East coast/G. Mexico/Caribbean Islands - In person

Major gaps:

1. Data availability in coastal ocean
- A lot of data available within individual groups
- Need for standardized (FAIR) data; hard money support needed to coordinate databases and help observational groups contribute to them

1. Gulf of Maine
- A lot of the data is shore-aliased (different problem!)

1. What is the bottleneck?
- Shelf/nearshore disconnect
- Need for real-time observations for short-term forecast

Solutions:

1. Hard money!
2. USGS good example for data availability
3. Higher level coordination of regional associations

East coast/G. Mexico/Caribbean Islands - Virtual

1. **What are the major gaps in our ability to predict physics/BGC/ecology in this region at the time scales of interest?**
    a. Better understanding the dominant climate modes, and climate signals may not be strong compared to the west coast.
    b. Better simulating the seasonal-to-interannual variabilities of the Gulf Stream, e.g.,
        i. Meridional shift of its main axis;
        ii. Warm-core rings activities in the slope region;
        iii. Meandering intensity

1. **What program would you design to fill these gaps?**
    a. Higher-resolution BGC reanalysis models
    b. Statistical modeling techniques
    c. Using ML techniques to investigate currently available data and reanalysis outputs
    d. Quantitative and qualitative

West coast/Pacif. Islands - In person

- West coast is “easy” - nice to have ENSO as the main driver of predictability.
  - ENSO diversity drives different teleconnections that can impact skill differently.
  - ENSO teleconnections are not always consistent, need to use large model ensembles to understand impact uncertainty.
- Need a better understanding of eddy-ecological interactions (physics, timescales, etc).
  - Eddy statistics vs individual eddy impacts on ecosystem, depends on the scale of interest.
  - Other flavors of eddies are also important, not just closed rings (filaments, bulk EKE).
- Difficult to simulate interactions across trophic levels.
  - Can’t advance models, strongly limited by our ability to observe those quantities. Hard to advance and/or validate the models with limited observations.
- Unclear how modeling tools translate to tangible actions.
  - General mistrust of models among stakeholders. In some cases it’s actually illegal to use model output to make decisions (west coast HABs).
  - Build trust by repeatedly showing stakeholders that it works (in real time), as opposed to attempting to communicate overall skill or forecast uncertainty.
  - When developing operational tools, need to partner with stakeholders in tandem.

West coast/~~Pacific Islands~~ - Virtual

**Note our breakout was comprised entirely of individuals from the US West Coast and thus that is the focus of the questions/answers below*

1. **What are the major gaps in our ability to predict physics/BGC/ecology in this region at the time scales of interest?**

- Focused process studies linking key physical mechanisms to ecological responses
- Need for observations of rate processes (birth, death, growth rate) with interactive variables
- Need for greater constraint on respiration, calcification, and dissolution rates
- Need for spatially-resolved time series with subsurface resolution
- Better integration between model development and observations
- Better resolution of upstream transport variation and its effects on the coastal ocean
    - E.g., influence of circulation off C. America on N. American coastal waters)

1. **What program would you design to fill these gaps?**

- Better linkage between (and perhaps evaluation of) disparate observation programs along the US West Coast, including:
    - Ocean informatics
    - Measurement collection
    - Standardized best practices across collection and data processing
- Better integration of shipboard with autonomous instrumentation for finer spatio-temporal resolution
- Opportunity for expanding collaborations / integrating efforts with colleagues in C. and S. America, and more broadly
    - E.g., Gap in transport observations from C. America to N. America

Arctic/Bering Sea - Hybrid

- What is the timescale to look for?
  - Seasonal to annual important to many stakeholders
- Eastern Bering Sea cold pool
  - Global model skill is an issue - lack of skill for winter winds which advect ice
- Sea ice concentration and thickness
  - Observations of volume were important
    - Continue and improve observations
    - Cryosat2 and Icesat2 for SI thickness
- Sea ice phenology
  - Impacts BGC and ecology
  - Sustained observations in N Bering
- River input - volume and BGC (nutrients and carbonate system)
  - Data availability issue - some new reanalysis products are helping
    - GLOFAS & JRA55-DO; GlobalNews
  - Large variability in different rivers systems
- What program to design?
  - EcoFOCI and DBO have been making observations
  - More funding for international collaboration in Arctic (obs and models)
    - Arctic GOOS Regional Alliance?

Session 2: Applications

Fisheries - In person

Major barriers:

- Lack of understanding mechanistic underpinnings
- Inertia of fisheries management process
- Fisheries data lack indices - no point of comparison, no data to validate your model

Suggestions:

- Stress the reforecast approach to fisheries
- Understanding current scientific approach in order to make improvements on current weaknesses
- Think about ways that ecological information can be used (other than just stock assessments)
- Proactive vs reactive (ecological forecasts could be useful for understanding presence/avoidance)
    - In season adaptive management approaches

Fisheries - Virtual

Barriers for management-relevant applications:

- Accuracy/uncertainty of model inputs cascades into forecasts

Knowledge of relevant process / Suitable methodological approaches:

- Lack of first-principles approach to ecology can result in the use of correlative models
    - May not forecast well when outside training data
    - May work well when they can exploit persistence
- Consider evaluating other “discipline-specific” approaches that can be applied to forecasting for fisheries applications

Data

- Better understanding of zooplankton and additional zooplankton data can help improve models
    - Prey (zooplankton / forage fish) often missing from, or poorly constrained in, habitat/abundance modeling
- Make efforts to merge data sets from different institutions/agencies to create larger more robust data sets
- Consider emerging approaches (machine learning techniques, AI) when designing or redesigning data collection efforts (especially large-scale or long-term efforts)

Harmful Algal Blooms (HABs) - hybrid

Major barriers to prediction for management-relevant applications

- Inherent paucity of species-level predictability (i.e., chaotic behavior at species level; parallel to chaotic atmospheric behavior)
- Data is sparse, but some cause for optimism:
  - Hyperspectral (PACE) and hyperspectral/geostationary satellites (GLIMMR)
  - Unmanned aerial vehicles to provide synoptic coverage of nearshore waters (the inner km)
  - Advances in in-situ observing systems (ESP, gliders) could be deployed at scale, though cost is still a barrier.
  - Expanded eDNA activities
- Mechanistic understanding of HABs is often limited
  - Empirical models are often based on emergent correlative relationships with what you have rather than careful mechanistic choices - cautions against long time horizon applications.
  - Better integration of HAB and hydrographic/BGC sampling could help improve.
  - The need to understand propagation through foodweb and translation to toxicity compounds mechanistic challenges.
- Challenge of providing decision-relevant data given the high threshold for action
  - Useful for optimizing monitoring effort to reduce risks?

Breakout 2. Coastal Water Quality

OA - long-term forecasts

- Characterization of indirect pathways
- Long-term time series
- How to motivate stakeholders to worry about long timescales (e.g., relate to number of generations of some critter)

OA - short-term forecasts

- Real-time pCO2 data; good new alkalinity measurements
- Citizen science, but require more care than physical variables

O_2 - long-term forecasts

- Improved terrestrial inputs from watershed models; earth system models?
- Ocean boundary conditions - need more shelf data
- Little information/data on benthic fluxes, shallow coastal environments; how these will change with warming

O_2- short term forecasts

- Trade-off between knowing things now (even if for the wrong reasons) and getting the reasons right for better understanding
- Building models that are versatile because stakeholders may have new focus/issues, or current problems may be solved and no longer need to rely on forecast

Coastal water quality (e.g., hypoxia, acidification) - virtual

Question: What are the major barriers to prediction for management-relevant applications? Inherent lack of predictability? Knowledge of relevant processes? Data? Suitable methodological approaches?

- Lack of high-resolution (1 km) biogeochemical models
- Paucity of consistent (space/time) coastal data to assimilate into (and validate) models
  - E.g., Arctic - shelf-wide ocean acidification, nutrients
- Inherent lack of predictability at timescales < interannual, reiterating need for finer spatio-temporal resolution and more data
  - E.g., Sea ice in the Arctic, wherein little skill beyond persistence before sea ice retreat
- Need for communication and engagement with stakeholders for product relevancy
- Disparate methodological approaches
  - Trade off between complexity, application need, what data is available
- Turf wars == opposes open science and progress for societal benefit

Marine ecosystem health - compound & extreme events

What are the major barriers to prediction for management-relevant applications?

- Undersampling (especially subsurface) (physical, bgc features)
- Lack of rapidly available data for quick assimilation
- Lack of basic mechanistic understanding of bgc processes and organisms (physical tolerances , bgc processes)

Inherent lack of predictability?

- Relevant time scales are hard to constrain
- Nonlinear behavior of physics and ecosystems, Nonlinear biological responses even if physical forcing is linear!
- 2nd and 3rd order interactions between drivers of compound events are poorly understood (e.g. land-ocean interactions, multivariable interactions, precipitation and hypoxia)

Knowledge of relevant processes?

- Physical: Along shore upwelling, favorable winds, transient storms causing mixing, coastally trapped waves
- bgc process (hypoxia, oa)
- Organismal generation time (sets time scale for relevant phenomenon)

Data?

- Satellite ocean color, SAR, SSH, SSS, SST, etc., and upcoming SWOT, PACE, NISAR, etc. High-res ocean reanalyses (e.g., GLORYS). Future observations of surface fluxes, winds and currents (WaCM), and Mixed layer depth.

Suitable methodological approaches?

- Multistressor experiments
- Large ensembles could be used more liberally to get more degrees of freedom.
- Linear Inverse Models (LIMS) can tease out key processes. Can only offer you variables that you feed it.
- Dynamical system might be better able to explain extreme events bc they produce dynamically consistent results.