A Request for Funds to Support the Workshop:

Variability and Change in the California Current Ecosystem

Proposal Submitted by:

Dave Checkley
Professor of Oceanography
Director, Cooperative Institute for Marine Ecosystems and Climate, CIMEC
Director, Scripps California Cooperative Oceanic Fisheries Investigations, CalCOFI
Scripps Institution of Oceanography, University of California, San Diego
9500 Gilman Drive, La Jolla, CA 92093
E-mail: dcheckley@ucsd.edu

Proposal Submitted to:

Kenric Osgood
Chief, Marine Ecosystems Division
National Marine Fisheries Service/Office of Science and Technology
National Oceanographic and Atmospheric Administration
E-mail: kenrick.osgood@noaa.gov

cc:
Ned Cyr <ned.cyr@noaa.gov>, Robert Detrick <robert.detrick@noaa.gov>, Roger Griffis <roger.b.griffis@noaa.gov>, Wayne Higgins <wayne.higgins@noaa.gov>, David Legler <david.legler@noaa.gov>, Richard Merrick <richard.merrick@noaa.gov>

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Abstract

The Cooperative Institute for Marine Ecosystems and Climate (CIMEC)[1] at University of California, San Diego's Scripps Institution of Oceanography (Scripps) proposes to host a workshop to review and update the 2007 plan "Climate Variability and Change in the California Current Ecosystem: A Plan for Research to Inform Management."[2] Over 60 scientists and managers from government and academia attended the La Jolla workshop in 2006 that generated the 2007 plan. The goal was to establish a new research program on climate and ecosystems, similar to programs for weather forecasting developed in the 1960s and 1970s, to skillfully forecast the physical state of the California Current and the biological status of selected species to inform decisions by resource managers and policy makers. In the seven years that have passed since this meeting, some of the report goals have been met, others have diminished in importance, and new goals and visions have emerged. In particular, observing systems, technology and models since 2007 have evolved and need to be addressed in the new plan.

CIMEC proposes a three-day workshop in La Jolla in mid-2014 (March-May) that engages scientists who represent the institutions comprising the West Coast Cooperative Institutes (CIs: CIMEC, CIMRS[3], and JISAO[4]), as well as representatives from NOAA, including the SW and NW Fisheries Science Centers, and other stakeholder groups. The draft agenda includes an overview of the previous plan, an introduction of straw-person modifications to that plan, and focused talks outlining the changes in science and technology since the report was finalized. The remainder of the workshop would focus on discussion and writing of an updated report and plan. In addition to the report, the proposed workshop will promote collaboration between the West Coast CIs and Centers, and will develop roles and funding for the CI partners who have yet to develop strong relationships with NOAA.

[1] http://cimec.ucsd.edu/
[2] "Climate Variability and Change in the California Current Ecosystem: A Plan for Research to Inform Management." 2007. J. Barth, H. Batchelder, D. Checkley, R. Davis, P. MacCready, J. McWilliams, W. Peterson, and T. Strub. ftp://ftp.iod.ucsd.edu/checkley/cce_climate/workshop_nov06/climate_CCE_29mar07.pdf
[3] Cooperative Institute for Marine Resources Studies, http://oregonstate.edu/cimrs/
[4] Joint Institute for the Study of the Atmosphere and the Ocean, http://jisao.washington.edu/

Background and Science Questions

The California Current Ecosystem (CCE) is a diverse assemblage of environments, communities and species of great societal value. Physical forcing of the ecosystem varies on time scales of days to decades, including event-scale, seasonal cycle, El Niño/Southern Oscillation (ENSO), and Pacific Decadal Oscillation (PDO). Exploited stocks, including sardine, anchovy, Coho salmon, and market squid, and protected species, including marine mammals and seabirds, respond to physical forcing. However, we lack an understanding of the mechanisms by which climate affects the ecosystem, which limits our ability to predict its future state. The CCE is ideal for this work because the climate signals and ecosystem variations are large and clear, and an extensive patchwork of program elements already exists.

In 2006, over 60 scientists and managers from government and academia attended a workshop to "create a program of coordinated and sustained observing systems, and coupled physical-biological modeling in the CCE that will result in products to inform management." The resulting plan recommended the following specifics, indented and italicized below. What has been accomplished and what now needs to be addressed due to changes in priorities and in technologies or methodologies follows each heading.

> *Observations*
> *Extensive observations of the ocean and atmosphere in the CCE now exist and new technologies and programs are emerging. Of particular interest, in addition to existing air and sea measurements, are improved*
> *a. estimates of winds and air-sea fluxes,*
> *b. quantification of the sources of nutrients to the surface layer, especially as influenced by changes in stratification, the California Undercurrent, wind-stress curl, freshwater input, and bottom topography,*
> *c. resolution of the spring transition, and*
> *d. latitudinal spacing of routinely occupied cross-shelf transects*.

Observing in the CCE has advanced significantly since 2007. Platforms have matured or been further developed and more widely deployed. Of particular note are new and more capable glider lines and moorings coastwide and the maturation of Ocean Observing Systems (NANOOS[5], CeNCOOS[6], and SCCOOS[7]) as well as the deployment and implementation of NSF's cabled and uncabled ocean observatories in the Pacific Northwest. Sensors are also developing rapidly including acoustics, optics, and 'omics' (e.g., genomics – taxonomy - and transcriptomics – function). New vessels are coming on board in the US fleet, e.g., NOAA's RV Reuben Lasker and UNOLS's RV Sally Ride, and also in Mexico (CICESE[8] and INAPESCA[9]). As a result of the overall increase in observing, habitats of many stocks, from sardine to whales, have been better characterized, including physical, biogeochemical, and biological variability. New techniques also resolve smaller time and space scales, considered important for ecosystem processes.

However, West Coast observing remains a patchwork with gaps that need filling to provide the comprehensive view necessary for models and forecasts. Ship costs are escalating and demand complementary, often autonomous, types of observing. While progress has been made on the air

[5] Northwest Association of Networked Ocean Observing Systems, http://www.nanoos.org/
[6] Central and Northern California Ocean Observing System, http://www.cencoos.org/
[7] Southern California Coastal Ocean Observing System, http://www.sccoos.org/
[8] Centro de Investigación Científica y de Educación Superior de Ensenada, http://www.cicese.edu.mx/
[9] Instituto Nacional de la Pesca, http://www.inapesca.gob.mx/

and sea measurements above, much remains to be done. Newly discovered phenomena, from ocean acidification to atmospheric rivers, require new observing approaches. Some prototype systems have been developed in the CalCOFI region, such as the CORC[10] and CCE-LTER[11]/SCCOOS moorings and gliders, which complement and are coordinated with ship surveys and process studies. These could be replicated elsewhere on the West Coast.

> *Process Studies*
> *Specific needs of models will also be addressed by process studies. These include, but are not restricted to, vital rates and behavior of the mesozooplankton and higher trophic levels that are not routinely measured. Of particular interest are feeding, mortality, and patchiness for larger zooplankton, especially euphausiids, and nekton. Results from process studies will be used to develop and parameterize deterministic models that include higher trophic levels.*

Only modest gains in these areas have been made since 2007. Particular interest remains in physical-biological interactions, necessary for a mechanistic understanding of how climate affects the CCE, and animal behavior, for it affects our ability to observe and predict and thus to inform management decisions. For example, improved understanding of harmful algal blooms and krill distributions would enhance public safety and assessment of forage.

> *Modeling*
> *Fisheries management in the context of the ecosystem and climate change requires a diversity of models of both the physical state of the CCE and selected trophic levels and taxa. We seek useful, verified biological forecasting tools, especially for populations of higher trophic levels. Statistical models, based on the past behavior of a system, will continue to be used, particularly for higher trophic levels, until mechanistic models are developed. Ecological indicators will be developed based on observations and models; see, for example, ocean indicators for marine salmon survival in the northern California Current. Dynamical models are progressing to include populations of organisms such as mesozooplankton and fish, which have complex dependencies on age structure and feeding, migration, aggregation and other behaviors.*

> *Forecasting*
> *Our goal is to better inform managers. The proposed observations and models will enable forecasts, initially in a research mode and ultimately in an operational mode. Forecast skill will be evaluated, much like for weather. Risk and uncertainty will be explicitly treated. It is likely that forecasts will be probabilistic rather than deterministic. A range of operational products will be sought, from short-term, statistically based forecasts with narrow probability distribution functions (pdfs), to longer-term, dynamically coupled models based on AOGCMs, box models, and IBMs, yielding pdfs that broaden as the prediction lengthens.*

Models of the ocean and atmosphere have advanced significantly since 2007. Global circulation models (GMCs) have matured and biology and biogeochemistry have been added (e.g., ESM at GFDL[12], CESM1 at UCAR[13]). Downscaling allows higher resolution on the scale of marine

[10] Consortium on the Ocean's Role in Climate, http://mooring.ucsd.edu/
[11] California Current Long Term Ecological Research, http://cce.lternet.edu/
[12] Earth System Model, Geophysical Fluid Dynamics Laboratory, http://www.gfdl.noaa.gov/
[13] Community Earth System Model, University Corporation for Atmospheric Research, http://www.cesm.ucar.edu/models/cesm1.0/

populations and regional climate changes (hypoxia, acidification, nutrient cycles) while retaining large-scale dynamics. New investigations of submesoscale currents and their effects on productivity and lower-trophic-level species diversity are underway. Hindcasts using 4DVar assimilation have improved our ability to characterize past states. End-to-end models, spanning physics to fishers, are developing (e.g., Atlantis, Curchitser/Rose CAMEO[14]). Non-linear forecasting methods show promise for the short-term. Progress has been made in intermediate (months)-scale forecasting. Meteorological testbeds allow improved analysis of processes such as atmospheric rivers.

The need remains for coordinated modeling and prediction of the CCE in support of management and policy. Our vision of a virtual modeling center persists. Like observing, modeling is a patchwork. While this is natural, the scale of the CCE and associated regulatory mandates necessitates a modeling and prediction effort that spans the entire West Coast and makes optimal use of the diverse expertise. Absent reliable forecasts, managers are forced to adopt the "precautionary approach" and, for example, reduce harvests of fish and other natural resources, impinging on the livelihoods of fishers and coastal communities.

> *Integrated Ecosystem Assessments*
> *In addition to specific changes and developments listed above, the proposed workshop will address Integrated Ecosystem Assessments, which "provide "a synthesis and integration of information on relevant physical, chemical, ecological, and human processes in relation to specified management objectives."[15] This process, as well as the framework provided by Coastal and Marine Spatial Planning (CMSP), need to be addressed in relation to the issues raised above, and for the CCE as a whole. Although it is not clear at this time who will be responsible for Integrated Ecosystem Assessments (IEAs) for the California Current, we will be well positioned to both contribute to such efforts as well as be directly responsible for them. Examples of different approaches to an IEA include the annual CalCOFI State of the California Current and the assessment of ocean conditions off British Columbia produced by the Canadian Department of Fisheries and Oceans.*

The West Coast IEA[16] is well underway. Its continued development and improvement will benefit from the program we will propose. For example, we would assist in the development of the Pacific Fishery Management Council's Fishery Ecosystem Plan[17]. CMSP is increasingly reliant on both the natural and social sciences, including economics, which we will include.

The CCE begins off Canada and ends off Mexico. We will include representatives of both countries in the workshop and resultant program proposal.

NOAA workforce needs will benefit from our efforts. The Cooperative Institutes, and other academic institutions, have a strong record of educating and training future NOAA employees. CIMEC, CIMRS, and JISAO are co-located with NOAA centers and laboratories and work with others more distant, including NCAR and GFDL. We anticipate accelerated graduation and training of experts in observing and modeling that will help fulfill NOAA's future workforce needs.

Benefits and Outcomes of the Workshop

[14] Comparative Analysis of Marine Ecosystem Organization, http://cameo.noaa.gov/
[15] http://www.noaa.gov/iea/next-gen-tool.html
[16] http://www.noaa.gov/iea/regions/california-current-region/index.html
[17] http://www.pcouncil.org/ecosystem-based-management/fep/

The goal of work we will propose as a result of the workshop will be to develop specific deliverables to be used to inform and improve decisions made by managers and policy makers. As in 2007, our ability to forecast and predict future states of marine populations and ecosystems remains insufficient. Future decisions in the face of unprecedented change require a mechanistic understanding of the effects of climate on ecosystems. We seek such an understanding and simultaneously the most effective means to inform management. Thus, the impact of our work will increase with time as, for example, we enhance our observing and shift from statistical to deterministic forecasting and prediction, particularly for populations of higher trophic levels. It is noteworthy that ocean acidification was not discussed in our 2006 workshop or the resultant alternative proposal, indicating how rapidly both science has progressed and the environment has changed. There is a real need for a new workshop and proposal.

Relationship to NOAA Goals

Climate Adaptation and Mitigation – The proposed workshop would address the two of the main questions under this goal by (a) characterizing the state of the climate system and how it is evolving and (b) improving regional climate predictions.

Healthy Oceans – The proposed workshop would address at least three of the main questions under this goal by investigating how (a) environmental change affects the California Current Ecosystem and (b) the chemistry of the region is changing and the effects of this change and (c) using emerging technologies to improve ecosystem-based management.

Resilient Coastal Communities and Economies – The proposed workshop would address at least one of the main questions under this goal by investigating how coastal species, from exploited to protected, respond to and relate to habitat loss, degradation, and change.

Draft Agenda

Day One
Evening reception with posters

Day Two
Plenary:
- Overview of the 2007 plan
- Overview of the changes in science and technology since the 2007 plan
- Introduction of straw-person modifications to 2007 plan

Break-out groups, e.g., A, B, and C, and detailed discussion of S&T changes that need to be addressed
Report back
Lunch
Plenary on topic tbd
Break-out group meetings
Report back
Group Dinner

Day Three
Plenary on topic tbd
Break-out group meetings
Report back
Lunch

All except writing team adjourn; writing team drafts outline of report

Venues

SIO UCSD (Day One reception at Forum, Day Two dinner at Martin Johnson House, breakouts at MESOM)

NOAA Southwest Fisheries Science (plenaries in Pacific Room, breakouts in meeting rooms)

Follow-up

Report – Draft report to be completed by writing team within weeks and circulated to workshop participants for comment. Final report to be completed within three months of workshop and submitted to NOAA.

Data Sharing – No new data will be produced as a result of this workshop. Data sharing will be a primary concern of any program that is proposed as a result of this workshop.

Key Personnel

Dave Checkley, CIMEC, SIO
Bruce Cornuelle, CIMEC, SIO
Uwe Send, CIMEC, SIO
Cisco Werner, SWFSC
Jim McWilliams, CIMEC, UCLA
Jack Barth, OSU