

# Crossing the “Valley of Death” with the California Harmful Algae Risk Mapping (C-HARM) System

IOOS | Integrated Ocean Observing System

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>



CeNCOOS



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

## 5 Step Process to Operations: Does it work?

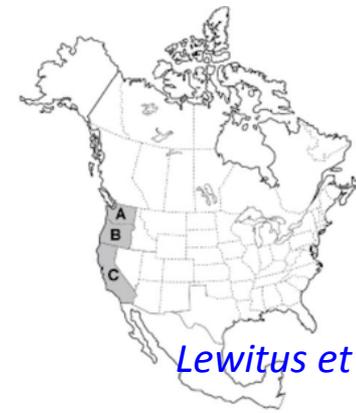
- I. Establish the need for a predictive capability
- II. Demonstrate model readiness and feasibility
- III. Continually conduct skill assessments  
*building on prior efforts in Anderson et al. 2009, 2011, 2016*
- IV. Engage stakeholders and agency end-user early on
- V. Cross the “Valley of Death” to operational environment

## Why predict HABs in California?

- Domoic acid (from *Pseudo-nitzschia* blooms) is the **leading HAB issue on the US West Coast**
- **Unprecedented West Coast-wide HAB of 2015 -closed Dungeness Crab Fishery** for the season; contributed to **Unusual Mortality Events**
- Shellfish growers, fishermen, and marine mammal rescue groups want an early warning system that will **enable mitigation efforts and resource management**

### INITIAL BASELINE FOR DECISION-MAKING

- CDPH monitors for DA if PN present in water
- Relies on fixed quarantine periods

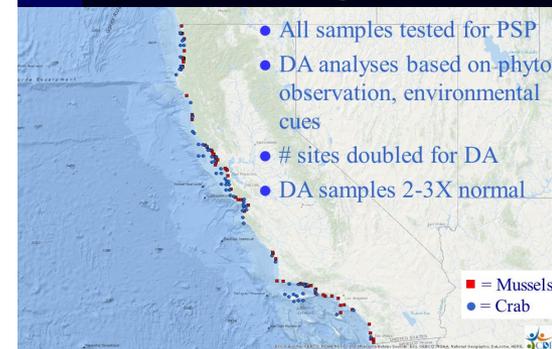


Lewitus et al. 2012

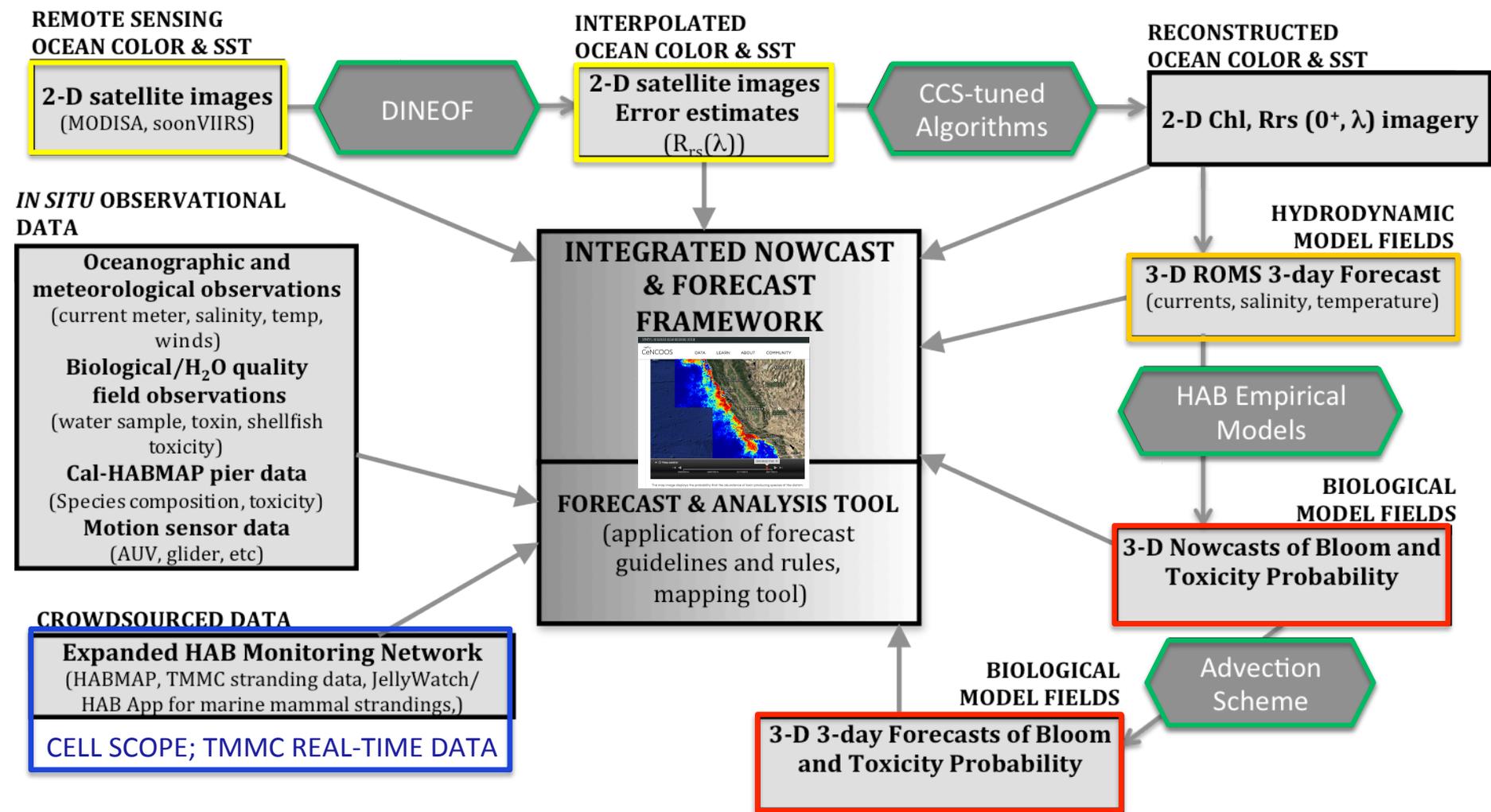


### CA Dept of Public Health

#### Shellfish Monitoring Sites: 2015



# California Harmful Algae Risk Mapping (C-HARM) System

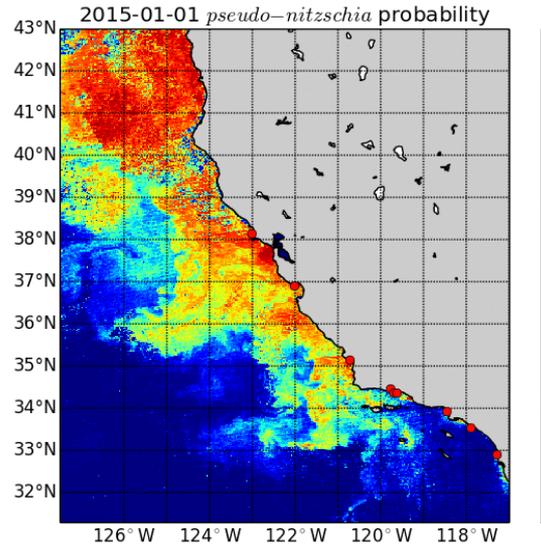


NASA Applied Sciences Program, Terrestrial Hydrology, Ocean Biology and Biogeochemistry Programs  
 “Ecological Forecasting for Conservation and Resource Management”  
 “Remote Sensing of Water Quality”

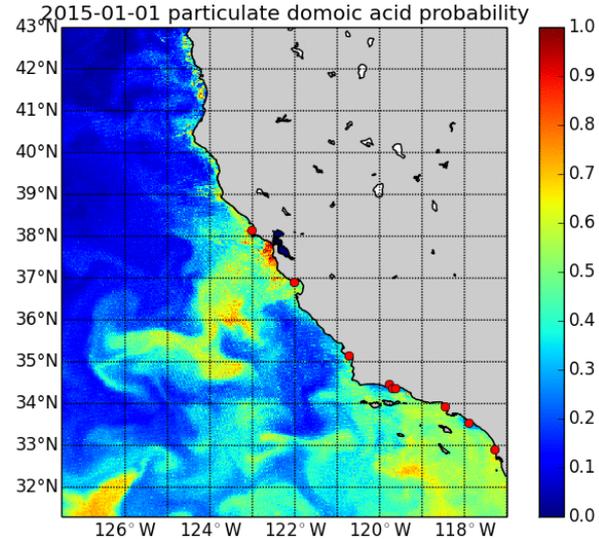
# Interactive Data Portal C-HARM Nowcasts and 3-day

<http://www.cenforecast.com/forecasts/models/habs/>

Probability  
Maps

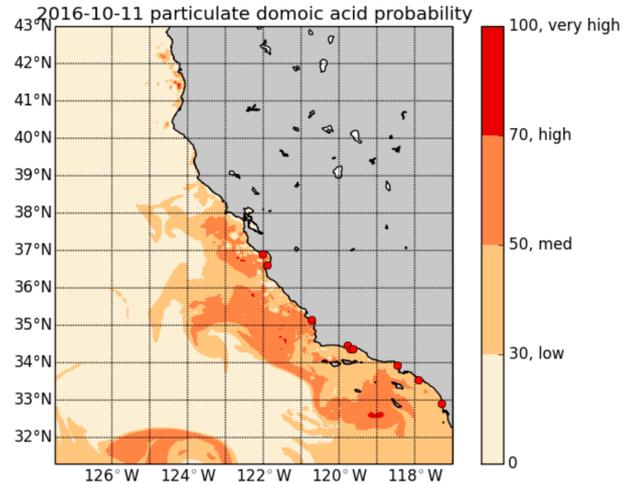
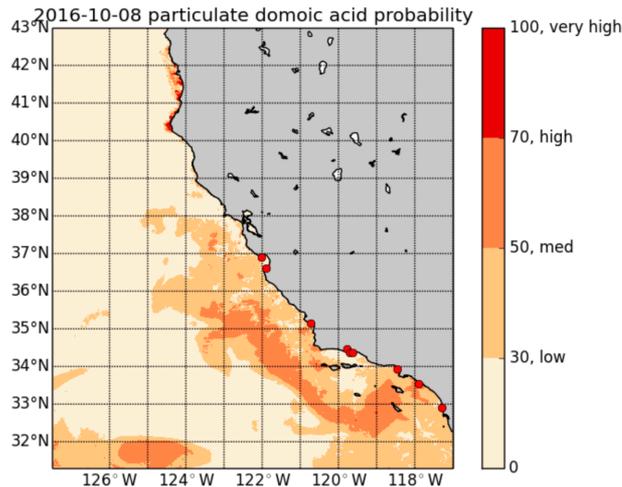


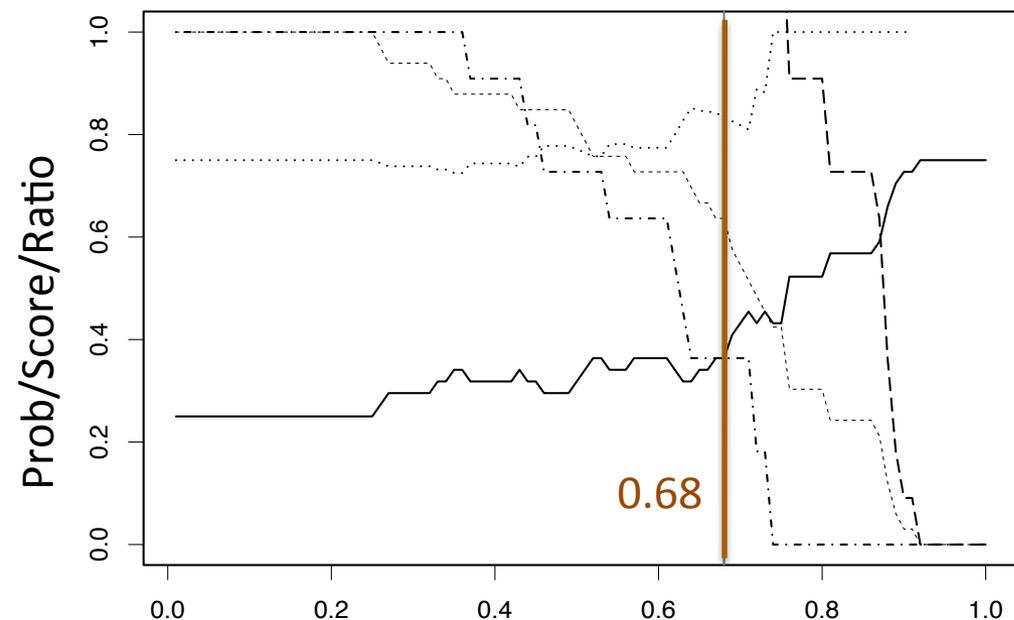
Particulate Domoic Acid Nowcast



Particulate Domoic Acid Forecast

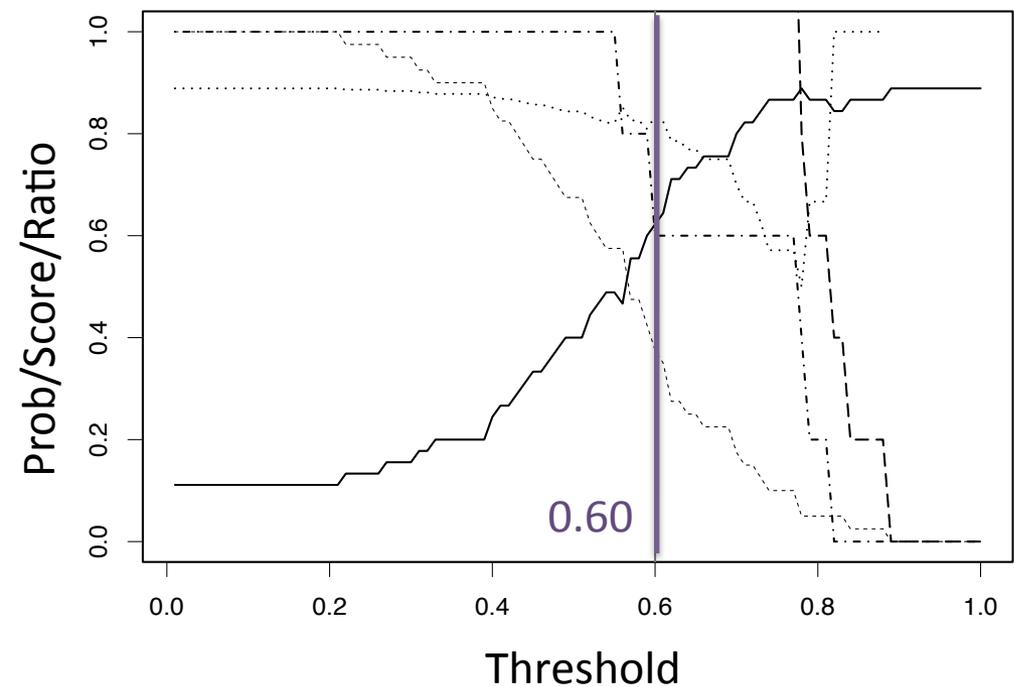
Risk Maps  
based on  
stakeholder  
feedback



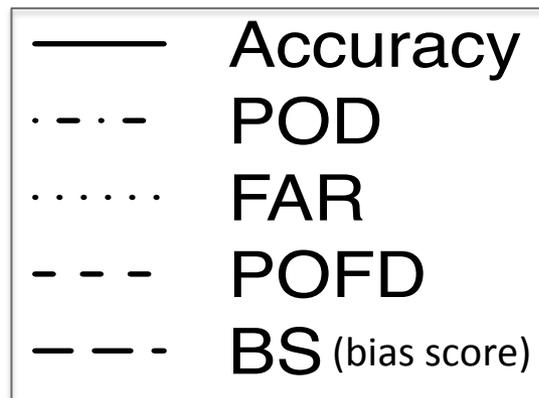


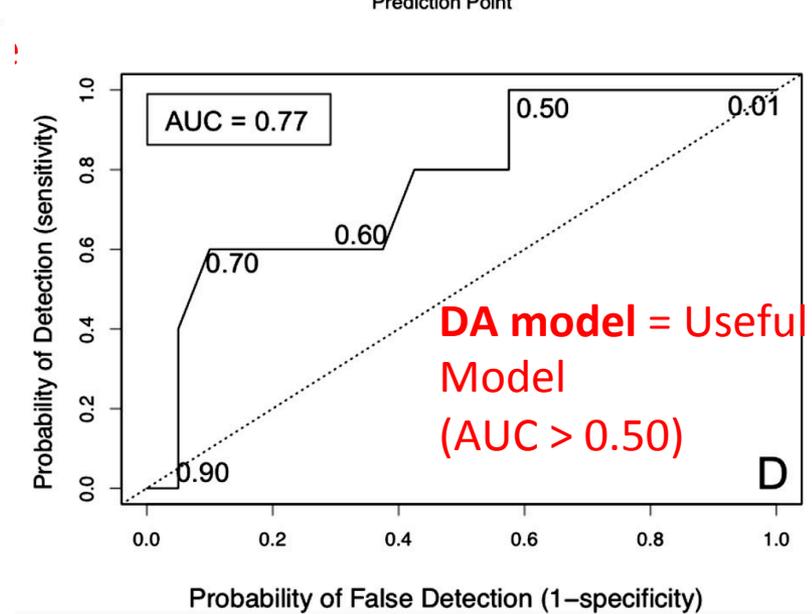
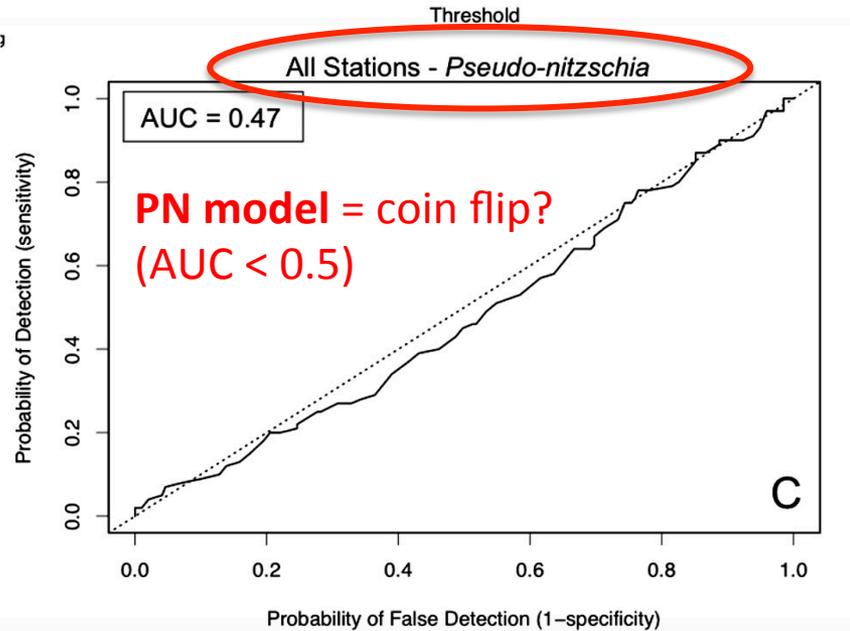
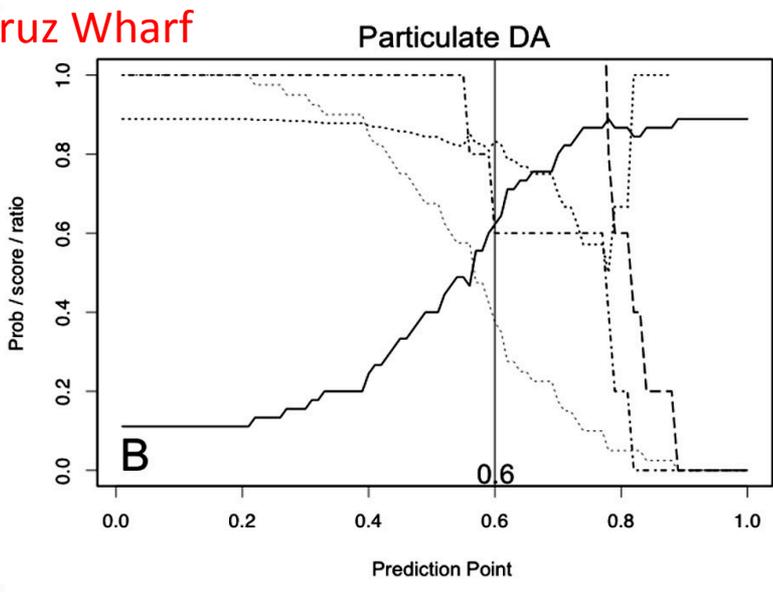
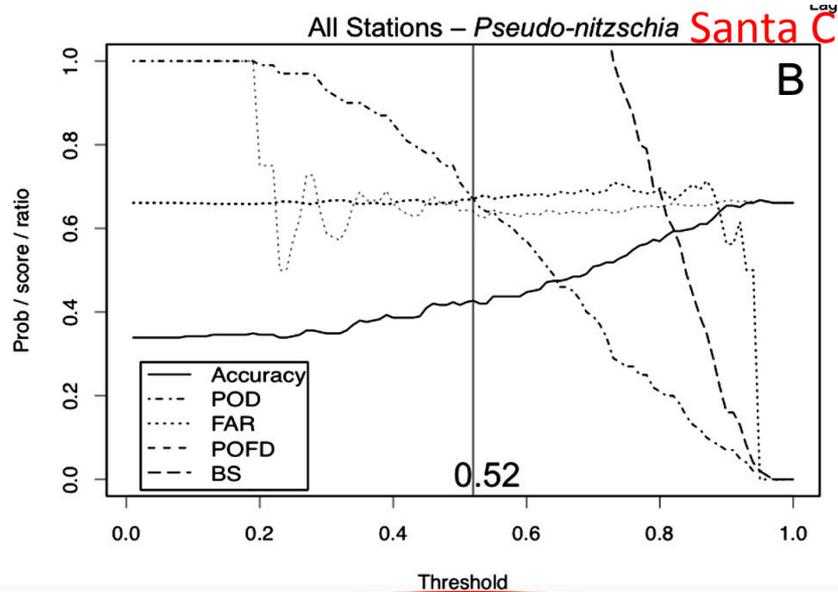
Contingency Plots to Assess Model Performance – Optimize Prob. Threshold

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



Domoic Acid at the SC Wharf vs. Nearest Model Pixel





RESEARCH LETTER

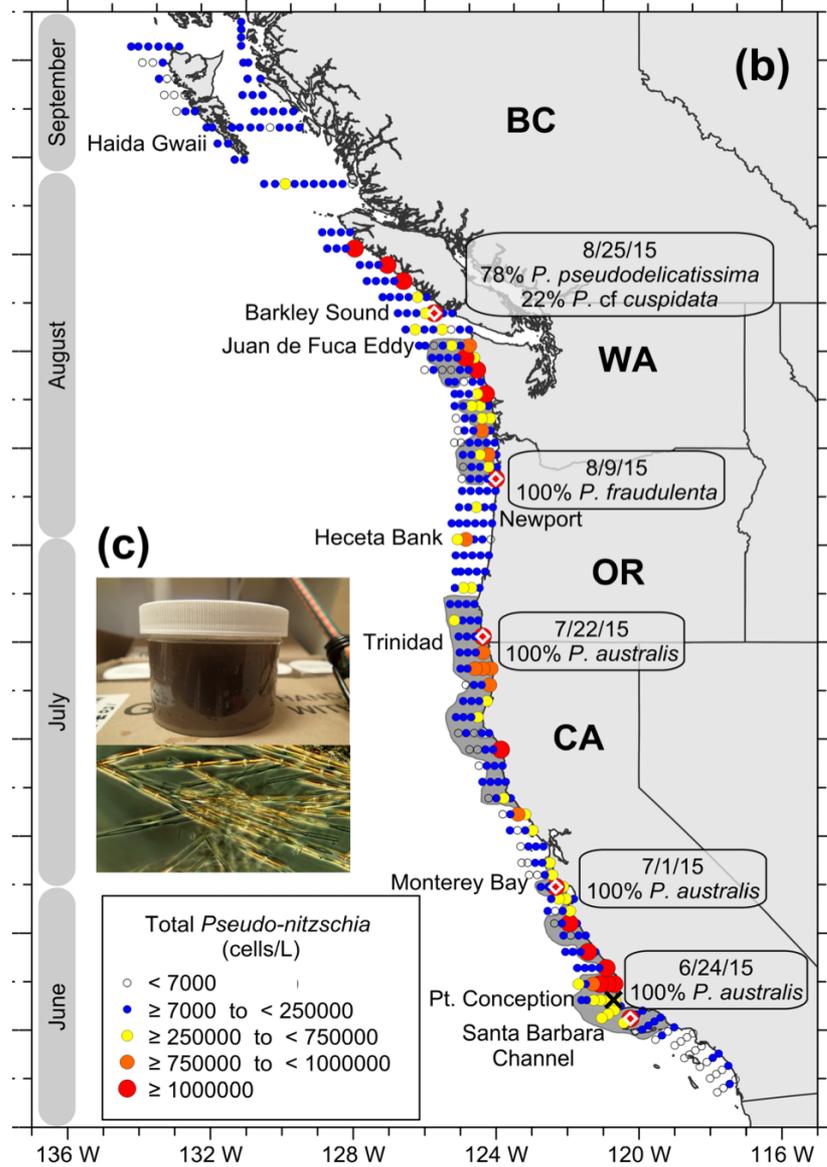
10.1002/2016GL070023

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>

Special Section:

Midlatitude Marine Heatwaves: Forcing and Impacts

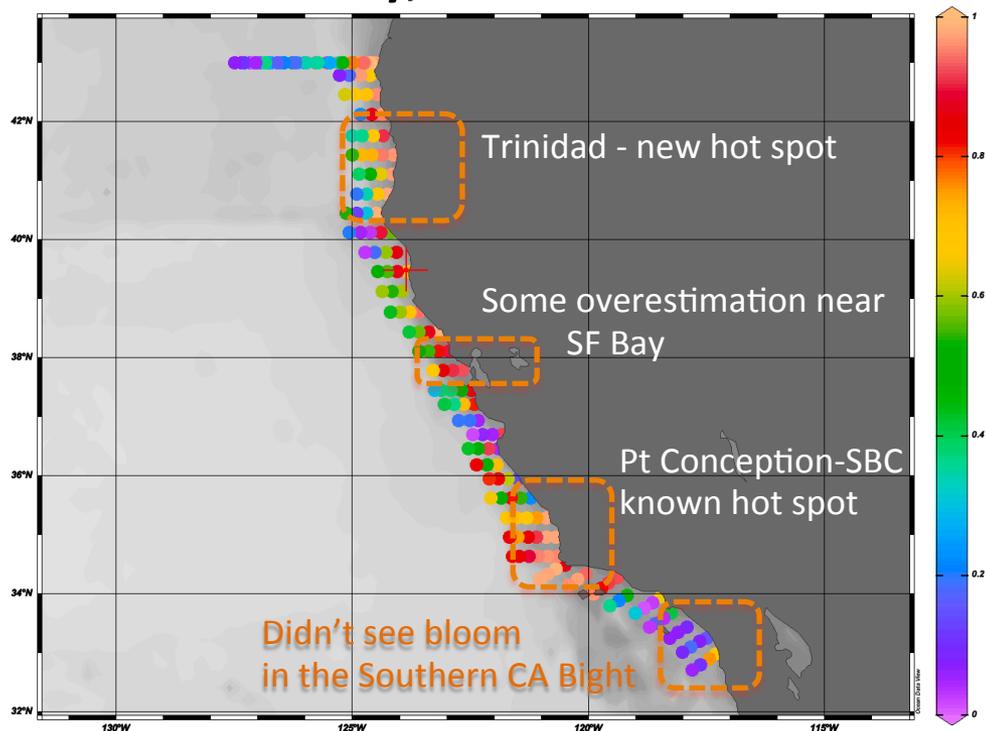


R/V Shimada NMFS Cruise-of-Opportunity

C-HARM ESTIMATES AT CRUISE STNS

Likelihood of a *Pseudo-nitzschia* bloom

64% Accuracy, 31% False Positives



**RESEARCH LETTER**

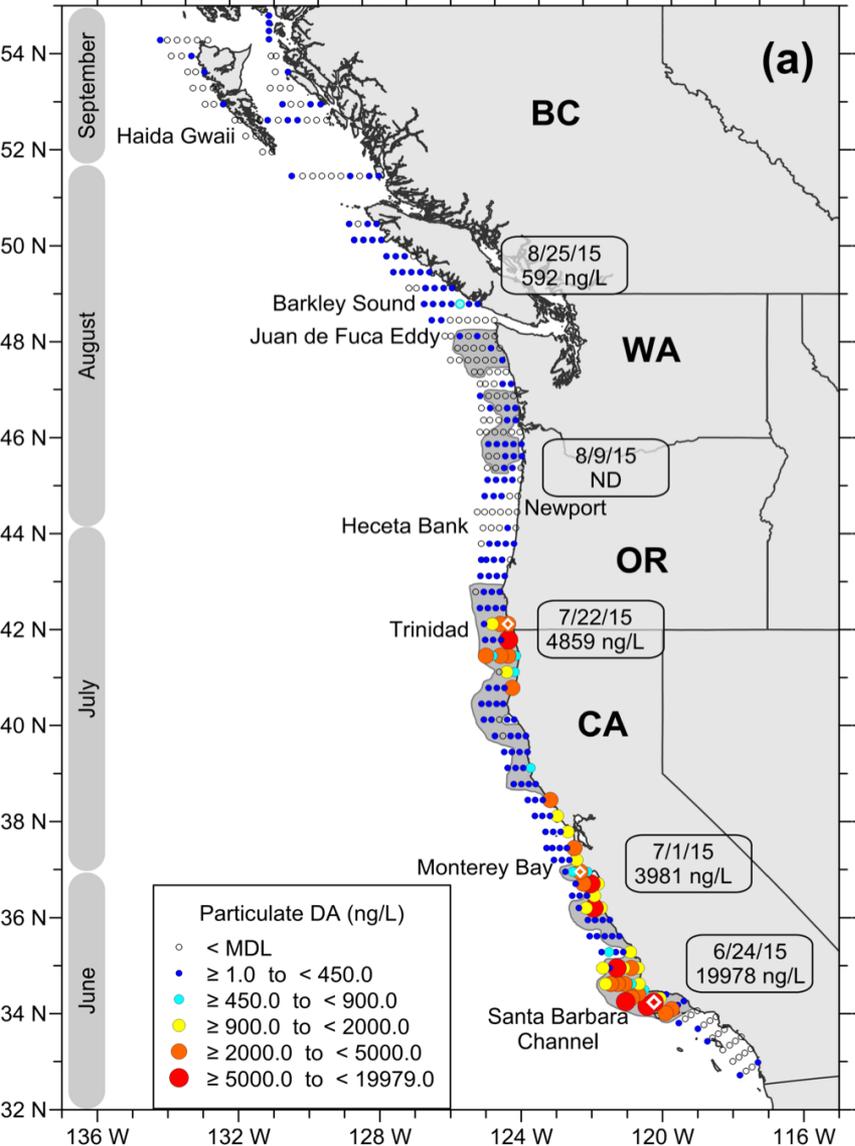
10.1002/2016GL070023

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

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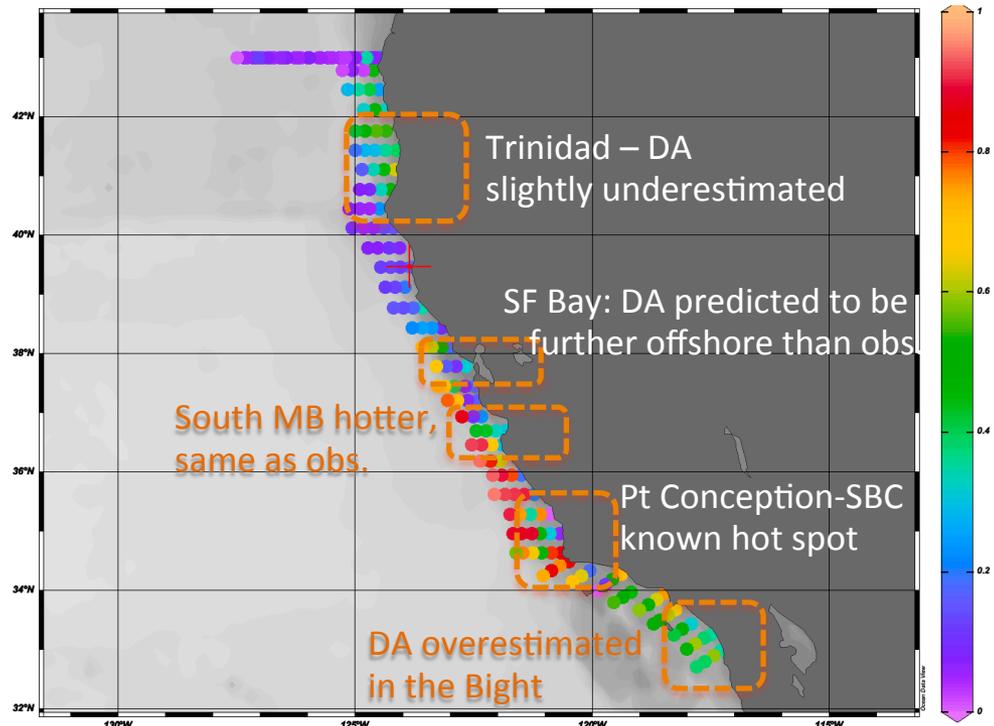
Ryan M. McCabe<sup>1</sup>, Barbara M. Hickey<sup>2</sup>, Raphael M. Kudela<sup>3</sup>, Kathi A. Lefebvre<sup>4</sup>, Nicolaus G. Adams<sup>4</sup>, Brian D. Bill<sup>4</sup>, Frances M. D. Gulland<sup>5</sup>, Richard E. Thomson<sup>6</sup>, William P. Cochlan<sup>7</sup>, and Vera L. Trainer<sup>4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



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

**C-HARM ESTIMATES AT CRUISE STNS**

Likelihood of elevated DA Levels  
**71% Accuracy, 20% False Positives**



# 2017 – Extensive HAB in Southern California

## Sea Lions Suffering From Domoic Acid Poisoning, Laguna Beach Rescue Says

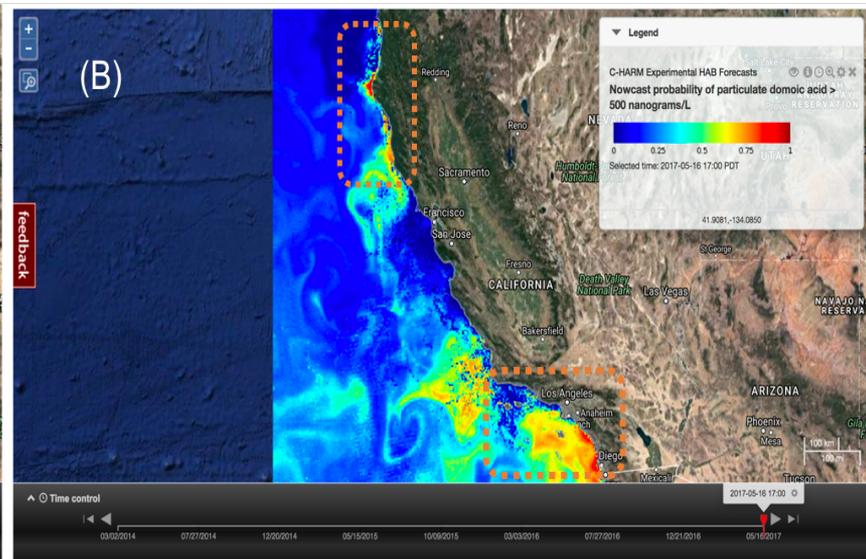
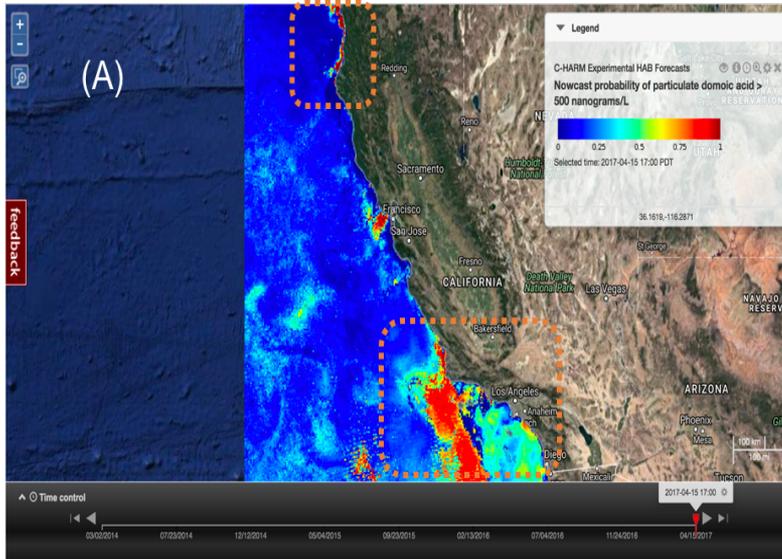
"In large concentrations, (the algae) produces neurotoxins that can destroy the brain," Pacific Marine Mammal Center said.

By Ashley Ludwig (Patch Staff) - April 11, 2017 12:23 pm ET | P |

Like 181 Share



Broad Impacts: Animal Strandings/Death [Sea Lions, Elephant Seals, Guadalupe Fur Seals, Seabirds (Common Murres, Grebes, CA Brown Pelicans); **Shellfish Advisories** in Santa Barbara/Ventura Counties



### April 15 = HAB Onset

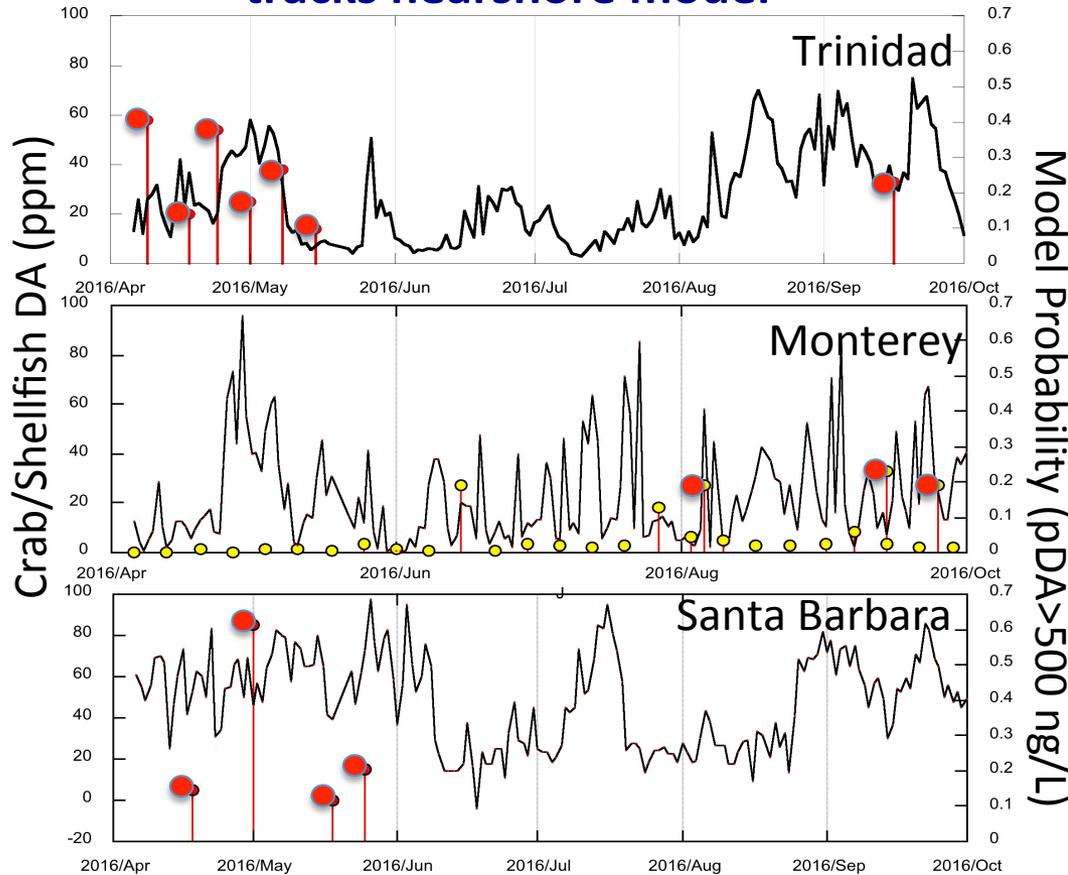
- Offshore Event
- Low toxins measured at piers
- Animals stranding in large numbers

### May 17 = HAB moves South & North

- More Impacts felt near San Diego
- HAB persists in Santa Barbara Channel
- Rock Crab fishery closed in Nor Cal

# What does C-HARM tell us about shellfish toxicity?

## 2016 – Crab/Shellfish toxicity tracks nearshore model



Red=Crab, Yellow=Mussel

Crab Data from: <http://www.cdph.ca.gov/healthinfo/pages/fdbdomoicacidinfo.aspx>

## New partners in Aquaculture 2016-2017

Greg Dale –

Coast Seafoods, Humboldt Bay

Kelly Stromberg –

Catalina Sea Ranch (first offshore site in U.S., San Pedro Bay)

Eric Bjorkstedt, Brian Tissot –

Humboldt State University

Jeff Anderson –

Northern Hydrology

### Objectives:

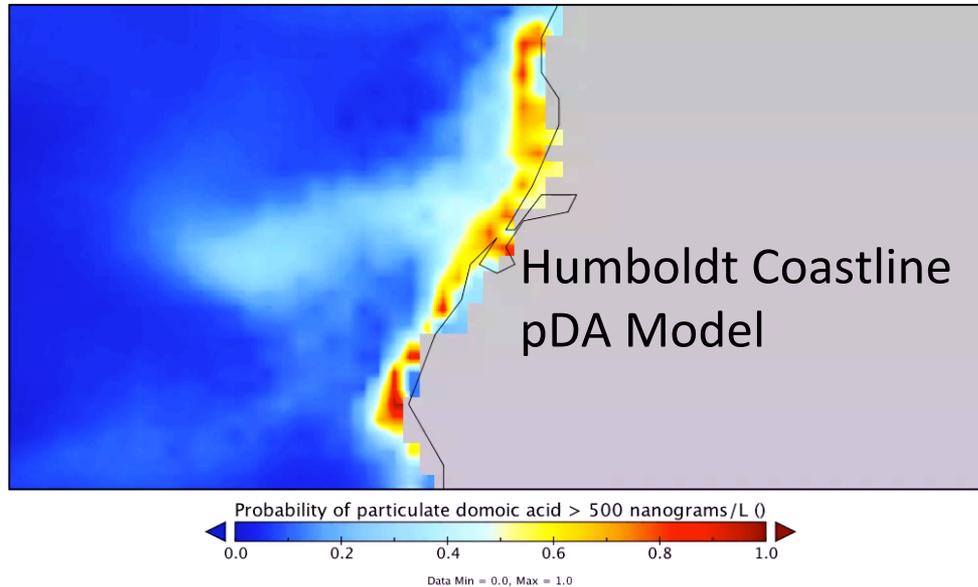
- Collect paired shellfish/water toxins
- Create statistical model of shellfish toxicity
- Hydrological model of HB

*Many thanks to NASA/Woody Turner for Stakeholder Engagement Funding*

# What does C-HARM tell us about shellfish toxicity?

Probability of particulate domoic acid > 500 nanograms/L

Time: 2016-04-11 00:00 +0000



## New partners in Aquaculture 2016-2017

Greg Dale –

Coast Seafoods, Humboldt Bay

Kelly Stromberg –

Catalina Sea Ranch (first offshore  
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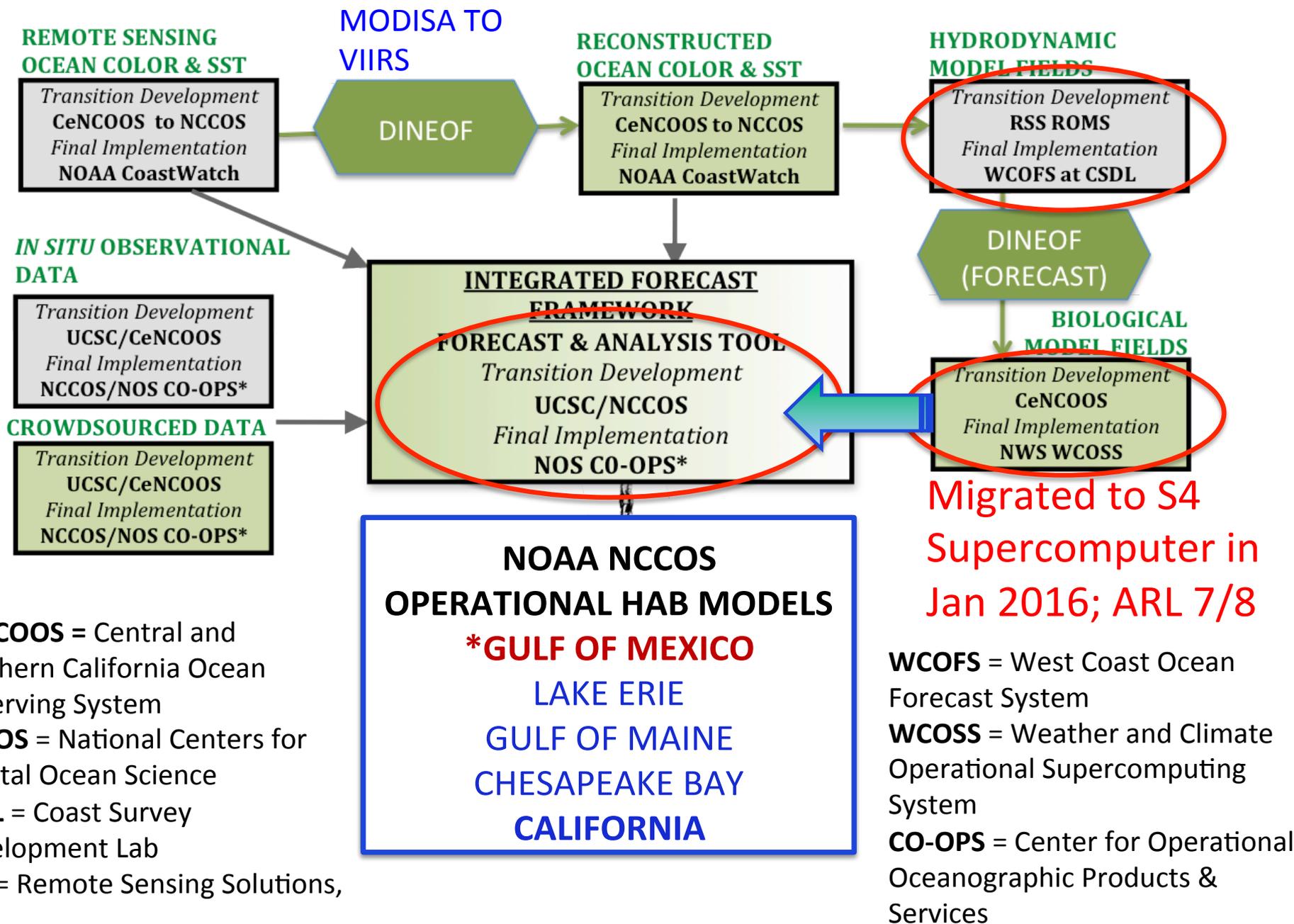
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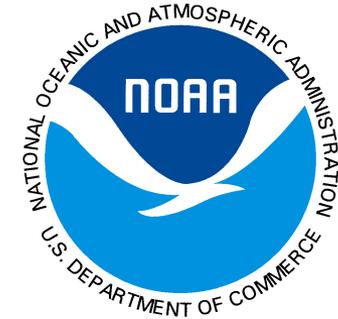


**CeNCOOS** = Central and Northern California Ocean Observing System  
**NCCOS** = National Centers for Coastal Ocean Science  
**CSDL** = Coast Survey Development Lab  
**RSS** = Remote Sensing Solutions, Inc.

## LESSONS LEARNED... *so far*

- Communicate early and often with partner agency/ operational end-user
- Be prepared for leadership turnover at agency level
- Carefully document and annotate your model system
- Stay flexible - do not get wedded to one idea of a model's "forever home"
- Continue R&D efforts - operational does not mean perfect

# THANK YOU!



**Terrestrial Hydrology & OBB**  
Jared Entin, Paula Bontempi  
**Applied Sciences Program**

Woody Turner  
Jay Skiles



**NOAA MERHAB & ECOHAB**  
**NCCOS**

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

New Position at SIO-SCCOOS  
clrande@ucsd.edu



# 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%

**salinity**  
**chl a**  
 **$R_{RS}(0^+, \lambda)$**

$a_p(\lambda)$   
 $a_g(\lambda)$   
**day of year**  
**ln(silicic acid:nitrate)**  
**silicic acid:phosphate**

temperature

ln(chl a)  
upwelling  
ln(Pajaro River)

ln(silicic acid)  
nitrate

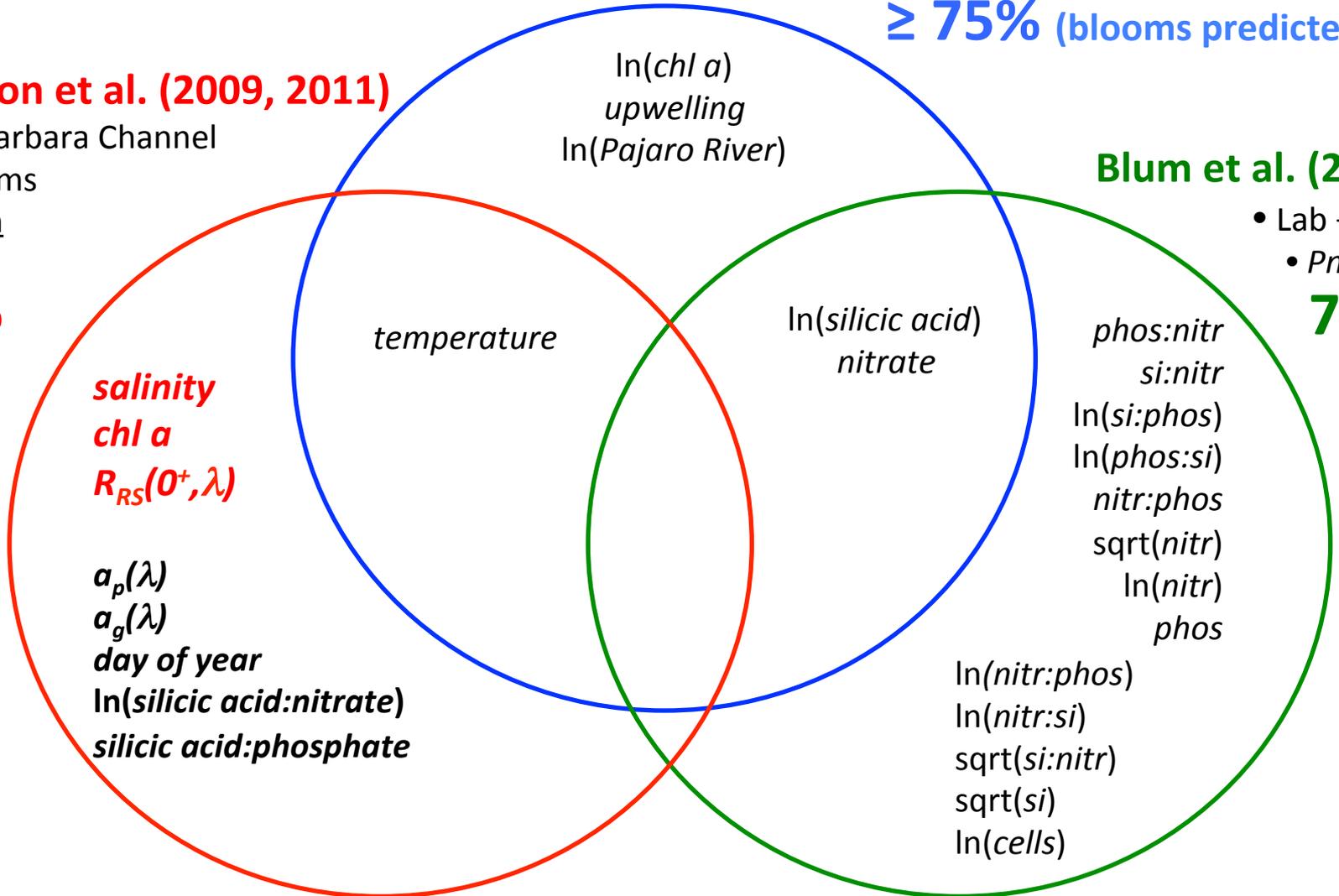
Blum et al. (2006)

- Lab + field
- *Pn* toxin

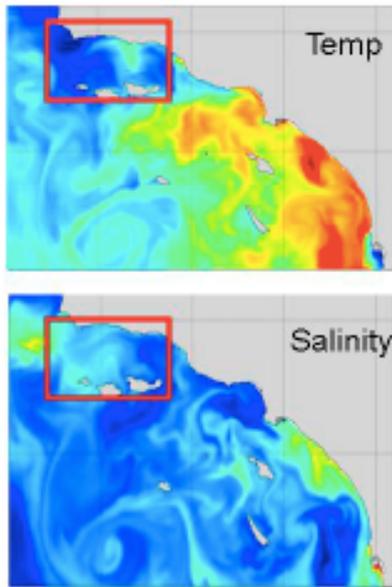
77%

phos:nitr  
si:nitr  
ln(si:phos)  
ln(phos:si)  
nitr:phos  
sqrt(nitr)  
ln(nitr)  
phos

ln(nitr:phos)  
ln(nitr:si)  
sqrt(si:nitr)  
sqrt(si)  
ln(cells)

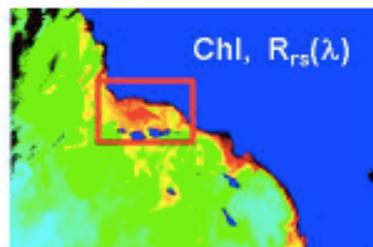


## ROMS Simulations



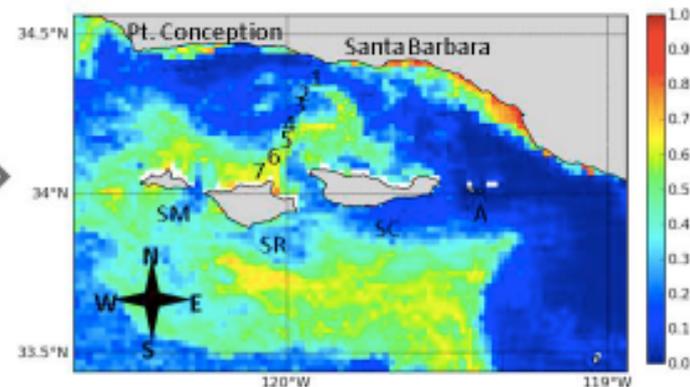
\*3-km CA ROMS with 3D-Var  
(Yi Chao/CeNCOOS&SCCOOS)

## MODIS-Aqua Satellite Data



Remote-Sensing  
HAB Model

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

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

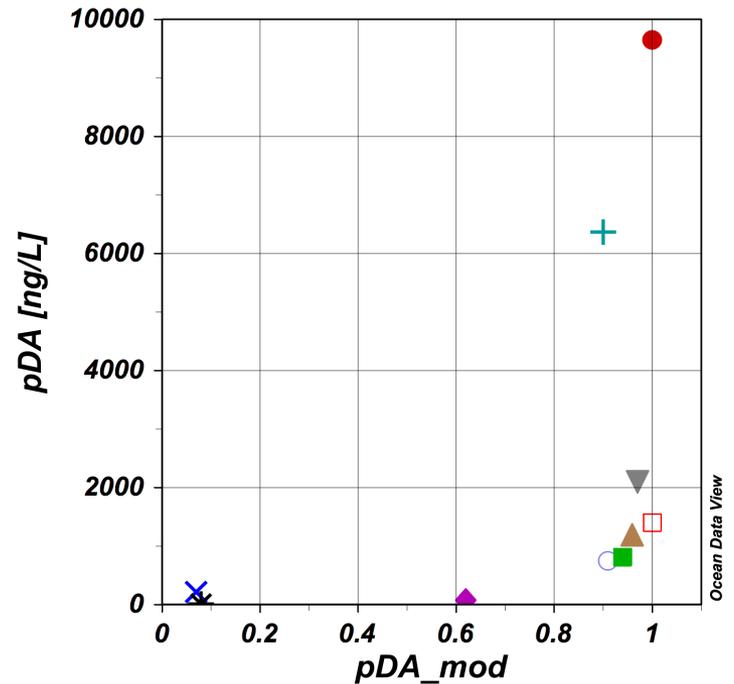
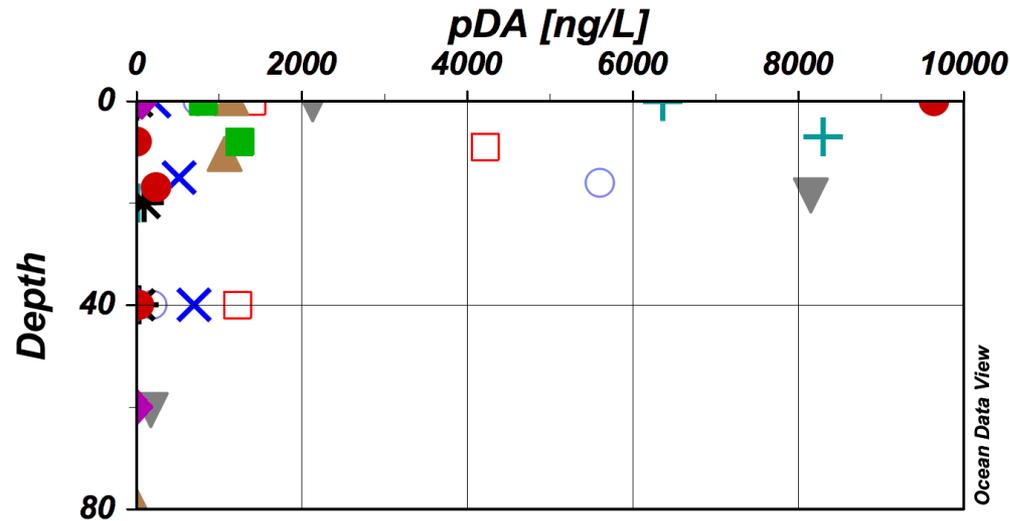
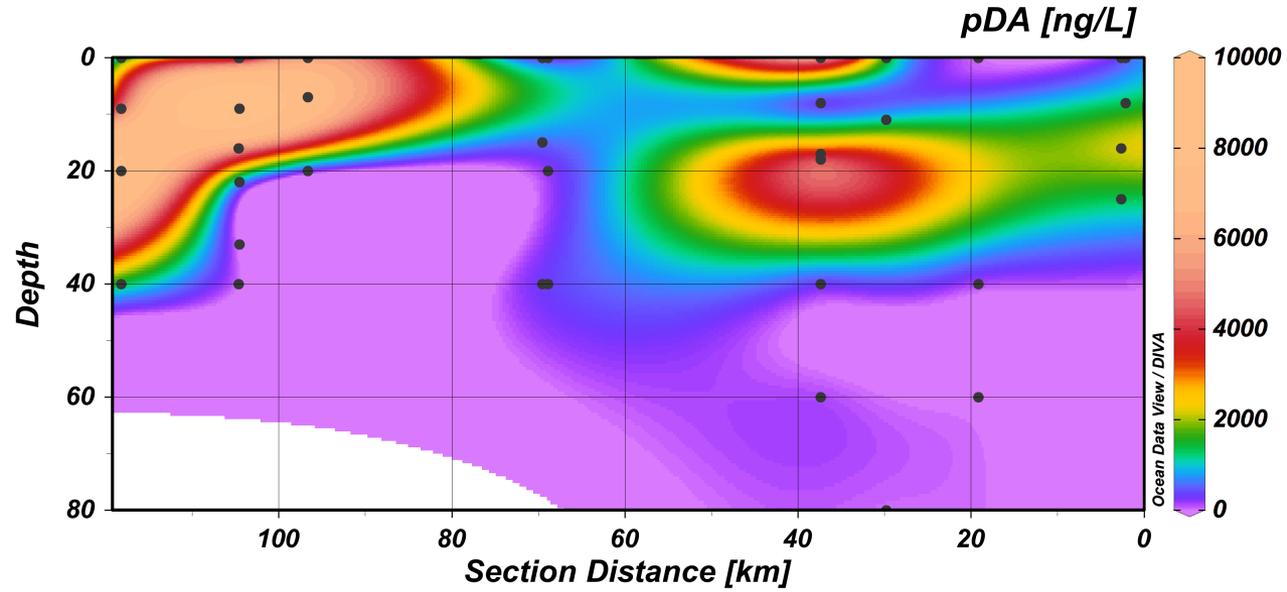
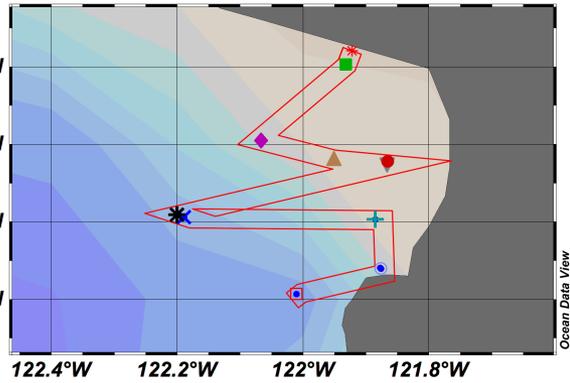
cDA  
( $10 \text{ pg cell}^{-1}$ )

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

Remote Sensing Reflectance  
Salinity  
Temperature  
Chlorophyll

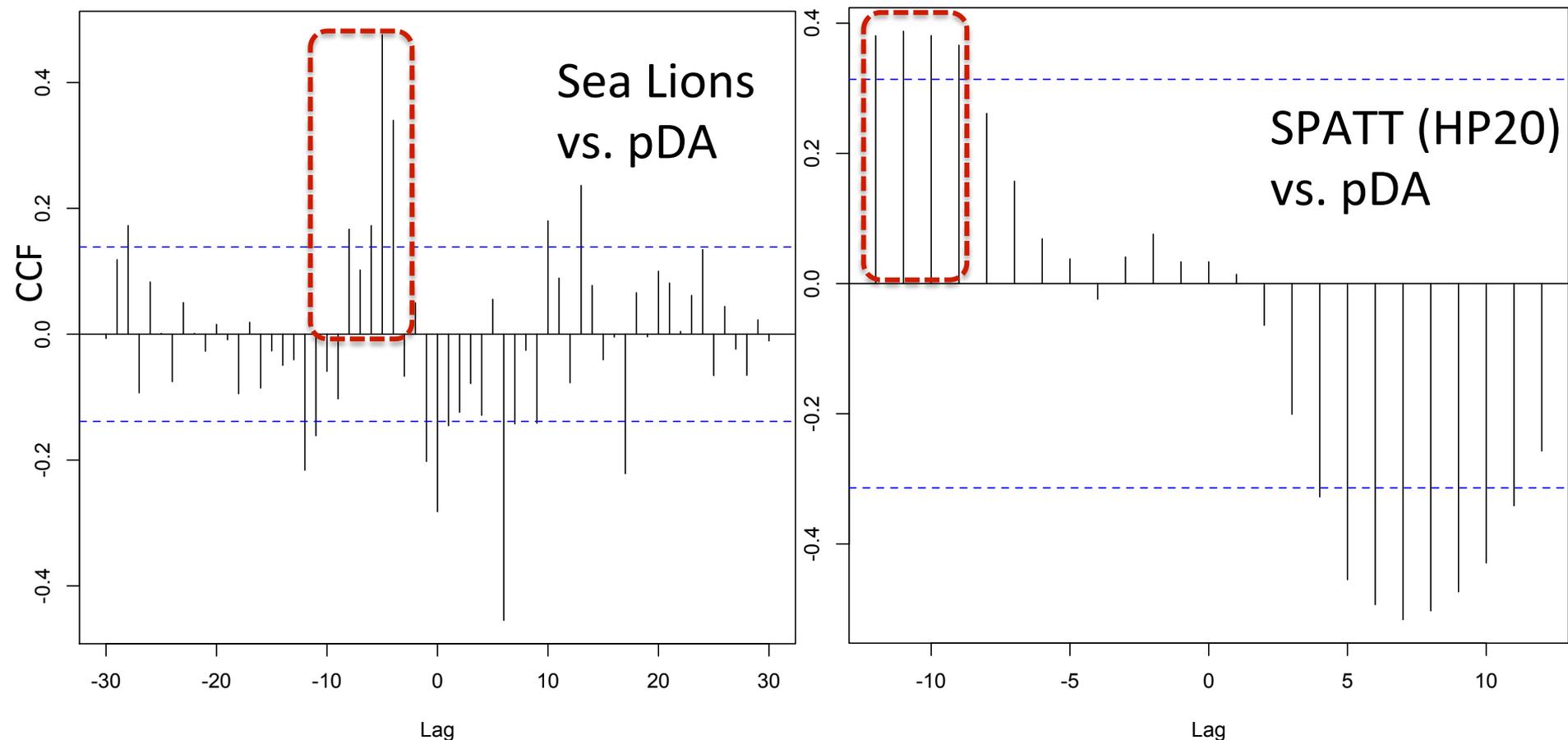
*Nitrate*  
*Phosphate*  
*Silicic Acid*

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



# 2014 FEASIBILITY STUDY - SKILL ASSESSMENT

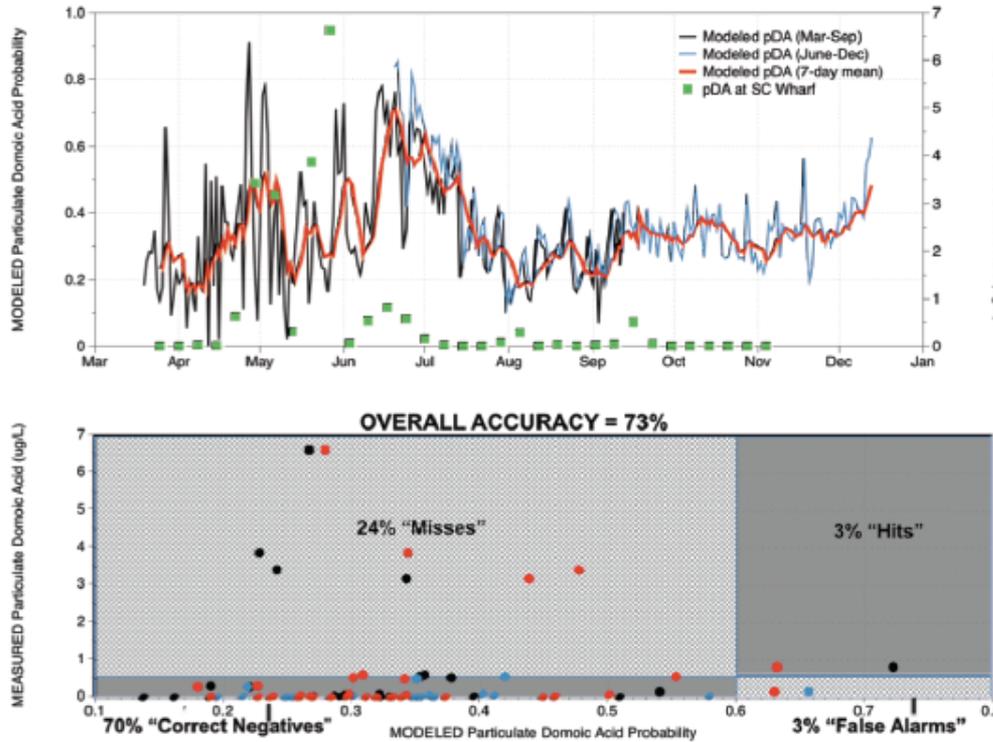
The pDA model correlates well with central CA stranding peaks as early as 7 days before they occur...and with SPATT DA 9-12 days ahead



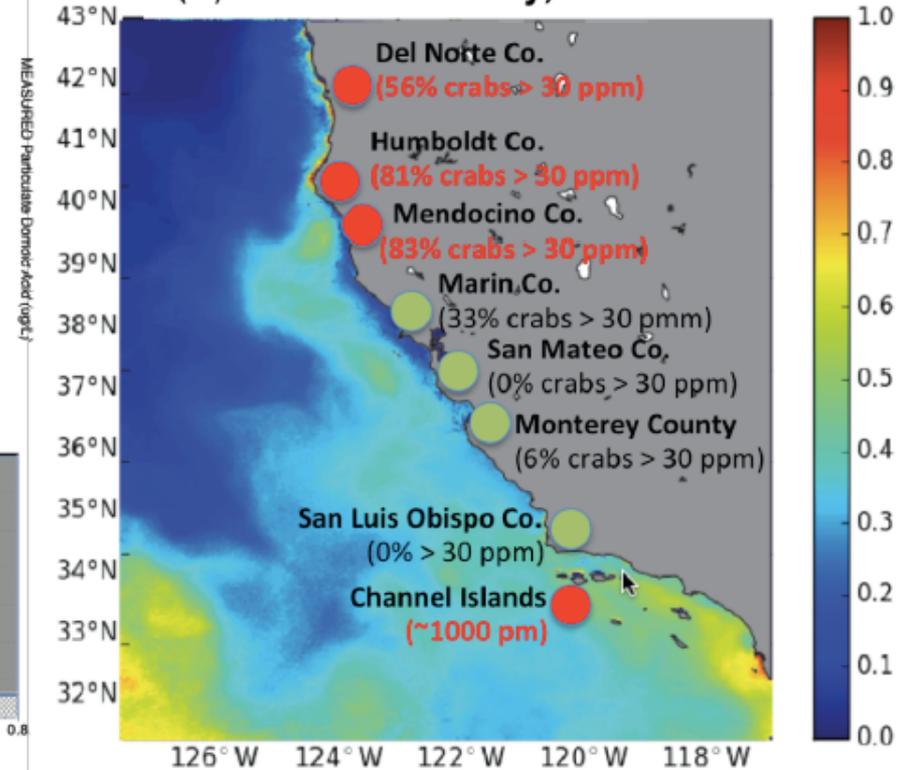
Cross correlation functions for the nearest **pixel corresponding with Santa Cruz Municipal Wharf**. ARIMA was applied to time series prior to analysis to account for non-stationarity.

# 2015 – Dungeness crab closures match climatological model

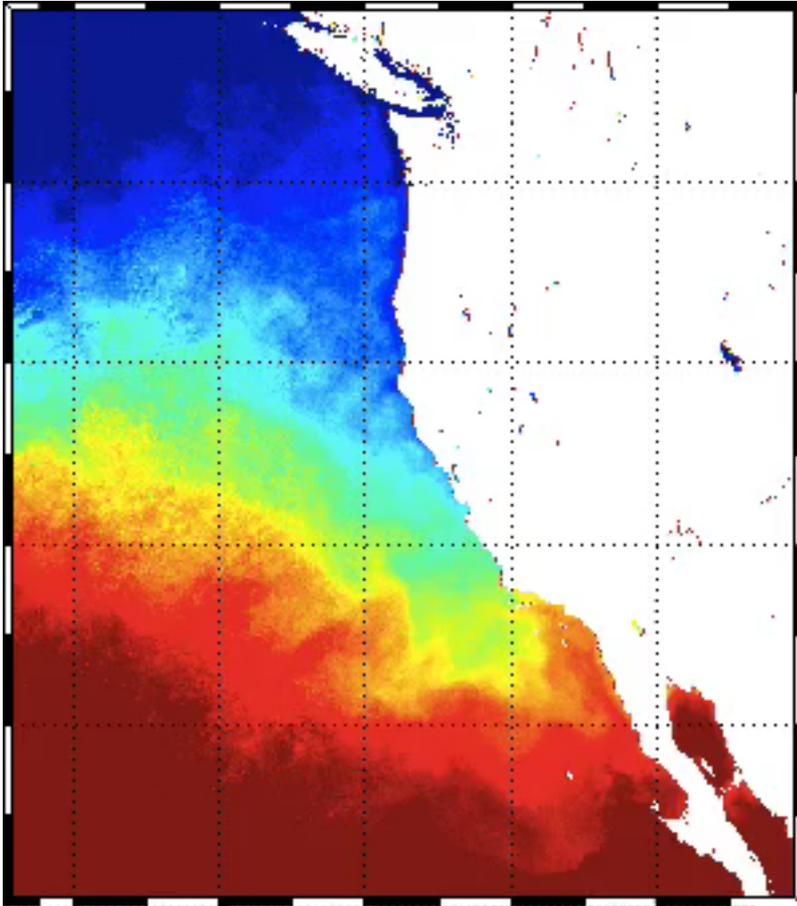
(A) Santa Cruz Wharf – Skill Assessment



(B) Toxin Probability, Oct-Nov 2015

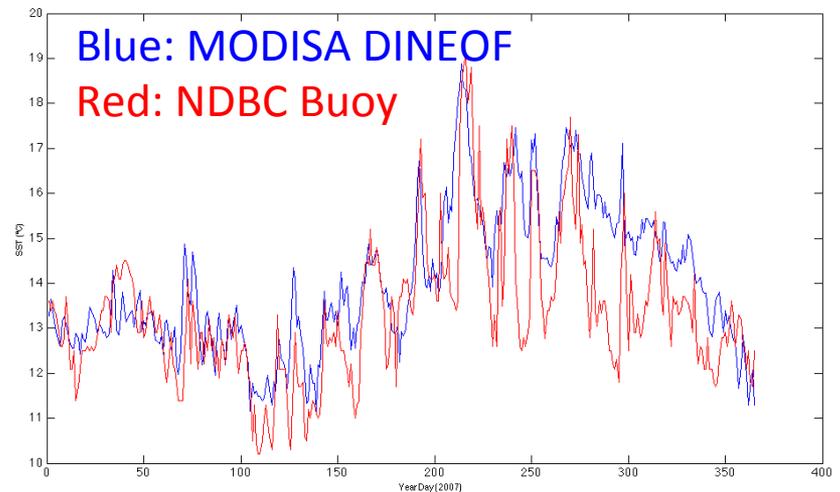


# Data Interpolating of EOFs (DINEOF)



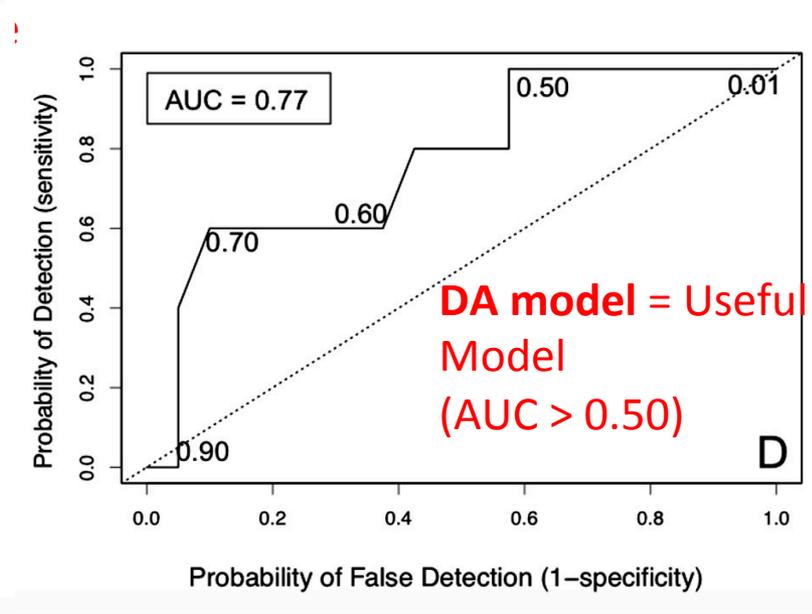
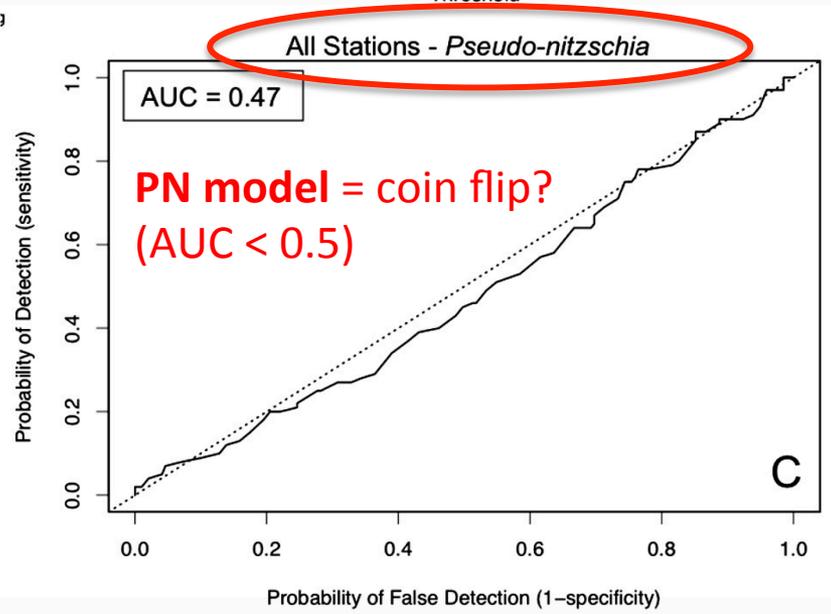
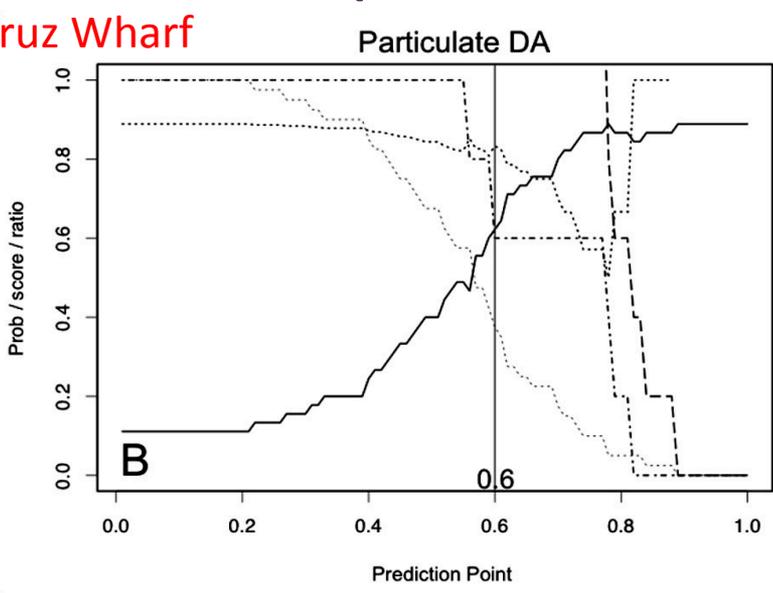
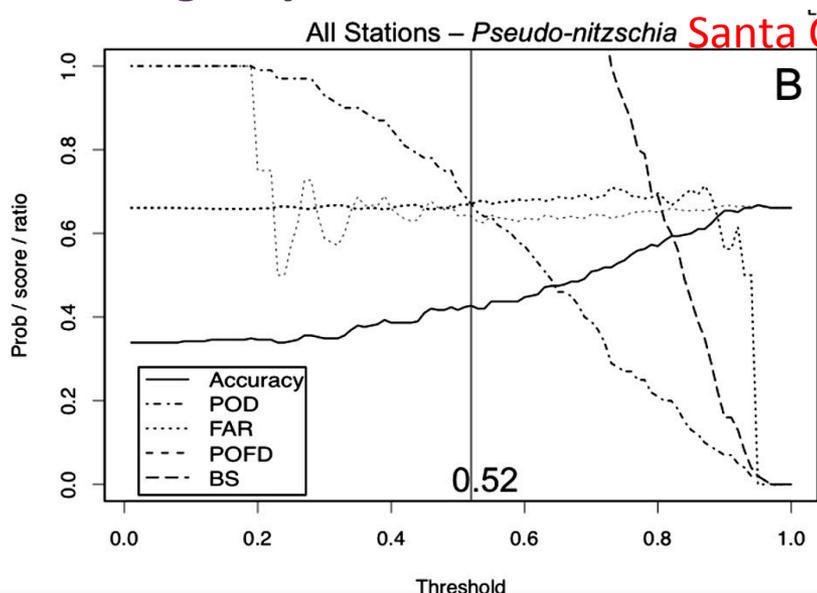
2007 SST Reconstruction (daily)

- 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:  $R^2=0.9$ ,  $RMSE < 1^\circ C$ , as good as Pathfinder AVHRR but daily!

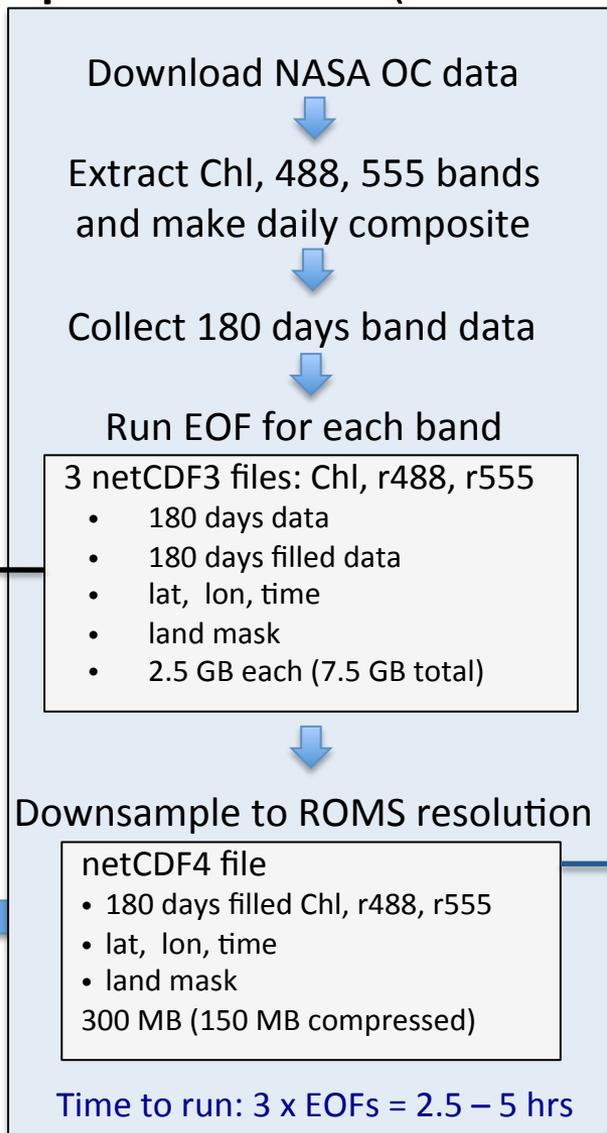


(NDBC 46054 West Santa Barbara)

# Contingency Plots to Assess Model Performance - Optimize Prob. Threshold



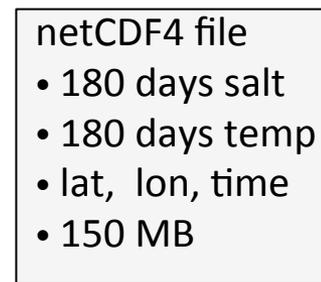
### Prep Satellite data (CoastWatch)



Archive  
Source data  
DINEOF results

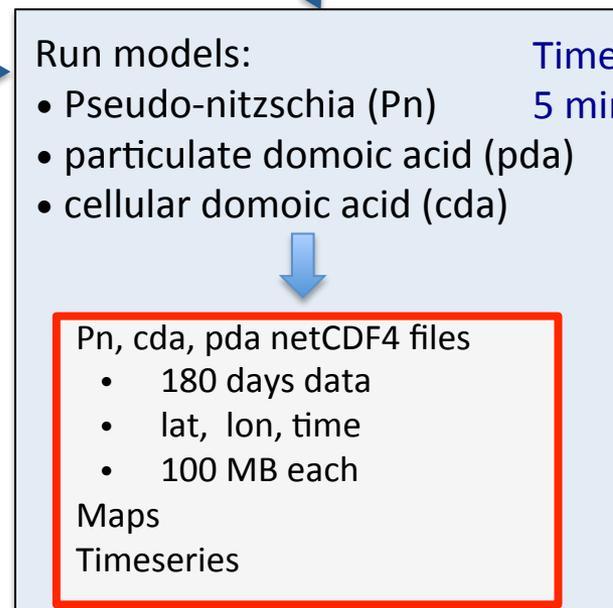
Use in forecast script  
(next slide)

### Collect ROMS data (CeNCOOS, S4)



Time to run  
4 min / day

### Nowcast (CeNCOOS, S4)



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

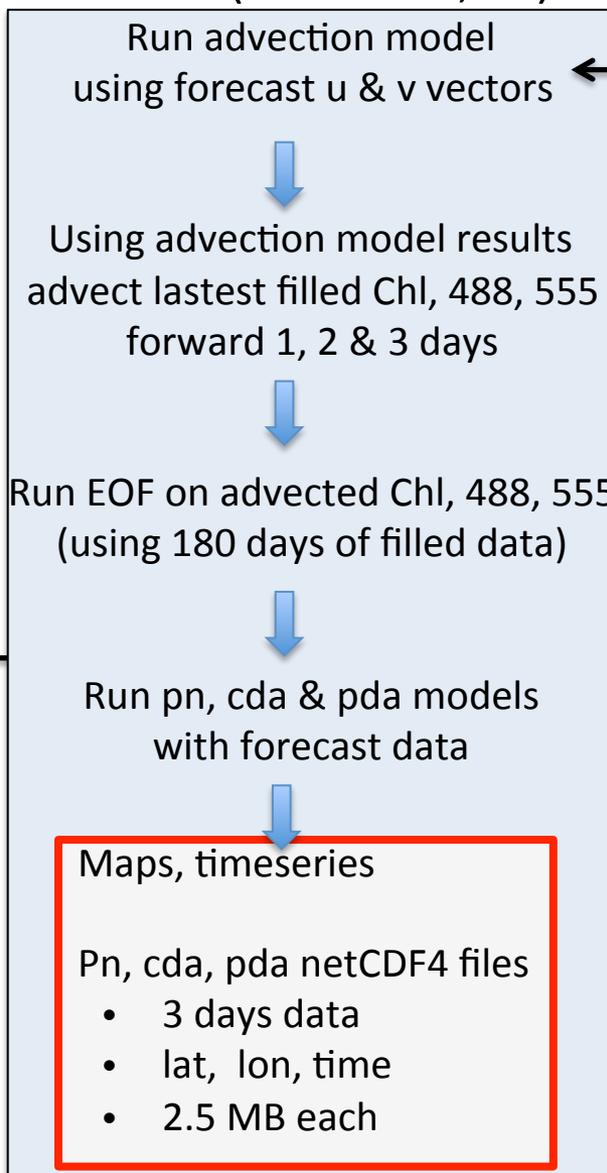
- salt,
- temp

**Time to run total: 56 min**

Adv. model: 10 min

Data advection & EOFs: 36 min

Pn, cda, pda models: 5 min



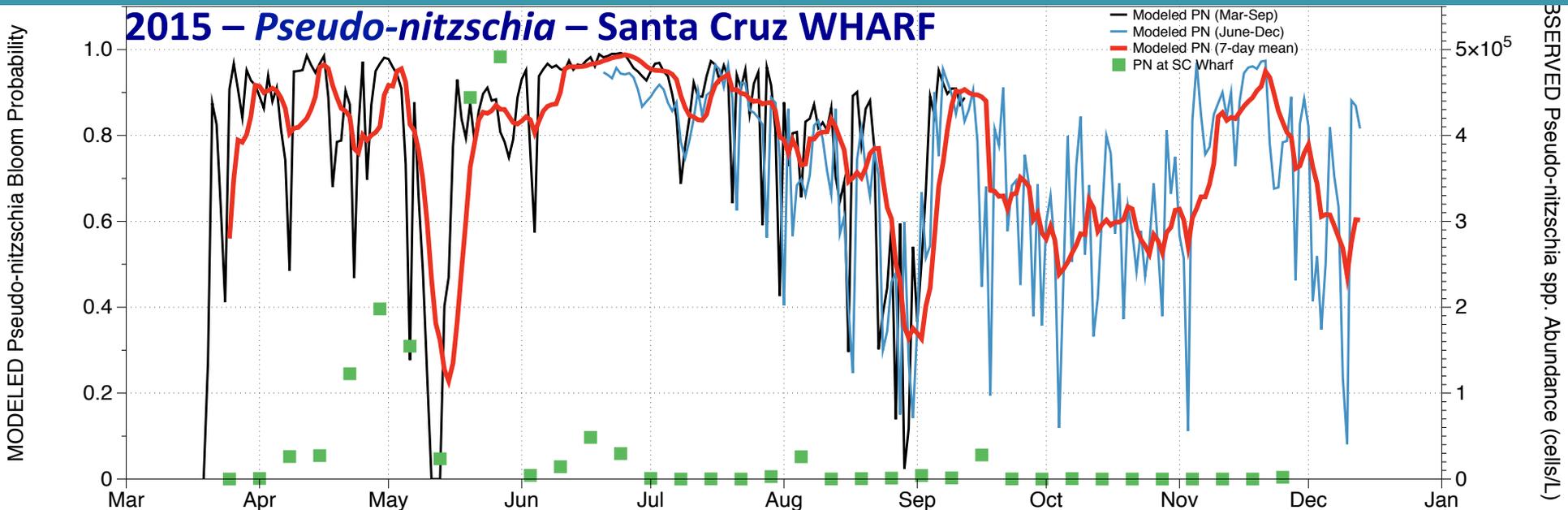
3-day ROMS forecast

- 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



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

