Can/Do user requirements shape HAB prediction tools in the coastal zone?

Clarissa Anderson, *Southern California Coastal Ocean Observing System (SIO/SCCOOS)*

**IOOS Coastal Ocean Modeling Testbed (COMT):** evaluate impact on regional models - UCSC, CA, OSU, LiveOcean (UW)
CONSISTENT NATIONAL CAPABILITY

DIVERSE LOCAL STAKEHOLDERS

Observations
Data Management
Forecasts/Modeling
User Products
Outreach and Education
Leverage and Link
IOOS Coastal Ocean Modeling Testbed Program

West Coast Coastal Ocean Modeling (WC-COMT) Testbed Project to Evaluate WCOFS

Developing a BGC model for WCOFS

4D-Var **Data assimilative, biogeochemical** model (UCSC model: Edwards/Mattern/Moore/Fiechter)

**Lead PI:** Christopher Edwards, UCSC  
**Transition PI:** Clarissa Anderson, SCCOOS

1) To advance coastal ocean modeling, analysis, and prediction through enhancements to the WCOFS model
   - Evaluation
   - Data Assimilation
   - Biogeochemical Model development – NEMURO (with OAH subsystem)

2) To transition established products relevant to NOAA Ecological Forecasting Roadmap to using WCOFS output
   - HAB prediction
   - Dynamic Habitat modeling
   - Ocean Acidification and Hypoxia
Observational Impacts in Data Assimilation

Fisheries Habitat

Ocean Acidification & Hypoxia

Harmful Algal Blooms

WC-COMT Stakeholder Workshop – Priority Themes

Broad participation of end-users and technical practitioners from the entire West Coast

+++ 38 Participants +++ Across Five Major End-User Sectors
COMT Stakeholder Workshop: Summary Table for Program Managers

Compiled a table of prioritized user requirements & metrics across themes

**Physics** (Report: Andrew DeVogelaere)
- Characterizing the physical environment for optimal placement of physical structures at sea
- Modeling of currents + winds to optimize commercial ship traffic speed + fuel consumption
- Plume models around ports to inform ballast water zones
- Trajectory Models for....

**Fisheries Habitat** (Report: Isaac Kaplan)
- Dungeness crab – forecasting fisheries catch + recruitment
- Whale entanglement in crab pot gear
- Real-time or 1-3 day forecasts of squid
- Seasonal predictions of whiting (a la Malick, Hunsicker, Siedlecki)
- Ratios of expected catch:bycatch (a la EcoCast)

**OA & Hypoxia** (Report: Tommy Moore)
- Thresholds + Indicators of chronic vs acute stress, habitat compression etc.
- Model reanalysis to evaluate vulnerable areas, long-term trends
- Real-time forecasts for event response
- Seasonal and annual forecasts to help policy makers
- Long-term climate scenario models

**Harmful Algal Blooms** (Report: Clarissa Anderson)
1) Improved lead times for warnings (out to 2 weeks)
2) Tracking the precise interstate trajectories of *Pseudo-nitzschia* blooms and their impacts
3) Nearshore impacts of HABs on aquaculture and fisheries
4) Complexity in food web interactions and surface to benthic coupling
5) Predicting offshore bloom initiation relative to nearshore dynamics
Weekly measurements:
- HAB spp. (8-9 taxa)
- Chl-a, Temp, Salinity, Nutrients
- Domoic Acid + SPATT toxins
- Weekly alerts to HABMAP listserv
- Monthly QC’d data now served via ERDDAP
- Synthesis with models: CA HAB Bulletin

10 academic institutions

HARMFUL ALGAL BLOOM MONITORING & ALERT PROGRAM
Grass-roots origin in 2008; now fully supported by SCCOOS + CeNCOOS

Limitations: Only provides a weekly snapshots of a highly dynamic system; $$$ prohibitive to do daily monitoring; toxins and nutrients not even close to real-time; users want forewarning!
California Harmful Algae Risk Mapping (C-HARM) System: CROSSING THE “VALLEY OF DEATH” to ARL9

R&D started w/ NASA Grad Fellowship in 2004 (Advisors: Dave Siegel & Mark Brzezinski), over a decade before 2015 Dungeness Crab crisis

**REMOTE SENSING OCEAN COLOR & SST**

- Transition Development CeNCOOS to NCCOS Final Implementation NOAA CoastWatch

**IN SITU OBSERVATIONAL DATA**

- Transition Development CeNCOOS Final Implementation SCCOOS & CeNCOOS

**CROWDSOURCED DATA**

- Transition Development CeNCOOS Final Implementation SCCOOS & Marine Mammal Health Map

**REGIONAL OPERATIONAL FORECAST PRODUCTS**

- Transition Development CeNCOOS to NCCOS Final Implementation NOAA CoastWatch

**INTEGRATED FORECAST & ANALYSIS TOOL**

- C-HARM Maps
- California HAB Bulletin
- HABMAP
- Near real-time Marine Mammal Stranding Data

**HYDRODYNAMIC MODEL FIELDS**

- Transition Development UCLA/JPL 3-km ROMS Final Implementation WCOFS at CSDL

**INTEGRATED FORECAST & ANALYSIS TOOL**

- *CROSSED* DINEOF

**BIOLOGICAL MODEL FIELDS**

- Transition Development CeNCOOS Final Implementation NOAA CoastWatch

**INTEGRATED FORECAST & ANALYSIS TOOL**

- *S4 HPC @ Univ of WI

**“Operational” Centers**

- NOAA Coast Watch, West Coast Node
- SCCOOS = Southern California Coastal Ocean Observing System
- 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**

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* IOOS = Integrated Ocean Observing System

* COMT = Coastal Ocean Observing Mission Tasking Office

* VIIRS = Visible Infrared Imaging Radiometer Suite

* DINEOF = Distributed Identiﬁcation of Empirical Orthogonal Functions

* HABMAP = Harmful Algae Bulletin Mapping

* HAB = Harmful Algae Bulletin

* CeNCOOS = Central and Northern California Ocean Observing System

* NOAA CoastWatch = National Oceanic and Atmospheric Administration, National Ocean Service, West Coast Node

* SCCOOS = Southern California Coastal Ocean Observing System

* NOAA = National Oceanic and Atmospheric Administration

* CESM = Community Earth System Model

* NASA = National Aeronautics and Space Administration

* NOAA = National Oceanic and Atmospheric Administration

* IOOS = Integrated Ocean Observing System

* COCORP = Continental Ocean Current Radar Observation Program

* WCOFS = West Coast Ocean Forecasting System

* CeNCOOS = Central and Northern California Ocean Observing System

* NCCOS = National Centers for Coastal Ocean Science
1b. Improving lead times for HAB warnings

California Harmful Algae Risk Mapping (C-HARM) System

**Operational model at NOAA Coast Watch provides spatially explicit nowcasts and 1-3 day forecasts**

Limitations: 3-km horizontal spatial resolution so does not capture nearshore variability; max accuracy 60-70% (missing BGC); only for PN/DA; no food web predictions

2. Tracking Interstate Trajectories

Development of a West Coast C-HARM with WCOFS?

**Comparing the UCLA ROMS Classic version of C-HARM with one that uses WCOFS inputs**

**With WCOFS backbone, could be extended to entire West Coast + PNW HAB Bulletin**

Limitations: currently no parameterization of C-HARM for the PNW; computationally $$$ to run DINEOF for entire West Coast (plus larger temporal gaps)
California Harmful Algae Risk Mapping (C-HARM) System

Probability of particulate domoic acid Jan 1-31, 2020

CA Marine Mammal Suspected DA Strandings

California Sea Lion Strandings Due to Suspected DA Toxicosis

HABMAP weekly sampling at 9 piers for HAB species & DA

CA Marine Mammal Suspected DA Strandings

California Department of Public Health (CDPH)

California Department of Public Health (CDPH) Phytoplankton Data

California Harmful Algae Risk Mapping (C-HARM) System

Probability of particulate domoic acid Jan 1-31, 2020

California Harmful Algal Bloom Bulletin

Provides context on regional variability as a measure of uncertainty in relation to food web impacts

Limitations: retrospective synthesis with 1-2 month delay (due to toxin, Public Health, and marine mammal data acquisition); only covers two major toxigenic taxa
C-HARM not good at predicting estuarine toxicity

Stakeholders need estuary and bay-level accuracy

- Crab toxicity generally tracks nearshore C-HARM model; shellfish toxicity often decoupled from C-HARM
- Humboldt Coast became a new hot spot for DA during the 2015-2016 heat wave

Anderson et al., Harmful Algae (2009), GRL (2011), Harmful Algae (2016)
Humboldt Bay is home to major oyster growing facilities. The goal is to use an ocean model like C-HARM to assess the likelihood of toxic HABs in estuaries due to coastal exchange. The limitation is that it is a passive tracer experiment only.

Humboldt Bay Circulation Model to examine coast-to-estuary connectivity:
- Simulates depth, velocity, salinity, and temperature
- Model is forced by:
  - Tide and sub-tidal sea levels
  - Freshwater flow (14 bay/coast inflows)
  - Salinity and temperature at boundaries
  - Wind and atmospheric data

Convert C-HARM probability to DA concentration as a conservative dye tracer (DA_conc (ng/L) = Prob_DA * 1000)
Very High-Resolution Estuarine (Physical) Models

Reveals that shellfish beds in N. Humboldt Bay can be theoretically exposed to high dissolved DA originating on the shelf and particulate DA from the nearshore

Limitations: lacks mechanistic or operational components; no biology

Tracer Experiment Results

2014-2016 simulation of DA transport

Model Time (d)

Example of DA (dye) results

*Lagrangian Particle Tracking
Expmts show same result

Remaining Mystery
Why do commercial shellfish beds rarely get closed in HB? Res time? Depuration rates?

C. Anderson, J. Anderson, R. Kudela, E. Bjorkstedt, B. Stacey, in prep
Predicting toxin contamination in harvested marine species to guide dynamic ocean management

Contamination in four wild capture species frequently exceeds management action thresholds
Stable Isotopes

*Contamination in four wild capture species frequently exceeds management action thresholds*
ECOHAB project establishes coupled modeling approach for toxin prediction

- ROMS-BEC is designed to allow study of HAB and OAH synergies

Leverages:
- Packard Foundation & CA Sea Grant investment in 0D DA model (Anderson, Edwards, Kudela)
- NOAA & CA OPC investment in ROMS-BEC and OAH modeling (McWilliams, Bianchi, Deutsch, Kessouri)
Genetic basis of DA production discovered

- Offshore regulation of \textit{dab} genes can be used to parameterize and validate ROMS-BEC
California IFCB Network - CA Ocean Protection Council Prop 1 funding

- Will provide high-frequency view of plankton dynamics along cross-shore gradients
- Many IFCBs will be collocated with pH and DO sensors – but we need more of that!

Imaging Flow Cytobot (IFCB) Network
12 IFCBs Total: 6 piers + 3 moorings

- 6 new IFCBs via OPC + 1 OCSD
- 1 new IFCB via ECOHAB (PI Allen)
- 3 extant IFCBs (PI Kudela)

2. Improving lead times for HABs
Thank you to the Ocean Sciences Meeting 2020 & Session Organizers

Stakeholder Recommendations

- WCOFS will be useful for a number of efforts but cannot replace the need for model hindcasts, seasonal to annual predictions, and long-term projections of ecosystem function.
- WCOFS will need to be coupled to a BGC model to provide the ecosystem benefits of extant models served by the IOOS West Coast RA Data Portals.
- Observations to support models are critical.
- Source attribution could be an important outcome of modeling efforts for tackling current challenges and charting future research.
- Economic valuation of data and model output will allow us to understand economic benefits of model predictions to stakeholders.

Thank you to the
Ocean Sciences Meeting 2020 & Session Organizers
SUMMARY – FUTURE RESEARCH

- Accurate nearshore forecasts remain elusive (aquaculture-scale)
  - Shellfish growers sample continually in collaboration with public health depts, which makes it hard to capture toxic events in models
  - Coupling offshore models to estuarine hydrological models should be stressed
  - Offshore initiation remains a focus for prediction
Thank you to the NOAA SAB for this opportunity

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