California Harmful Algae Risk Mapping (C-HARM) System

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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

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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

**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

**Lane et al. (2009)**
- Monterey Bay; toxigenic *Pn* blooms

**Blum et al. (2006)**
- Lab + field
- *Pn* toxin

**Anderson et al. (2009, 2011)**
- Santa Barbara Channel
- *Pn* blooms
- *Pn* toxin

**Formulae:**
- $\ln(\text{silicic acid})$
- $\ln(\text{nitrate})$
- $\ln(\text{temperature})$
- $\ln(\text{chl } a)$
- $\ln(\text{Pajaro River})$
- $\ln(\text{cells})$
- $\ln(\text{phos:nitr})$
- $\ln(\text{phos:si})$
- $\ln(\text{nitr:phos})$
- $\ln(\text{nitr:si})$
- $\ln(\text{sqrt(si:nitr)})$
- $\ln(\text{sqrt(si)})$
- $\ln(\text{RRS(0+, \(\lambda\))})$
- $\ln(\text{ap(\(\lambda\))})$
- $\ln(\text{ag(\(\lambda\))})$
- $\ln(\text{day of year})$
- $\ln(\text{silicic acid:nitrate})$
- $\ln(\text{silicic acid:phosphate})$

**Prediction:**
- $\geq 75\%$ (blooms predicted)
- $75\%$
- $77\%$
Remote Sensing Reflectance
Salinity
Temperature
Chlorophyll

Nitrate
Phosphate
Silbic Acid

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

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

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

Accuracy

- POD
- FAR
- POFD
- BS (bias score)

Anderson et al. 2016, *Harmful Algae*
2014 FEASIBILITY STUDY - SKILL ASSESSMENT

Anderson et al. 2016, Harmful Algae

PN model = coin flip? (AUC < 0.5)

DA model = Useful Model (AUC > 0.5)
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.

Anderson et al. 2016, Harmful Algae
An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

Ryan M. McCabe¹, Barbara M. Hickey², Raphael M. Kudela³, Kathi A. Lefebvre⁴, Nicolaus G. Adams⁴, Brian D. Bill⁴, Frances M. D. Gulland⁵, Richard E. Thomson⁶, William P. Cochlan⁷, and Vera L. Trainer⁴

C-HARM ESTIMATES AT CRUISE STNS

Likelihood of a *Pseudo-nitzschia* bloom

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

Trinidad - new hot spot

Some overestimation near SF Bay

Pt Conception-SBC known hot spot

Didn’t see bloom in the Southern CA Bight
An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

R/V Shimada NMFS Cruise-of-Opportunity

C-HARM ESTIMATES AT CRUISE STNS

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

Trinidad – DA slightly underestimated
SF Bay: DA predicted to be further offshore than obs
South MB hotter, same as obs
Pt Conception-SBC known hot spot
DA overestimated in the Bight
OVERALL ACCURACY = 61% (7-day mean); 43% (daily matchups)

3% “Misses”
33% “Hits”
28% “Correct Negatives”
36% “False Alarms”
2015 - Particulate Domoic Acid - Santa Cruz Wharf

OVERALL ACCURACY = 73%

70% “Correct Negatives”
3% “False Alarms”
3% “Hits”
24% “Misses”
2015 – Dungeness crab closures match climatological model
IV. Are stakeholders and agency end-users engaged?

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

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

Trinidad
Monterey
Santa Barbara

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
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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”?

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.

MODISA TO VIIRS

Migrated to S4 Supercomputer in Jan 2016

NOAA NCCOS OPERATIONAL HAB MODELS

*GULF OF MEXICO
LAKE ERIE
GULF OF MAINE
CHESAPEAKE BAY
CALIFORNIA

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

http://www.cenkoos.org/data/models/habs
http://www.sccoos.org/data/habs
clrander@ucsd.edu
Collect ROMS data (CeNCOOS, S4)

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

Nowcast (CeNCOOS, S4)

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

- Time to run: 5 minutes

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)

- Use in forecast script (next slide)

- Archive Source data DINEOF results

- Time to run: 3 x EOFs = 2.5 – 5 hrs
**Forecast (CeNCOOS, S4)**

- **Run advection model using forecast u & v vectors**
  - Using advection model results advect latest filled Chl, 488, 555 forward 1, 2 & 3 days
  - Run EOF on advected Chl, 488, 555 (using 180 days of filled data)
- **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

**From CoastWatch**
- Last 180 day plus 3-day ROMS forecast
  - salt,
  - temp

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

**From CoastWatch West Coast**
- 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

- **Courtesy of CoastWatch West Coast**
Contingency Plots to Assess Model Performance - Optimize Prob. Threshold

2014 FEASIBILITY STUDY - SKILL ASSESSMENT

All Stations – Pseudo-nitzschia

AUC = 0.47

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

All Stations - Pseudo-nitzschia

Accuracy
POD
FAR
POFD
BS

Probability of Detection (sensitivity)

Probability of False Detection (1-specificity)

Threshold

Lag

Lag

0.0
0.2
0.4
0.6
0.8
1.0

0.0
0.2
0.4
0.6
0.8
1.0

0.0
0.2
0.4
0.6
0.8
1.0

0.0
0.2
0.4
0.6
0.8
1.0

30
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