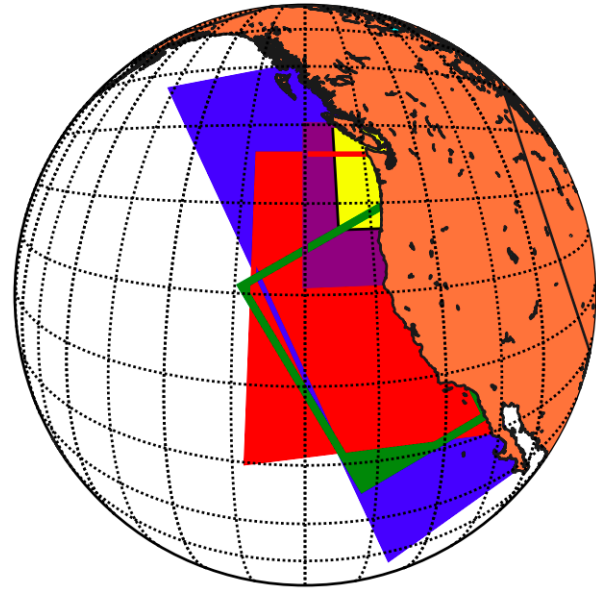


Toward a next-generation coastal observing network for ecosystem (and Marine Life) monitoring and prediction

Clarissa Anderson, *Scripps Institution of Oceanography + SCCOOS + CIMEAS*

IOOS Advisory Committee Meeting, 6 December 2022, Washington, D.C.



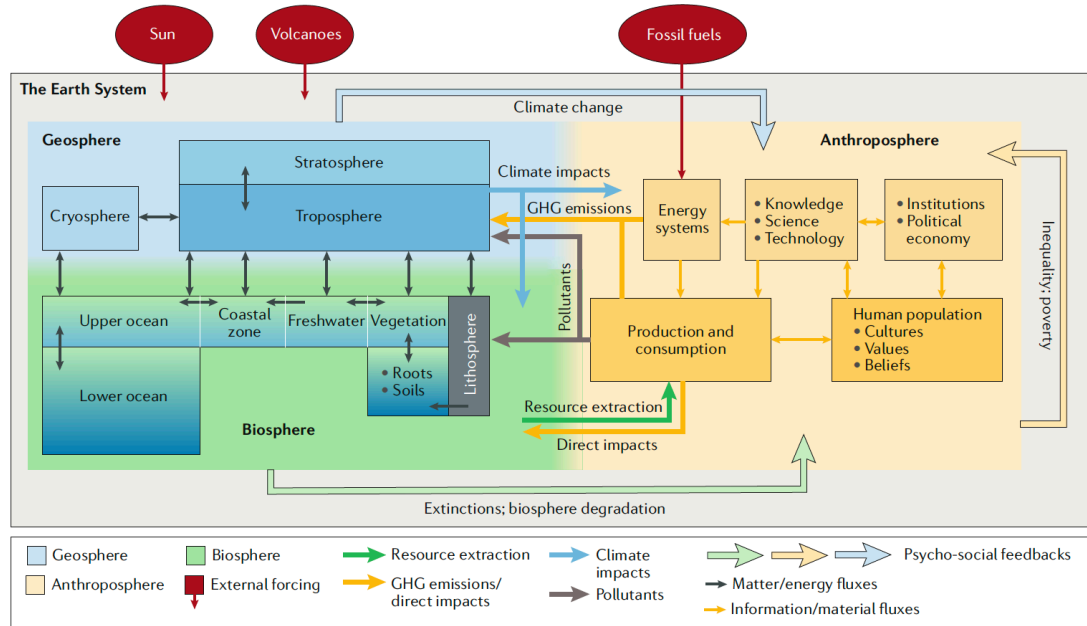
IOOS Coastal Ocean Modeling
Testbed (COMT): evaluate
impacts on regional models -
UCSC, CA, OSU, LiveOcean
(UW)



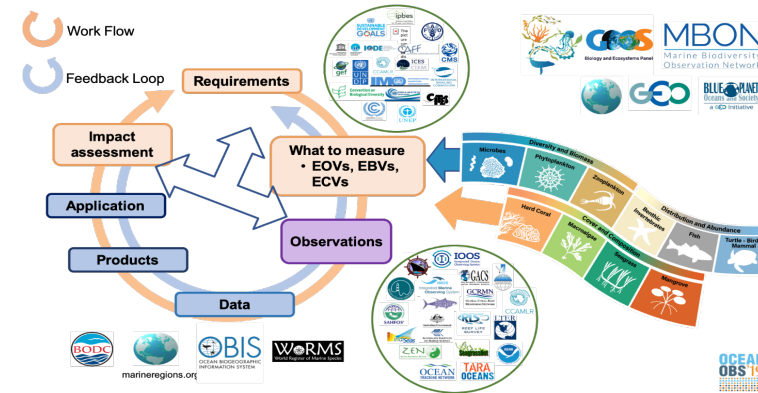
Stakeholder-driven Process to Develop Tailored Data Products



NASA Bretherton Diagram Updated 2020 ES System



Steffen et al., 2020. The Emergence and Evolution of Earth System Science.
Nature Reviews Earth and Environment



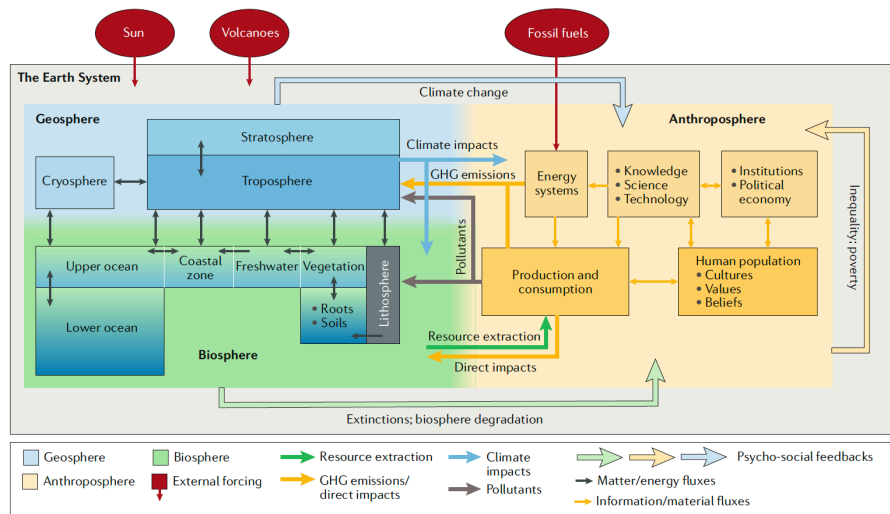
Expected Outcomes/Recommendations:

- Integrate biological observations into the global observing system as an integral and necessary component of ocean ecosystem science and understanding.
- Implement available technologies for biological observing now, maximizing access to biological data and information to quantify, explain, and forecast biodiversity changes.
- Advance decadal plans for a fully encompassing global ocean observing system that integrates biology, biodiversity, physical and biogeochemical observations.

Ecosystem Health
and Biodiversity
Task Team
at OceanObs-19

Bridging Earth System Science and Ocean Observing

Time to bridge the gap between global ocean and coastal ocean science to fully address societal challenges



How predictable is nature? ...while questions about predictability cross all disciplines of ecology, there has been comparatively little discussion on the nature of prediction in ecology, from either a theoretical or practical perspective (Evans et al. [2013](#), Mouquet et al. [2015](#), Petchey et al. [2015](#), Houlahan et al. [2017](#)). The importance of ecological predictability for practical applications is clear: **to make ecology more relevant to policy, management, and decision making, we need a better understanding of what we can forecast and how those forecasts can be improved** (Clark et al. [2001](#), Dietze [2017](#), Dietze et al. [2017](#)).

M.C. Dietze. 2017. Prediction in Ecology: A First Principles Framework. *Ecological Applications*

NOAA Model for Service Delivery



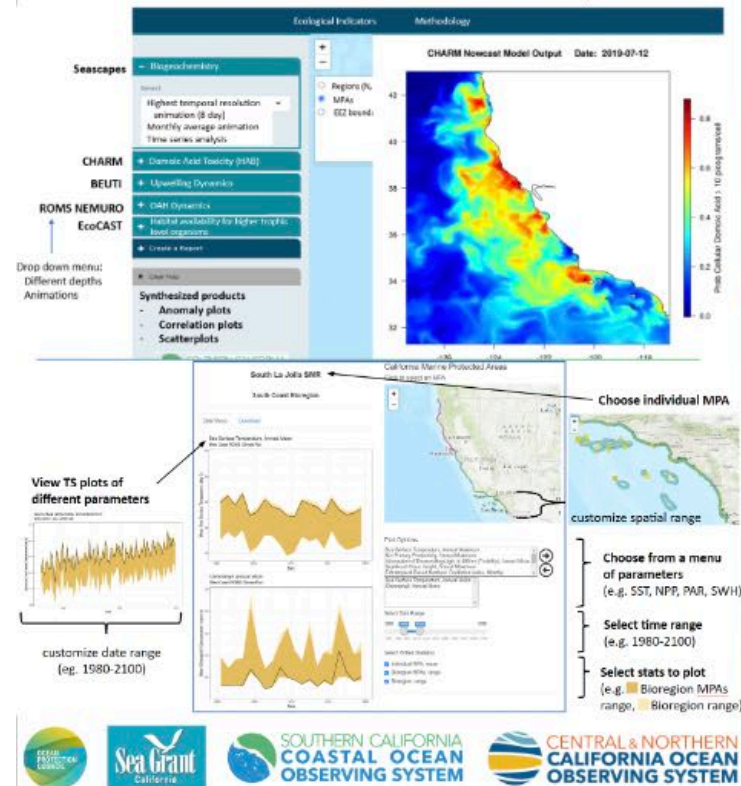
NOAA, 2020. A Model of Service Delivery for the NOAA Water Initiative: *A proven framework for integrating service delivery and decision support*. Authored by the NOAA Water Team

Are Earth System Science and Service Delivery compatible?

NOAA Vision of Service Delivery is entirely reliant on the solutions provided by the ESS Community

MPA Dashboard

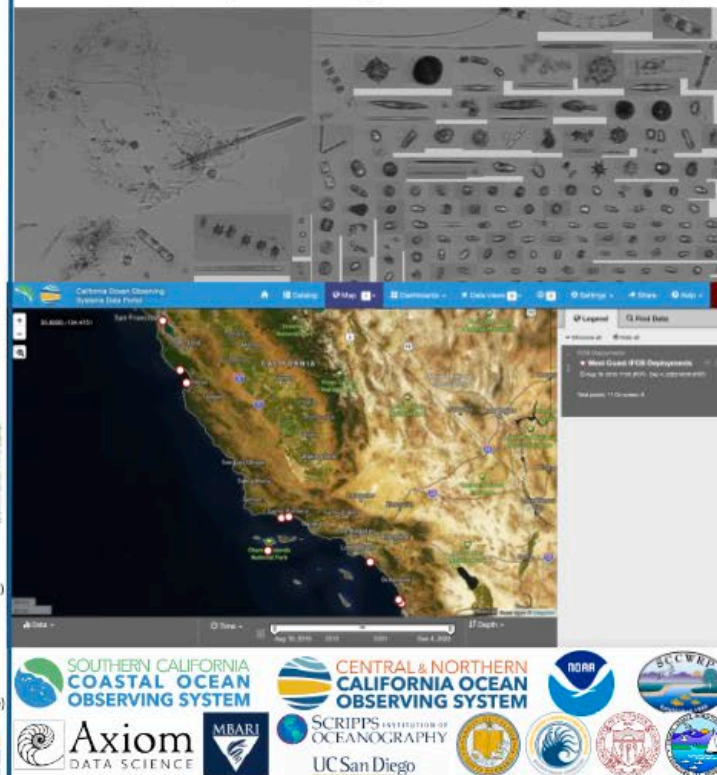
(PI: [Ruhl H.](#), Anderson C., Edwards C., Kahru M., Hazen E., Jacox M., Feichter J.)



mpa-dashboard.caloos.org/

IFCB Dashboard

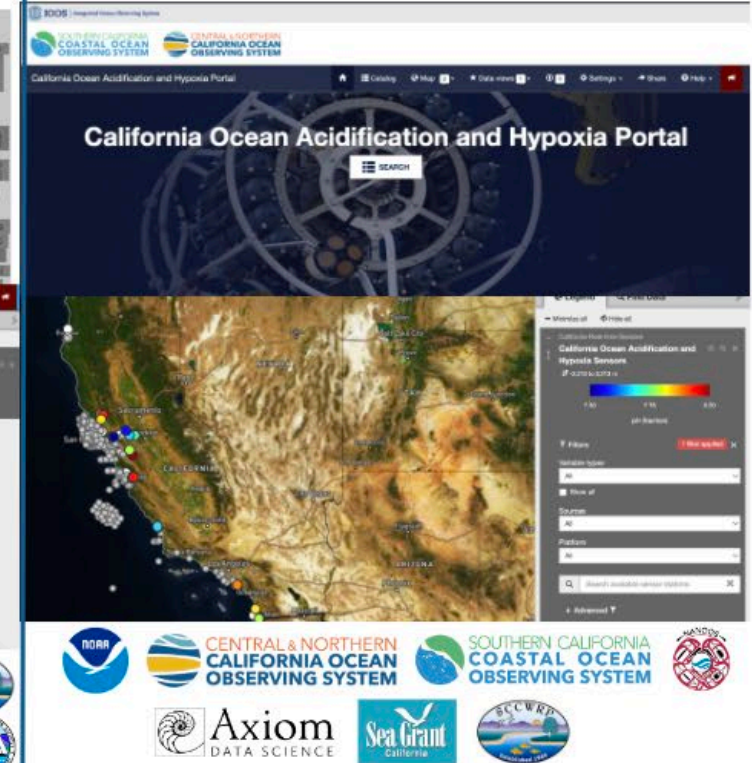
(PI: [Anderson C.](#), Abell J., Barton A., Bowman J. Brzezinski M., Caron D., Carter M... & Smith J.,



ifcb.caloos.org/dashboard

OAH Dashboard

(PI: [Harper A.](#), Ruhl H., Anderson C., Newton J., Carini R., Satterwaite E., Bochenek R., Kessouri F.)



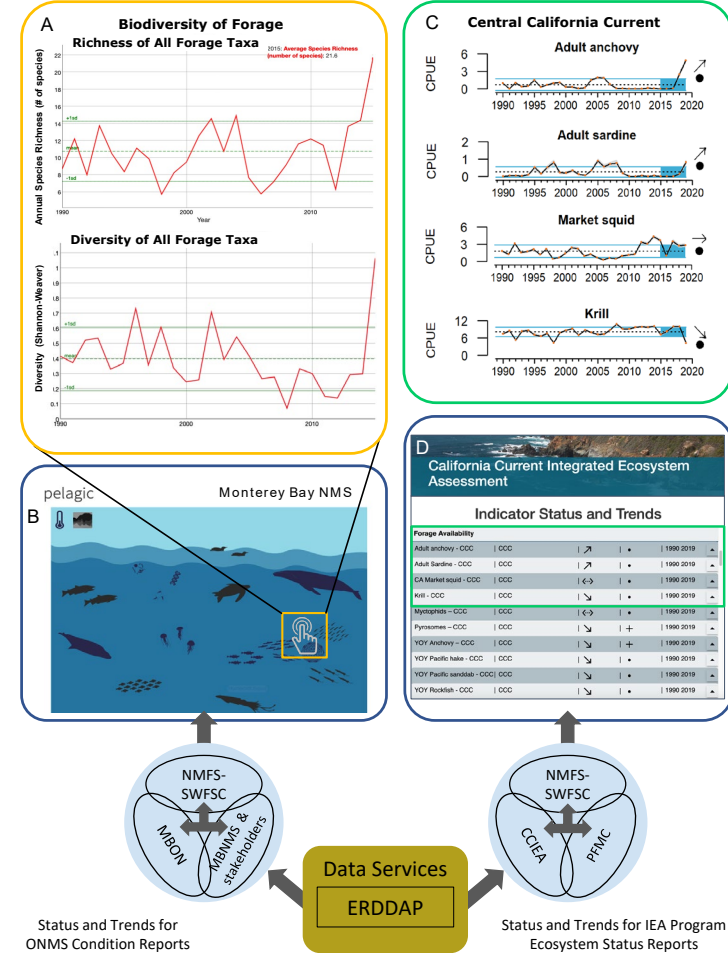

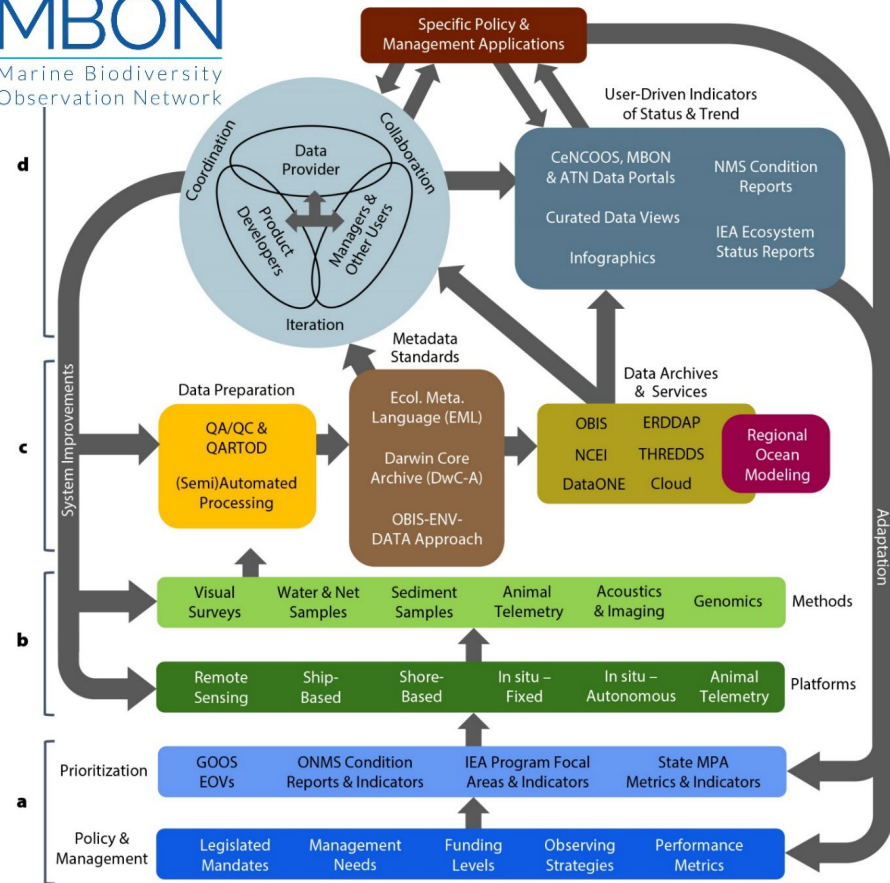
oah.caloos.org (beta)



Pan-Regional Products – Climate Change + Marine Life

Goal for 21st c. ocean observing is to facilitate science-based estimates of current & future ecosystem conditions for a range of coastal questions and activities





*U.S. Marine Biodiversity Observation Network offers a systems approach + interagency partnership
....but are we missing opportunities within the RA network?*



Observations

Data Management

Forecasts/Modeling

User Products

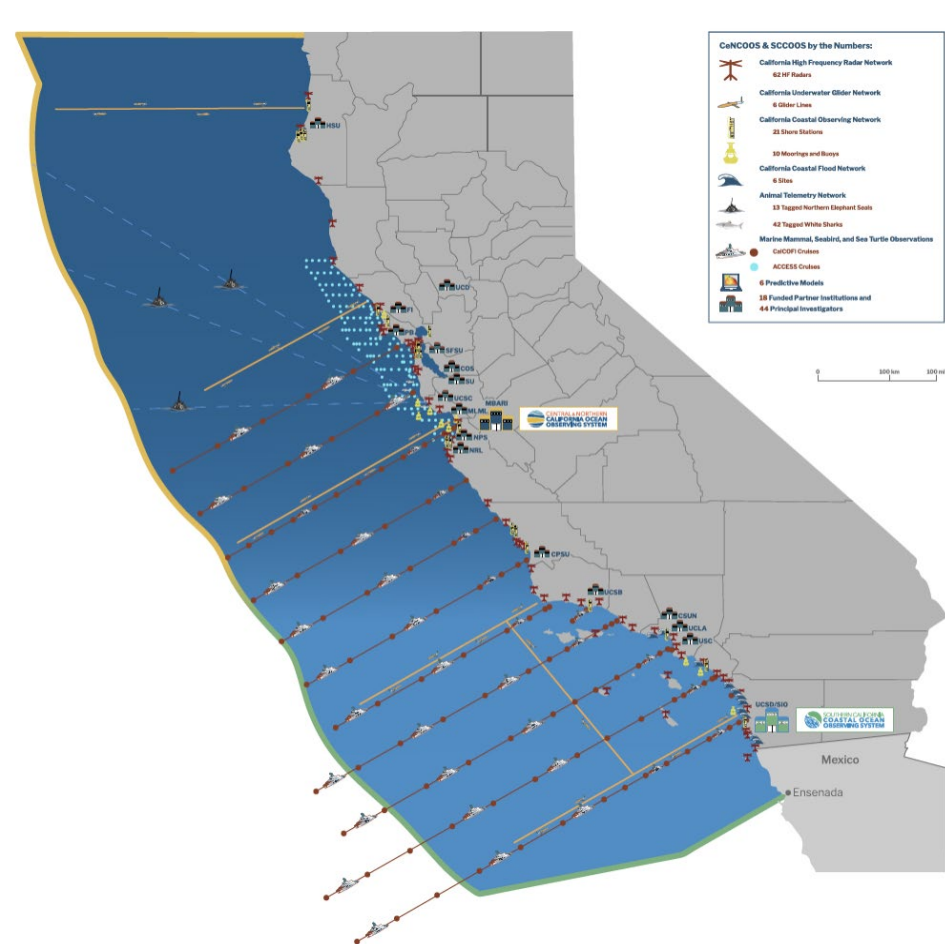
Outreach and Education

Leverage and Link



CONSISTENT NATIONAL CAPABILITY

DIVERSE LOCAL STAKEHOLDERS



Our Ocean Vision:

A healthy and prosperous California coastal ocean powered by information solutions

Total 30 Projects at \$6M/Year,
included 45 Principal Investigators
from 20 institutions

- Tier 1 - 12 Projects (\$3M/yr)
- **Tier 2 - 18 Projects (\$6M/yr)**



**SOUTHERN CALIFORNIA
COASTAL OCEAN
OBSERVING SYSTEM**



**CENTRAL & NORTHERN
CALIFORNIA OCEAN
OBSERVING SYSTEM**

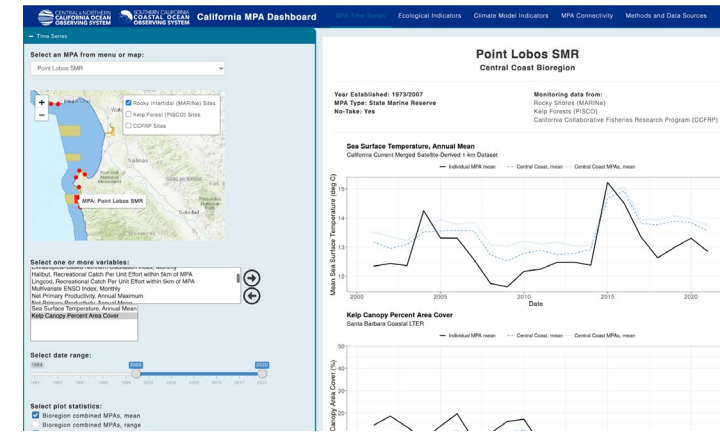
California Ocean Observing Systems – Regional Collaboration

Mission: *To produce, integrate and communicate sustained high-quality, science-based information to promote coastal ocean safety, resilience, and sustainability for all members of society*

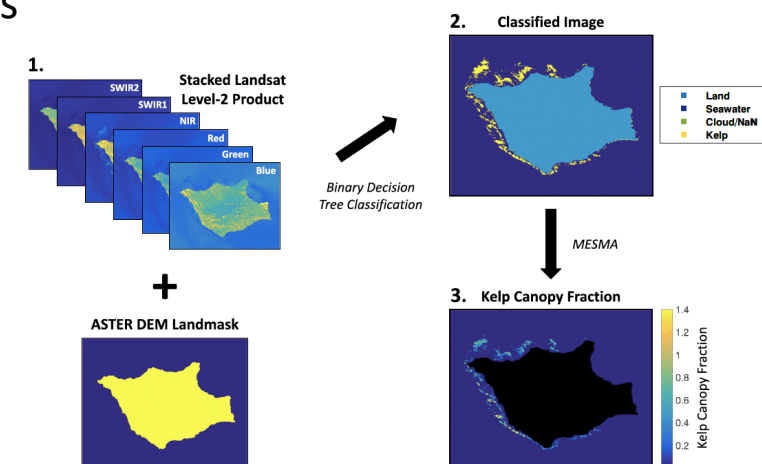
1. Cal OOS Data Portal
2. CA HAB Bulletin
3. Cal HABMAP Dashboard
4. California IFCB Network Dashboard
5. Marine Protected Area Dashboard
6. CalCOFI + Infographics for IEA Assessment/Sanctuaries
7. HF Radar Hourly Surface Currents Map
8. Automated Shore Station Dashboard
9. California Underwater Glider Network Dashboard
10. Statewide Kelp Canopy Area/Biomass Dynamics
11. Multivariate Ocean Climate Indicator
12. California operational 4DVAR ROMS 3km + Drop-a-Drifter
13. West Coast Ocean Forecast System, searchable nowcasts and forecasts
14. Seabirds on the CalCOFI/CCE-LTER Survey (PI: Sydeman, FI)
15. SoCal Index (PI Rudnick, SIO)
16. La Jolla Cove Area of Special Biological Significance Dashboard
17. Ports and Harbor Dashboard
18. NAVAIR Dashboard (SCCOOS & ADS)
19. Imperial Beach and Cardiff Beach Flood Forecasts (PI Merrifield, SIO)
20. Tijuana Plume Tracker (PI Terrill, SIO)

- SCCOOS/CeNCOOS Co-funded Product
- SCCOOS product only

MPA
Dashboard
(PIs Ruhl,
Anderson,
Edwards)



Kelp Biomass
PI T. Bell



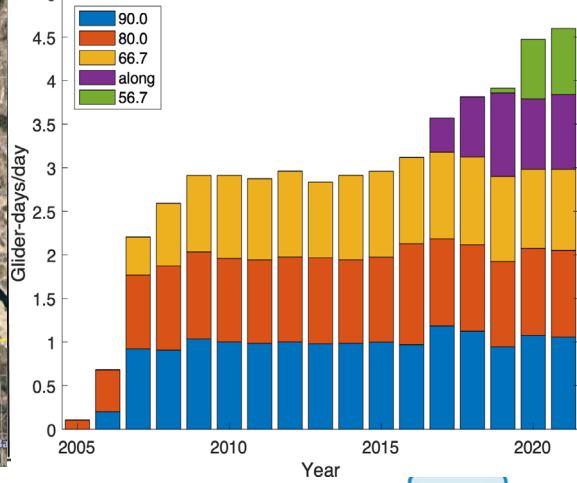
SOUTHERN CALIFORNIA
COASTAL OCEAN
OBSERVING SYSTEM



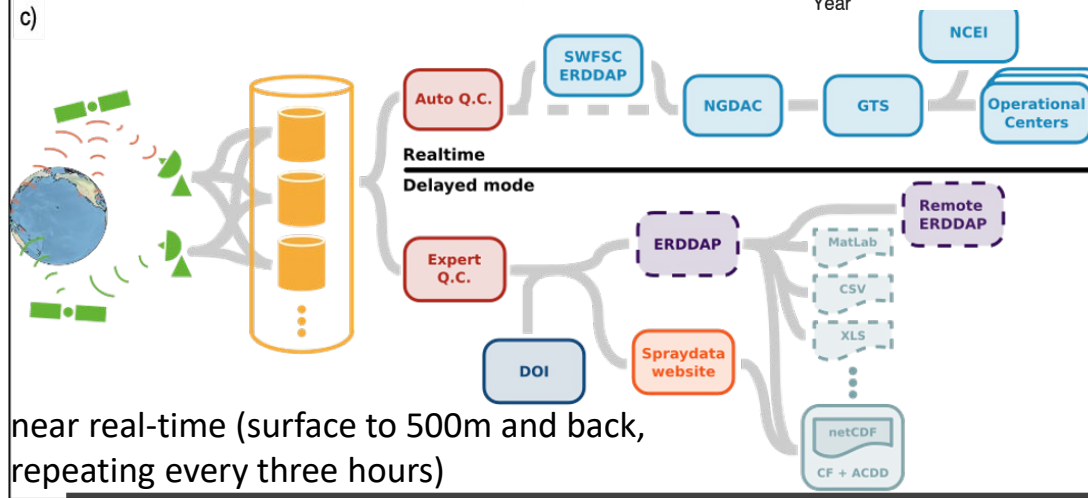
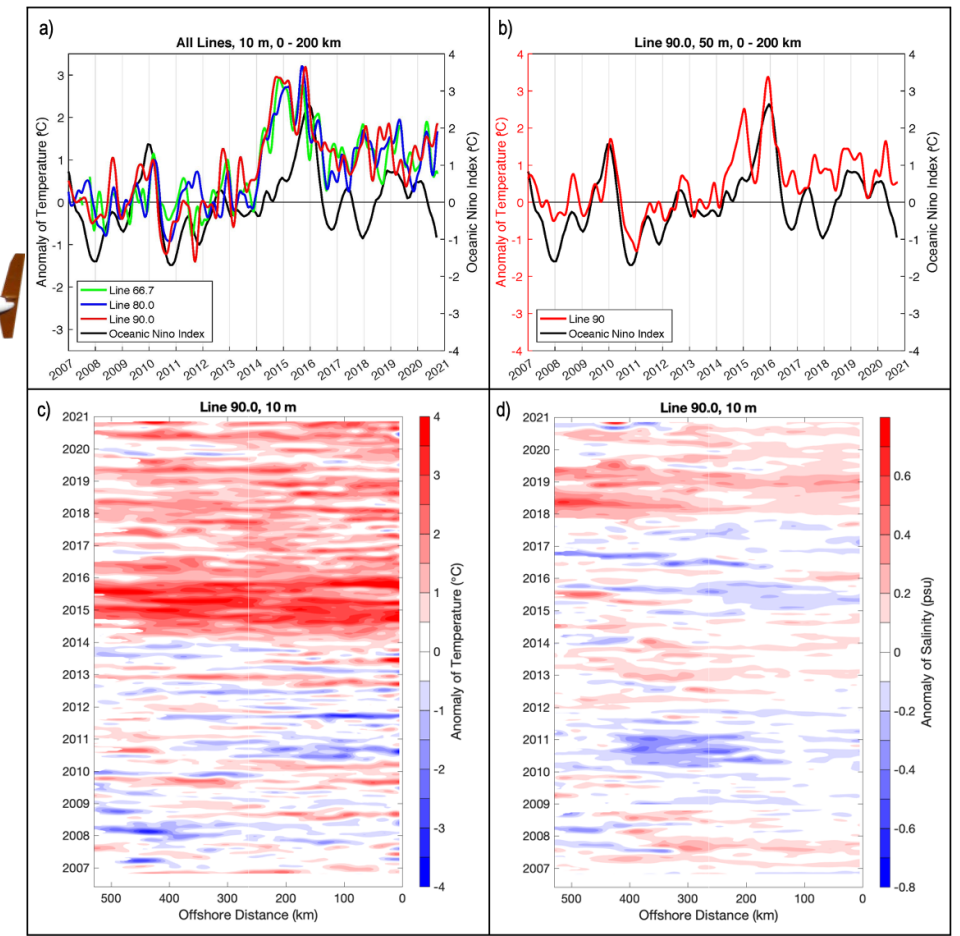
CENTRAL & NORTHERN
CALIFORNIA OCEAN
OBSERVING SYSTEM

Ecosystem State Products for Stakeholders – at least 13 shared products

- Bringing in new PIs with each funding round or via collaborative, extramural proposals to NOAA, NASA, NSF etc.
- Ensuring that the best science is transitioned to operations to build a fully end-to-end system



PI: D. Rudnick
(UCSD)

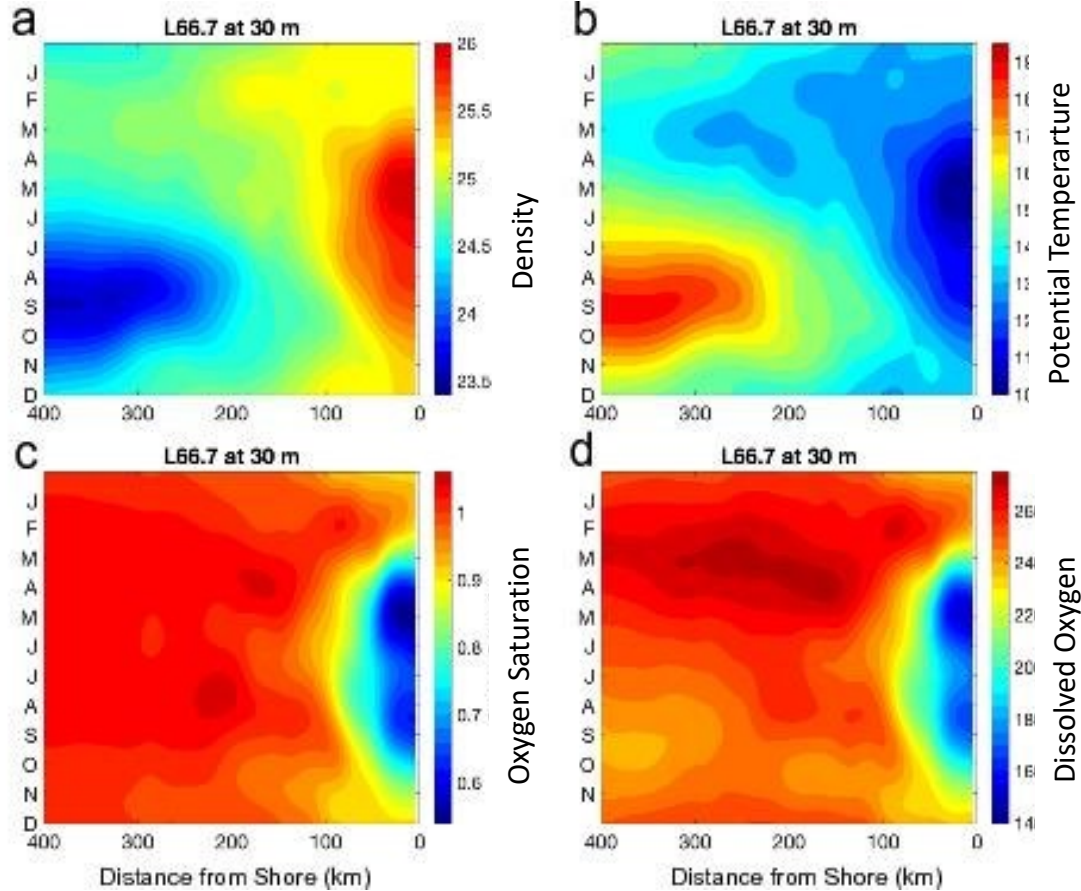


near real-time (surface to 500m and back,
repeating every three hours)

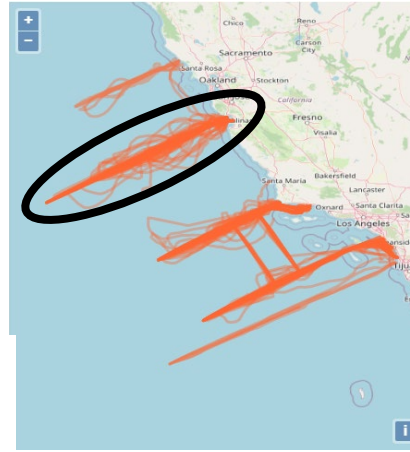


California Underwater Glider Network

SIO Spray Glider program provides essential information on subsurface heat content and ocean state of coastal California in relation to the Pacific Basin, especially the equatorial Pacific

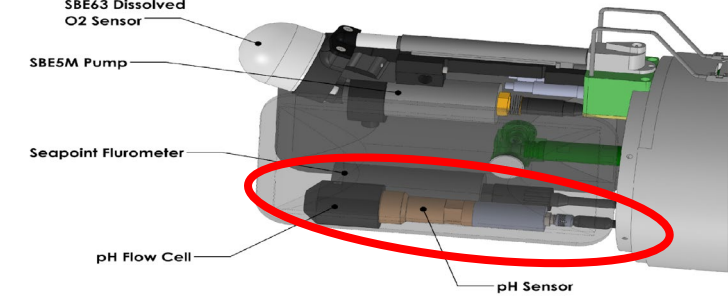
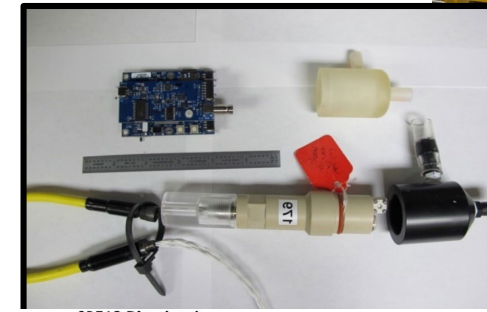


Annual O₂ Cycle

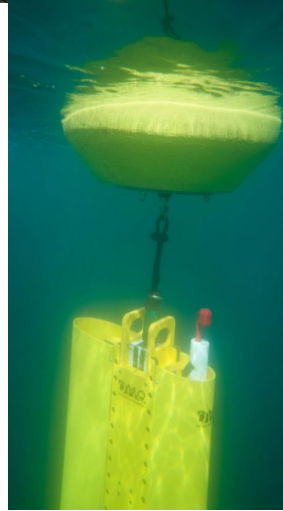


Yui Takeshita, MBARI
Alice Ren, SIO

- Deep-Sea-Durafet pH Sensor
- Seabird 63 w/ DO sensor
- ISUSv2
- Planktivore Camera



NOTE: HYDRAULIC PUMPED CIRCUIT TUBING NOT SHOWN



T
Takeshita et al. 2021



SOUTHERN CALIFORNIA
COASTAL OCEAN
OBSERVING SYSTEM

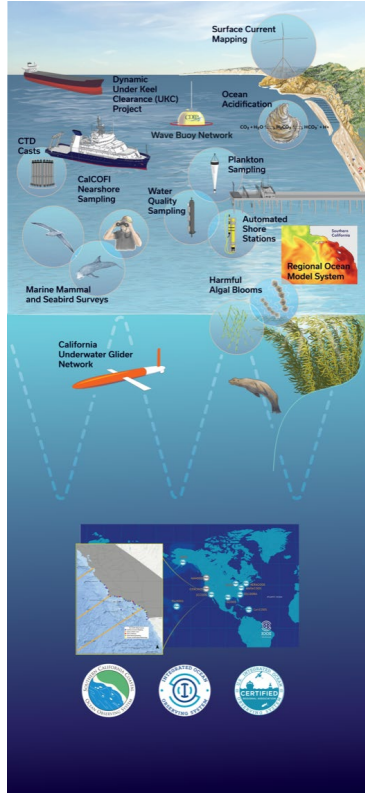


CENTRAL & NORTHERN
CALIFORNIA OCEAN
OBSERVING SYSTEM

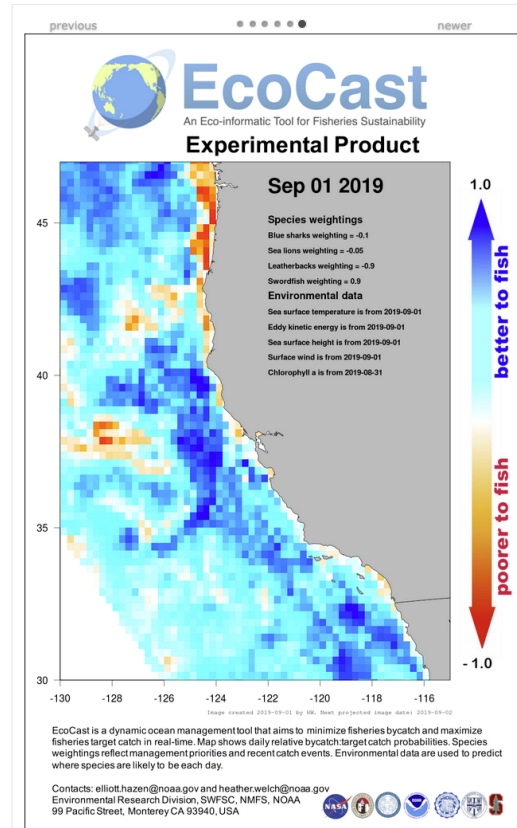
Biogeochemical-Eco Gliders – moving towards Spray 2 glider recap

Need colocated measurements on sustained glider lines to capture the coastal climate signal, establish baselines for change, and provide the raw material to improve ecological forecasts

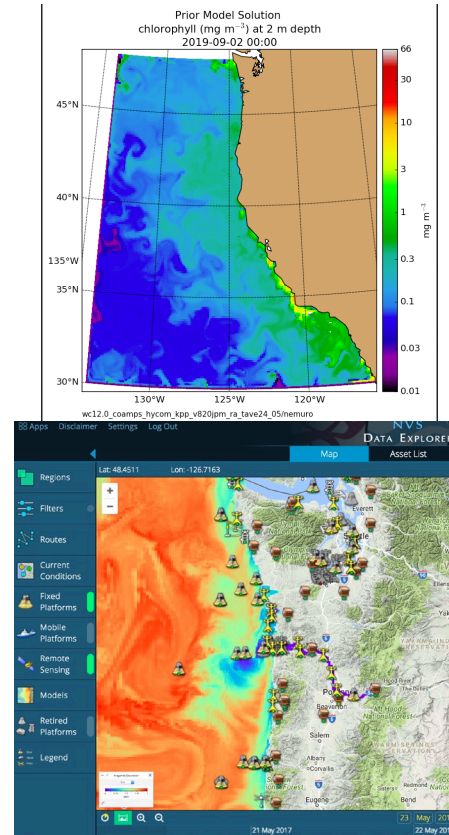
Observational Impacts in Data Assimilation



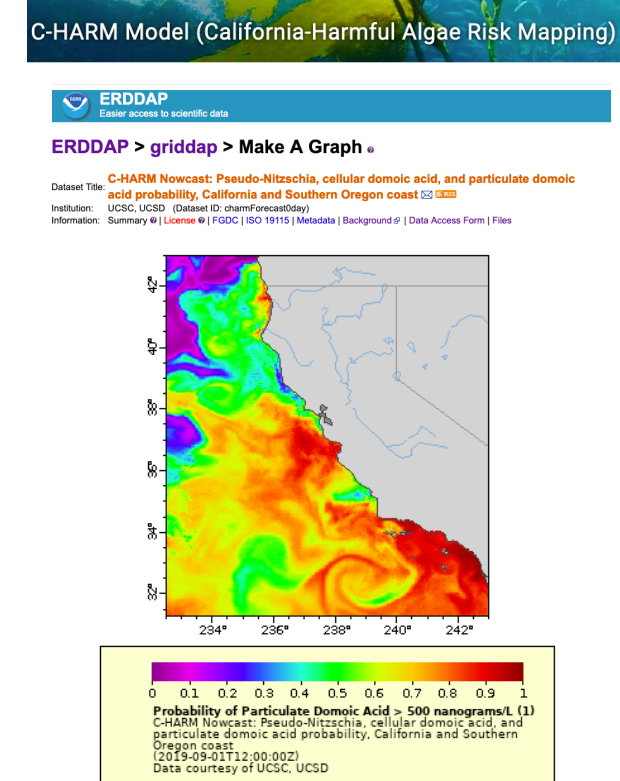
Fisheries Habitat



Ocean Acidification & Hypoxia



Harmful Algal Blooms



IOOS West Coast Coastal Ocean Modeling Testbed

*Evaluating impacts of operational NOAA West Coast Ocean Forecast System
on existing /planned Ecological Forecasts*





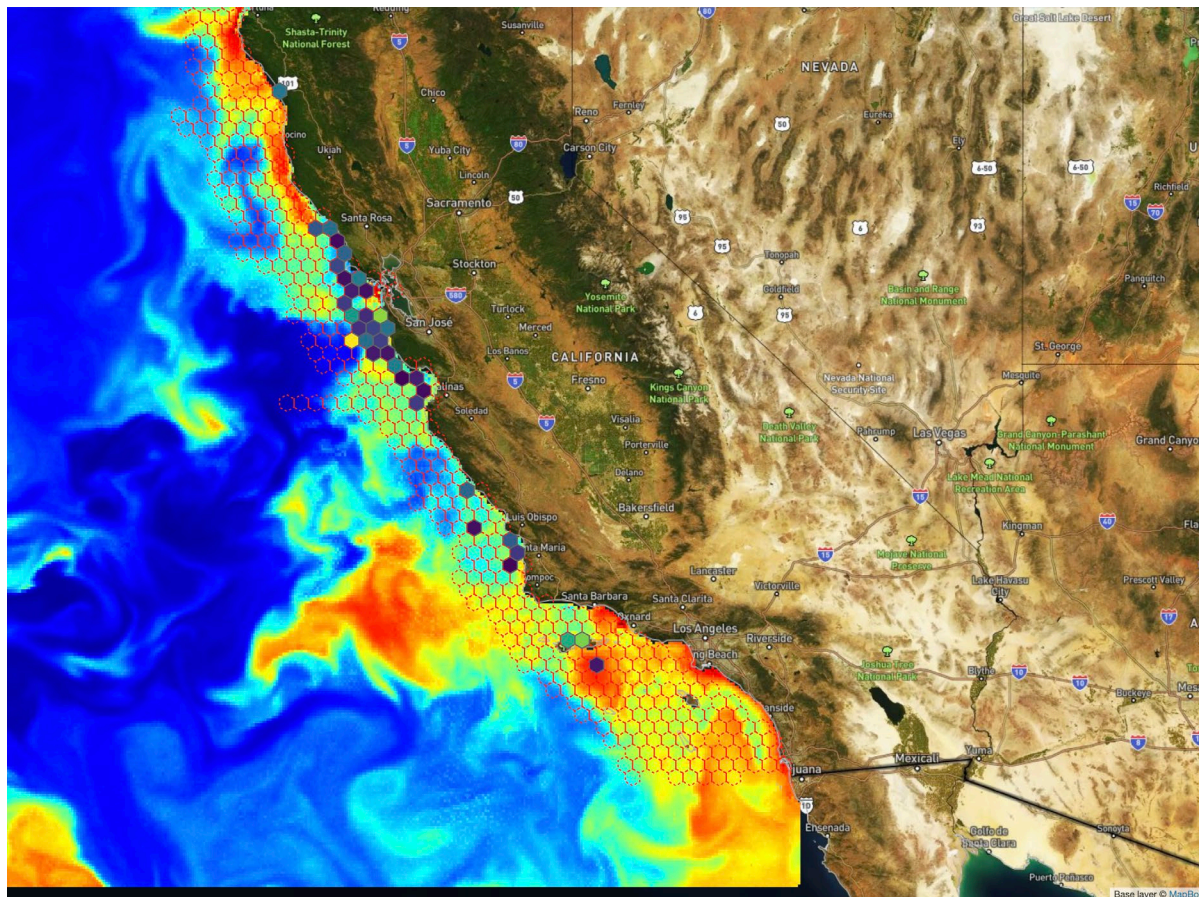
SIO/SCCOOS



Rick Stumpf
NOAA



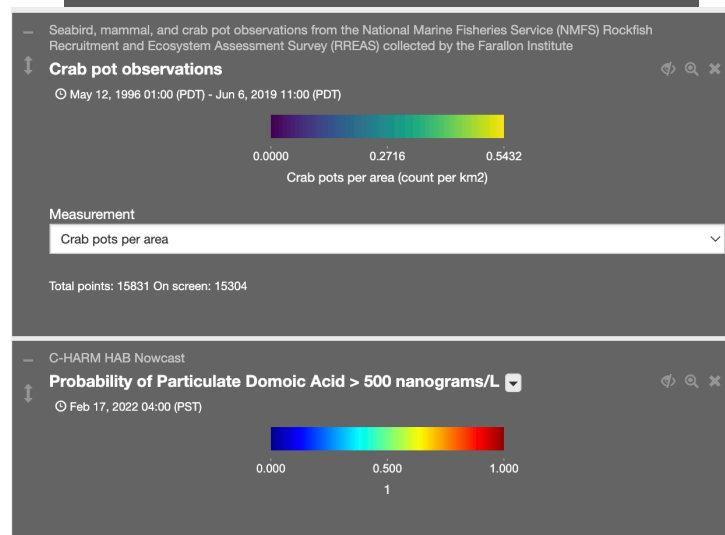
Dale
Robinson
NOAA



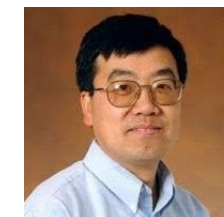
CalOOS Portal

Particulate Domoic Acid
February 2022

Crab Pot Locations Overlayed



Raphe Kudela
UCSC

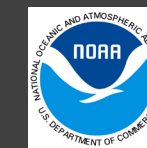


Yi Chao -
Seatrec



California Harmful Algae Risk Mapping (C-HARM) System

Operational model at NOAA Coast Watch provides spatially explicit nowcasts and 1-3 day forecasts of domoic acid risk in the California Current – synthesis in CA HAB Bulletin



Imaging Flow Cytobot Network

Leads: C. Anderson,
R. Kudela, A. Barton, K. Kenitz,
U. Send, F. Chavez, H. Ruhl



- **Largest IFCB array in the world**
- Close to having 9 IFCBs running in real-time, most at stations with full hydrological and nutrient sampling suites
- 12 IFCBs total in the network
- O&M now covered via IOOS/NCCOS support to SCCOOS and CeNCOOS (NHABON Pilot Projects)

CA IFCB Network – HAB alerts + ecosystem science

*We are using extramural funds and state support
to build a statewide ecological observatory*



NOAA NCCOS PCMHAB Project to build a national repository & computational framework for IFCB data – Central clearing house where Level 1 data are QCd, Level 2 and 3 products generated

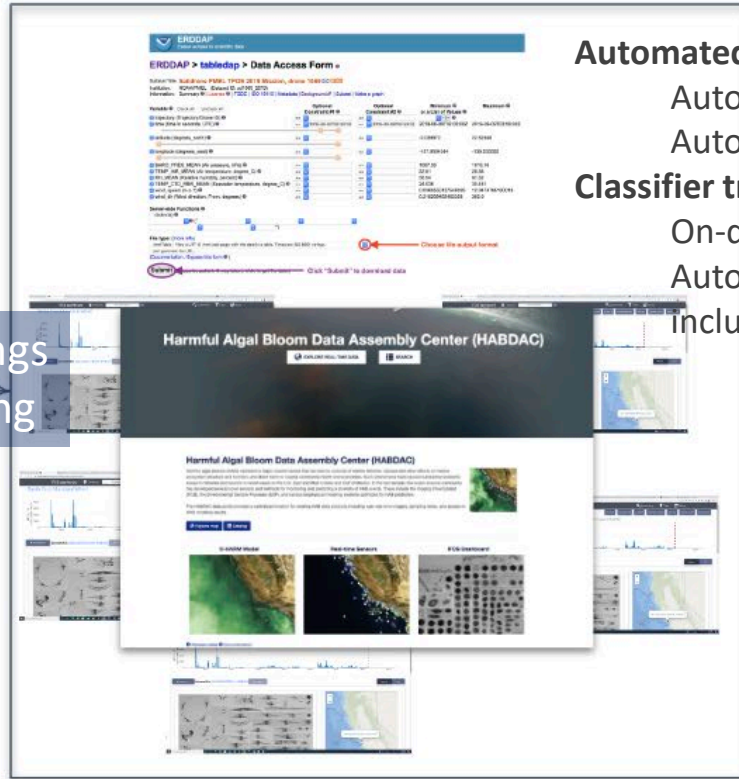
HAB Data Assembly Center (DAC) Development

Team Leads

C. Anderson, SIO
R. Bochenek, ADS
H. Sosik, WHOI
S. Beaulieu, WHOI
H. Ruhl, MBARI
R. Kudela, UCSC



Internet of Things
Edge Computing



Automated data accession

Automated image product generation

Automated image product access

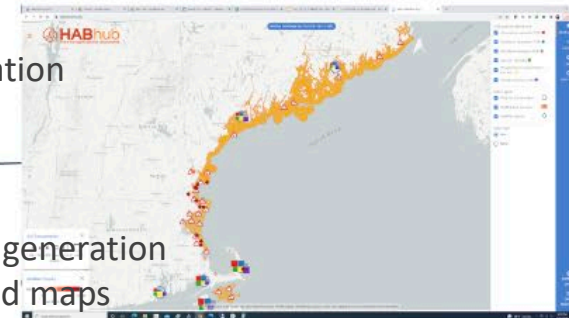
Classifier training and evaluation tools

On-demand classifier application

Automated **level 2 and 3** product generation

Including summary time series and maps

WHOI, PI Brosnahan, MERHAB

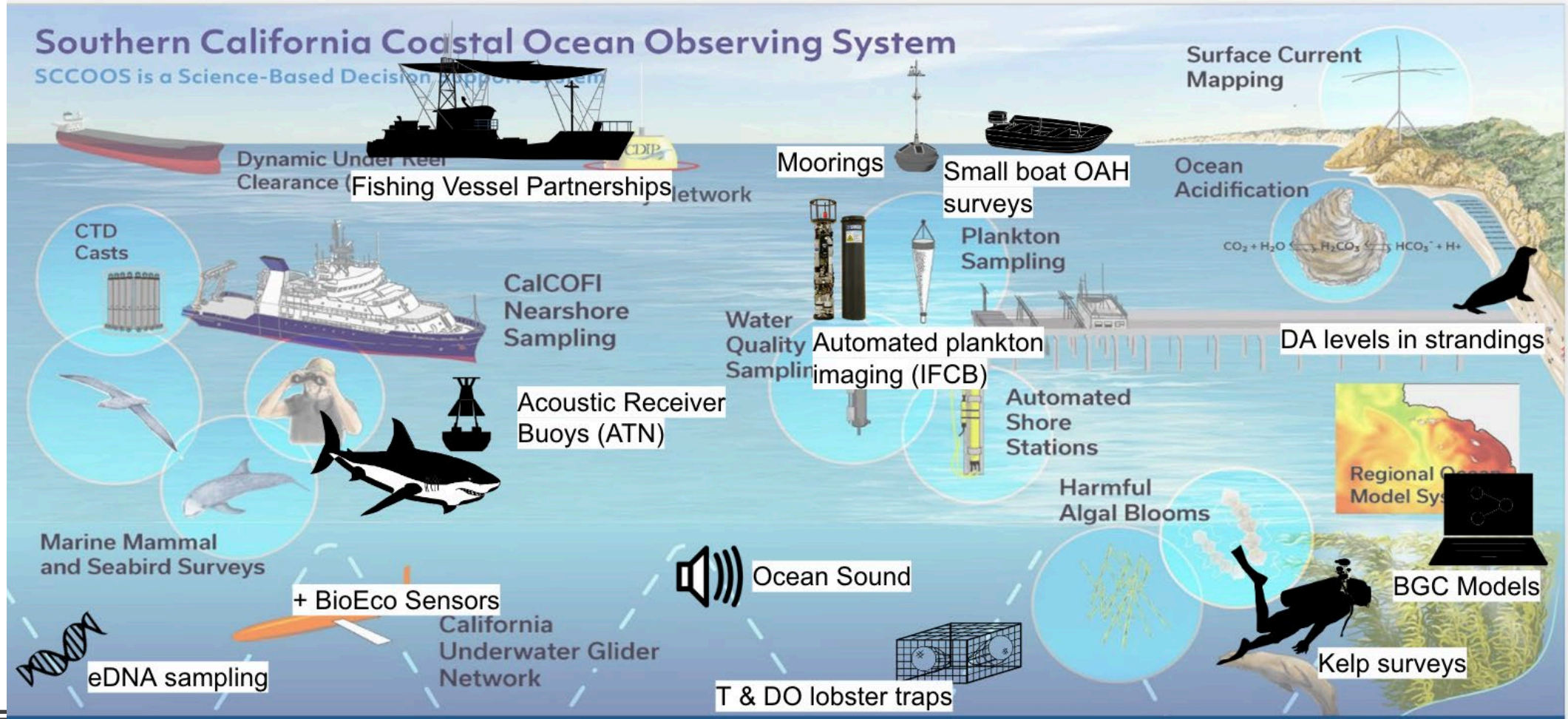


Regional Decision-Enhancing Products



“Plankton/Microbial” Database scaled up to national programs

Ocean Observing systems driving creation of community analysis tools for facilitating downstream improvements in ecosystem science and prediction



So... what does it take to build an end-to-end observing system from physics to marine life?

- IOOS consistently underfunds the regional ocean observing systems – can't get to Tier 2!
- Requires at least double the investment to build out a true ecosystem monitoring and prediction system

MBON Data Portal

EXPLORE MAP

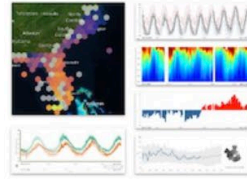
SEARCH 270+ DATASETS

Welcome to the Marine Biodiversity Observation Network (MBON) Portal, where you can:

- Search and download real time, delayed-mode, and historical data for in situ and remotely-sensed physical, chemical, and biological observations
- Compare datasets across regions and disciplines
- Generate and share custom data views
- Link to information about protocols, methods and best practices for biological observing
- Access a full suite of tools developed with a broad range of IOOS and MBON partners

How to use the portal

- Documentation
- Demonstration Video (coming soon)
- Release notes



PARTNERS



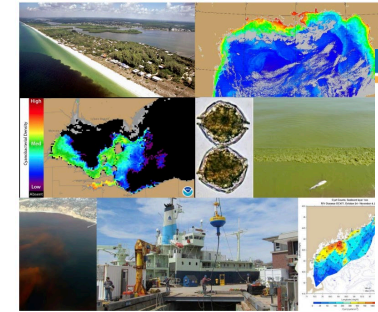
IOOS Association initiatives to consider from perspective of the MBON Framework:

DETECTING THE COASTAL CLIMATE SIGNAL: THE IOOS CONTRIBUTION



IOOS
ASSOCIATION

Framework for the National Harmful Algal Bloom Observing Network: A Workshop Report



National Centers for Coastal Ocean Science and
U.S. Integrated Ocean Observing System
National Oceanic and Atmospheric Administration
December 18, 2020

OCEAN SHOT

Ecological Forecasts for a Rapidly Changing Coastal Ocean

Gabrielle Canonica ¹, NOAA/US IOOS/US MBON, Charles Anderson ², Scripps Institution of Oceanography/Southern California Coastal Ecosystem System, Billy McEwen ³, Asian Ocean Observing System, Joe Boyer ⁴, University of Washington/Northeast Association of National Ocean Observing Systems, and Jane Garavito ⁵, IOOS Association
Corresponding author email: gabrielle.canonica@noaa.gov

ABSTRACT
The U.S. Integrated Ocean Observing System (IOOS) has a vision to provide ecological forecasts that inform response to multiple stressors in the face of rapid changes in our ocean and Great Lakes. IOOS supports 11 nationally distributed Regional Associations, each with established ties to local decision makers and regional coastal scientists. IOOS also supports thematic networks of platforms and observations to characterize and monitor marine ecosystems and living resources throughout the nation. IOOS serves as the U.S. contribution to the Global Ocean Observing System. This observation, stakeholder engagement, and local-to-global reach uniquely positions IOOS to advance development of an ecological forecast system, across sectors and disciplines, that is responsive and effective.

Vision and Potential Transformative Impact
The health of our coastal communities, economies, and ecosystems depends upon not only on understanding the complexities of changing coastal conditions but also the ability to provide timely high-resolution forecasts for decision making. With increasing rates of environmental change, the need for more comprehensive information on our coasts has never been greater. Additionally, since climate and weather changes play out differently in different regions, depending on latitude, species, and societal dependencies, the distributed approach for regional coordination that IOOS offers is a large advantage.

The vision is to provide accurate and informative forecasts for a variety of users on how changes – from gases to cells to organisms to the ecosystem – may impact their lives, livelihoods and prospects. With such a complete range of rapidly evolving information, decision makers, emergency managers, resource managers, and others will access forecasts of future conditions for their all aspects of the ecosystem in four dimensions: latitude, longitude, depth, and time. Moreover, such will allow users to quickly test scenarios and hypotheses to determine the best course of action.

Success will depend on an interdisciplinary approach of multiple scales with robust observations to support, validate, and advance the predictive capacity. Social scientists, fisheries, oceanographers, computer scientists, product developers, and communication experts will work together with users to develop user-to-user capabilities. Advances in remote and autonomous sensing, machine learning, and the Internet of Things makes this possible. Such a system will transform our ability to respond and adapt to ecosystem changes in time, region, and global scales.

Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public-Private Partnerships
The U.S. Integrated Ocean Observing System (IOOS), with its partnership of 11 federal agencies, national network of 11 Regional Associations, and numerous private sector partners, provides the foundational infrastructure for robust ecological forecasting. IOOS provides services to the entire coastline of the United States and links federal expertise with regional scientists, management agencies, the private sector, and non-governmental agencies. IOOS partners include the Marine Biodiversity Observation Network (MBON), the Annual Inventory Network (AIN), the Ocean Acidification Program, among others. Two grant programs administered by IOOS, the Ocean Technology Transfer program that supports the transfer of emerging technology to operators and the Coastal Ocean Modeling Toolkit that serves as a conduit between federal operations and the research community, along other federal and private sector investments, will spur the needed innovation.

Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences
Scientific and technical innovations will allow for assimilation of high temporal and spatial resolution observations into multiple streams, operational, multi-scale forecasts. Social scientists, oceanographers, computer scientists, product developers, and communication experts will work together with users to develop user-to-user capabilities. Advances in remote and autonomous sensing, machine learning, and the Internet of Things makes this possible. Such a system will transform our ability to respond and adapt to ecosystem changes in time, region, and global scales.

Revisit MBON – *how do we grow the vision within NOAA as a whole?*

Interagency mission with NASA, BOEM, IOOS support – what are the operational objectives?

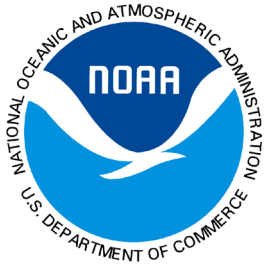
- Ocean Observing of Marine Life is not restricted to IOOS, which is a 17-agency program in theory
- Need to leverage all observing efforts and build on the rich legacy of investment across the IOOS Regions

RECOMMENDATIONS

- Next-generation observing systems must take advantage of current RA investments from a variety of sources, i.e. honor legacy “backyard” time series but move forward deliberately and intentionally to include marine life observations
- Leverage interagency resources to meet global to coastal observing requirements – NEW PARTNERSHIPS
- Skillful ecosystem prediction will require robust sensor suites on fixed and Lagrangian platforms (cross and alongshore scales), complemented by successful and fully funded biological/ecological monitoring programs

NOTHING ELSE LIKE THIS EXISTS IN THE USA!
(or anywhere)

- HOW? 1. Fill critical gaps in marine life and biodiversity observing through top-down investment in R2O from MBON to all regions. 2. Encourage a grass-roots RA initiative around marine life with several flagship programs or motives (e.g. NHABON, Ecological Forecasting, centralized biological DMAC).



Need slide on WC Biology Workshop
And ESON