For assistance in accessing this document please send an email to EPACyanoHABs@epa.gov

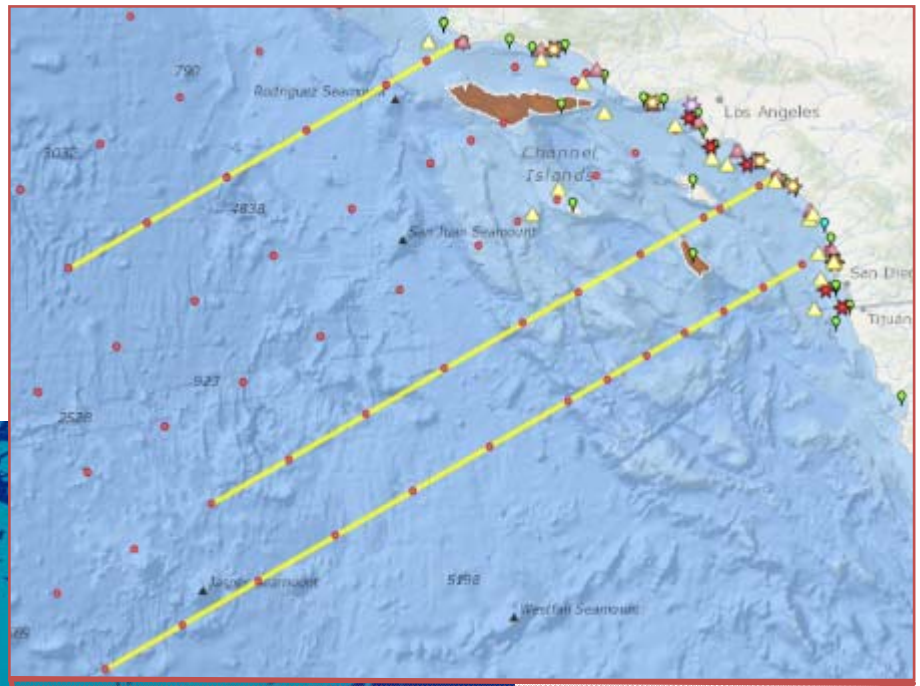
California Harmful Algae Risk Mapping (C-HARM) System

Clarissa Anderson[1], Raphael Kudela[2], Fred Bahr[3], Dave Anderson[3], Yi Chao[4], Dale Robinson[5], and Richard Stumpf[6]

[1]Southern California Coastal Ocean Observing System (SCCOOS) @ SIO
[2]University of California, Santa Cruz
[3]Central & Northern California Ocean Observing System (CeNCOOS)
[4]UCLA JIFRESSE/RSS Inc.
[5]NOAA CoastWatch
[6]NOAA National Ocean Service

U.S. Integrated Ocean Observing System

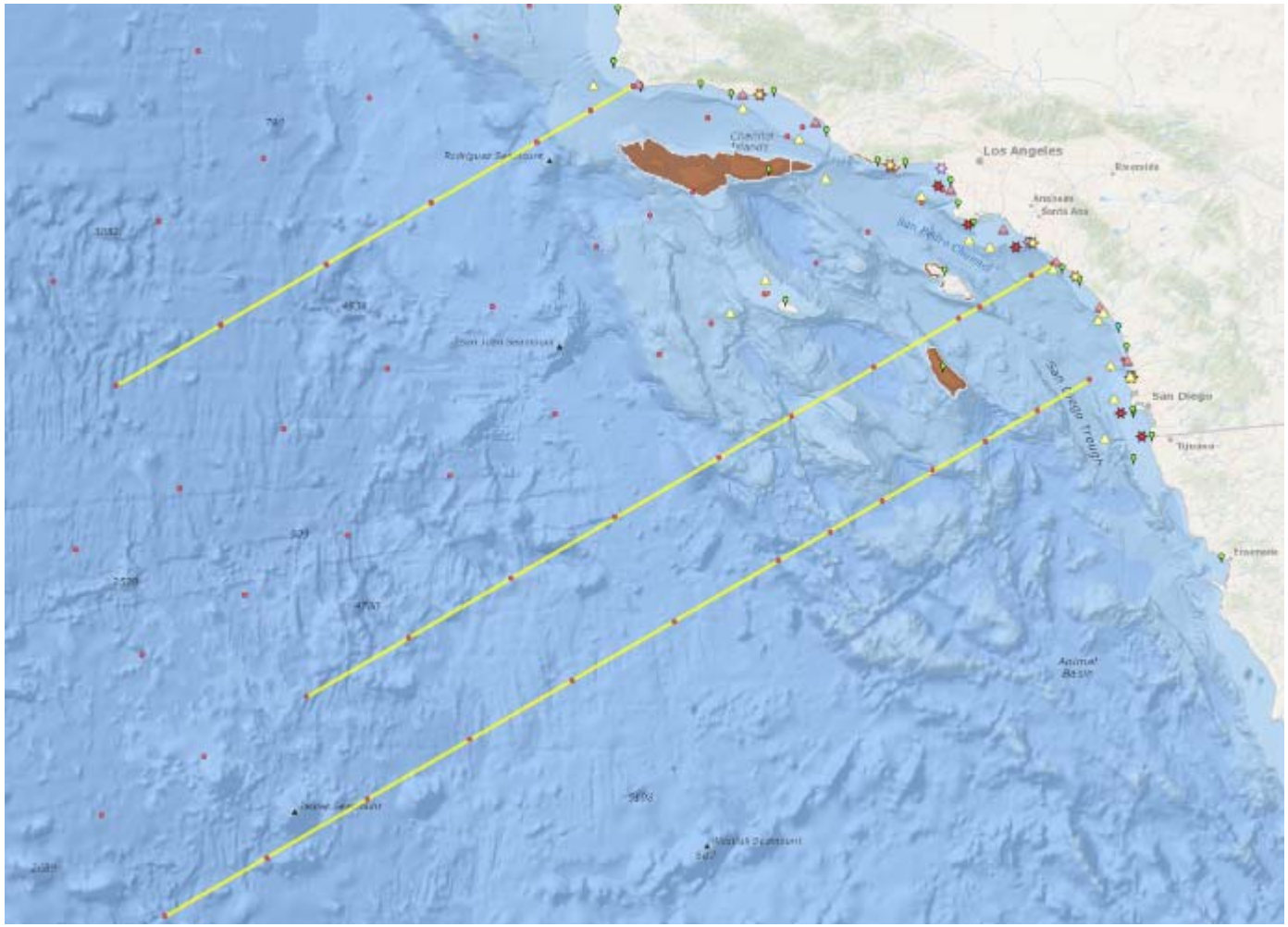
The **Integrated Ocean Observing System** or IOOS was born from the Integrated Coastal and Ocean Observation Act of 2009.



This law designated **11 regional associations** that act as a science-based decision support system.

Southern California Coastal Ocean Observing System (SCCOOS)

Our Collaborative Network of Ocean Observations



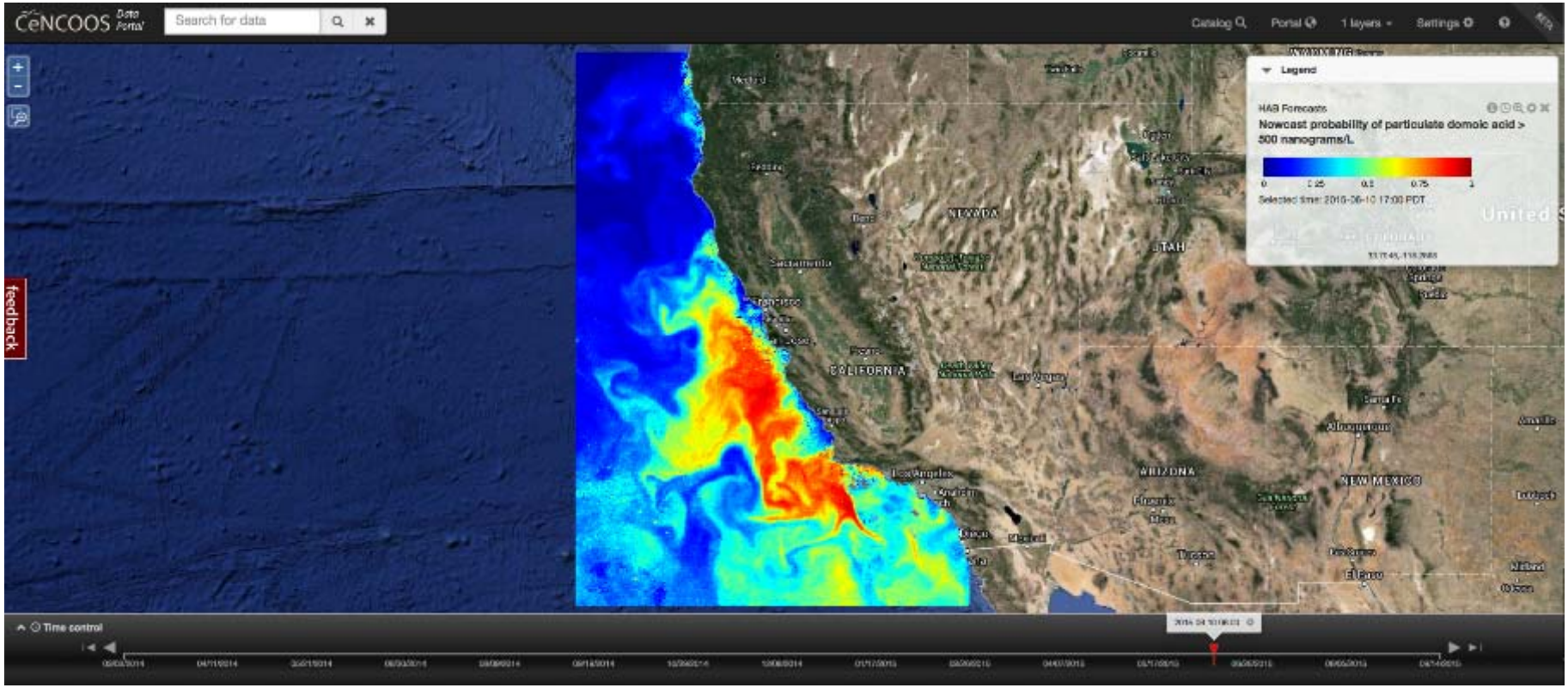
- High Frequency Radar 2005
- Ocean Acidification 2014
- CalCOFI Stations 1949
- CDIP Wave Buoys 1975
- CalCOFI SCCOOS Stns 2004
- Spray Glider Paths 2007
- ASBS Regions 2014
- Automated Shore Stns 2005
- Outfall Sites 2017
- Manual Shore Stns 1916

info@sccoos.org (858) 534.9808 www.sccoos.org

California Harmful Algae Risk Mapping (C-HARM) System

HAB Nowcasts and Forecasts for the California Coast

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



NASA Guidelines for Creating an Operational Ecological Forecasting model… at NOAA

I. Is there a need for a predictive capability for domoic acid events?

II. Is the model system ready and feasible?

III. Does the model have skill?

IV. Are stakeholders and agency end-users engaged?

V. Can we successfully cross the "valley of death" between research and operations?

I. Why predict HABs in California?

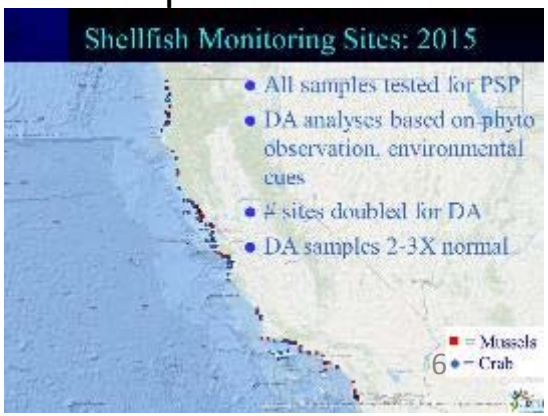
- Domoic acid (from *Pseudo-nitzschia* blooms) is the **leading HAB issue on the US West Coast**

- **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**

Lewitus et al. 2012

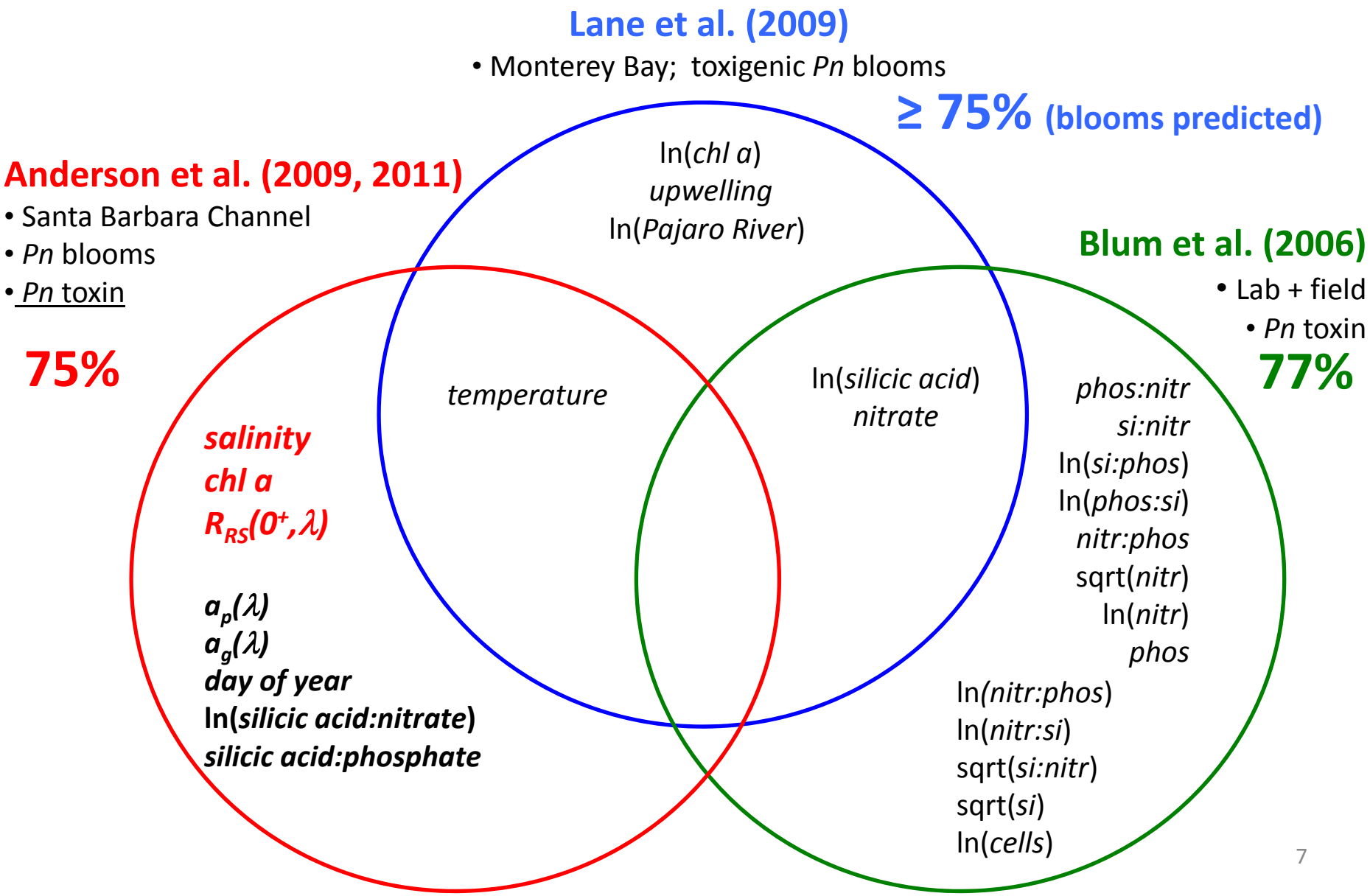
CA Dept of Public Health

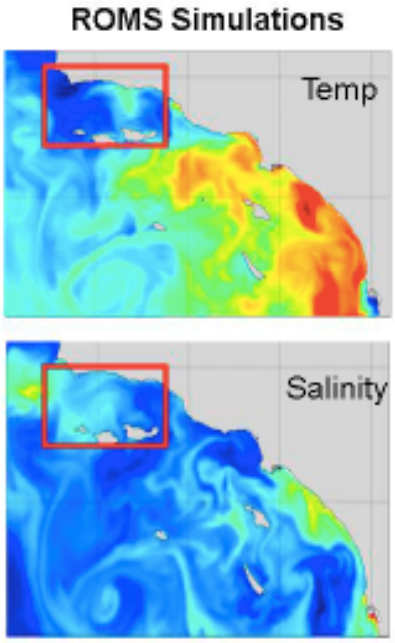


INITIAL BASELINE FOR DECISION-MAKING

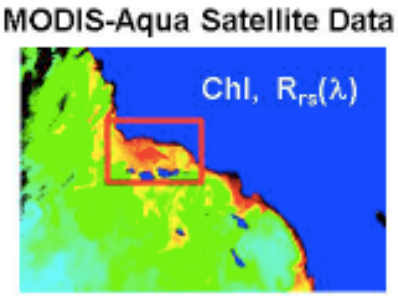
- CDPH monitors for DA if PN present in water
- Relies on fixed quarantine periods

Empirical prediction models for *Pseudo-nitzschia* and Domoic Acid

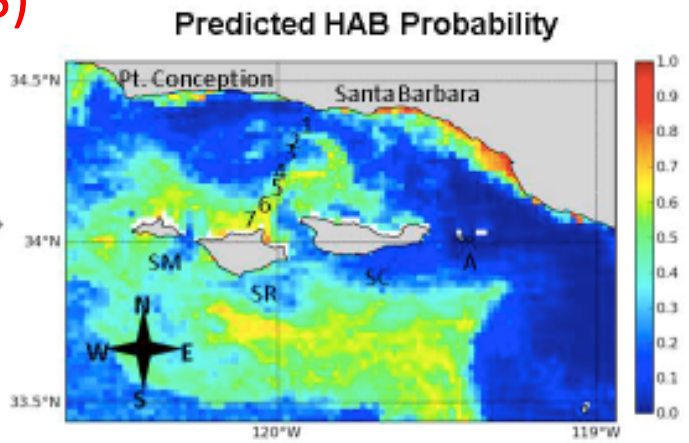




*3-km CA ROMS with 3D-Var
(Yi Chao/CeNCOOS&SCCOOS)



Remote-Sensing HAB Model



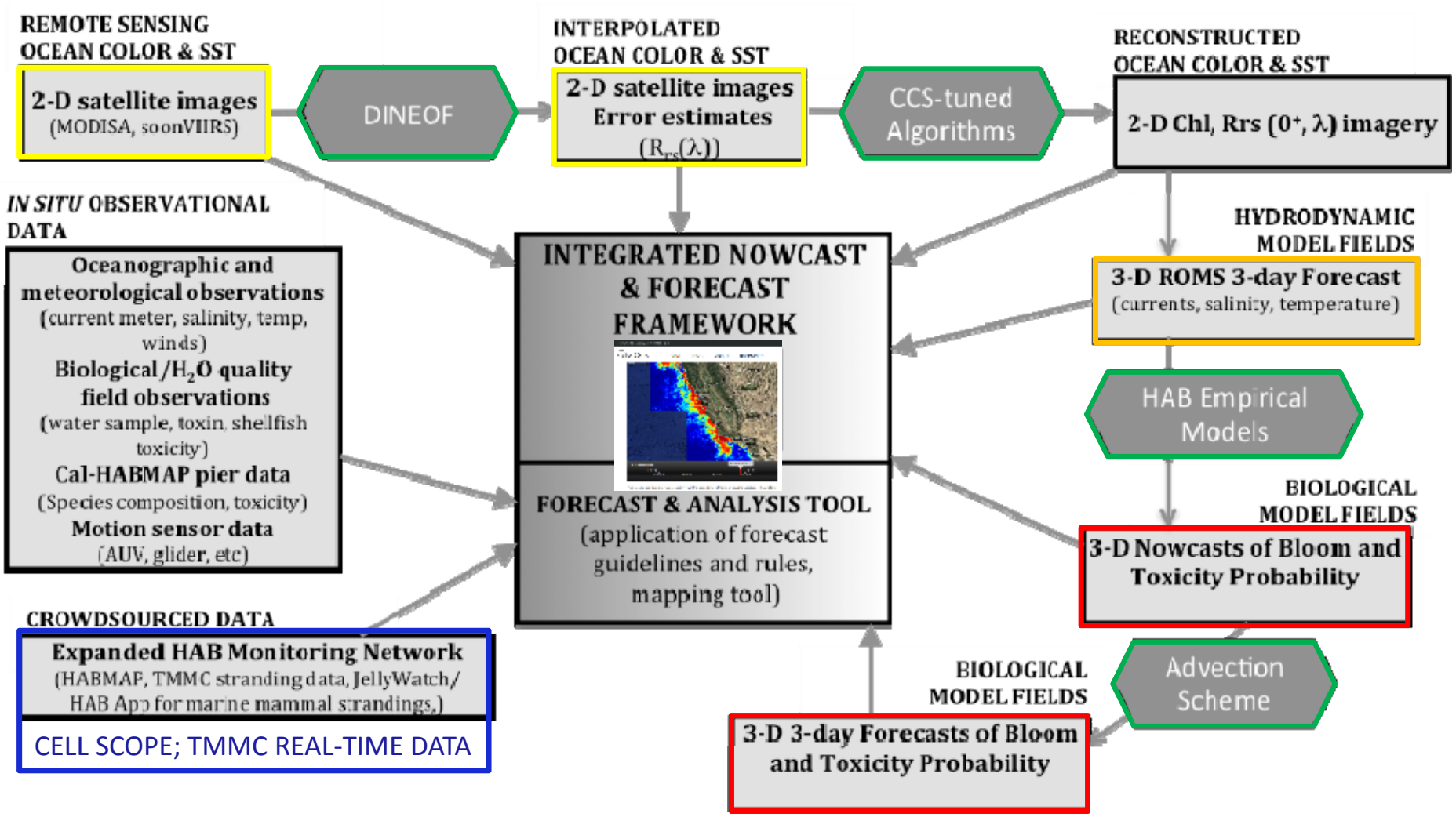
HAB Variable (Threshold)	Best-fit Logistic GLM - **RS** $P_{bloom} = e^{(logit)}/[e^{(logit)} + 1]$
Pseudo-nitzschia (10^4 cells mL^{-1})	**(i)** logit = 8.54 - 10.84*[R_{rs} (510/555)] – 0.216*[Month] + 4.67*[R_{rs}(490/555)]
	(ii) logit = 5.32 – 2.87*[R_{rs} (490/555)] – 0.165*[Month]
pDA (500 ng L^{-1})	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 diatom blooms from ocean color and a regional ocean model. Geophysical Research Letters L04603

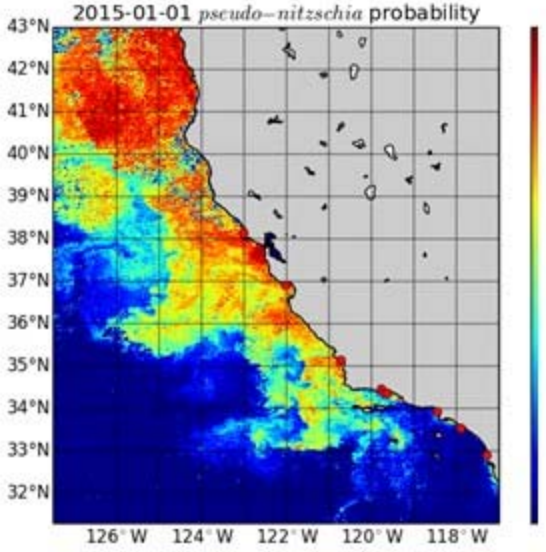
California Harmful Algae Risk Mapping (C-HARM) System



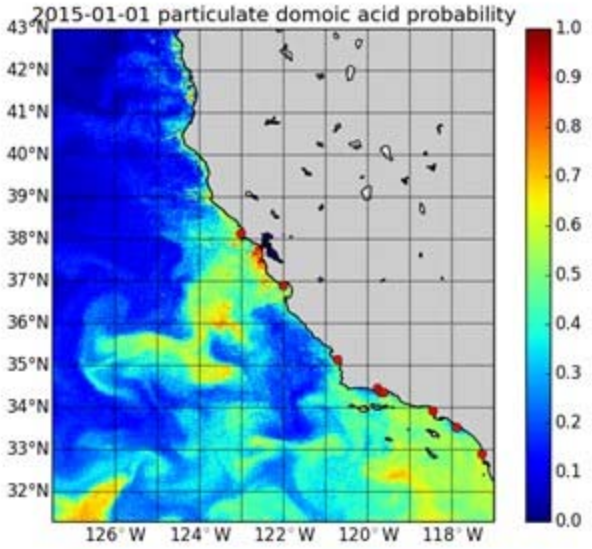
NASA Applied Sciences Program, Terrestrial Hydrology, Ocean Biology and Biogeochemistry Programs
"Ecological Forecasting for Conservation and Resource Management"
"Remote Sensing of Water Quality"

II. Is the Model System Ready and Feasible?

Probability Maps

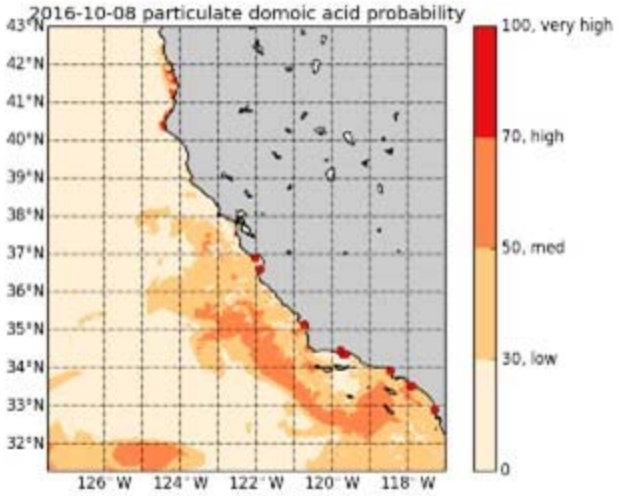


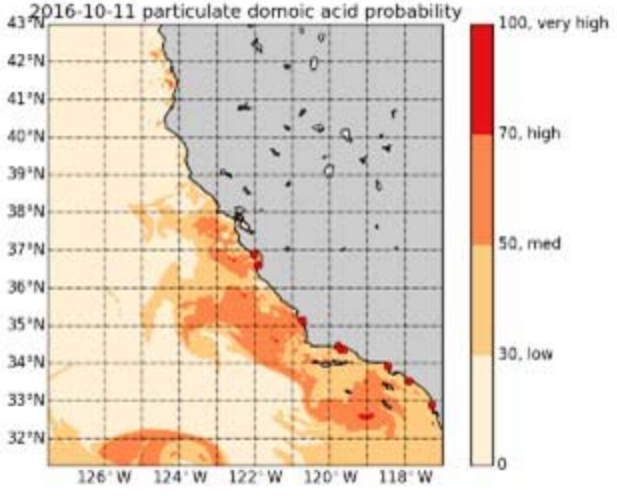
Particulate Domoic Acid Nowcast



Particulate Domoic Acid Forecast

Risk Maps based on stakeholder feedback



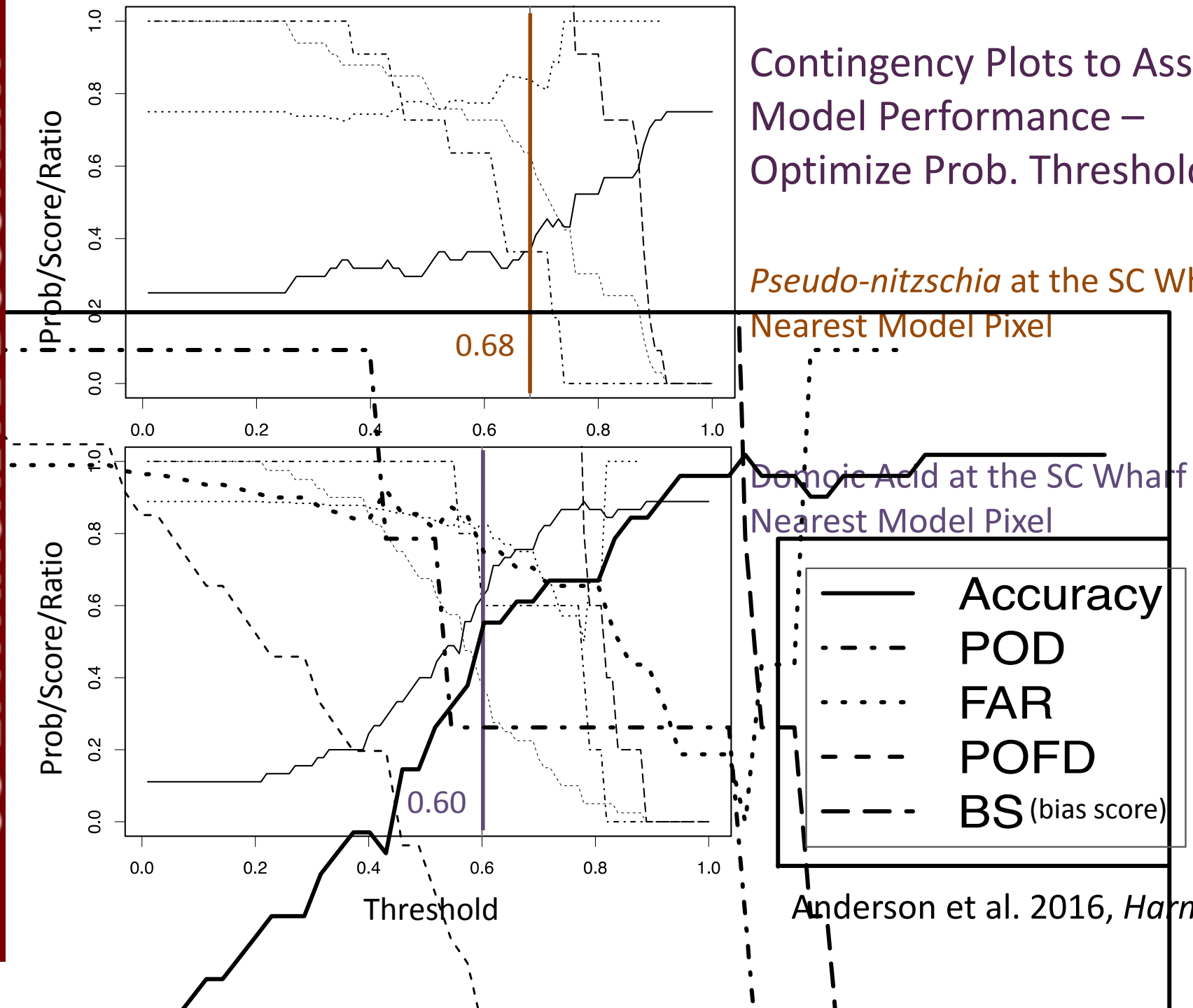


III. Does the model have skill?

Contingency Plots to Assess Model Performance – Optimize Prob. Threshold

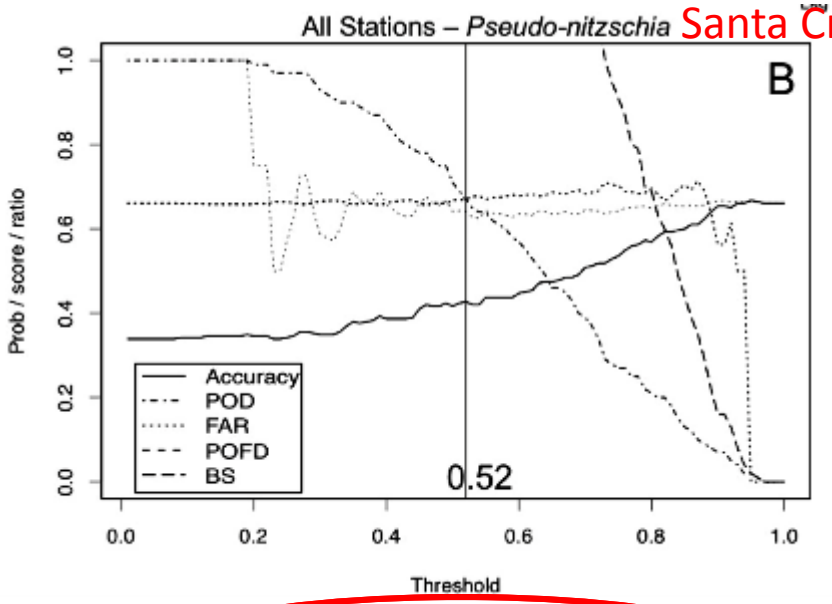
Pseudo-nitzschia at the SC Wharf *vs.* Nearest Model Pixel

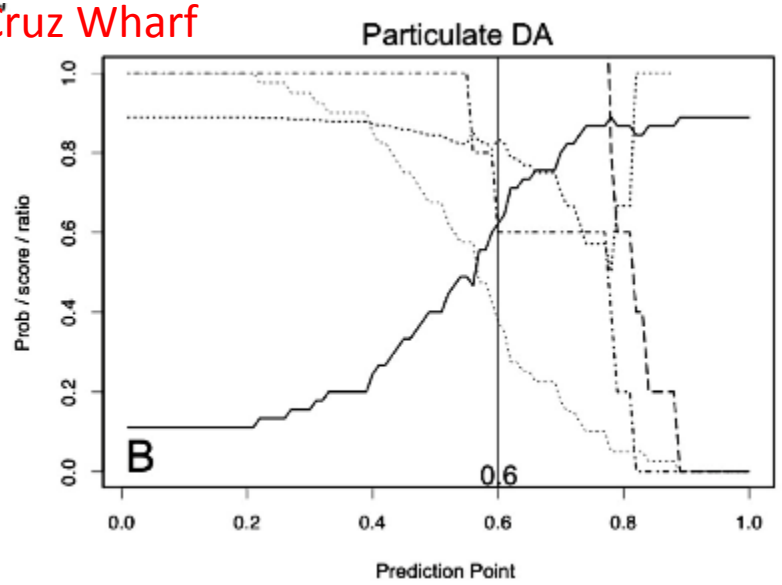
Domoic Acid at the SC Wharf *vs.* Nearest Model Pixel

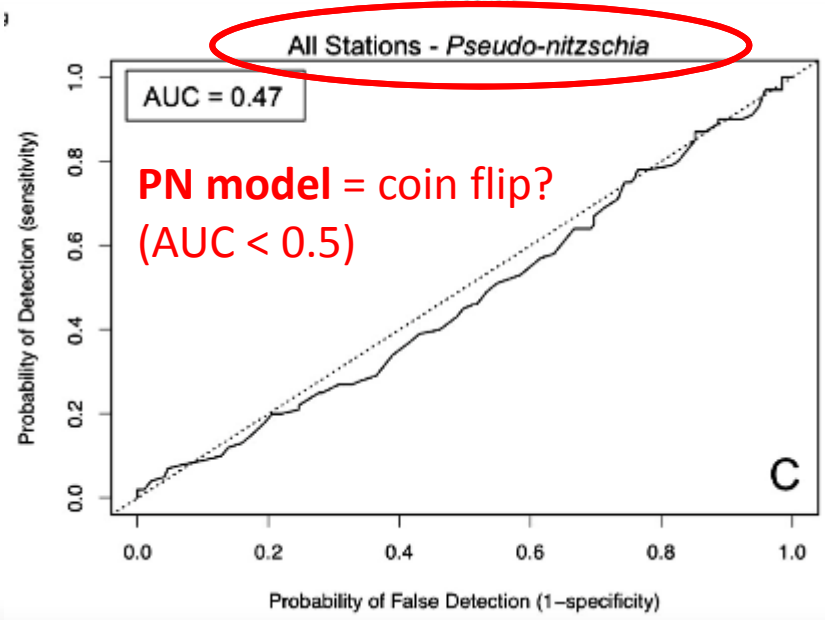


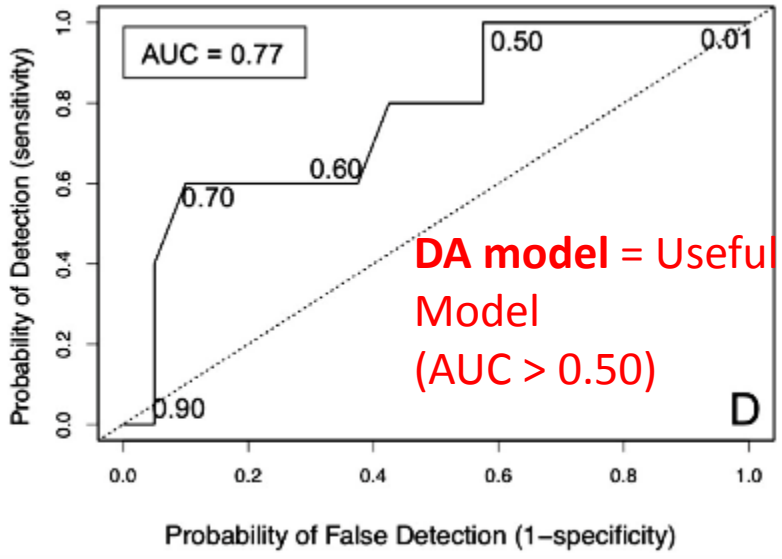
Anderson et al. 2016, *Harmful Algae*

2014 FEASIBILITY STUDY - SKILL ASSESSMENT





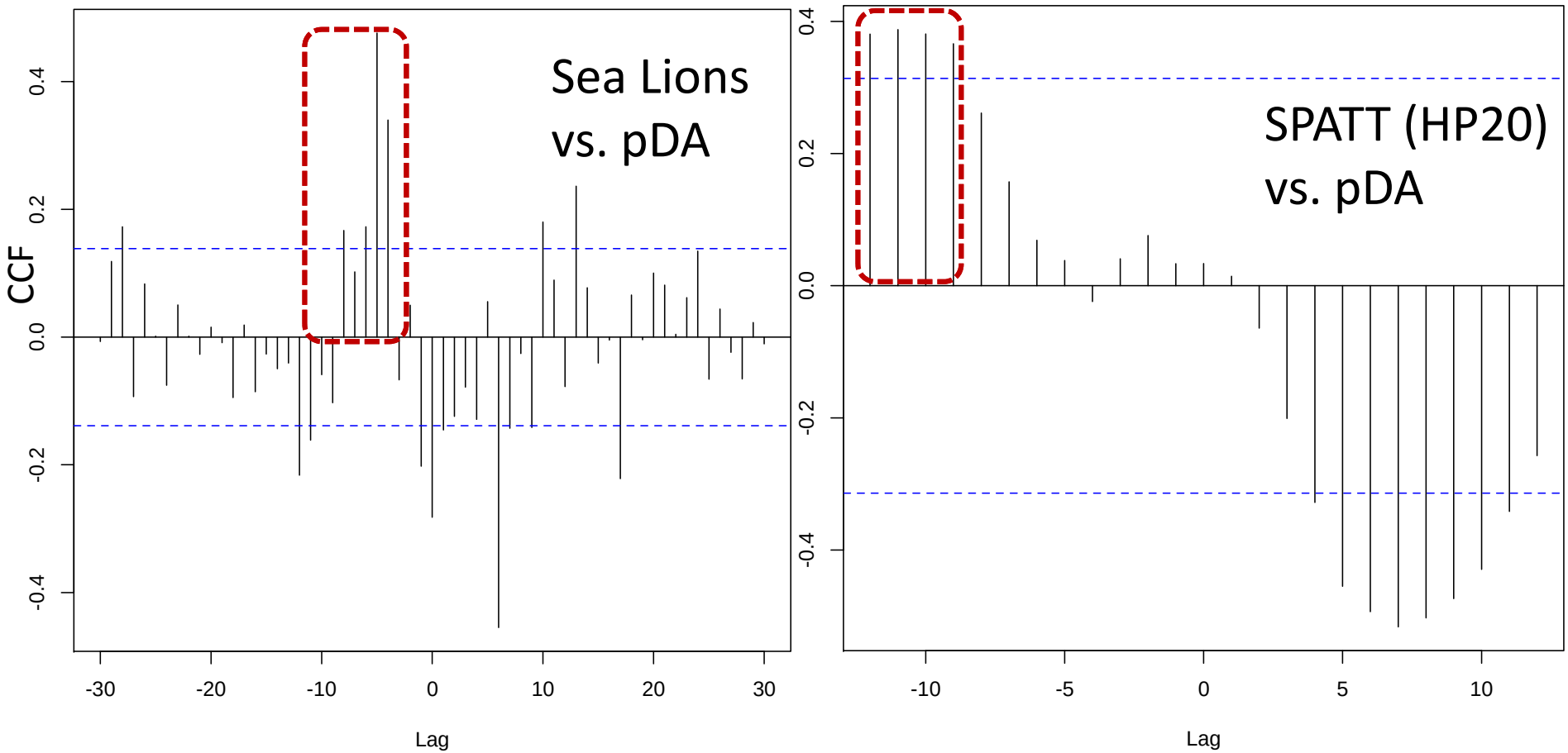




Anderson et al. 2016, *Harmful Algae*

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.

Anderson et al. 2016, *Harmful Algae*

Geophysical Research Letters

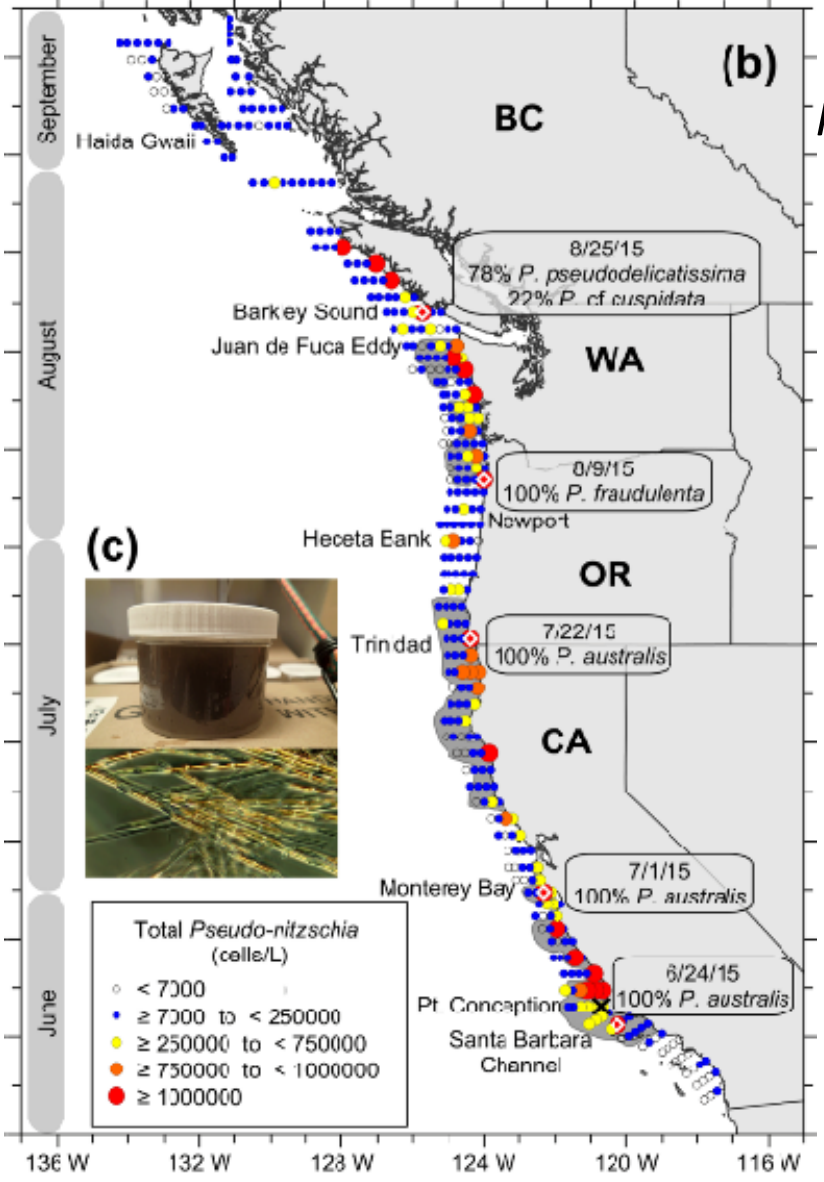
2015 FEASIBILITY STUDY

RESEARCH LETTER
10.1002/2016GL070023

Special Section:
Midlatitude Marine Heatwaves: Forcing and Impacts

An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

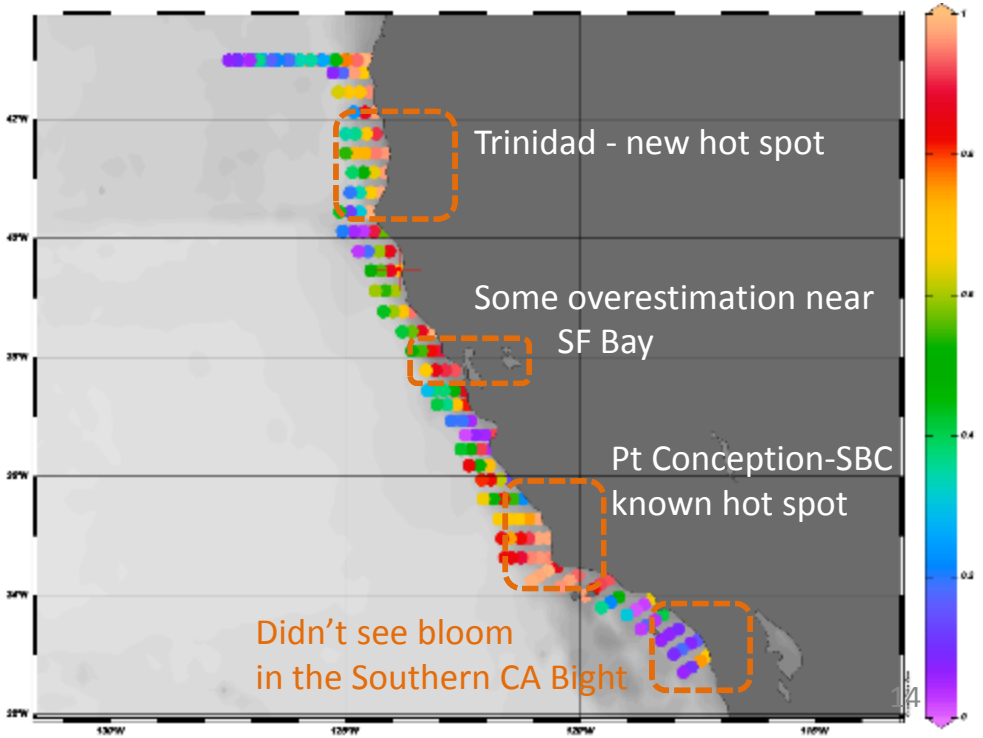
Ryan M. McCabe[1], Barbara M. Hickey[2], Raphael M. Kudela[3], Kathi A. Lefebvre[4], Nicolaus G. Adams[4], Brian D. Bill[4], Frances M. D. Gulland[5], Richard E. Thomson[6], William P. Cochlan[7], and Vera L. Trainer[4]



R/V Shimada NMFS Cruise-of-Opportunity

C-HARM ESTIMATES AT CRUISE STNS

Likelihood of a *Pseudo-nitzschia* bloom



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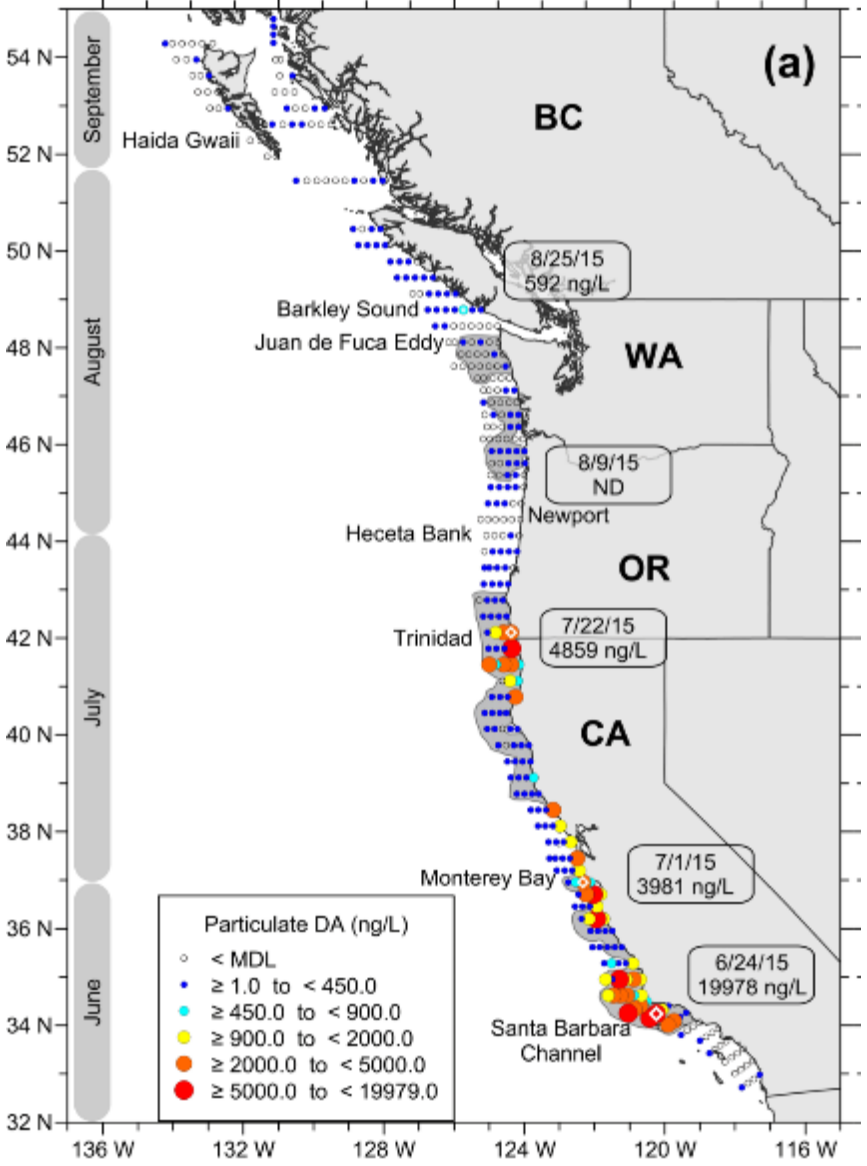
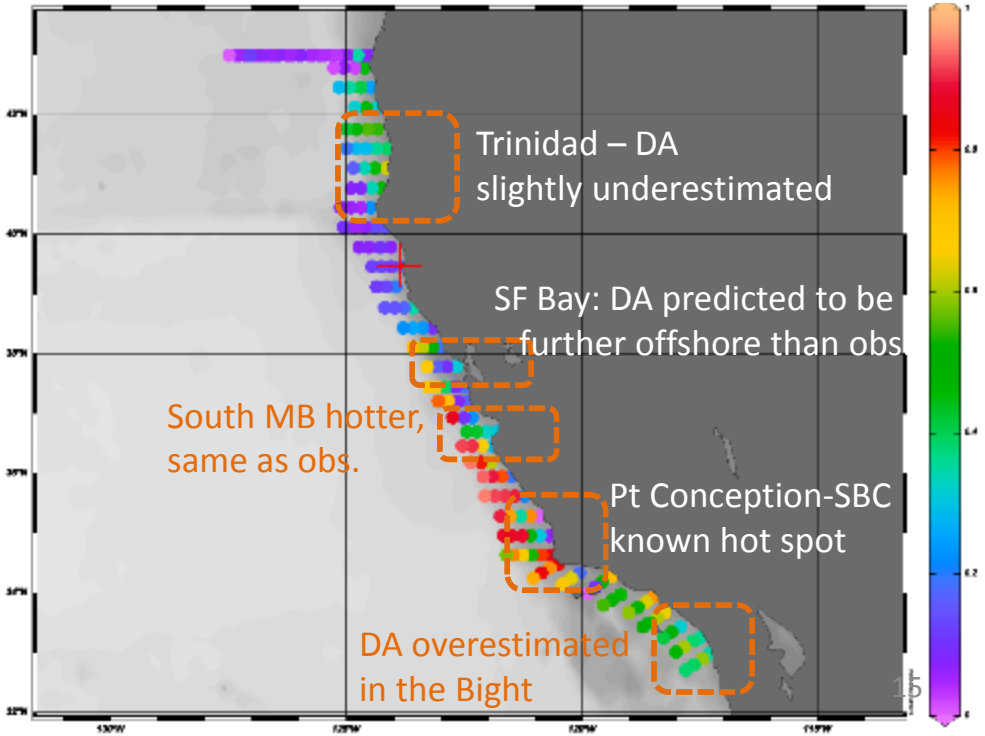


R/V Shimada NMFS Cruise-of-Opportunity

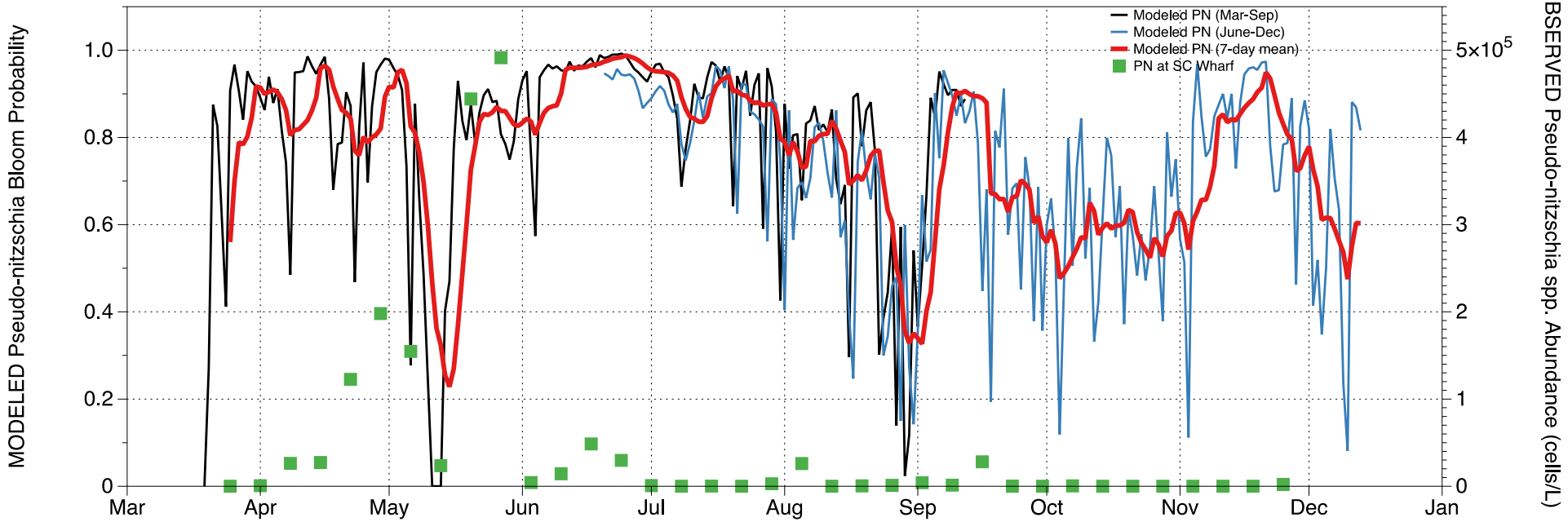
C-HARM ESTIMATES AT CRUISE STNS

Likelihood of elevated DA Levels

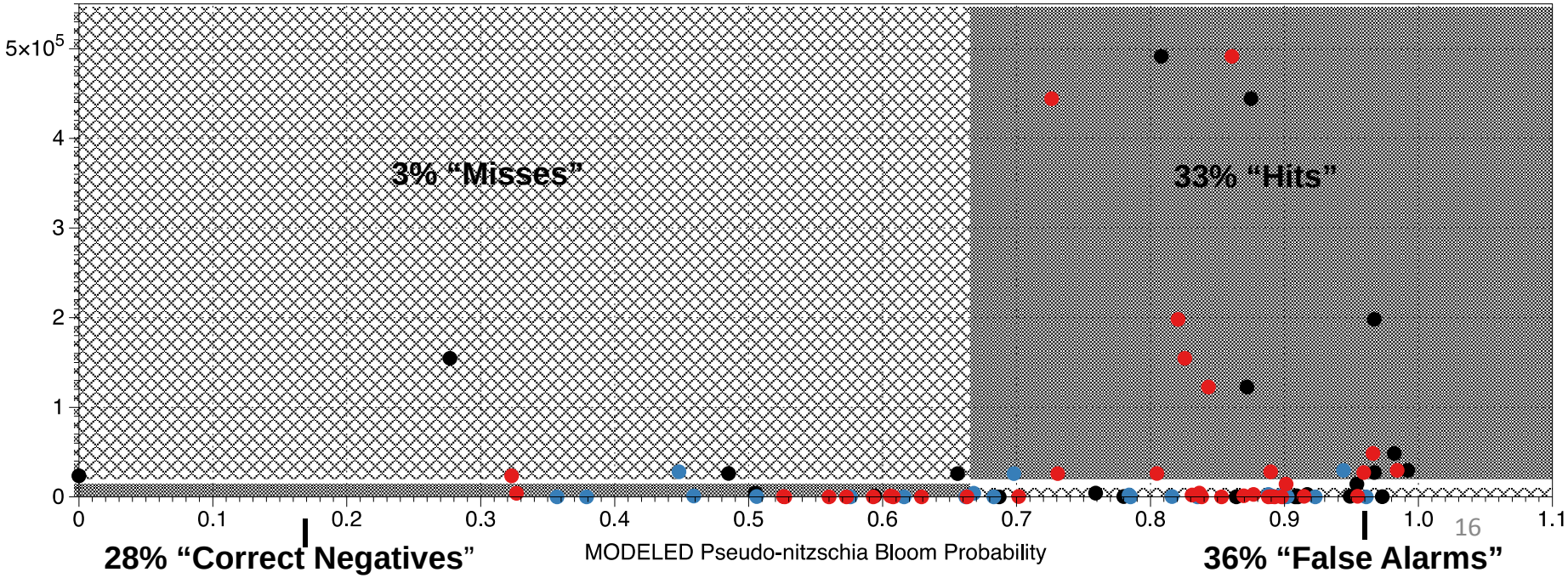
71% Accuracy, 20% False Positives



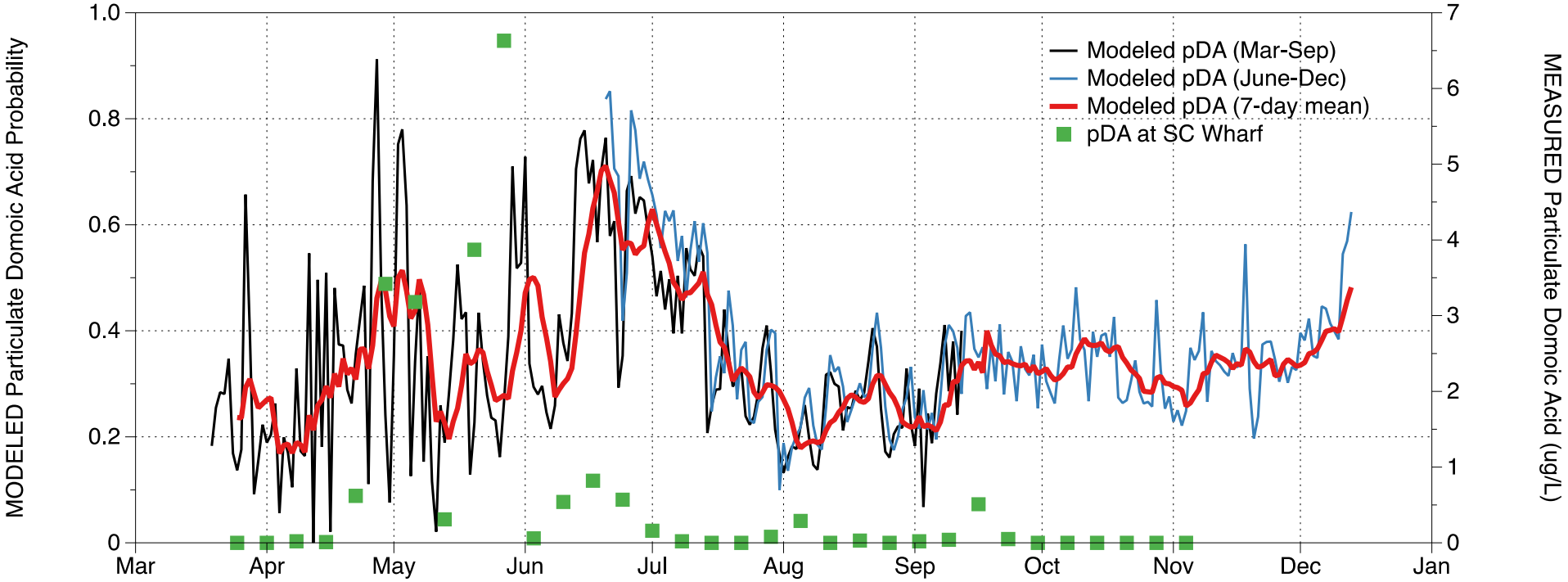
2015 – *Pseudo-nitzschia* – Santa Cruz WHARF

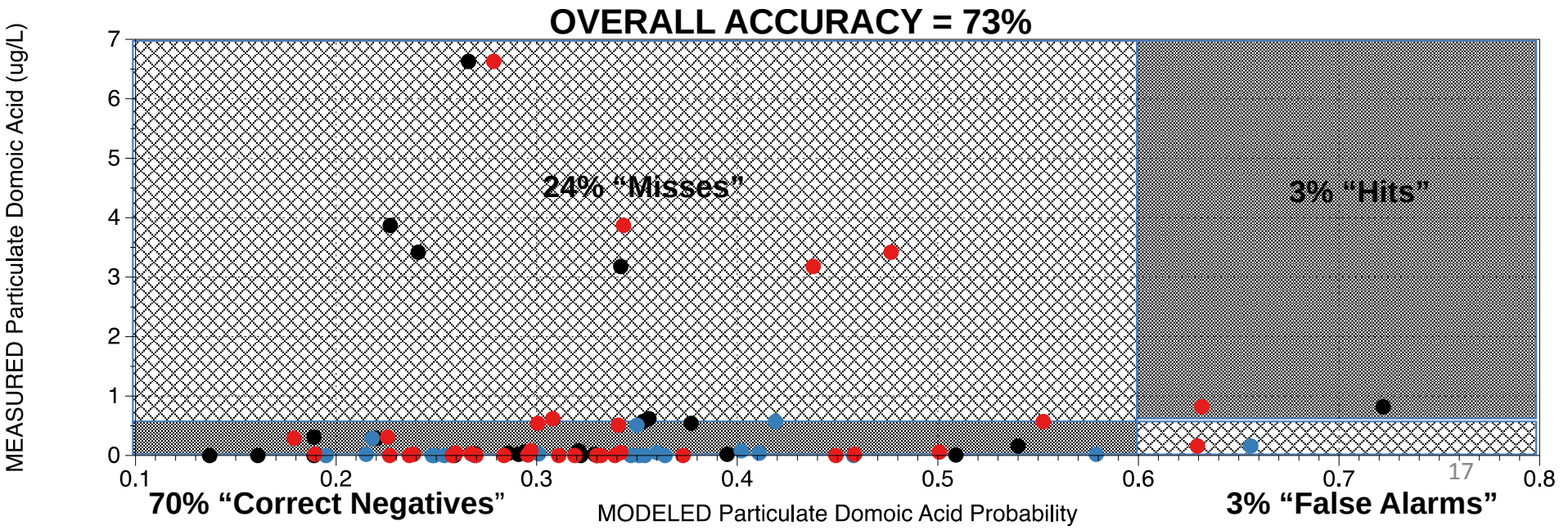


OVERALL ACCURACY = 61% (7-day mean); 43% (daily matchups)

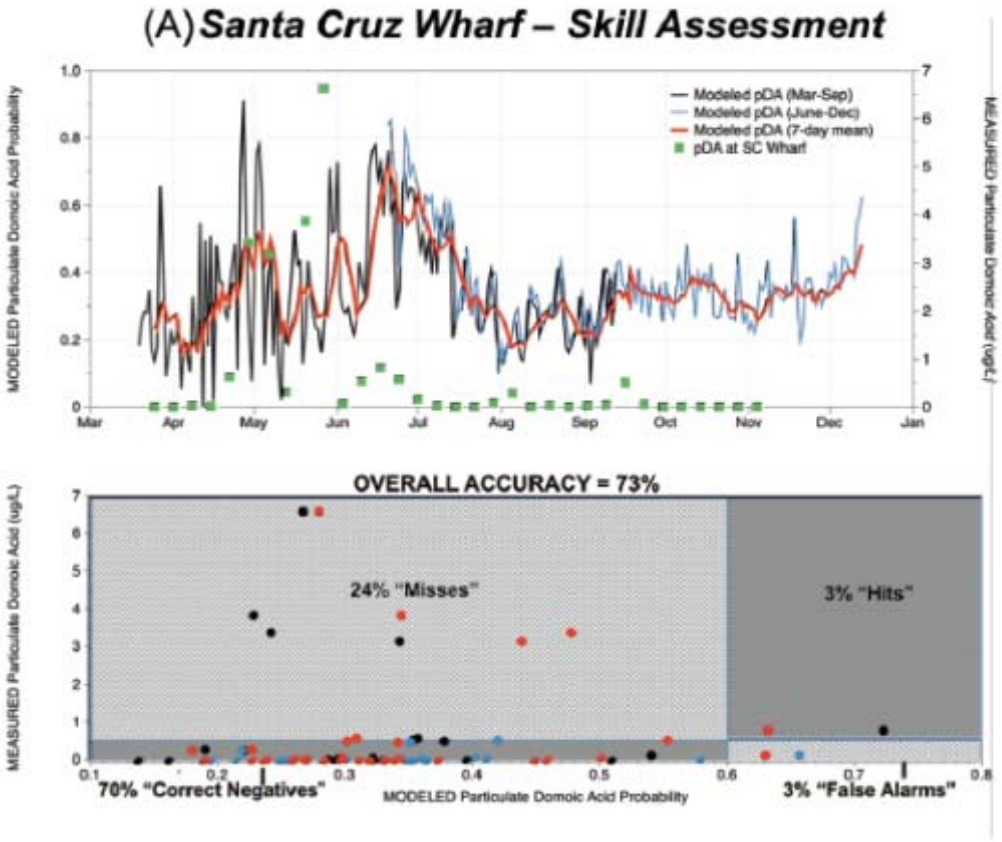


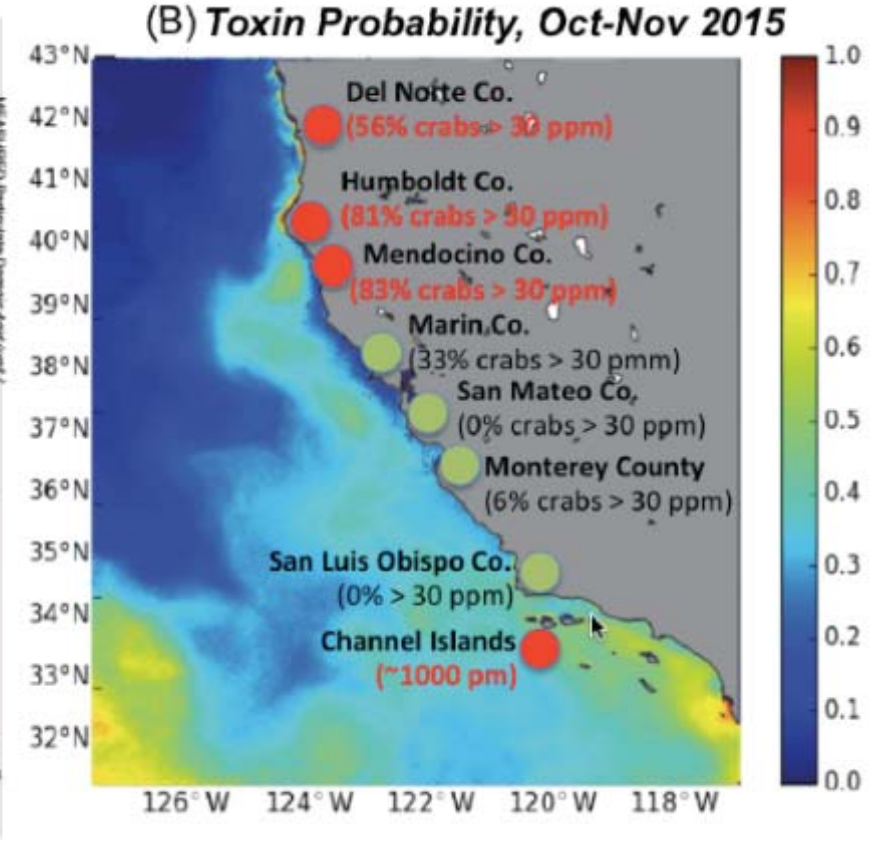
2015 - Particulate Domoic Acid - Santa Cruz Wharf





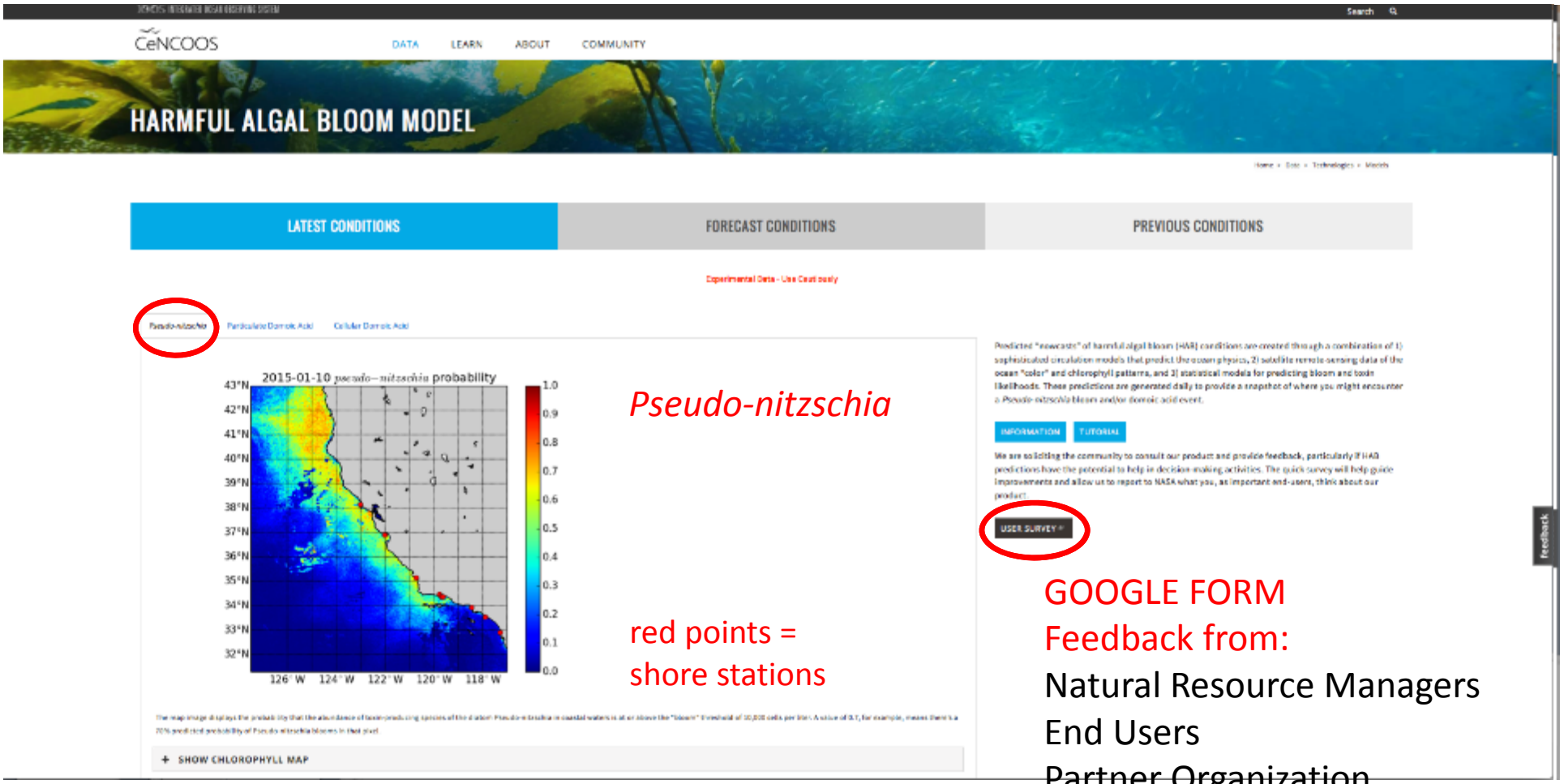
2015 – Dungeness crab closures match climatological model





IV. Are stakeholders and agency end-users engaged?

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

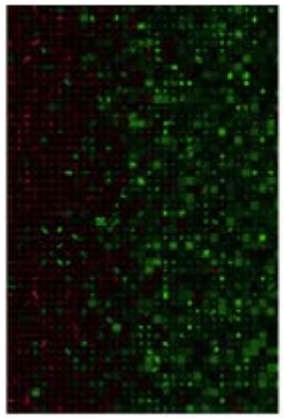


Pseudo-nitzschia

red points =
shore stations

GOOGLE FORM
Feedback from:
Natural Resource Managers
End Users
~~Partner Organization~~
(NOAA NOS & NWS)

CellScope
UC Berkeley



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

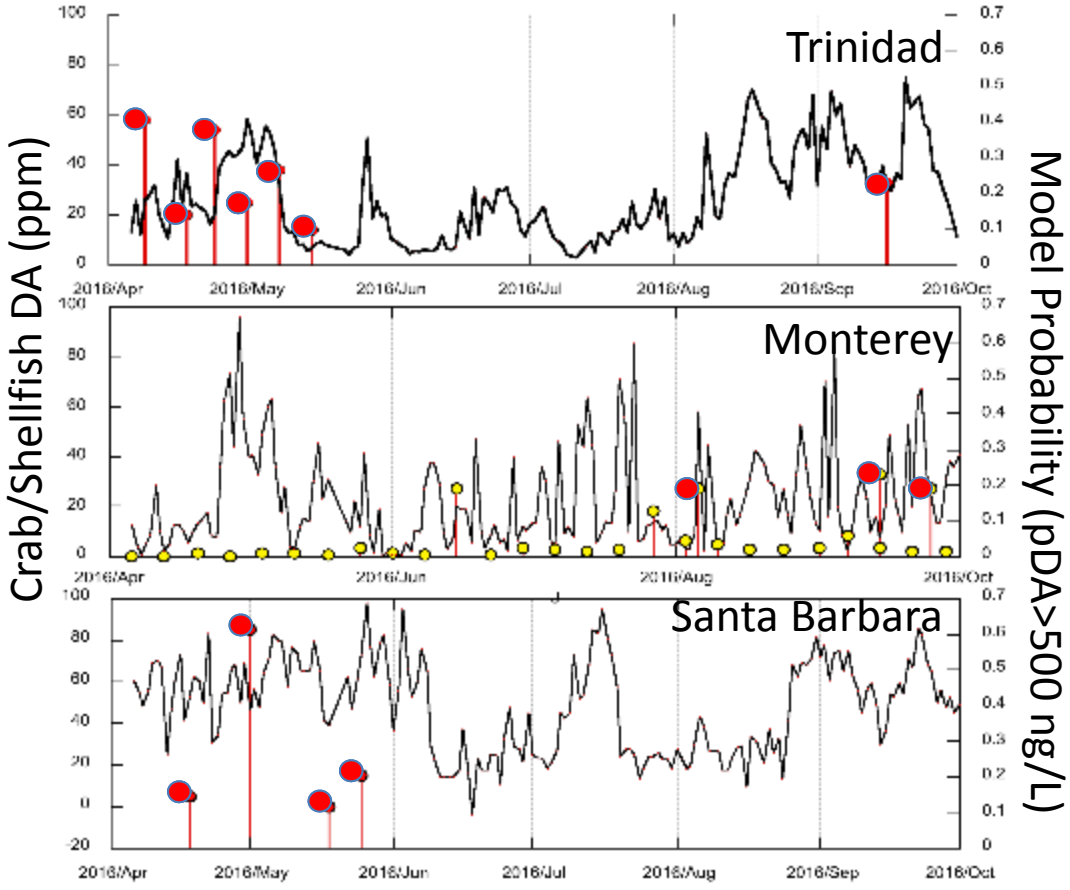
Together with collaborators around the world, we are testing the use of mobile microscopy to solve real-world problems in places including Vietnam, India, Thailand, Cameroon, the Ivory Coast, and Hawaii.

Publications | Applications

Teaming up with Ben Pitterle from Santa Barbara Channelkeepers & Carrie Culver @ UCSB

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

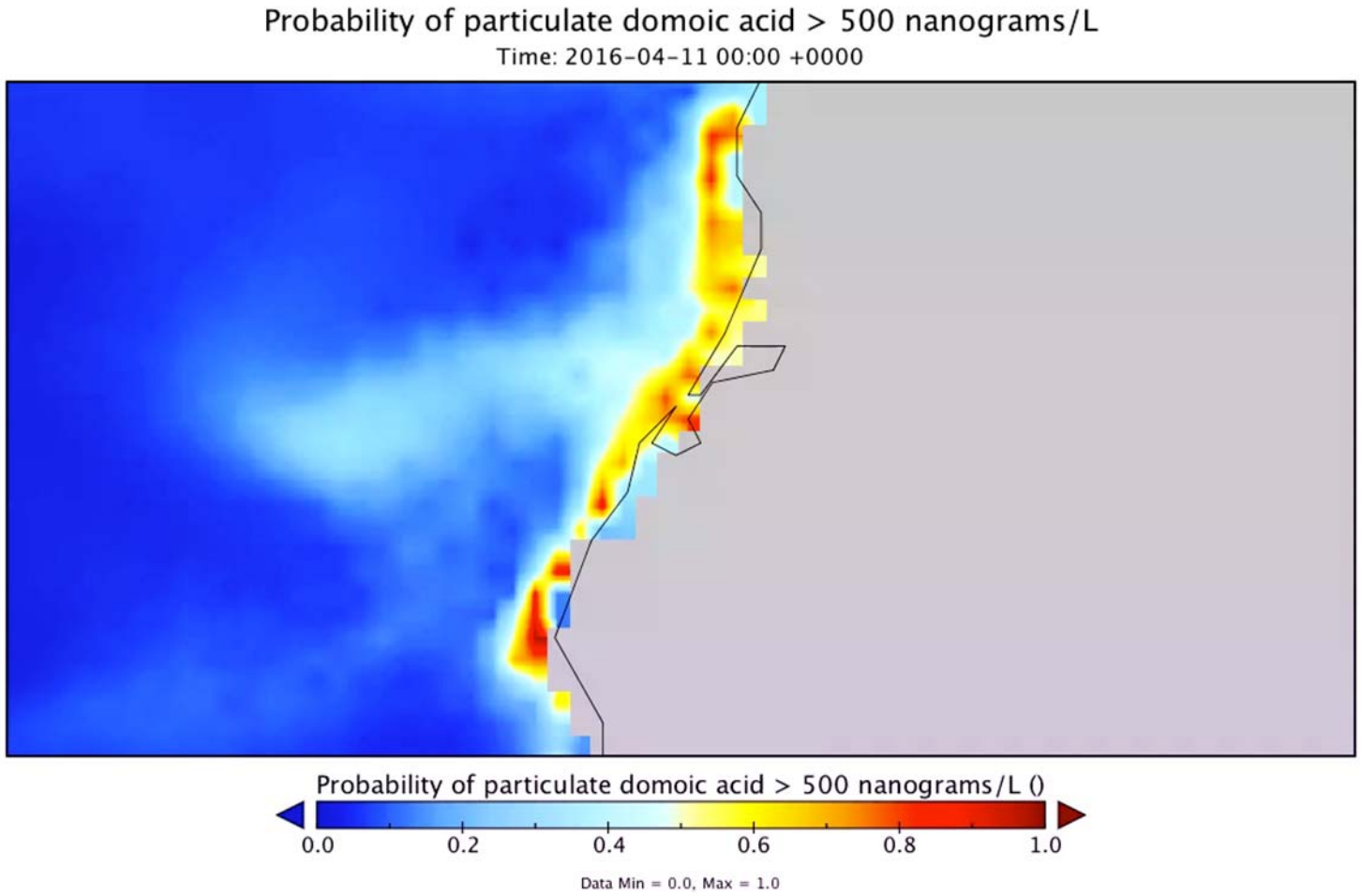
Objectives:

- 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?

Brett Stacy – UCSC Graduate Student
Jeff Anderson - Northern Hydrology



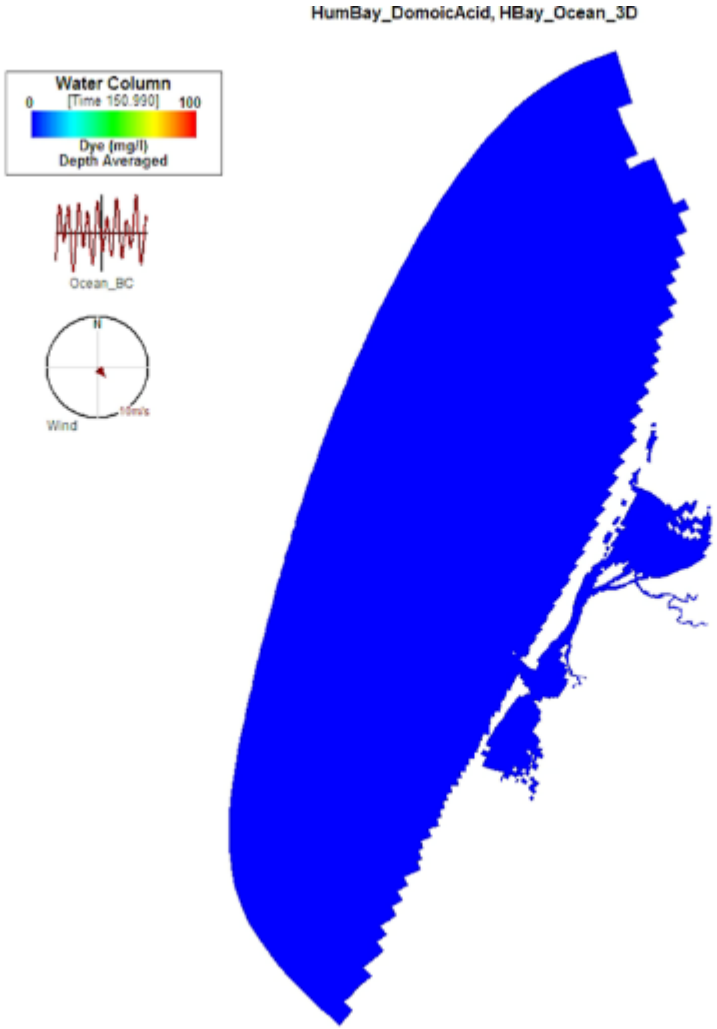
What does C-HARM tell us about shellfish toxicity?

Brett Stacy – UCSC Graduate Student
Jeff Anderson - Northern Hydrology

What does C-HARM tell us about shellfish toxicity?

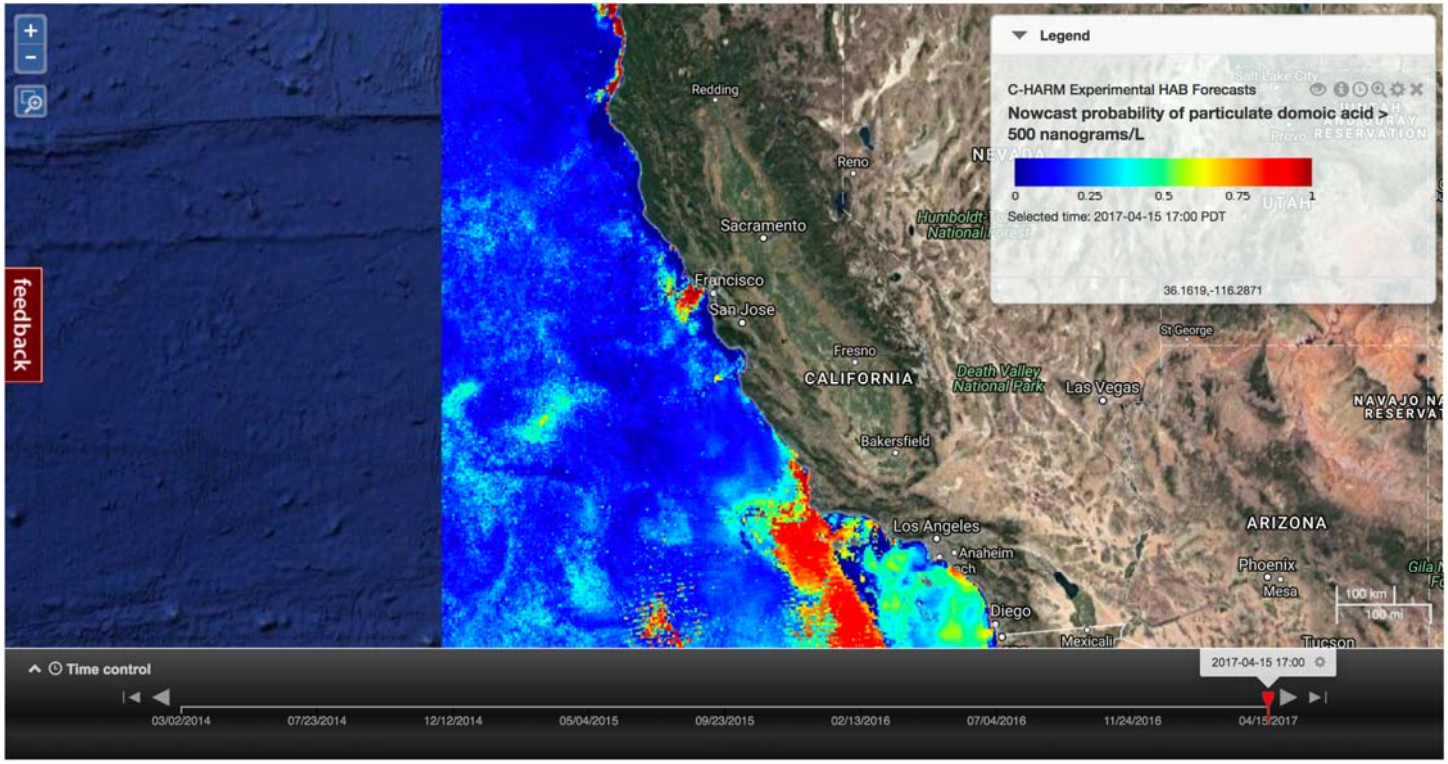
Brett Stacy – UCSC Graduate Student
Jeff Anderson - Northern Hydrology

Dye Simulation

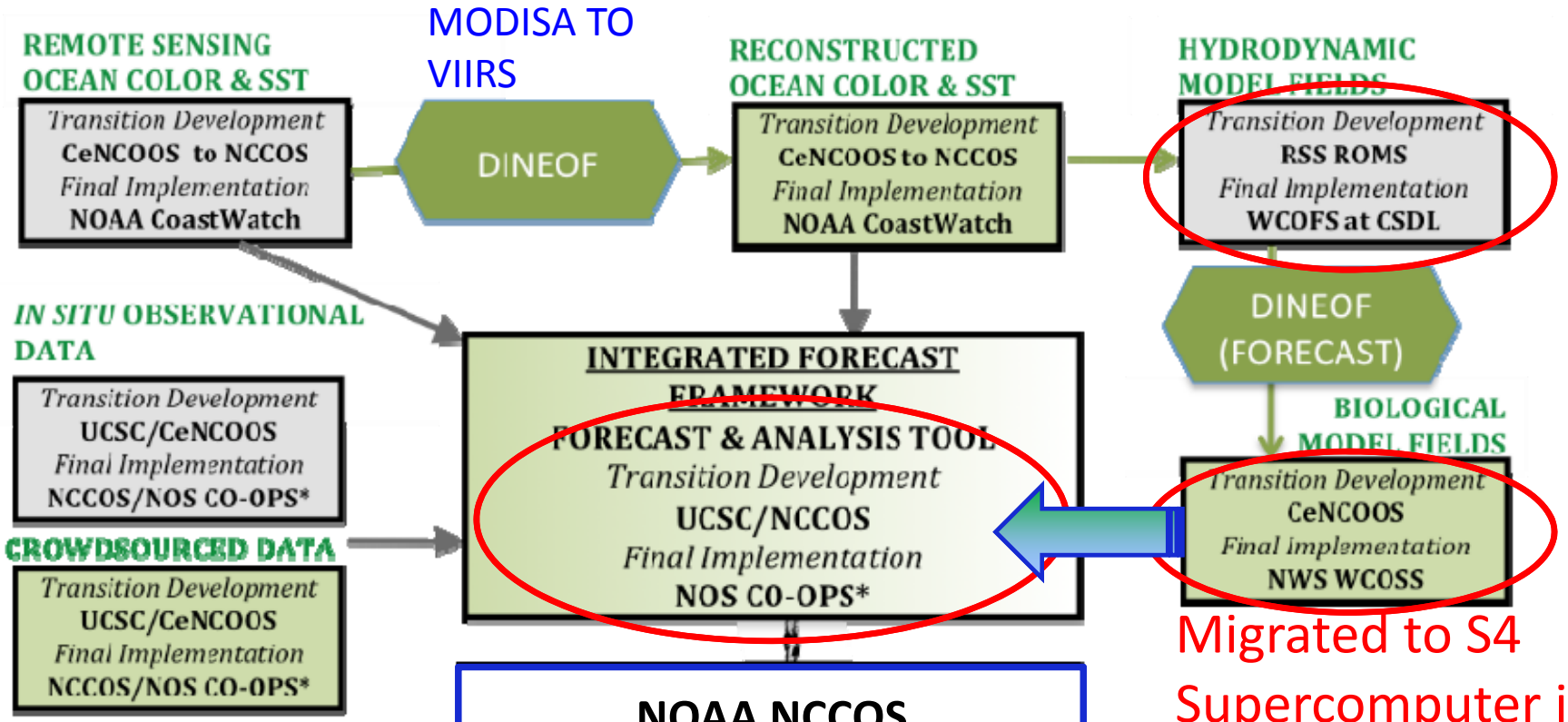


Update: Southern California Domoic Acid Event, April 2017

- Mass stranding event throughout food web - Santa Barbara to San Diego
- Shellfish advisories in Santa Barbara; Strandings of Sea lions, Dolphins, Elephant Seals, Guadalupe Fur Seals, Loons, Grebes, Cormorants, & Brown Pelicans
- Mostly adult female (pregnant) sea lions; many fatalities reported



V. Can we successfully cross the "valley of death"?



NOAA NCCOS OPERATIONAL HAB MODELS

***GULF OF MEXICO**

LAKE ERIE

GULF OF MAINE

CHESAPEAKE BAY

CALIFORNIA

Migrated to S4 Supercomputer in Jan 2016

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 Ocean Forecast System

WCOSS = Weather and Climate Operational Supercomputing System

CO-OPS = Center for Operational Oceanographic Products & Services

THANK YOU!

NOAA MERHAB & ECOHAB

Applied Sciences Program

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

http://www.sccoos.org/data/habs

clrander@ucsd.edu

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)

Archive
Source data
DINEOF results

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

Use in forecast script (next slide)

Collect ROMS data (CeNCOOS, S4)

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

Time to run
4 min / day

Nowcast (CeNCOOS, S4)

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

Courtesy of CoastWatch West Coast

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

Run advection model
using forecast u & v vectors

3-day ROMS forecast
- u and v currents

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

Run pn, cda & pda models
with forecast data

Maps, timeseries

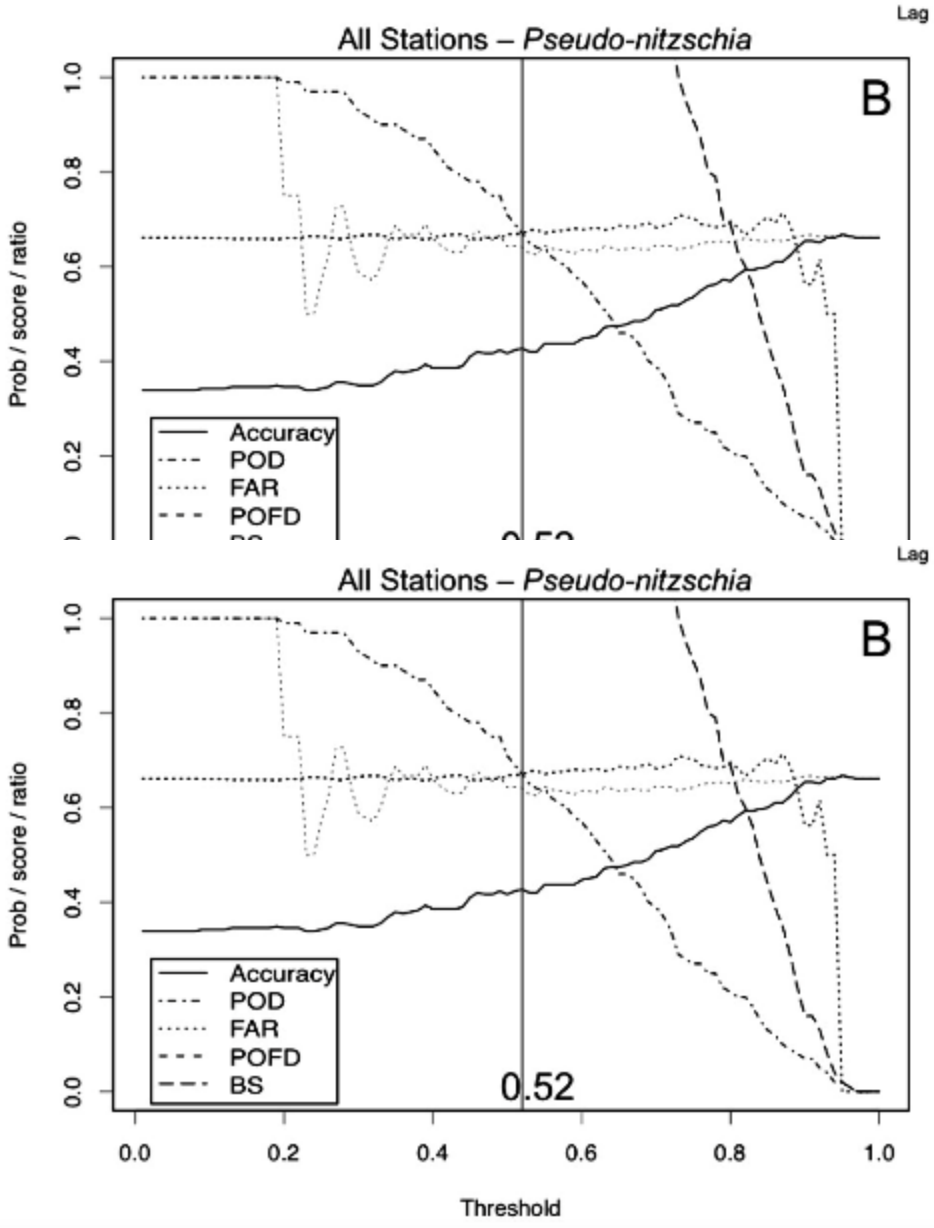
Pn, cda, pda netCDF4 files
- 3 days data
- lat, lon, time
- 2.5 MB each

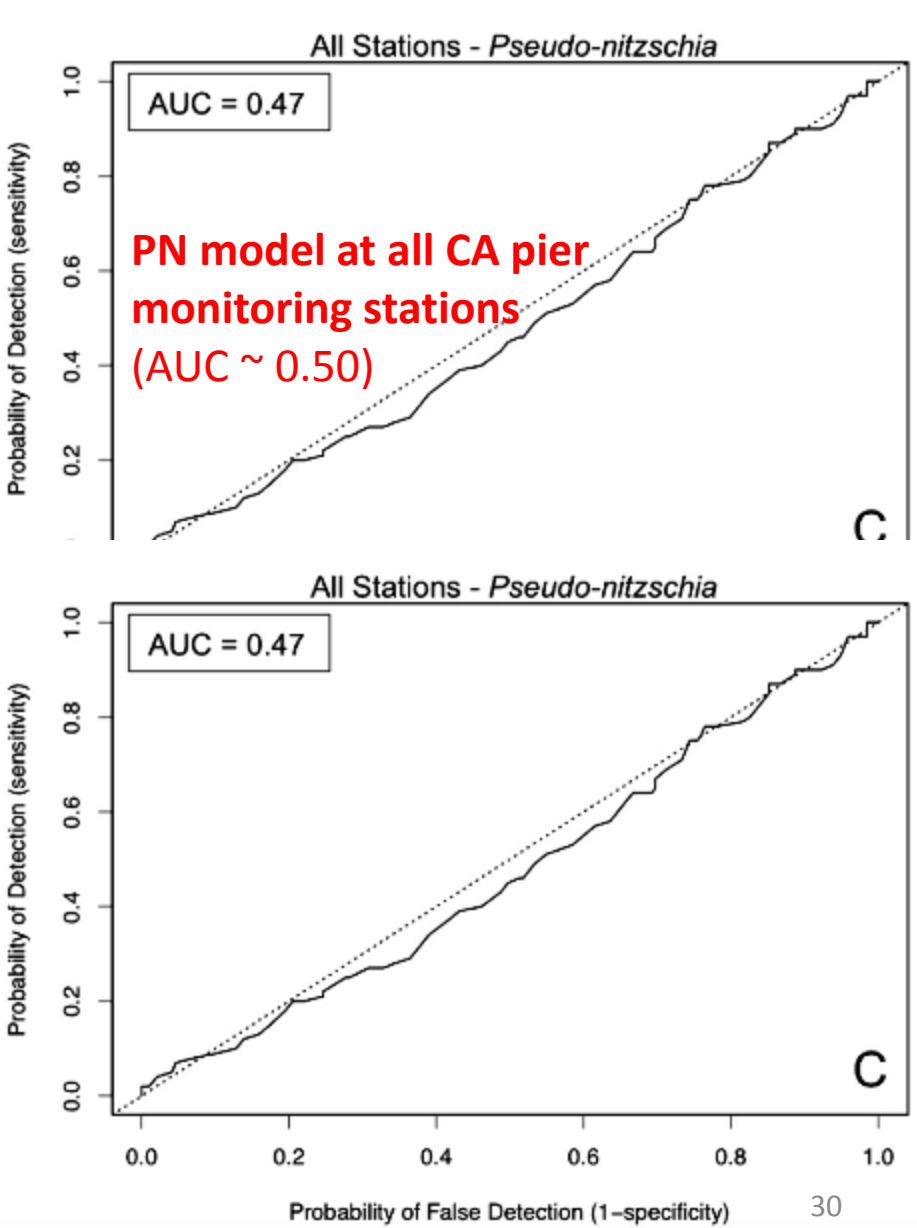
Time to run total: 56 min
- Adv. model: 10 min
- Data advection & EOFs: 36 min
- Pn, cda, pda models: 5 min

Courtesy of CoastWatch West Coast

2014 FEASIBILITY STUDY - SKILL ASSESSMENT

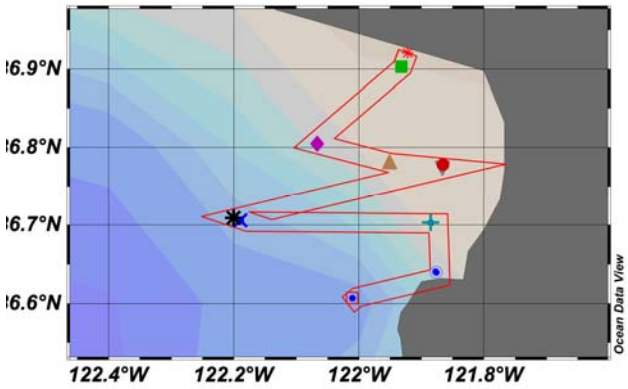
Contingency Plots to Assess Model Performance - Optimize Prob. Threshold

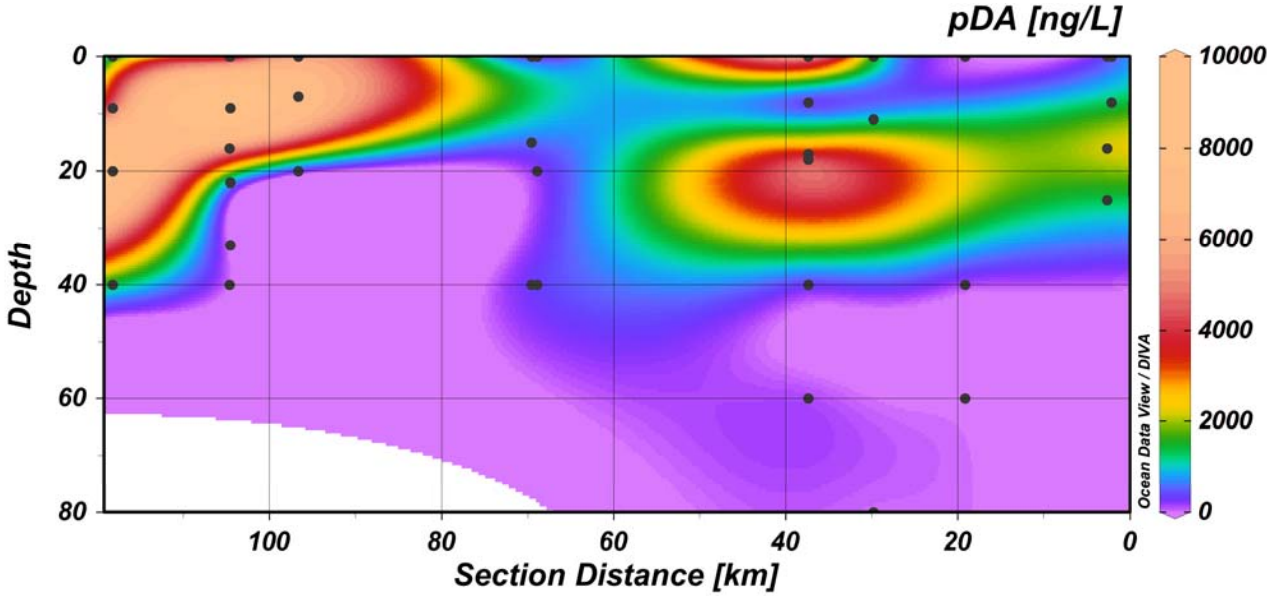


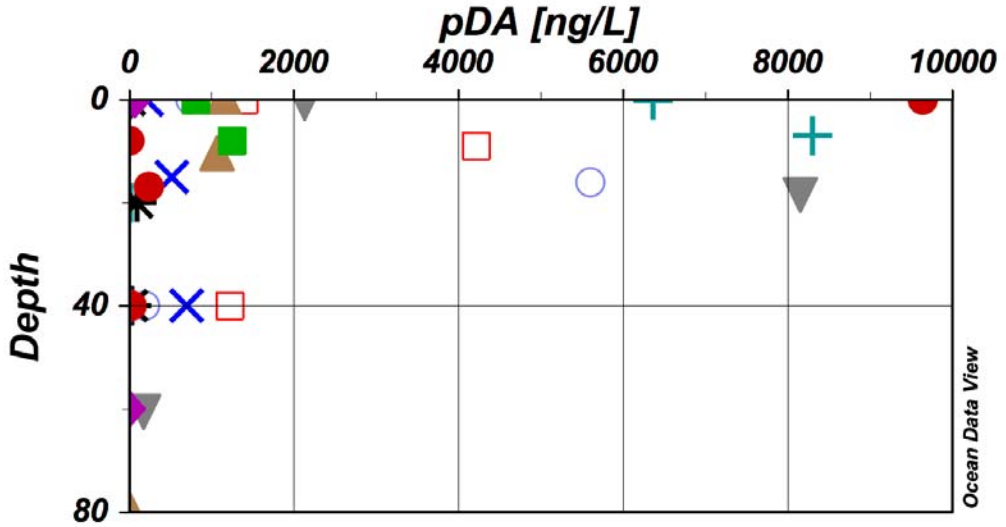


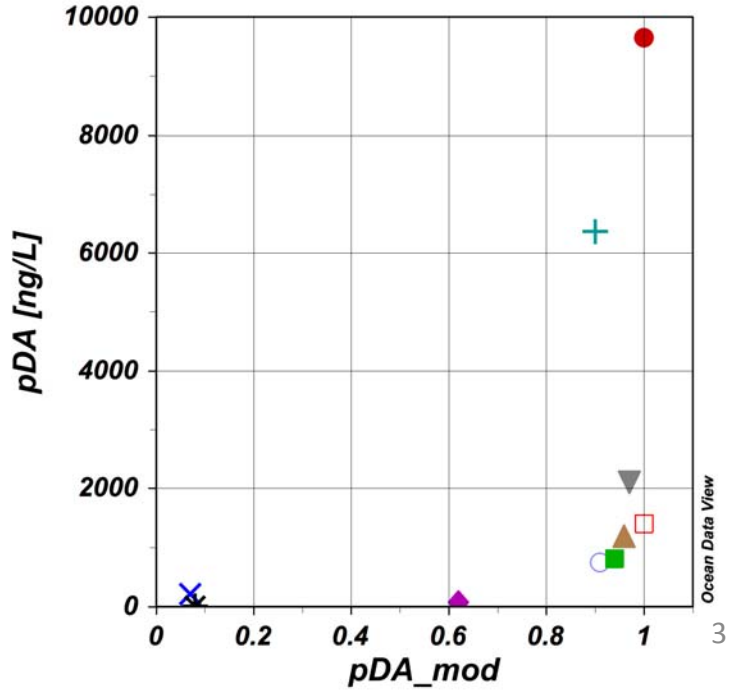
PN model at all CA pier monitoring stations
(AUC ~ 0.50)

ECOHAB – *R/V Carson* Day Cruises (May 12 – June 5)









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