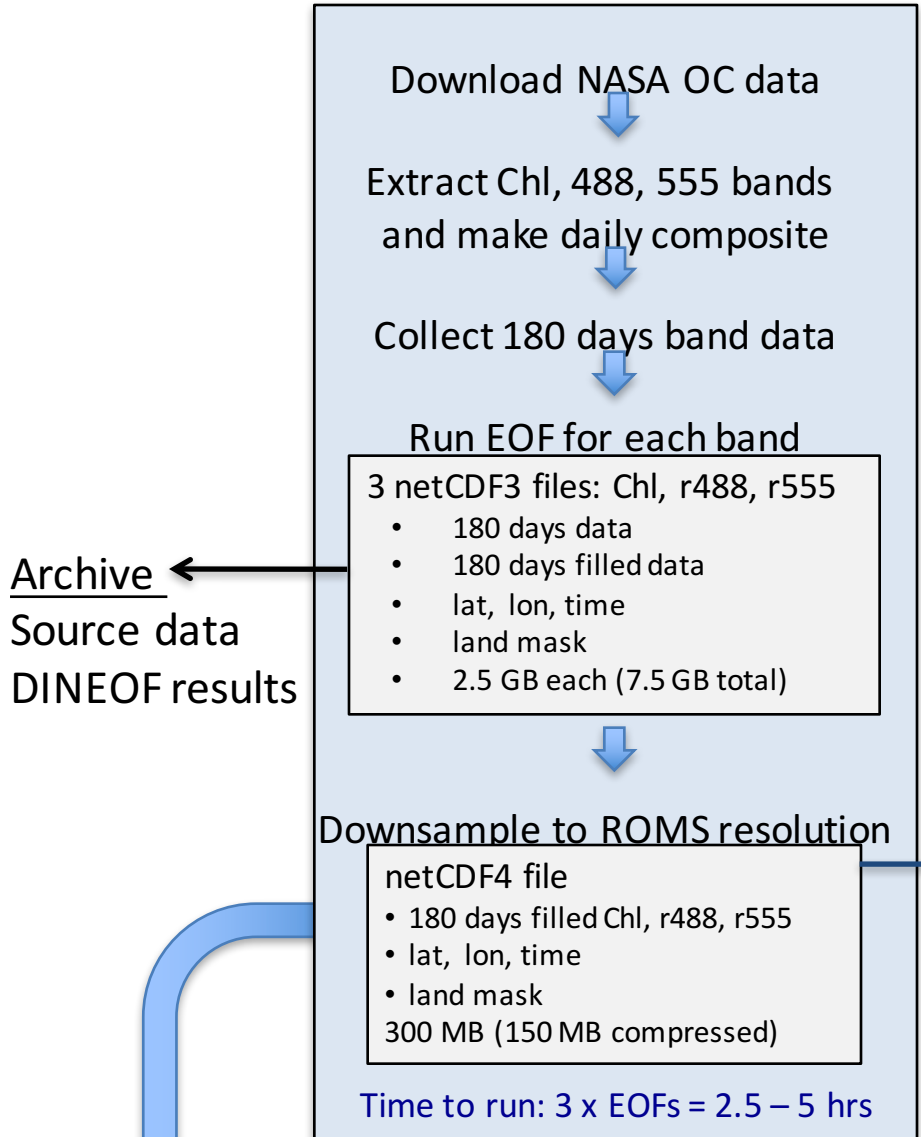
2007 SST Reconstruction (daily)



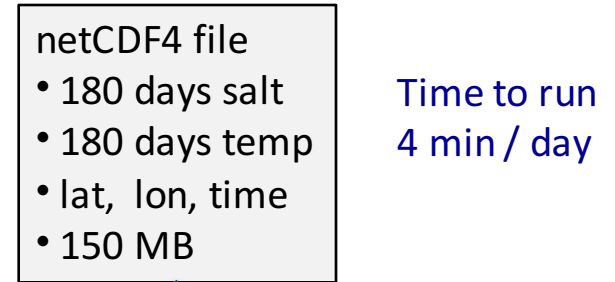
(NDBC 46054 West Santa Barbara)

# S4: NOAA Weather Prediction Supercomputer at Univ. of Wisconsin

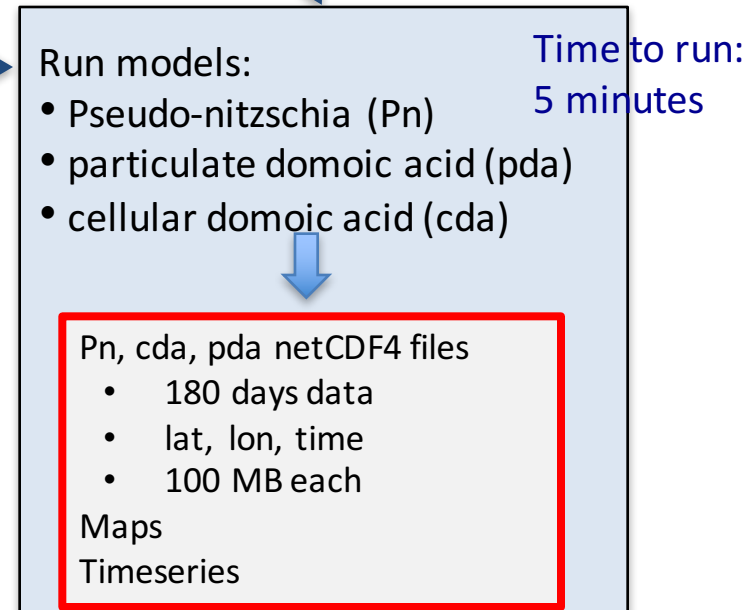
## Prep Satellite data (CoastWatch)



## Collect ROMS data (CeNCOOS, S4)



## Nowcast (CeNCOOS, S4)



Use in forecast script  
(next slide)

From Prep Satellite data  
(last slide)

## Forecast (CeNCOOS, S4)

netCDF4 file

- 180 days filled Chl, r488, r555
- lat, lon, time
- land mask

300 MB (150 MB compressed)  
From CoastWatch

Last 180 day plus  
3-day ROMS forecast

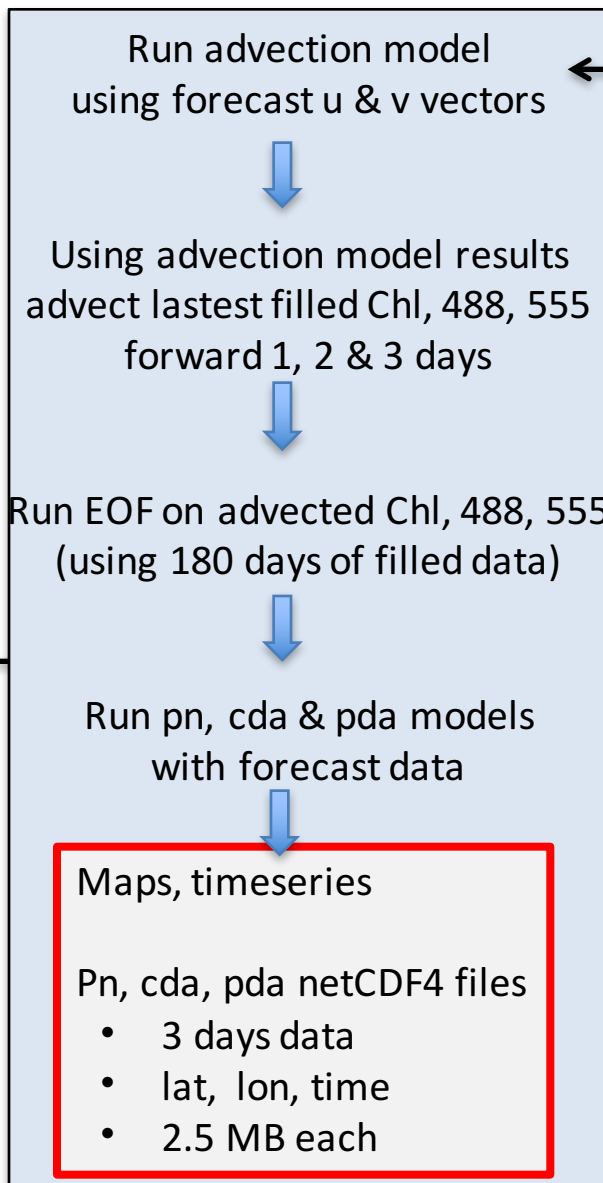
- salt,
- temp

**Time to run total: 56 min**

Adv. model: 10 min

Data advection & EOFs: 36 min

Pn, cda, pda models: 5 min



3-day ROMS forecast

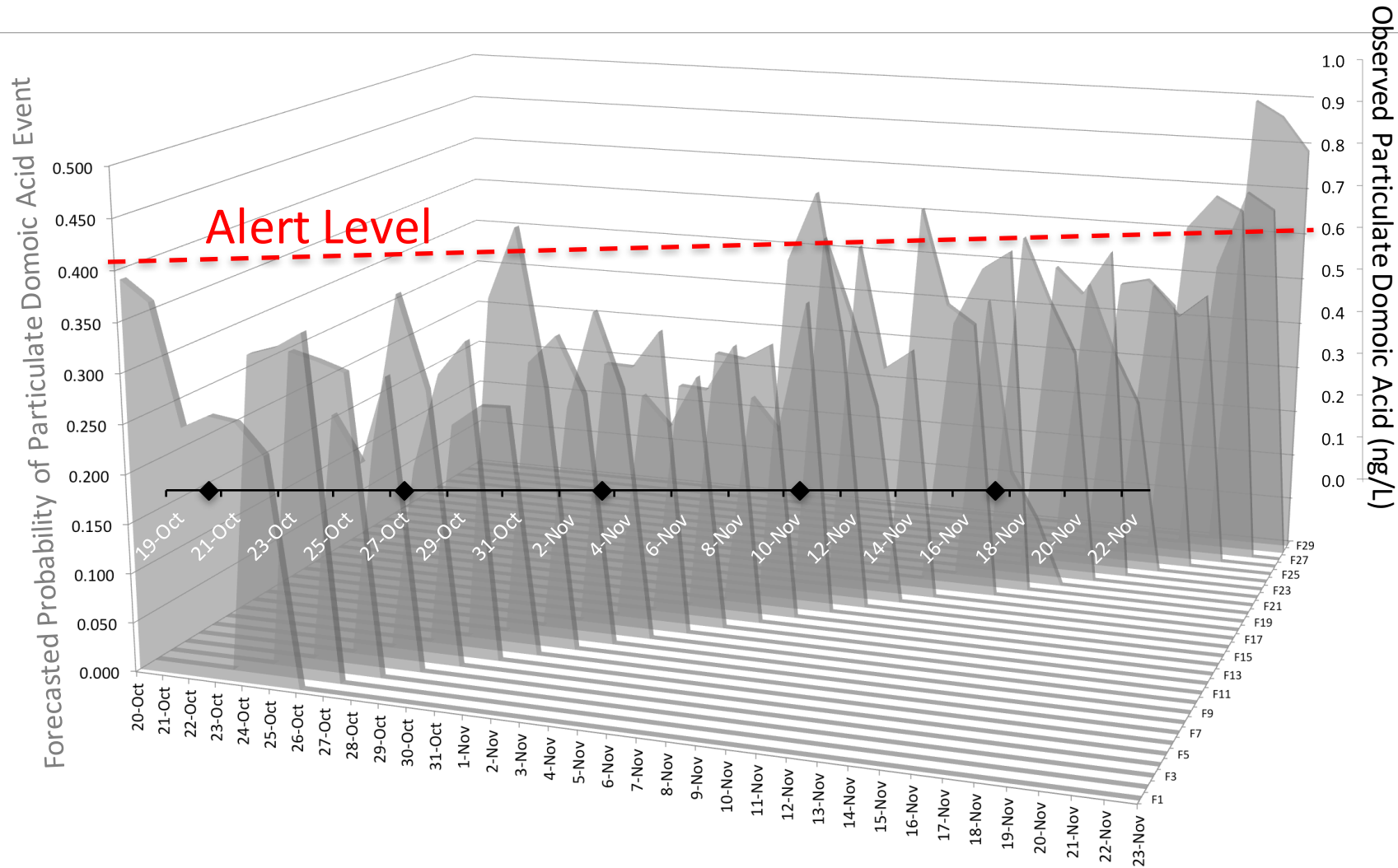
- u and v currents

Chl, r488, r555 .nc files

- 180 days filled data  
plus 3 advected days
- lat, lon, time
- land mask
- ROMS resolution
- 100 MB each

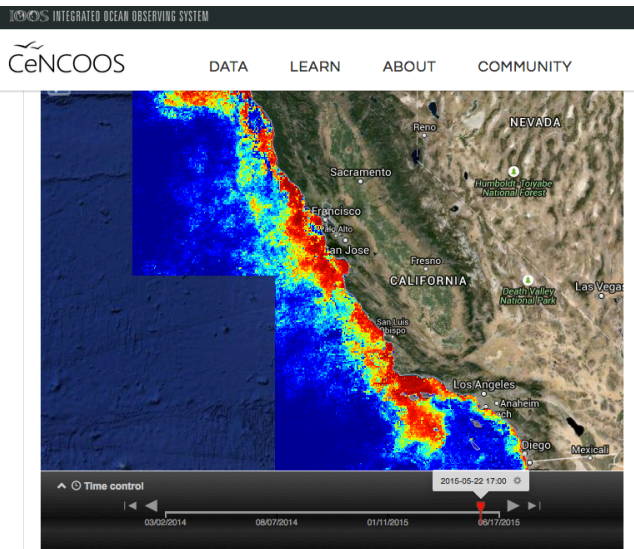
Same file as above except  
- 3 advected days are filled

# TOXIN FORECASTS @ SC WHARF (OCTOBER – NOVEMBER)





# 2015 BLOOM of DOOM: May – September (and beyond)

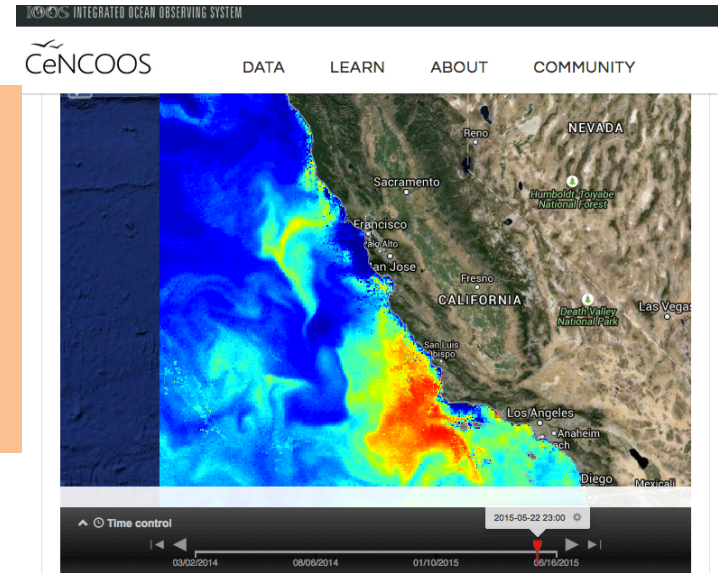


The map image displays the probability that the abundance of toxin-producing species of the diatom

## Santa Barbara to Alaska:

anchovy & sardine  
closures

shellfish advisories  
and closures



## 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](mailto: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.

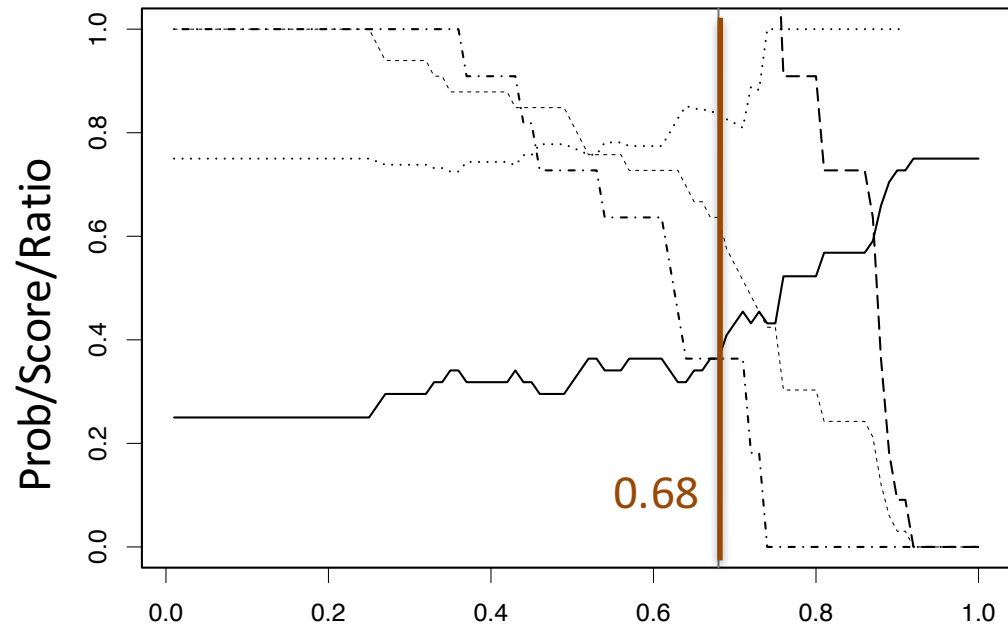
## Unusual Mortality Event – includes 11 fin whales



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).

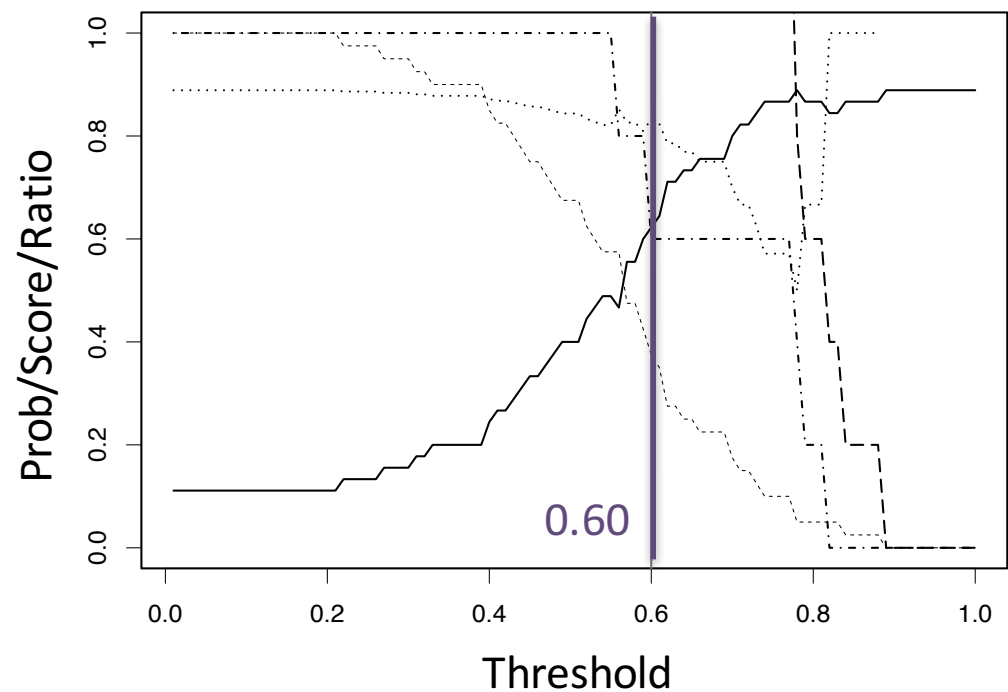


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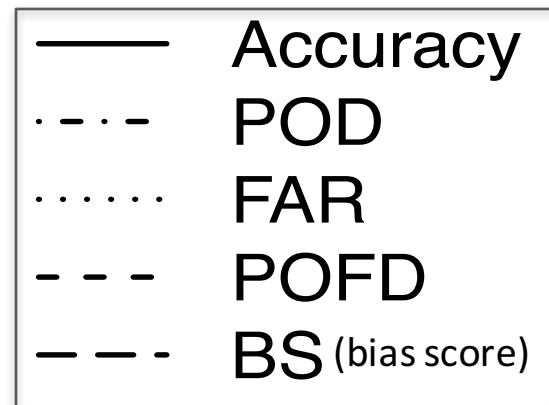


Contingency Plots to Assess Model Performance – Optimize Prob. Threshold

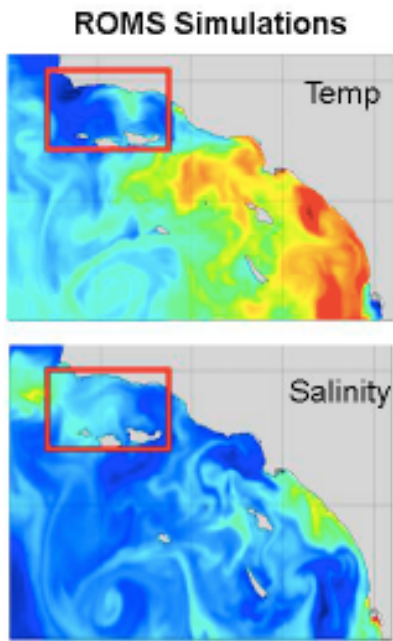
*Pseudo-nitzschia* at the SC Wharf vs. Nearest Model Pixel



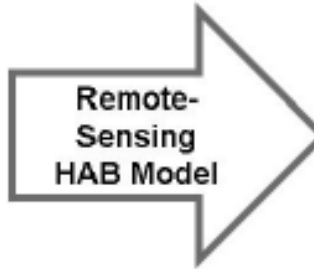
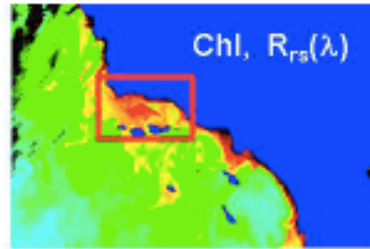
Domoic Acid at the SC Wharf vs. Nearest Model Pixel



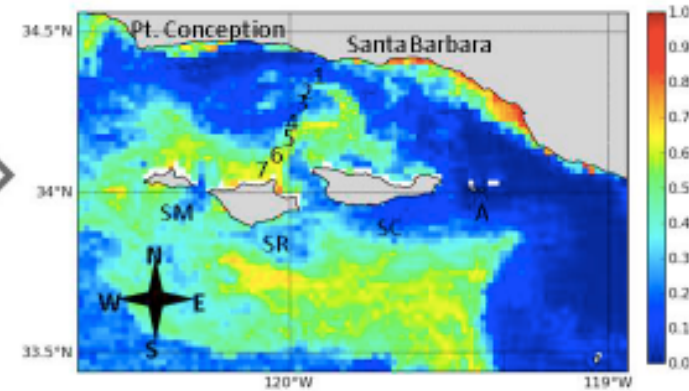
**\*3-km CA ROMS with 3D-Var  
(Yi Chao/CeNCOOS&SCCOOS)**



MODIS-Aqua Satellite Data



Predicted HAB Probability



HAB Variable (Threshold)

Best-fit Logistic GLM - RS

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

*Pseudo-nitzschia*  
( $10^4$  cells  $\text{mL}^{-1}$ )

(i)  
 $\text{logit} = 8.54 - 10.84 \cdot [R_{rs}(510/555)] - 0.216 \cdot [\text{Month}] + 4.67 \cdot [R_{rs}(490/555)]$

(ii)  
 $\text{logit} = 5.32 - 2.87 \cdot [R_{rs}(490/555)] - 0.165 \cdot [\text{Month}]$

pDA  
(500  $\text{ng L}^{-1}$ )

$$\text{logit} = -134.3 + 0.253 \cdot [\text{Chl}] + 4.0 \cdot [\text{Sal}] - 502 \cdot [R_{rs}(555)]$$

cDA  
(10  $\text{pg cell}^{-1}$ )

$$\text{logit} = -90.0 - 0.35 \cdot [\text{Temp}] - 666 \cdot [R_{rs}(555)] + 2.87 \cdot [\text{Sal}]$$

Remote Sensing Reflectance  
Salinity  
Temperature  
Chlorophyll

*Nitrate*  
*Phosphate*  
*Silicic Acid*

# August 2015 vs August 2016

