Proposal to NOAA Fisheries and the Environment (FATE) program

Project Title: Refinement of J-SCOPE Forecast System for the California Current Integrated Ecosystem Assessment

Project Investigators

Isaac Kaplan[1*], Nicholas Bond[2], Albert Hermann[2], Phil Levin[1], Jan Newton[3], William Peterson[4], Samantha Siedlecki[2]

1. NOAA Northwest Fisheries Science Center, Conservation Biology Division
2. Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
3. Applied Physics Laboratory, University of Washington, Seattle
4. NOAA Northwest Fisheries Science Center, Fish Ecology Division

*Isaac.Kaplan@noaa.gov, (206)302-2446, 2725 Montlake Blvd E, Seattle WA 98112

Project Title: Refinement of J-SCOPE Forecast System for the California Current Integrated Ecosystem Assessment

Project Investigators

Isaac Kaplan, Nicholas Bond, Albert Hermann, Phil Levin, Jan Newton, William Peterson, Samantha Siedlecki

Background

A seasonal ocean prediction system (J-SCOPE, JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem) has been developed for the coastal waters of the Pacific Northwest, with funding provided by the NOAA FATE program. J-SCOPE has been designed to provide quantitative forecasts of physical, chemical and biological ocean properties under the auspices of the California Current Integrated Ecosystem Assessment (IEA). The goal has been to provide seasonal (six to nine month) predictions of ocean condition that are testable and relevant to management decisions for fisheries, protected species and ecosystem health components of this Large Marine Ecosystem. The results from J-SCOPE (http://www.nanoos.org/products/j-scope/home.php/) will be used to directly inform the IEA process, including subsequent IEA products (e.g. forecasts of ecological indicators), and in an ongoing dialogue with the Pacific Fishery Management Council.

Brief descriptions of output from J-SCOPE for 2009 in hindcast mode, and for 2013 in forecast mode, are provided below. A key point is that a working system has been developed and that the early results are encouraging. Through a continuation of regular forecasts, additional insights will be gained on seasonal ocean prediction in the Pacific Northwest. Moreover, we are poised both to refine the model upon which the predictions rely, and to better tailor the system's products to fishery management needs.

Objectives

Our goal is to improve the seasonal forecasts from J-SCOPE of oceanographic conditions along the coast of the Pacific Northwest. We propose additional model development, products of ecosystem relevance, and active engagement with potential users of J-SCOPE:

A. Tailored predictions of ocean conditions relevant to four fisheries: crab, shellfish, pelagic fish (albacore tuna), and salmon.
B. Improved forecast system by improving model initial conditions, and incorporating additional satellite data and river flow runoff forecasts
C. Algorithms for tracking boreal versus subtropical waters and zooplankton
D. Continued forecasts, formal evaluation of model skill, and vetting with stakeholders
E. Incorporation of feedback from NANOOS members, as well as other audiences via website.

Approach

Model Description

The J-SCOPE model system is based on the climate forcing as specified by the Coupled Forecast System (CFS) global climate model. The CFS is a coarse-scale, coupled atmosphere-ocean-land model that assimilates both in-situ and satellite-based ocean and atmospheric data (Saha et al. 2006, 2010). The CFS has been shown to forecast both PDO and ENSO indices up to six months in advance (Wen et al, 2012).

We use CFS to force a high-resolution (grid spacing ~1.5 km) version of the Regional Ocean Modeling System (ROMS) that includes a state-of-the-art biogeochemical module and nutrient, phytoplankton, zooplankton, detritus (NPZD) module (Banas et al. 2009, Davis et al in prep) with an additional detrital pool and oxygen submodel (Siedlecki et al, in prep.) The ROMS output features specific oceanic properties crucial to the nearshore and coastal marine ecosystem such as temperature, currents, upwelling, pH, oxygen concentration, and plankton distributions.

Forecasted Products

The ROMS model, forced by CFS, predicts spatial patterns of nutrients, chlorophyll, zooplankton, and oxygen for the coastal zone (e.g. for the domain shown in **Figure 1**). We have applied regional algorithms (Alin et al, 2012) to relate oxygen and temperature to pH and aragonite undersaturation horizons, which define ocean acidification risk. Regional simulations have been carried out in hindcast and re-forecast mode for 2009 as well as a forecast for 2013 (see below). Spawning areas and spatial distribution of pelagic fish (e.g. sardine) respond directly to sea surface temperature, salinity, chlorophyll, and other ocean variables. The ROMS simulations have been used to predict sardine distributions from three surveys during 2009, and to forecast 2013 spatial distributions. A new set of predictions (with at least daily time resolution) is available every 1-2 months.

Communication

The results described below are available on the Northwest Association of Networked Ocean Observing Systems (NANOOS) website (http://www.nanoos.org/products/j-scope/home.php/), part of U.S. IOOS, for public use and comment. There has been considerable interest in these products from the media and from stakeholders including coastal tribes, aquaculture operations, seafood processors, and recreational fishers.

Initial Results of Hindcast and Re-forecast for 2009

We have compared model results to observations such as those from moorings in the Olympic Coast National Marine Sanctuary along the northern Washington coast. The hindcast captures even the event scale variability in all fields (e.g. 3-5 day

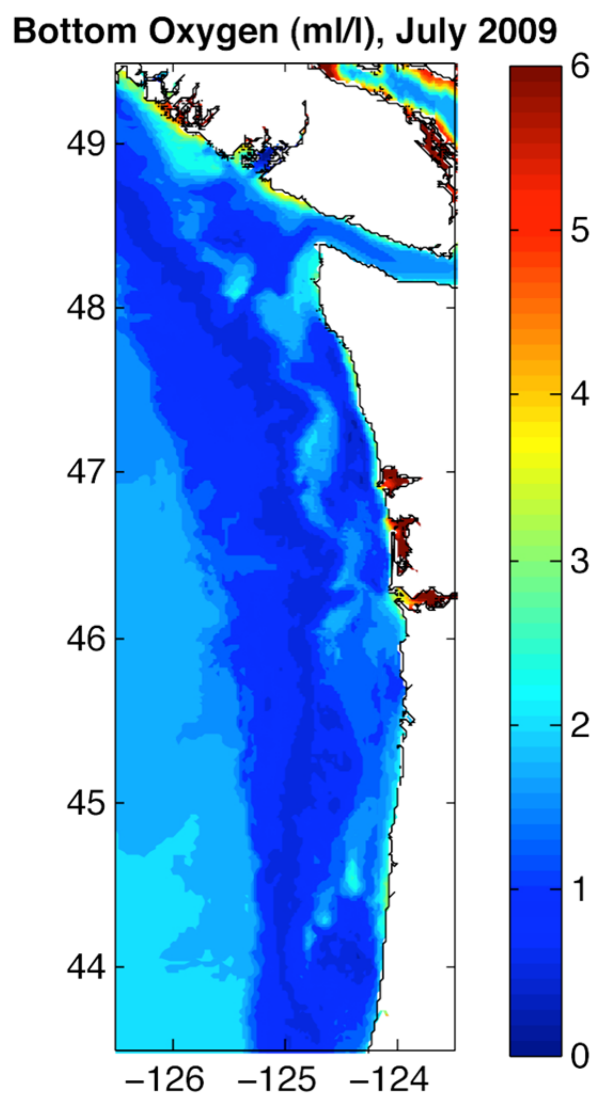

Figure 1. Domain for forecast and hindcast ocean conditions (ROMS model forced by CFS) showing bottom oxygen concentration in July 2009 from the hindcast.

upwelling events). This is facilitated by the fact that the CFS used in these hindcasts is informed by buoy observations and observed winds, allowing the model to capture upwelling events. The modeled fields represent the seasonal cycle – surface chlorophyll is low in the winter and increases during the upwelling season.

The re-forecast of 2009 does not include data assimilation by CFS, since in true forecast mode we cannot know what future buoy observations will be. Thus the re-forecast model is the best test of model skill for predicting future ocean conditions. The re-forecast performs better with temperature and oxygen than with surface chlorophyll. In the re-forecast, river forcing is projected at climatological (i.e. average) values, and the difference between this and observed river flow contributes to the underestimate in the modeled chlorophyll fields. In summary, the re-forecasts behave as expected given the forcing methods, with room for the potential improvements discussed below.

Forecast for Summer 2013

Full forecast results are available on the J-SCOPE website for upwelling, oxygen, chlorophyll, temperature, and pH. For instance, we predict lower than average chlorophyll in September-December 2013, and we predict that the source waters for upwelling will be lower in oxygen than average. Initial results indicated that the emergence of hypoxia on the Washington coast was predictable 6 months in advance (**Figure 2**). Hypoxia detected in the Olympic Coast National Marine Sanctuary in July was predicted by J-SCOPE, facilitated by the development of the oxygen module within ROMS.

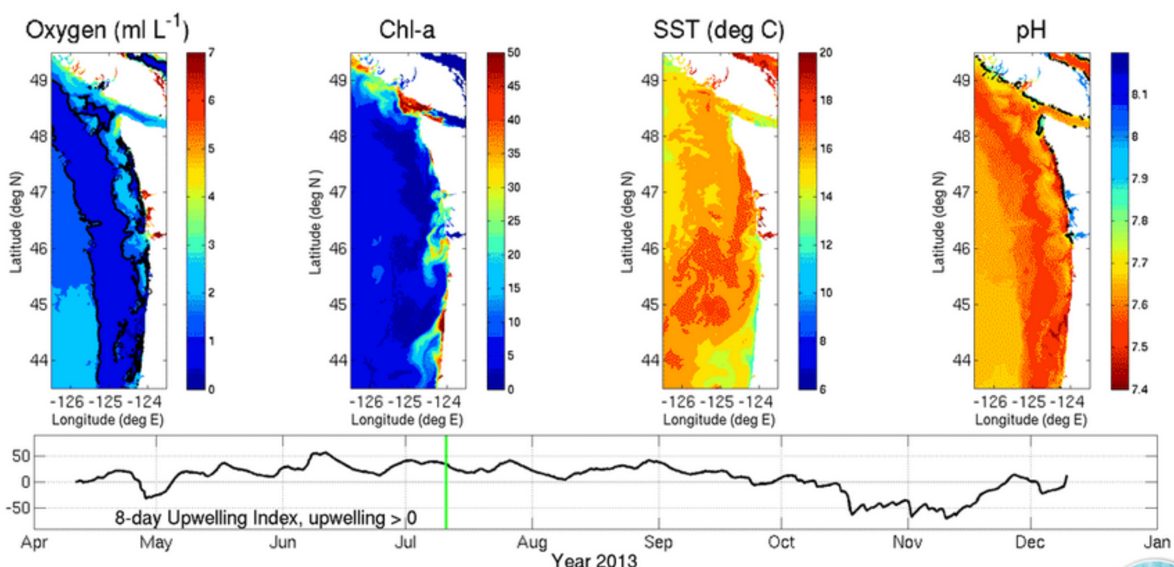

Figure 2. ***Forecasts of late July 2013 ocean conditions as posted on the website. Forecasts produced during April 2013, projecting from May through December.***

The Pacific Fishery Management Council has requested that NOAA scientists involved in the IEA provide a specific set of indicators of the present oceanographic and ecological conditions in the California Current [1]. We use our model system to forecast these indicators for the 2013 upwelling season (http://www.nanoos.org/products/j-scope/forecasts.php -> California Current Indicators). Specifically, quantitative forecasts were made for the cumulative upwelling index, SST, chlorophyll stock, and dissolved oxygen.

Objectives for 2014-2015

Predictions for fisheries:

We aim to continue translating the forecasts (**Figure 2**) into predictions relevant to commercial fisheries:

Crab: Based on model skill at predicting oxygen off the Washington Coast in 2013, we aim to provide hypoxia forecasts that can be used to inform management of Dungeness crab. Providing state and tribal managers of this $170million fishery with ‘early warning’ forecasts of hypoxia hotspots would allow them to curtail the setting of traps in low-oxygen waters, which can lead to mortality of crabs in the traps, and would allow fishers to avoid these areas (**see letters of support**).

Shellfish: Shellfish aquaculture is particularly sensitive to ocean acidification, and hatcheries are already monitoring pH to avoid exposing shellfish larvae to acidified water. We will provide predictions of bottom-water pH just outside estuaries with shellfish operations.

Pelagic fish: Albacore tuna, and the fishery, concentrate in areas with surface temperatures and chlorophyll conditions preferred by this species. Through a separate project, NANOOS already provides a portal to provide fishers with near real-time observations of temperature and chlorophyll, and 48 hr forecasts of temperature, resulting in 9,126 web visits in August (**http://nvs.nanoos.org/TunaFish?section=Plots**). Extending the habitat prediction methodology we have developed for sardine, we aim to provide forecasts of albacore habitat on the timescale of fishing seasons -- weeks to months.

Salmon: The dominance of boreal copepods in the California Current, rather than subtropical copepod species, appears to be critical for coho and Chinook salmon marine survival and adult returns. (see FATE funded project, Peterson et al, <http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm>). Recent work by Keister et al. (2011) and Bi et al. (2011) points to the importance of water transport in determining copepod community composition. Simulated drifter studies (see below) that represent vertical distributions and behavior of copepods are a promising method for linking J-SCOPE to predictions of salmon survival and returns (**see WDFW letter of support**).

Improvements to the Forecast System

We propose three technical improvements to the forecast system. The first two improvements are aimed at biological predictions, such as surface chlorophyll in the re-forecasts (discussed above). First, we will improve the initial conditions of each forecast, better matching the starting conditions in each ROMS forecast to extant conditions in the ocean. Our present method merely interpolates from the coarse data-assimilating CFS physical nowcast and has minimal biological detail. Our improved method will create initial conditions from a multiyear regional hindcast driven by CFS reanalysis (e.g. Fig. 1), continued up to the initialization time.

---

[1] http://www.pcouncil.org/wp-content/uploads/K3a_SUP_ATT1_DRAFT_CA_CURRENT_NOV2012BB.pdf

Secondly, we will force ROMS with time-varying forecasted river runoff rather than averages from recent years. Our procedure will be based on interior land runoff values from the CFS, routed using the model of Lohmann et al (1996, 1998).

Finally, we will implement a procedure for tracking boreal versus subtropical water masses, because of their relationship to zooplankton community structure and juvenile salmon survival (Peterson et al, see above). This procedure will include the vertical migrations and depth limits characteristic of the two zooplankton groups, and will predict their relative concentrations throughout the ROMS domain.

Continued Validation

To date, we have been able to validate model results by comparison to 2009 observations, and to emerging observations for 2013. We aim to continue testing model skill, with at least quarterly forecasts for 2014-2015, and more extensive comparisons to buoy, cruise data, and satellite data. With the additional forecasts, we propose both formal model skill assessment (such as Friedrichs et al. 2009) as well as vetting by stakeholders such as sardine and crab fishermen.

Outreach

We will continue to use our existing partnership with NANOOS to: 1. extend the J-SCOPE forecast information through their web portal; and 2. to connect with their membership and user base, which includes fisheries managers with the Quinault Indian Nation, Quileute Tribe, Port Gamble S'Klallam Tribe, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Northwest Indian Fisheries Commission, as well as NANOOS' ability to convene small focus groups of local fisheries managers to test and evaluate the tools and forecasts.

Benefits

1. Improved projections of the properties of the coastal Pacific Northwest of relevance to the marine ecosystem.
2. Improved model capability, initial conditions, skill assessment, and vetting.
3. Communication of core results to the Fishery Management Council via the IEA.
4. Better knowledge in hands of state and tribal fisheries managers via tailored products related to hypoxia, acidification, and shifts in ocean temperature.

Deliverables

1. Forecasts (out six to nine months) of ocean conditions, provided at least quarterly via http://www.nanoos.org/products/j-scope/home.php/
2. Four targeted products for state and tribal managers of crab, albacore, shellfish, and salmon.
3. A journal article summarizing results of continued model validation and skill assessment through 2014-2015.
4. A journal article documenting the sensitivity of the model projections to initial and boundary conditions versus regional atmospheric forcing, with recommendations for cost-effective seasonal model system development
5. Incorporation of model projections into 2014 and 2015 IEA framework.
6. Presentation at two national or international meetings as well as the FATE PI meeting.