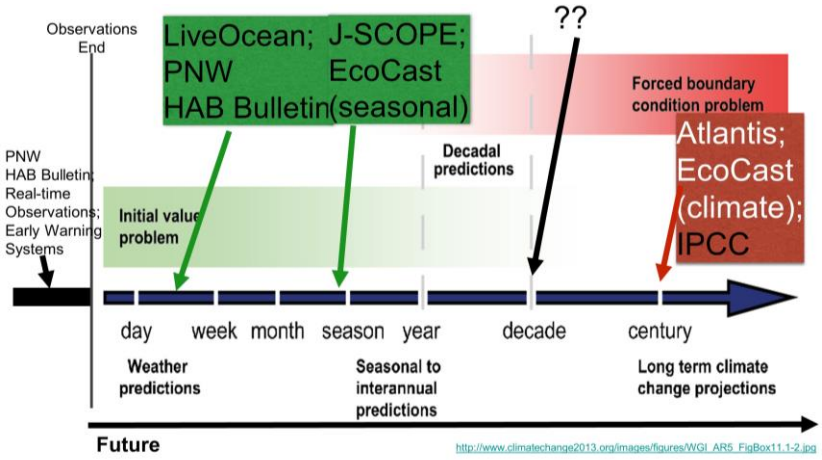
THE STATE OF THE ART FOR ECOLOGICAL FORECASTING AT SHORT-, MEDIUM- AND LONG-TERM TIME FRAMES



Isaac Kaplan[1], Vera Trainer[1], Michael Jacox[2], Samantha Siedlecki[3]

[1]NOAA Northwest Fisheries Science Center

[2]NOAA Southwest Fisheries Science Center

[3]University of Connecticut

OUTLINE

Introduction: The forecasting toolbox

Part 1: Short-term forecasts: ‘real-time’ to 1 month

Part 2: Seasonal ocean forecasts: 1-12 months

Part 3: Medium-term forecasts: 1-20 years

Part 4: Long-term forecasts: Decades

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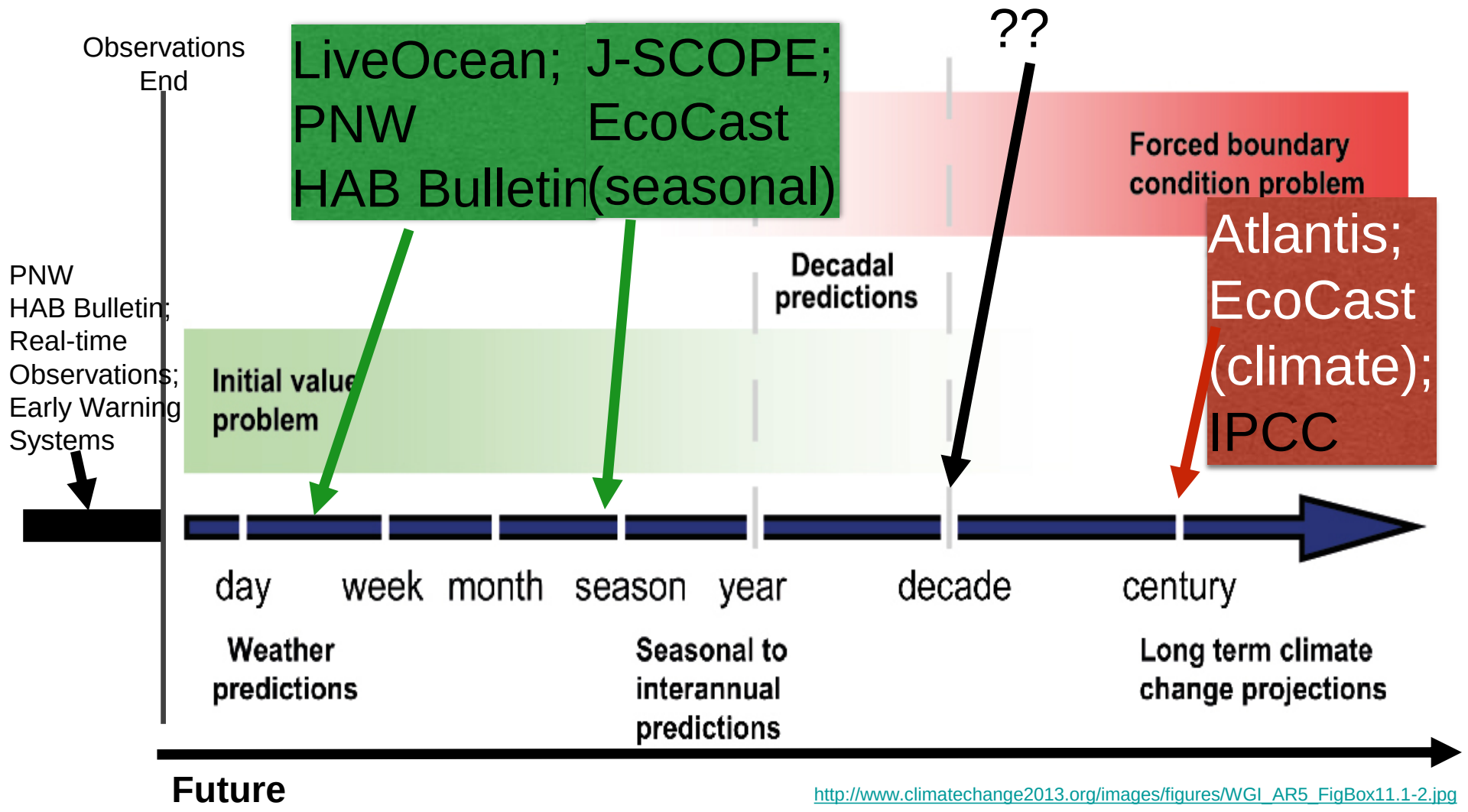
THE FORECASTING TOOLBOX

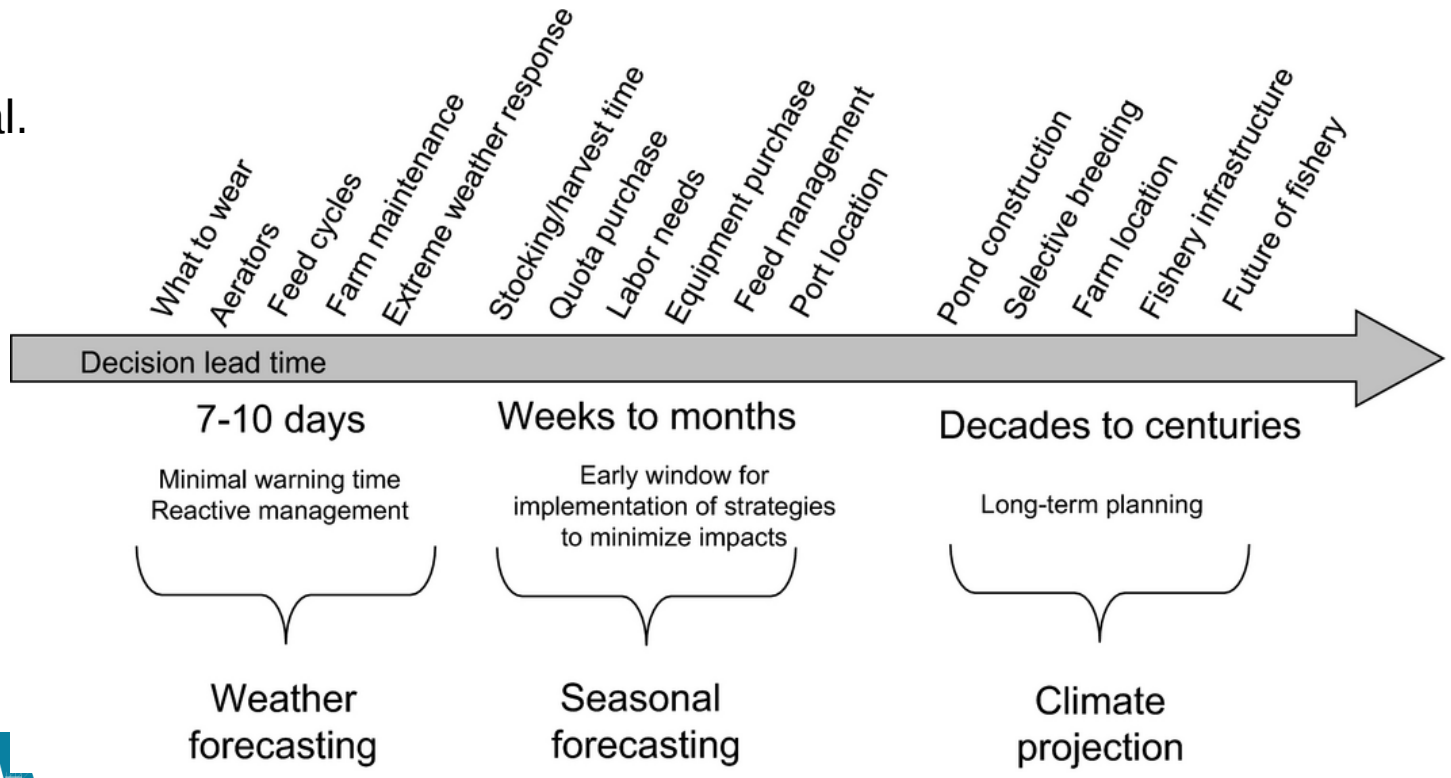


http://www.climatechange2013.org/images/figures/WGI_AR5_FigBox11.1-2.jpg

INTRODUCTORY POINT 1: TAILORED FORECASTS

- Forecasts on any timescale should be tailored for, and delivered to, clients.
- Pacific Fishery Management Council has unique needs for short-term, seasonal, and long-term forecasts.

Australian example (Hobday et al. 2016)

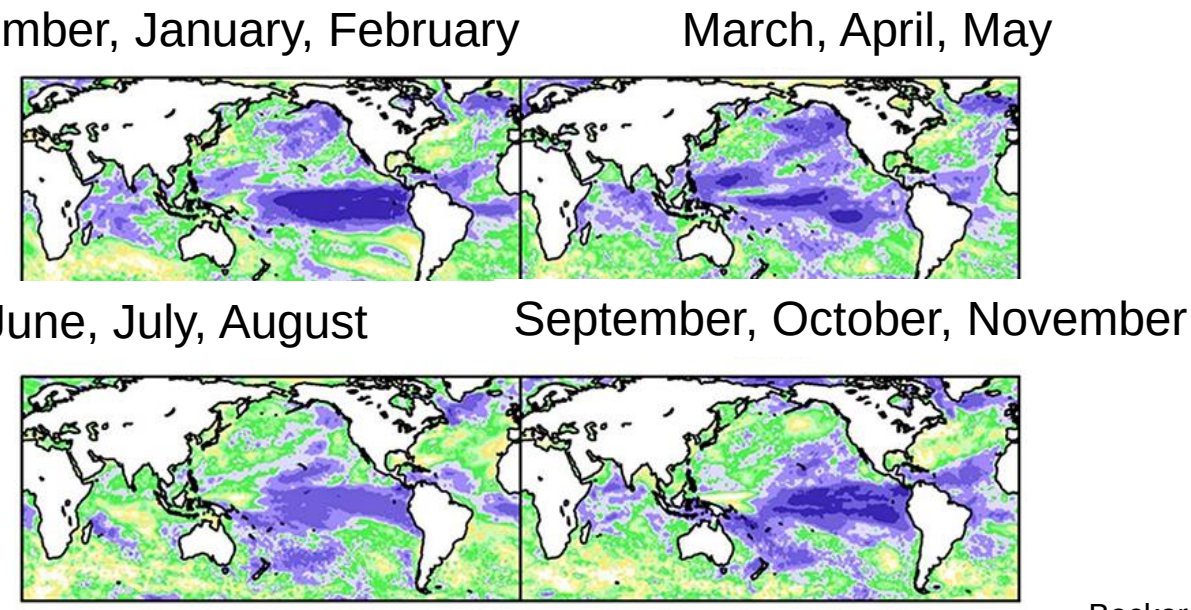


INTRODUCTORY POINT 2: SKILL ASSESSMENT

- Model skill and performance metrics are essential (e.g. anomaly correlation coefficient)
- Model skill and performance usually best for ensembles
- Model skill and performance should be evaluated for ocean conditions relevant to PFMC fisheries and species

Sea Surface Temperature 1-month forecast skill

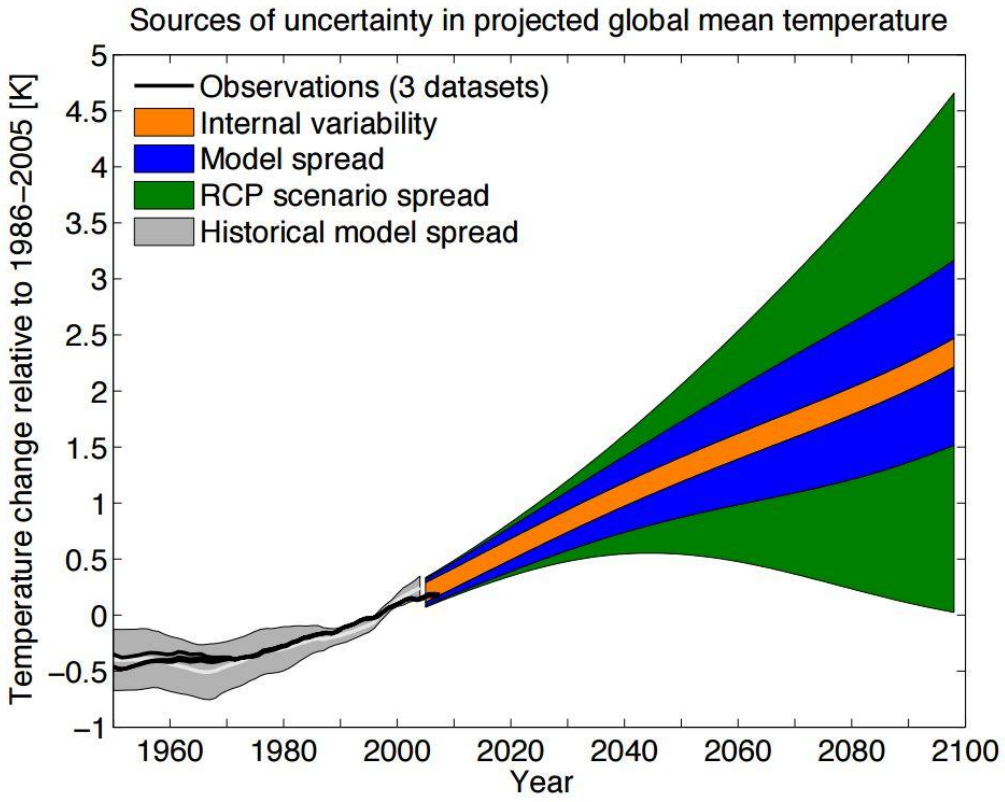
North American Multi-model Ensemble (NMME)



Becker et al. 2014 *J. Clim.*
Payne et al. 2017 *Front. Mar. Sci.*

INTRODUCTORY POINT 3: SOURCES OF UNCERTAINTY

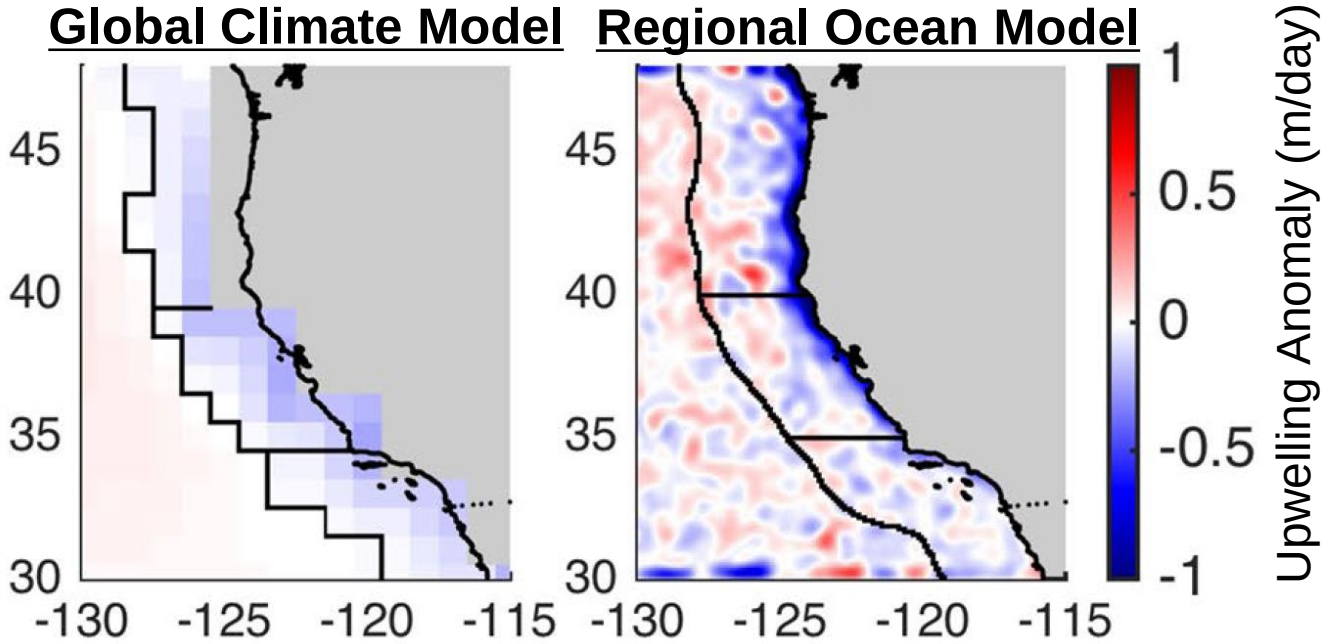
- The main source of model uncertainty depends upon the timescale of the forecast
- Uncertainty arises from model spread, internal variability, emissions scenario



IPCC AR5 Report

INTRODUCTORY POINT 3: SOURCES OF UNCERTAINTY

- The main source of model uncertainty depends upon the timescale of the forecast
- Uncertainty arises from model spread, internal variability, emissions scenario
- Important coastal processes not resolved with typical spatial resolutions: downscaling required



Jacox et al. (2017)

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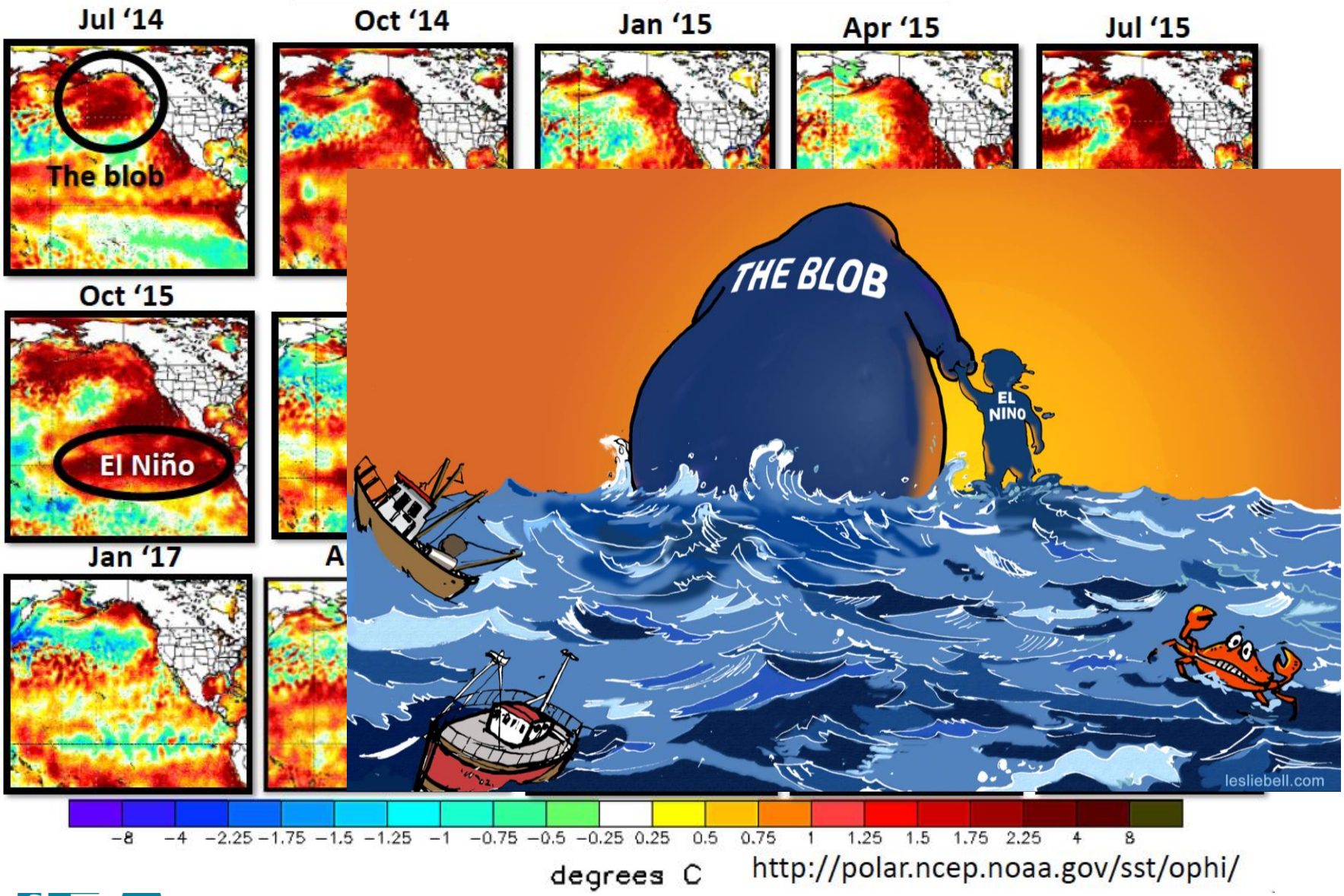

North Pacific surface temperature anomalies
Jul '14
Oct '14
Jan '15
Apr '15
Jul '15
The blob
Oct '15
El Niño
Jan '17
THE BLOB
EL NIÑO
lesliebell.com
−8 −4 −2.25 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2.25 4 8
degrees C
http://polar.ncep.noaa.gov/sst/ophi/

2015 *Pseudo-nitzschia* bloom impacts

Shellfish closures, mammal deaths

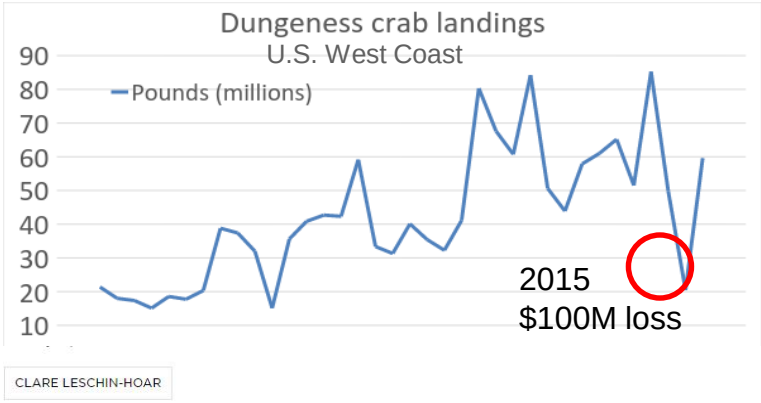
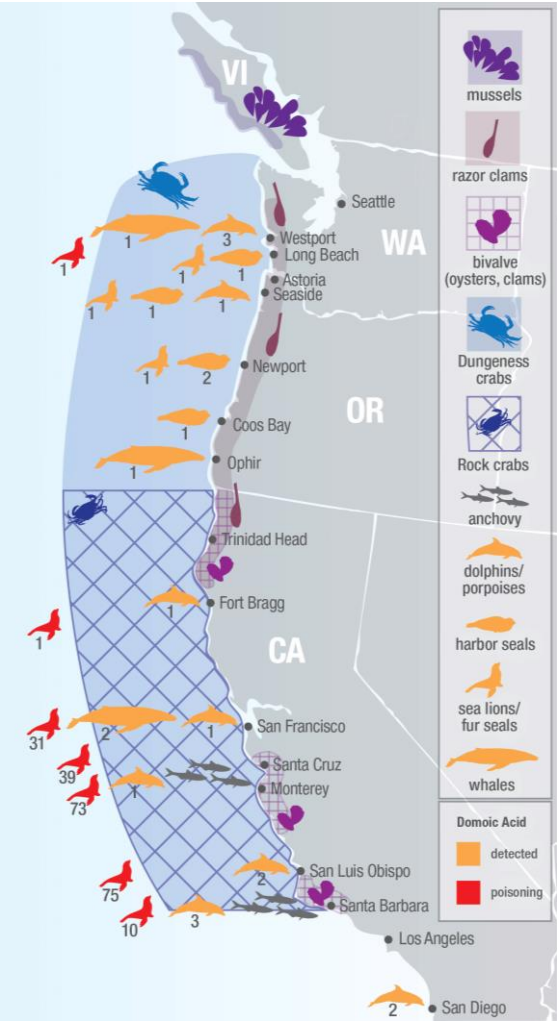


Photo: npr.org/sections/thesalt/2017



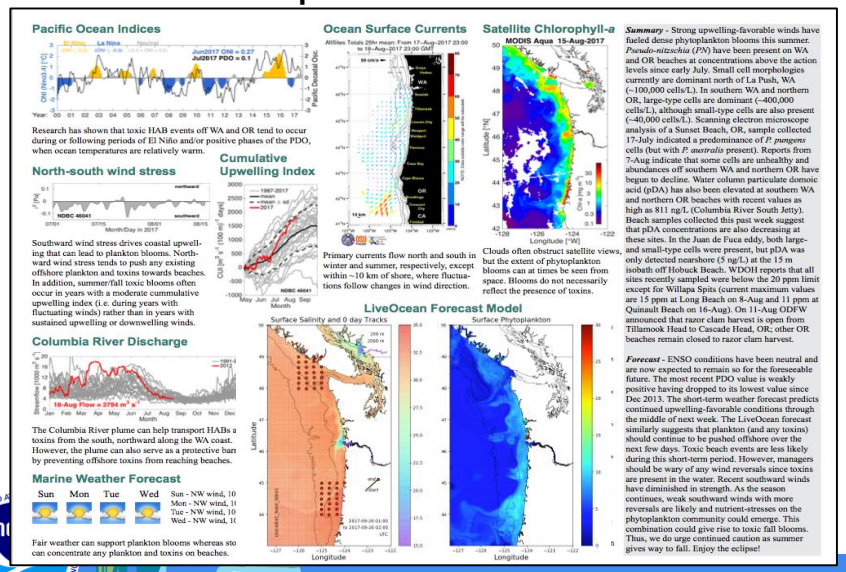
Elements of PNW HAB forecast

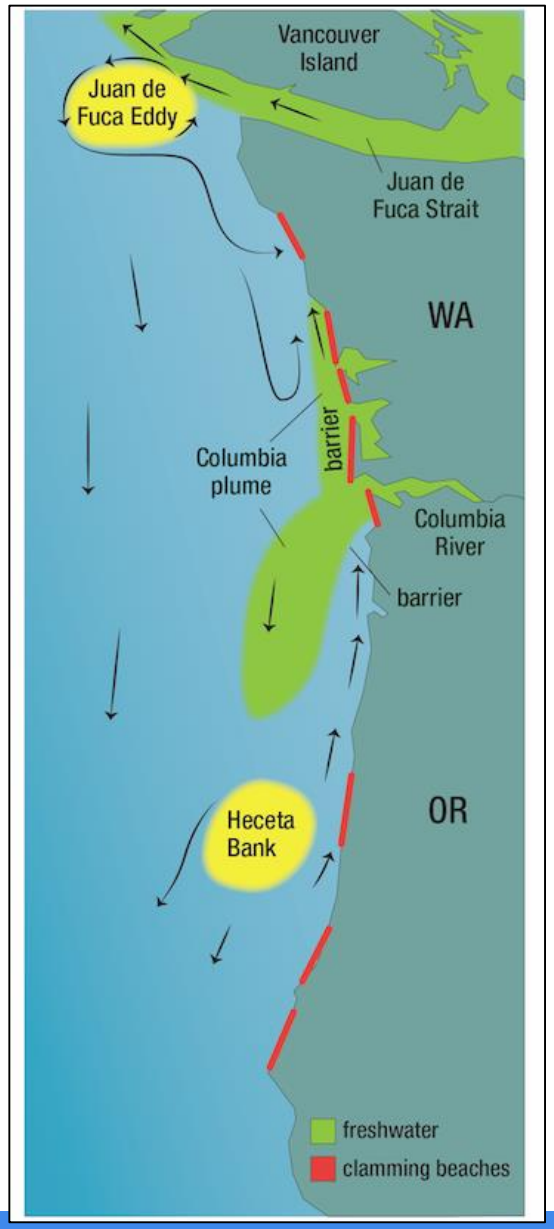
Data integration & interpretation:

- Toxin & cell monitoring at coast
- Offshore boat sampling at hotspots
- Weather predictions
- Models (cell transport & Columbia River plume)
- Climate change indicators

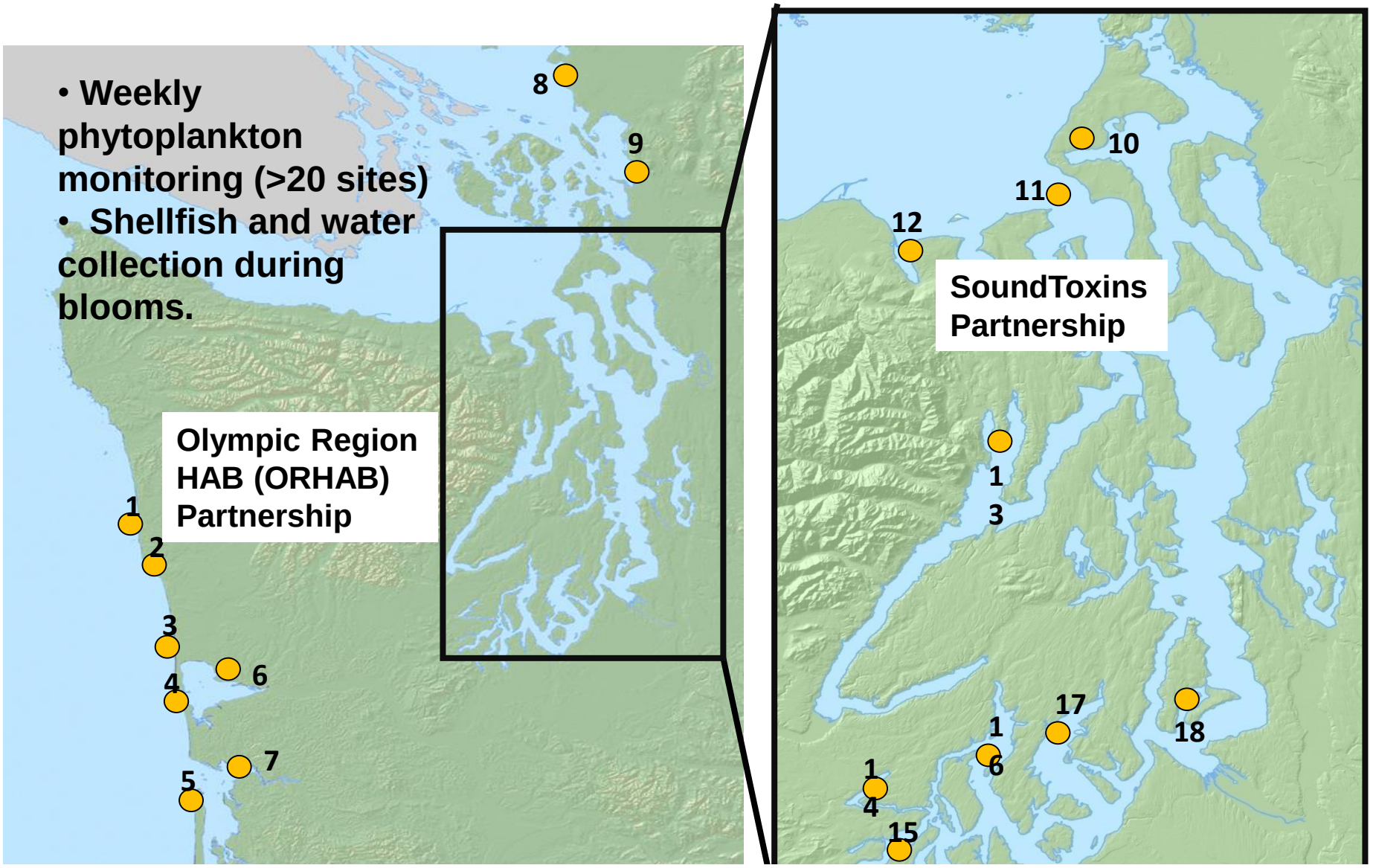
Facilitates management decisions:

- Selective harvest at safe locations
- Pre-emptive increase in harvest limit





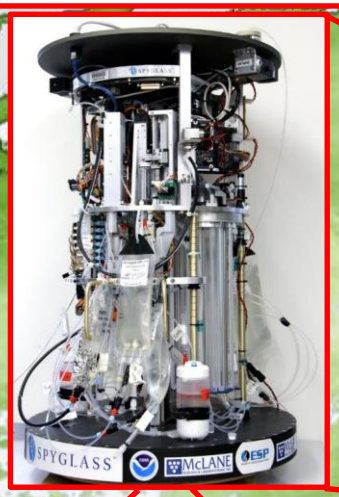
Foundation of the forecast – phytoplankton & shellfish monitoring

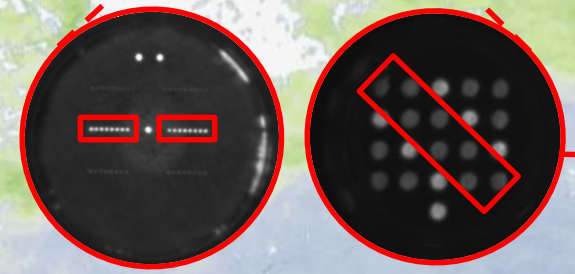


Partners include WDFW, WDOH, UW, Tribes

Partners include Taylor, Coast, & Penn Cove Shellfish, Tribes, WA SeaGrant, UW, Evergreen College, volunteers

Environmental Sample Processor





Harmful algae Toxin

Phytoplankton bloom

July 2015
chlorophyll (mg/m³)
0 0.05 30
NOAA Climate.gov
Data: Suomi NPP
NOAA View

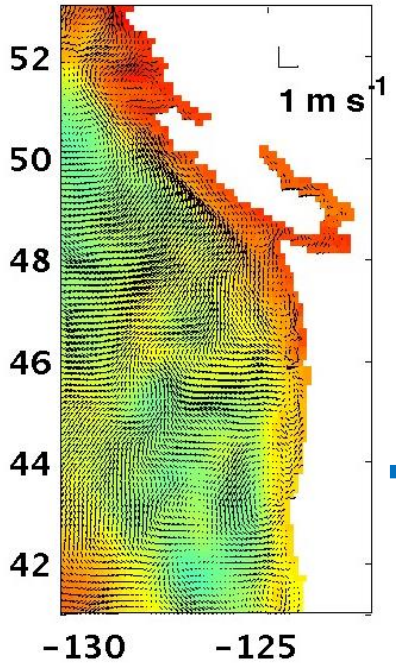
AK BC WA OR CA

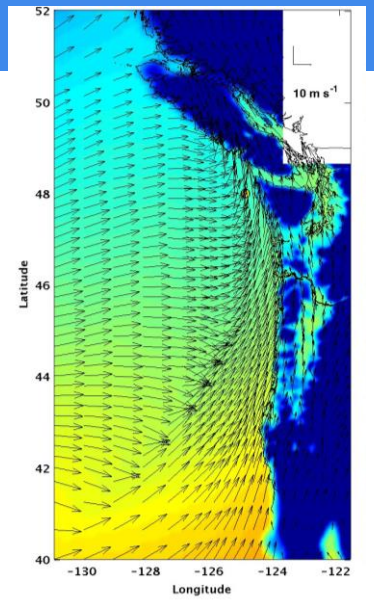
Pacific Northwest Harmful Algal Blooms Bulletin

Sep 26, 2017 HAB risk =

HAB risk key:
= low
= medium
= high

LiveOcean



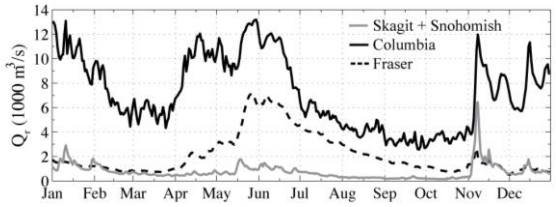


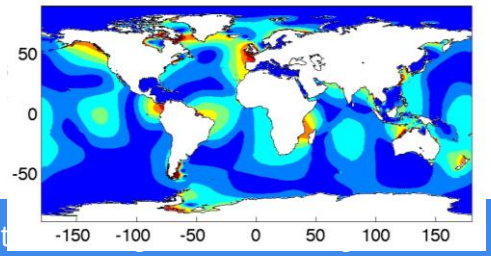
WRF Winds and Heating

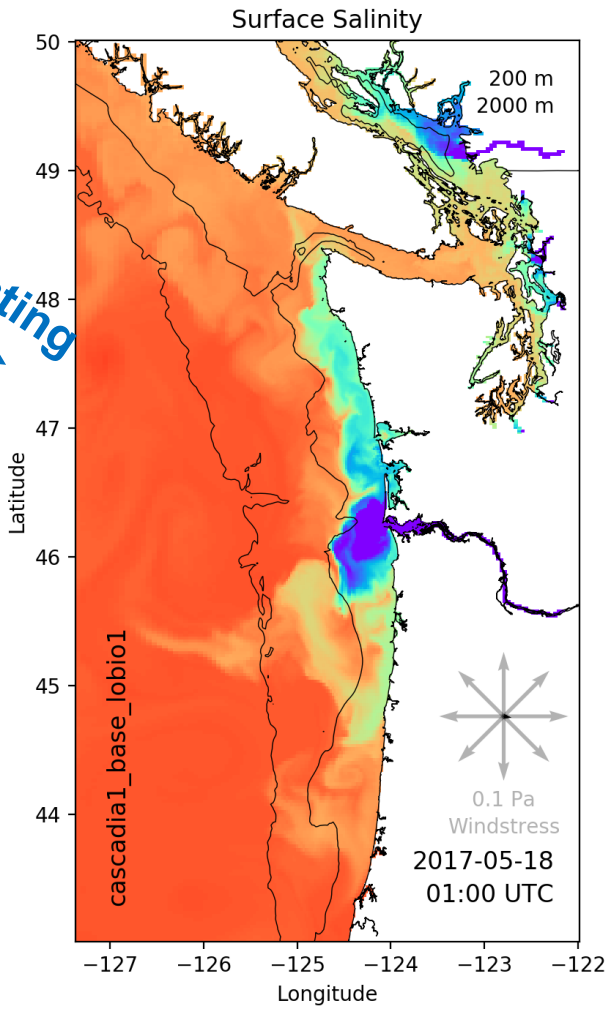
HYCOM Ocean Fields

USGS Rivers

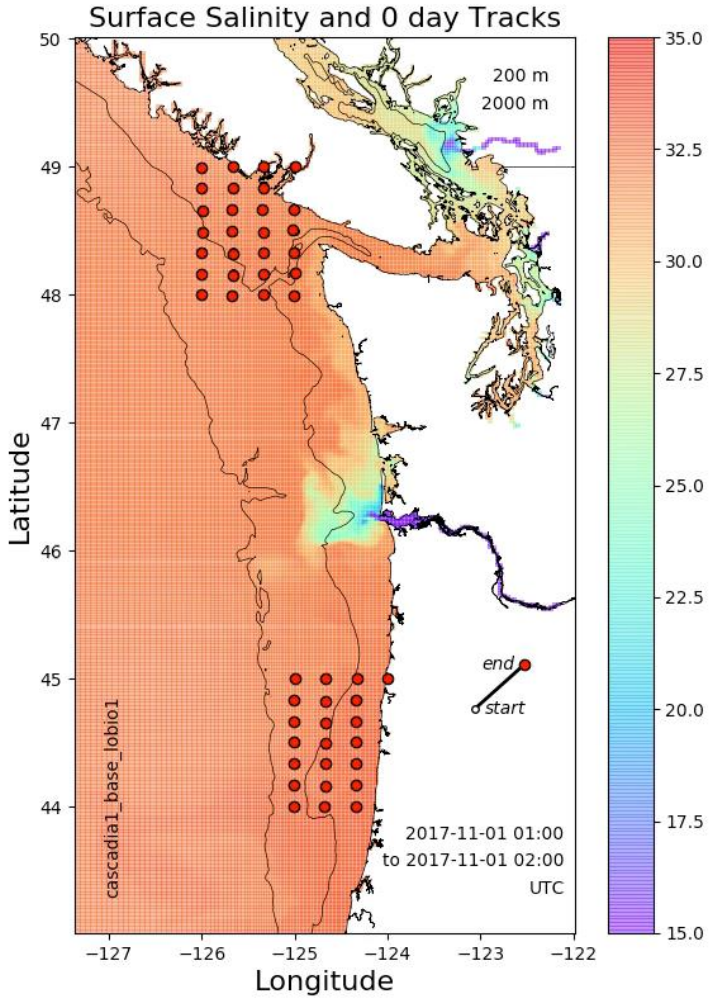
TPXO Tides

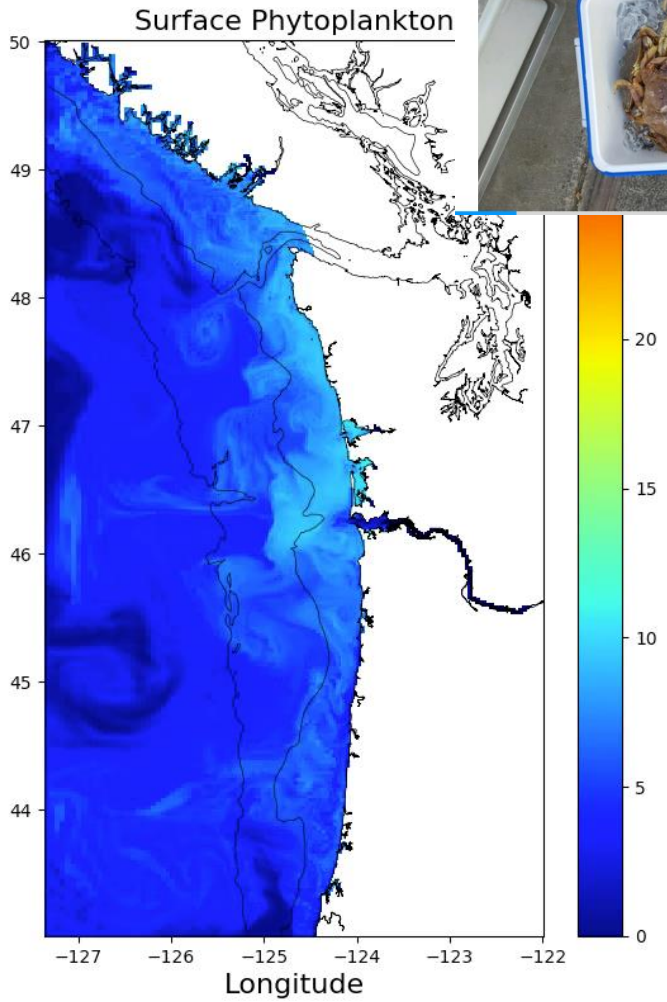






Live Ocean Model
Nov 2016: threat to OR beaches

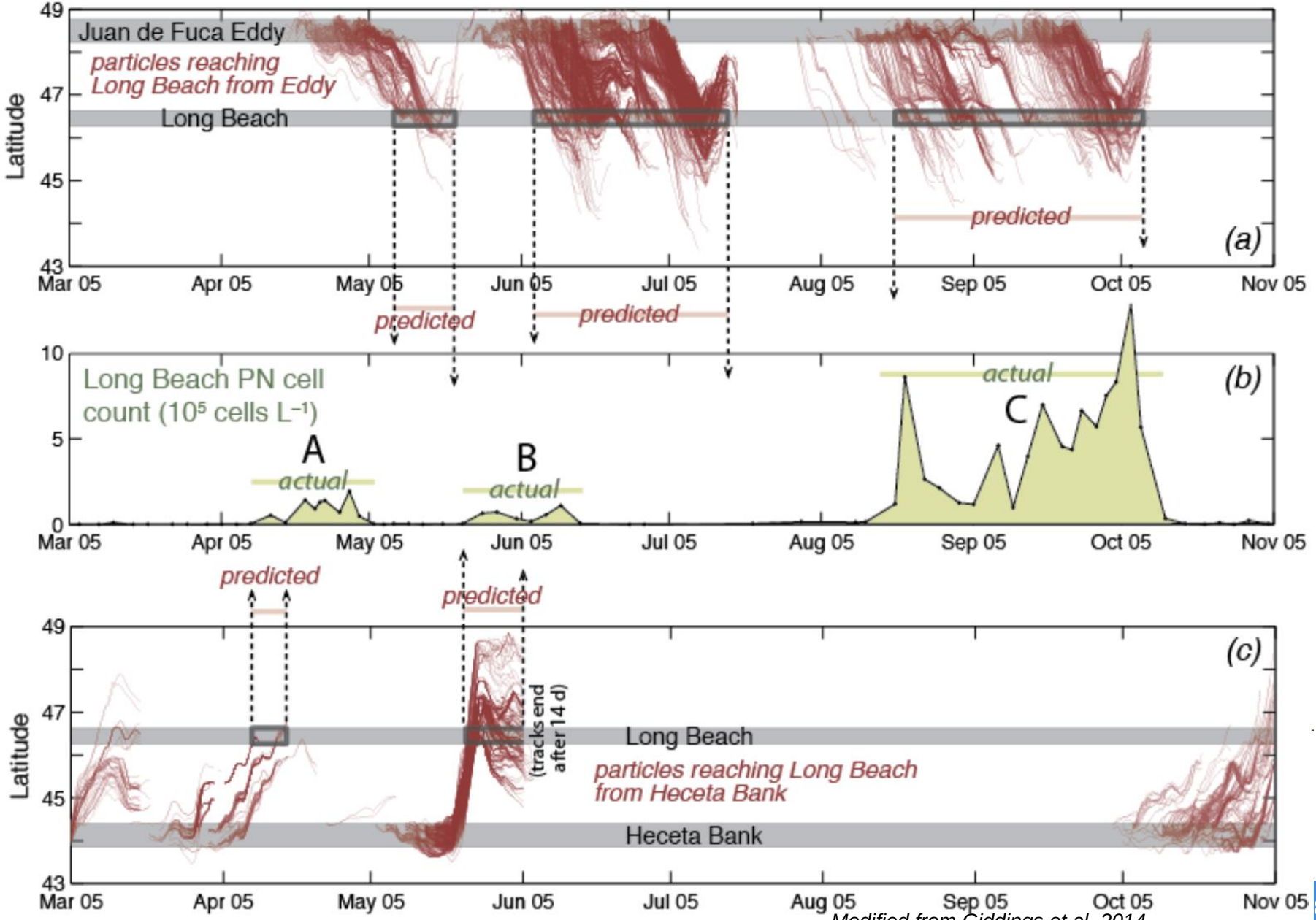




October 2017

Cells transported from HAB initiation site to beach in OR (not in WA)

Skill assessment of Live Ocean model in hindcast mode



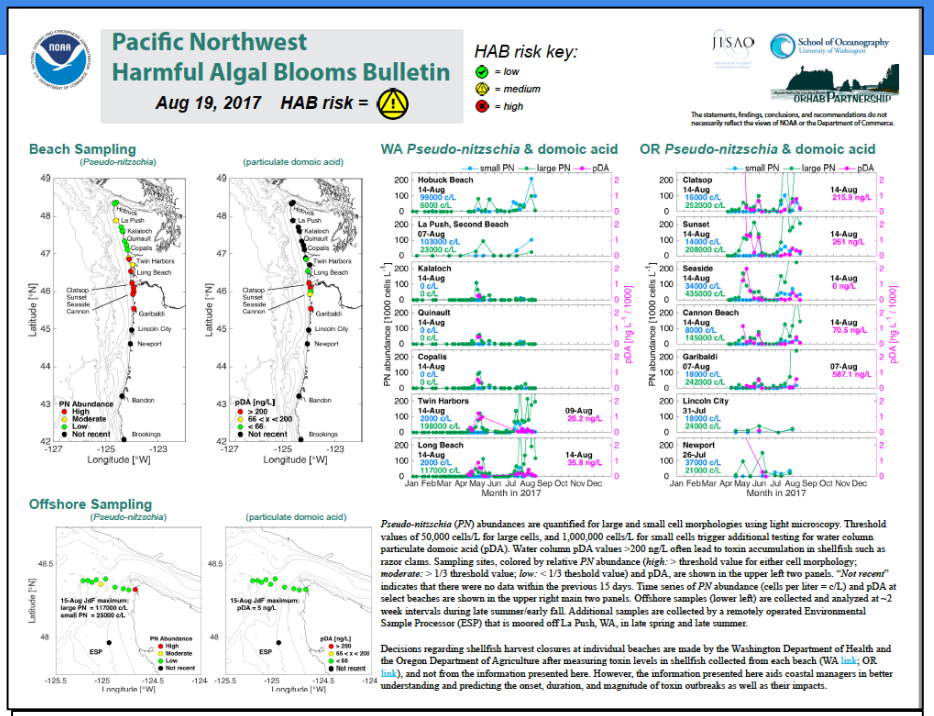
Modified from Giddings et al. 2014

Tailored Forecasts
PNW HAB Bulletin

evolution since 2007

Feedback from managers
- Explanatory key
- Long-term forecast
- More “traffic light” graphics

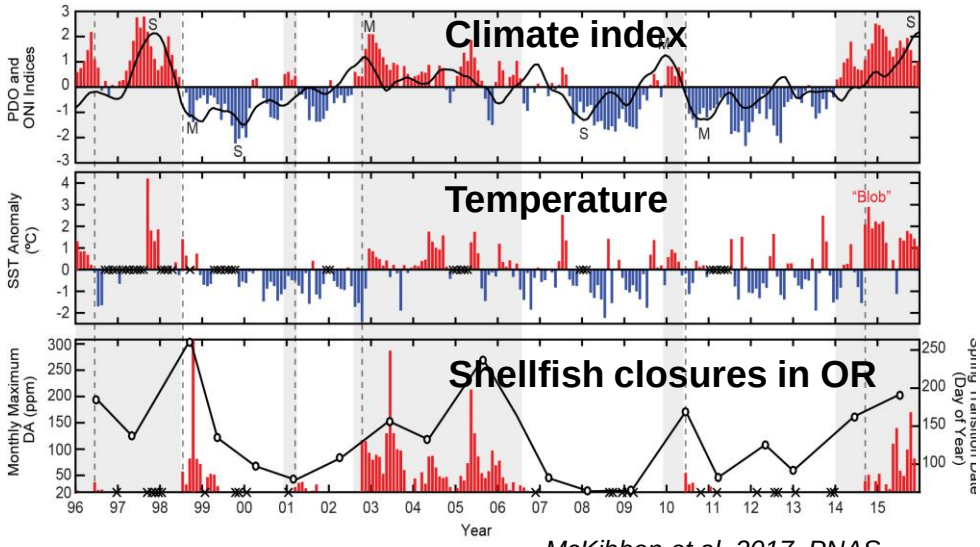
New features
- Live Ocean
- Offshore samples at “hotspots”
- ESP
- Ocean indices
- Glider flights



Seasonal forecast: *Pseudo-nitzschia* blooms

Linkage to warm ocean conditions (Climate Change)

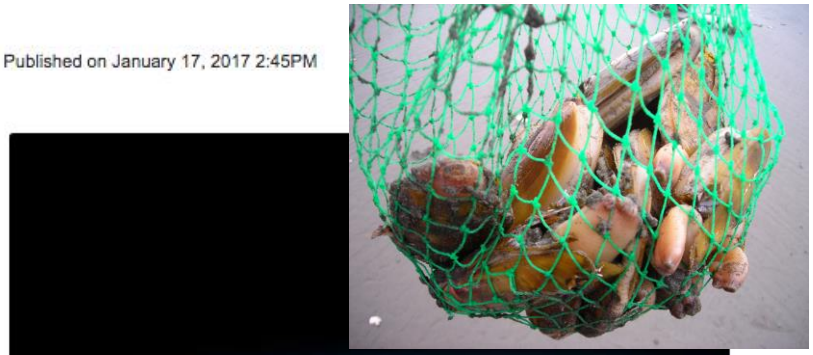
Oregon data



McKibben et al. 2017. PNAS

Scientists: Clam toxin, warmer ocean go together

Published on January 17, 2017 2:45PM



NASA PHOTO

Darker green colors near the West Coast of the U.S. reflect blooms of phytoplankton and high algal levels, some of which are toxic.

Key Messages
Short-term forecasts: *Pseudo-nitzschia* blooms

- Blooms signal environmental stress
- Tailored forecasts enable management action
- Model skill is assessed using mooring & monitoring data
- Short-term bloom conditions inform long-term projections

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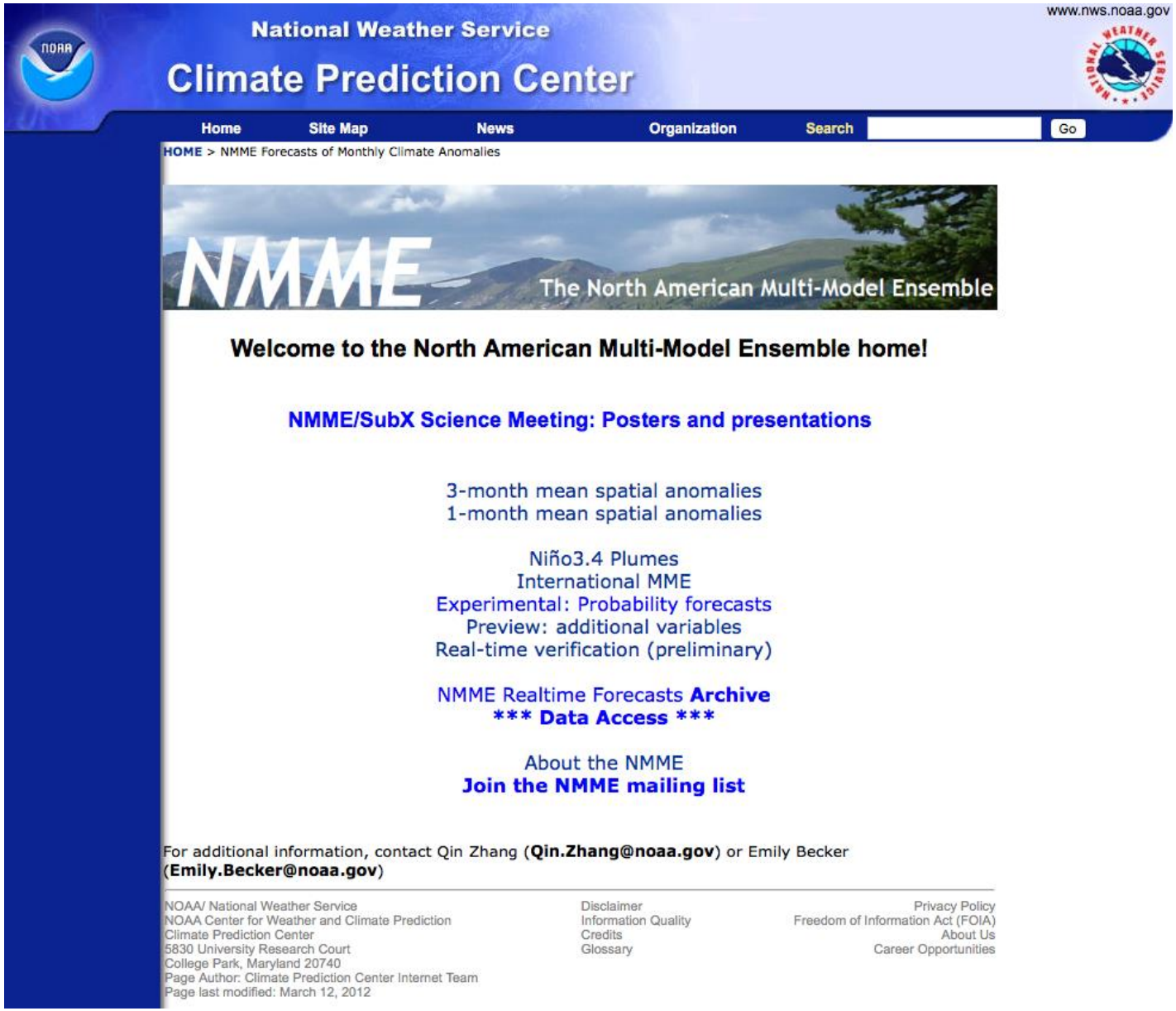
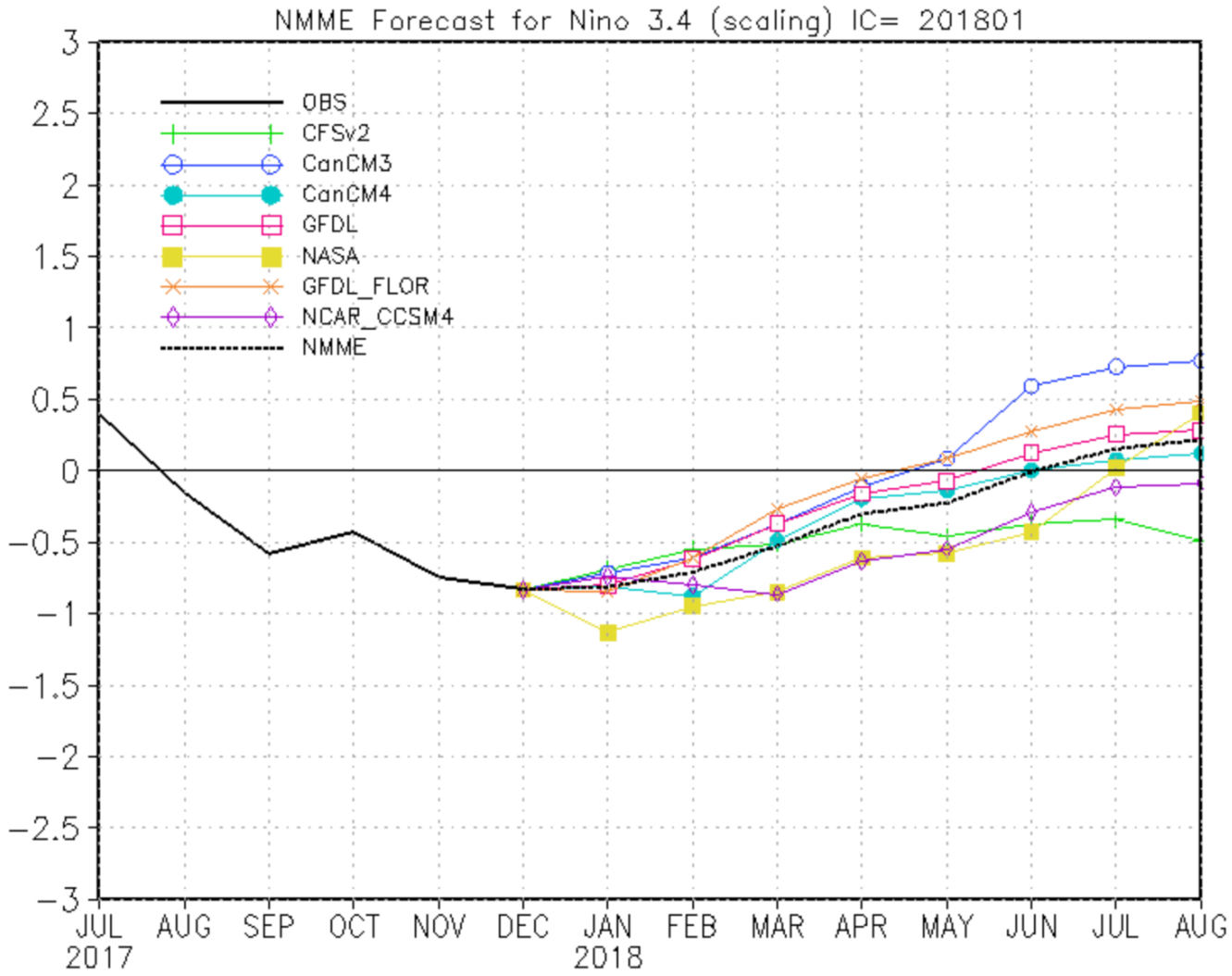


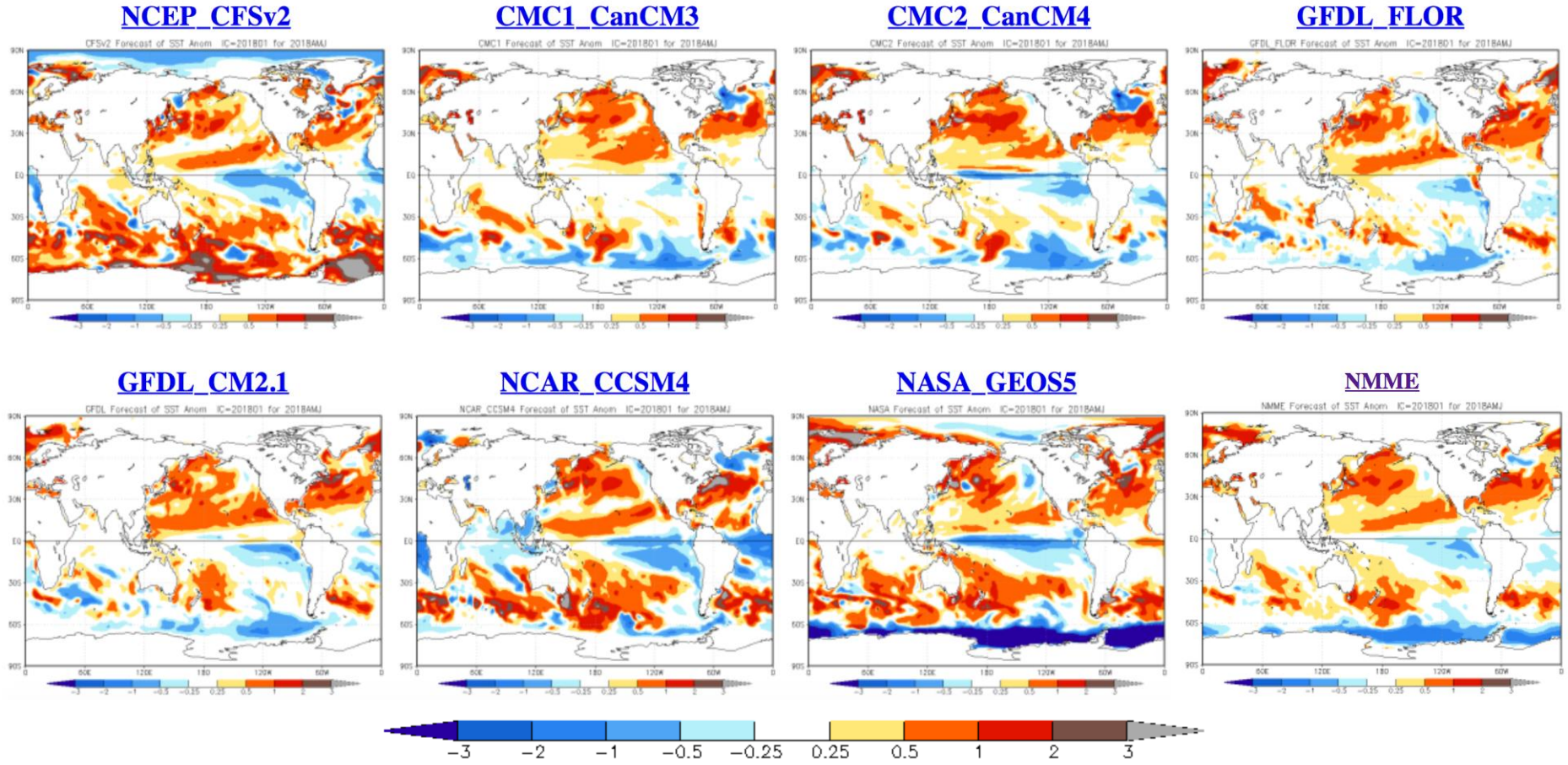
http://www.cpc.ncep.noaa.gov/products/NMME/

January Forecasts of ENSO Conditions



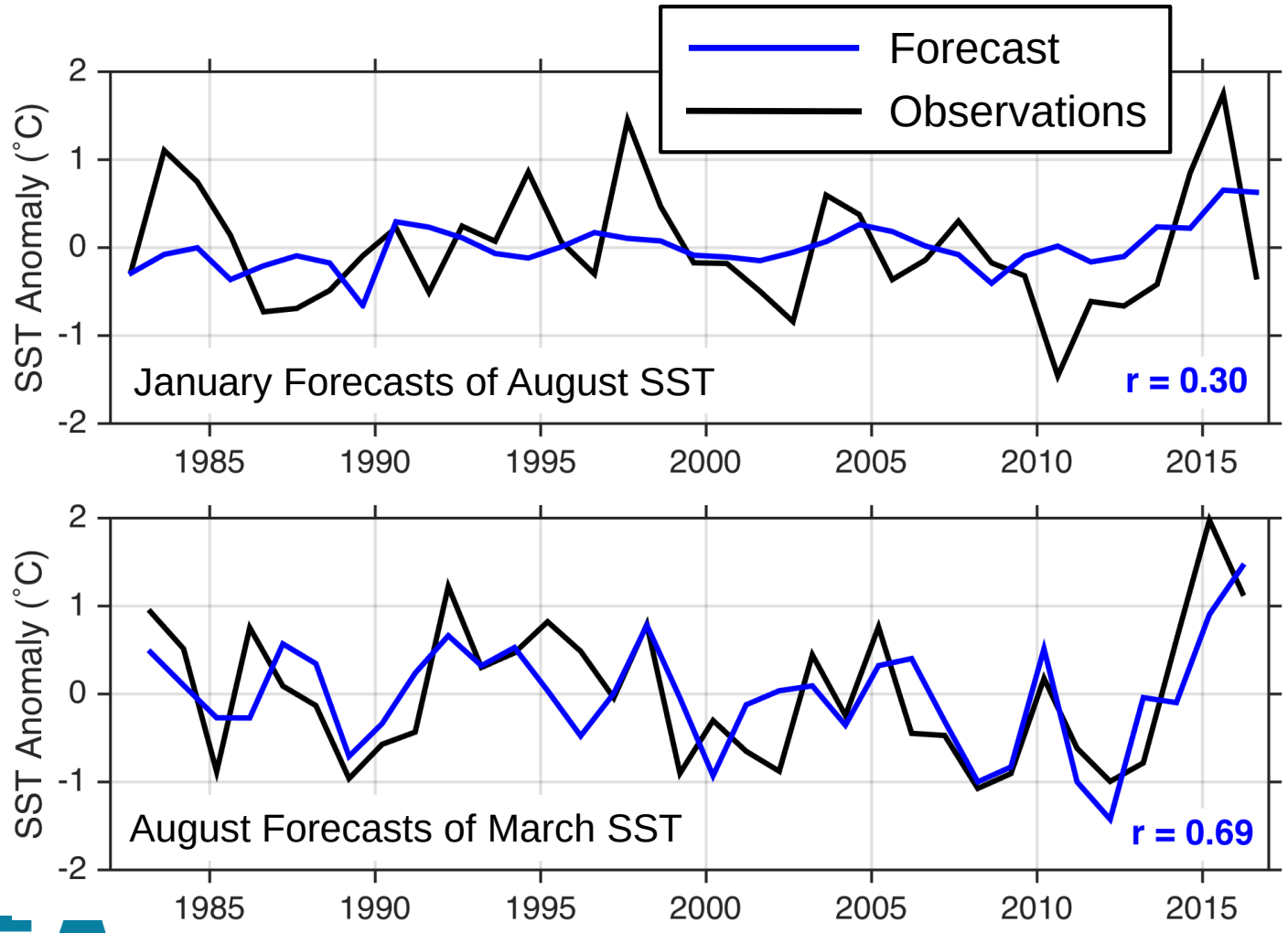
http://www.cpc.ncep.noaa.gov/products/NMME/current/images/nino34.rescaling.ENSMEAN.png

January Forecasts of Spring (April-May-June) Sea Surface Temperature

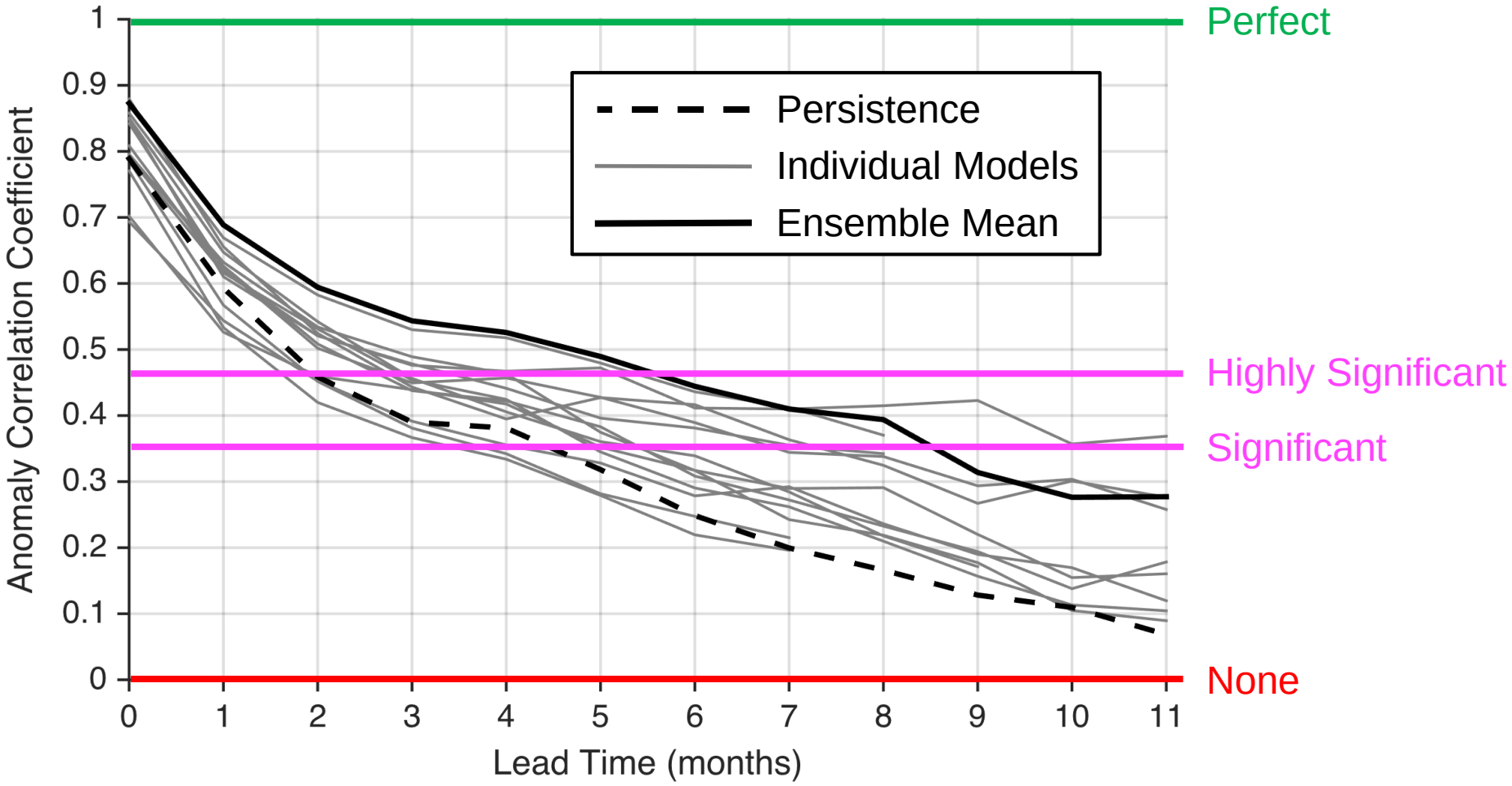


http://www.cpc.ncep.noaa.gov/products/NMME/current/tmpsfc_Seas3.html

Forecast Skill Assessment for the California Current

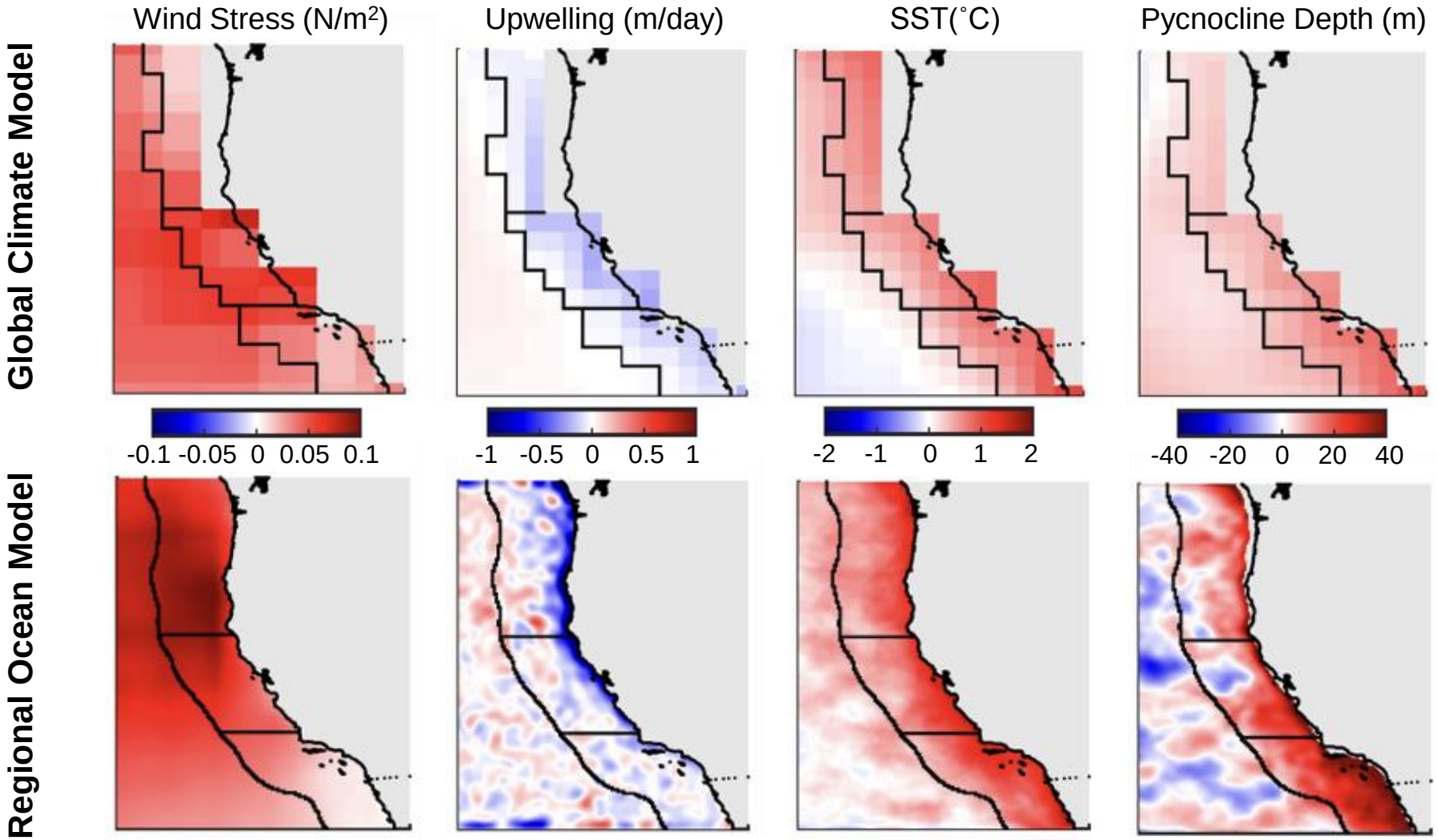


Forecast Skill for California Current Sea Surface Temperature

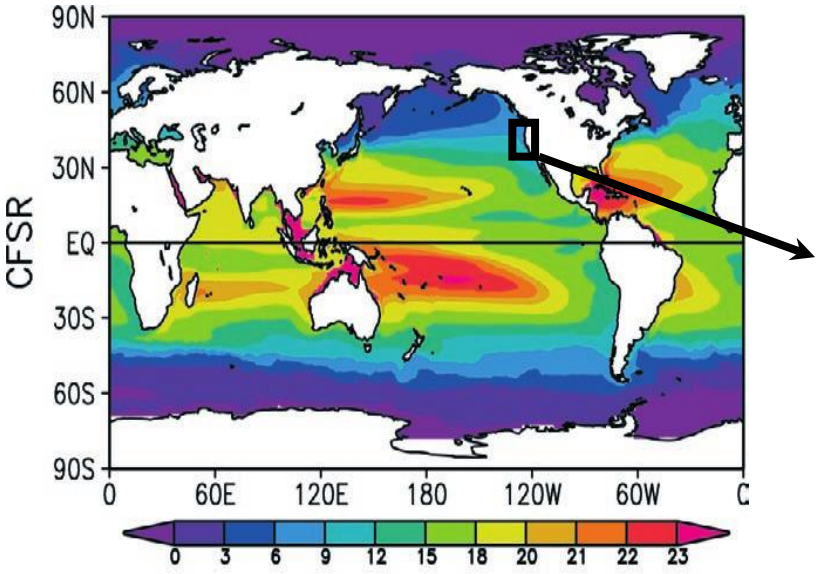


Jacox et al., Climate Dynamics (2017)

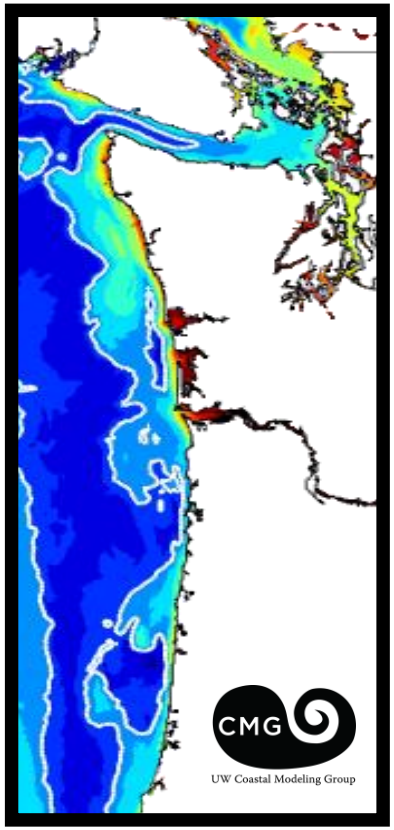
What mechanisms generate predictability?



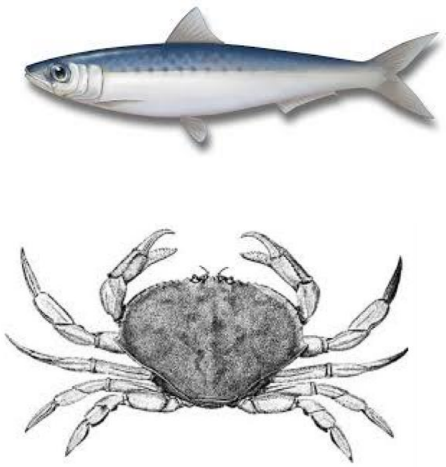
JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE)



Climate Forecast System (CFS)
~200 km atmospheric resolution
~50 km ocean resolution

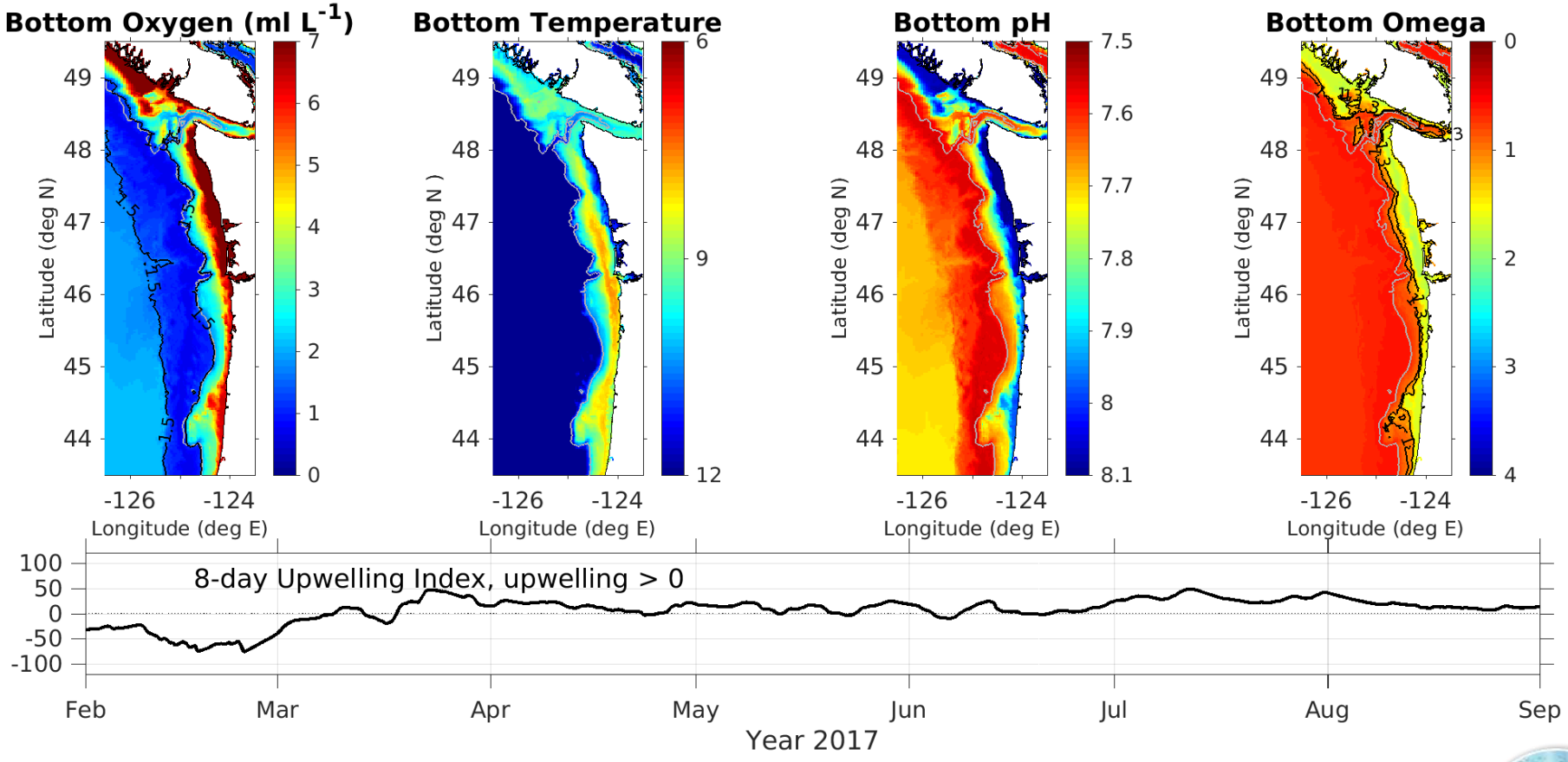


Regional Ocean Model (UW Cascadia)
~1.5 km resolution
Physics and biogeochemistry
(temperature, salinity, chlorophyll, nitrate, oxygen, pH, aragonite saturation state)
http://faculty.washington.edu/pmacc/cmg/cmg.html; Giddings et al. (2014)



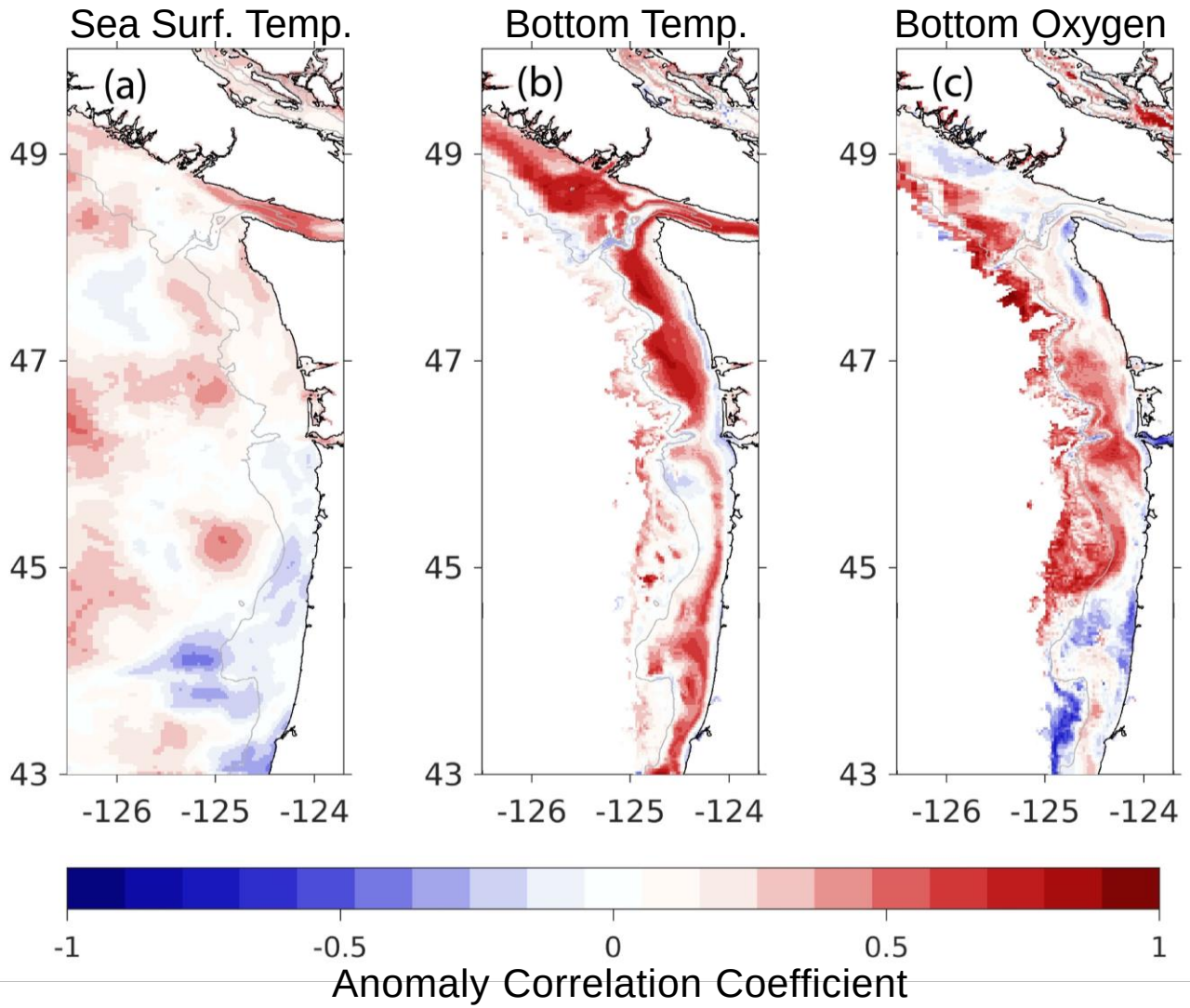
Habitat Models and Indices
Sardine (Kaplan et al., 2016)
Hake and Crab
(Malick, Hunsicker, Norton, in prep.)

JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE)



http://www.nanoos.org/products/j-scope/forecasts.php

Forecast Validation – **Skill Assessment**



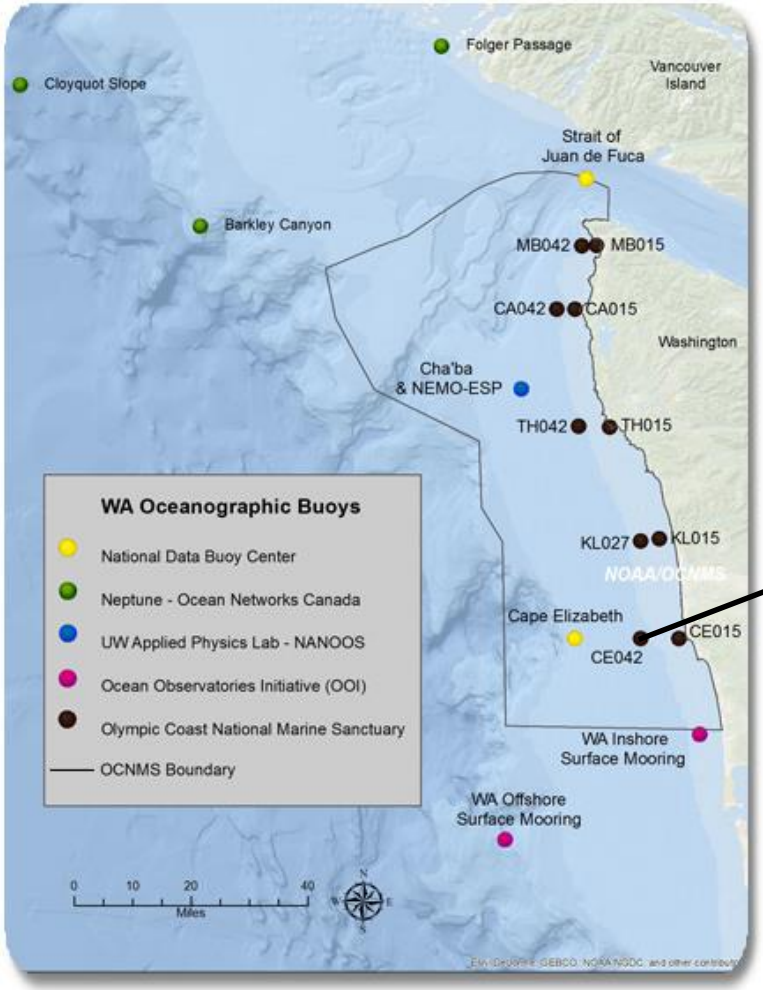
2009, 2013, 2014

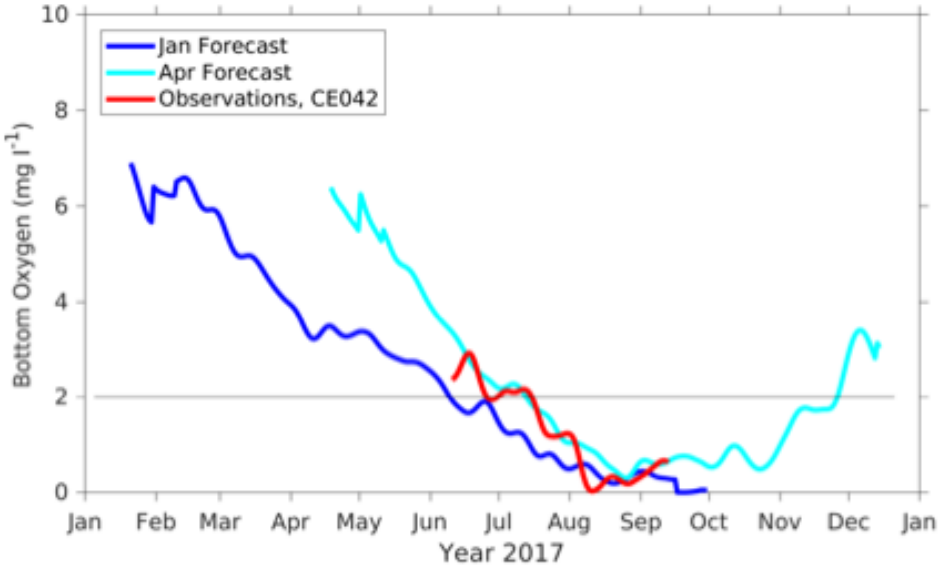
Averaged over the upwelling season

Siedlecki et al., *Sci. Rep.,* 2016

Forecast Validation - **Moorings**

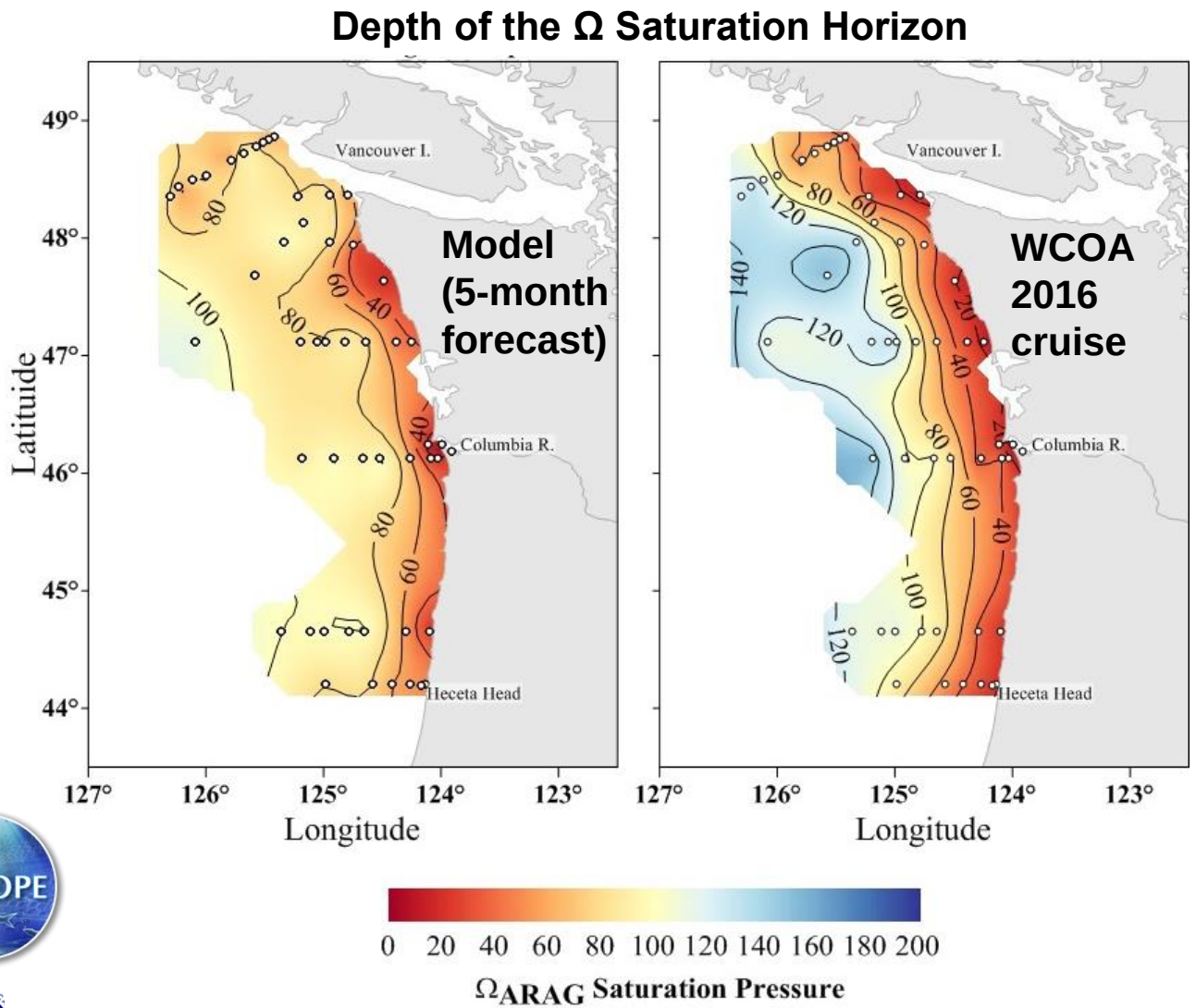
Olympic Coast National Marine Sanctuary





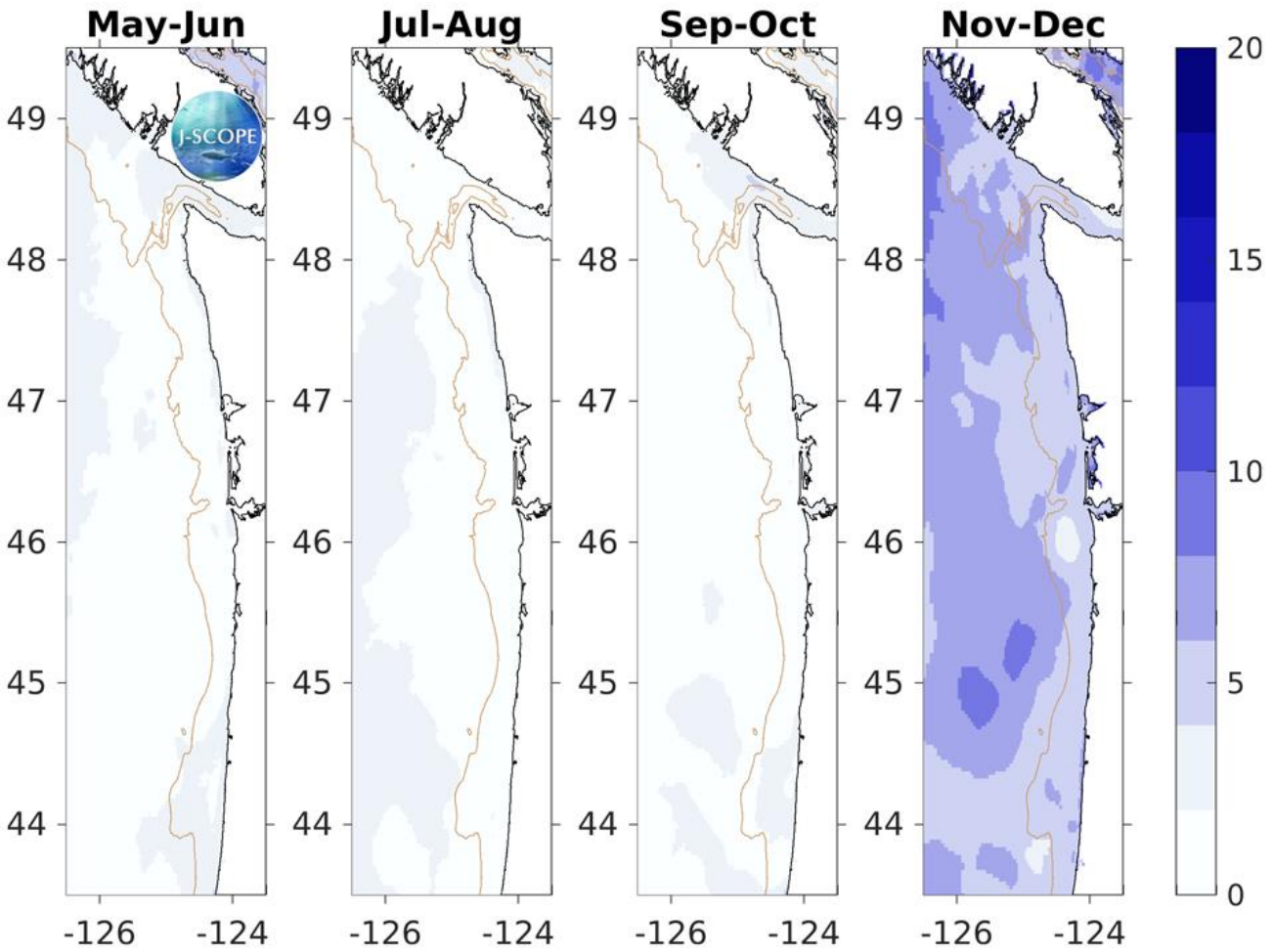
https://olympiccoast.noaa.gov

Forecast Validation – **Shipboard Data**



Data courtesy of NOAA-PMEL (Alin and Feely), preliminary

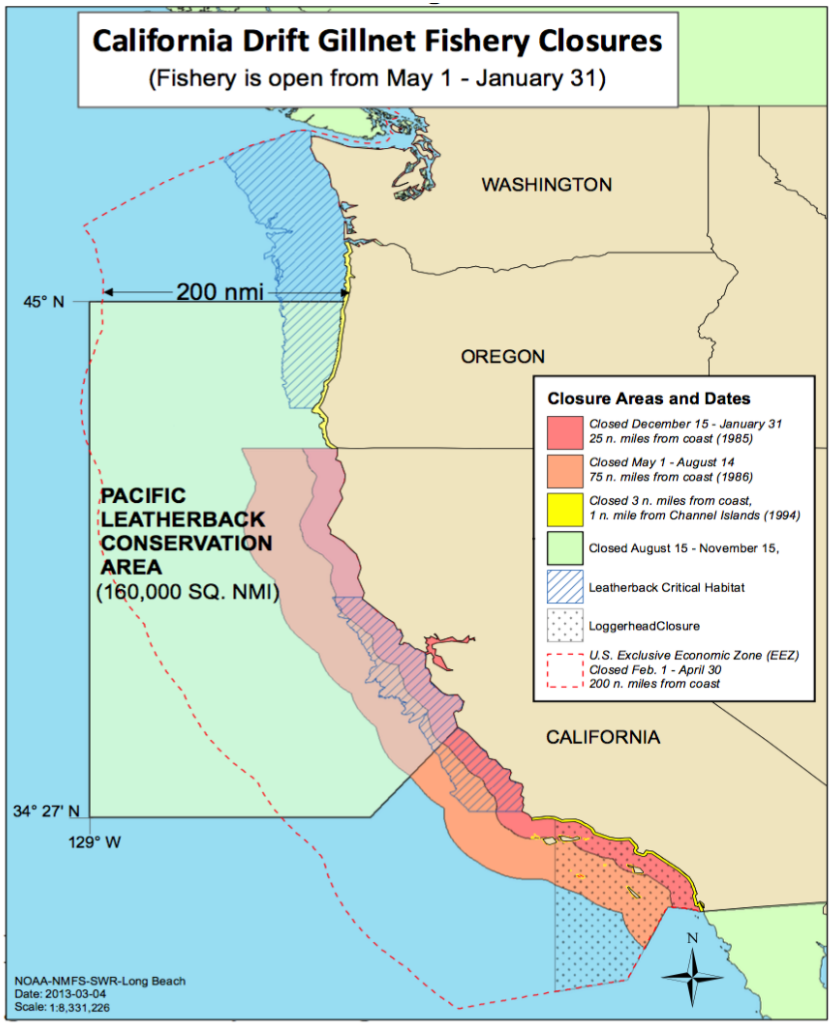
Forecast Validation – **Uncertainty from Model Ensemble**



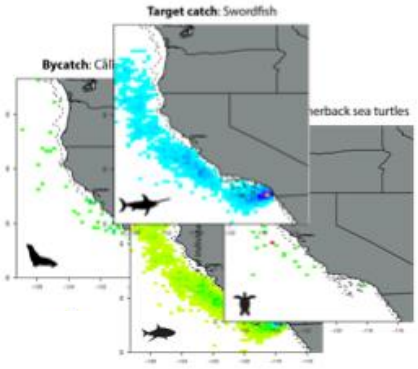
Coefficient of variation (as %) of SST in 3-member ensemble

EcoCast: An Eco-informatic Tool for Fisheries Sustainability

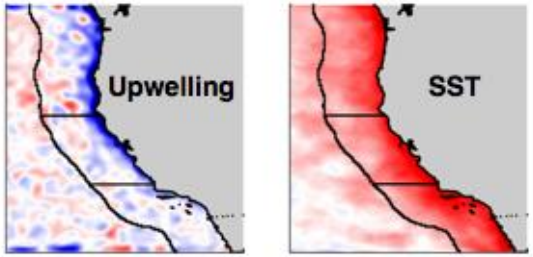
Overarching Goal:
Forecast distributions of targeted and bycatch species to inform management actions for an environmentally and economically sustainable fishery



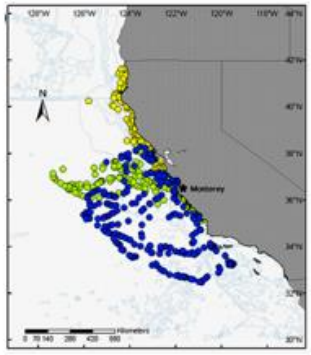
Fishery Observer Data



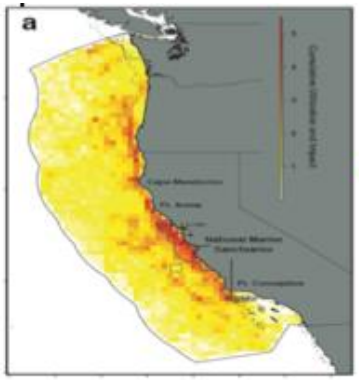
Regional Ocean Reanalysis



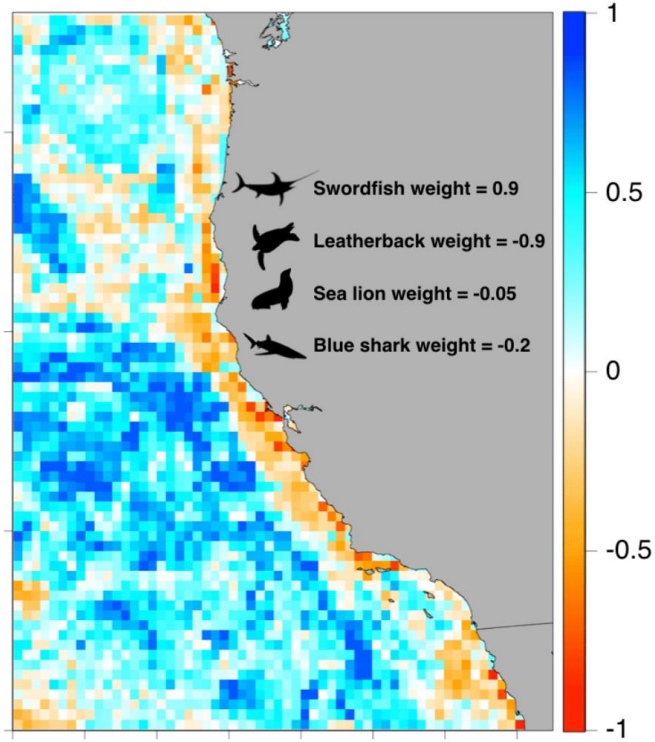
Tracking/Survey Data



Species Distribution Models



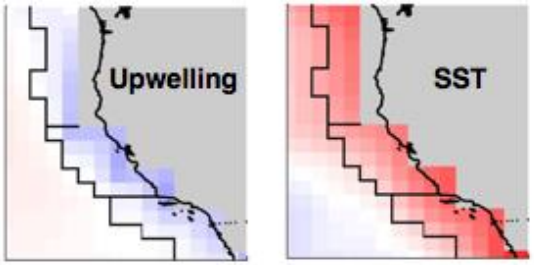
EcoCast Product



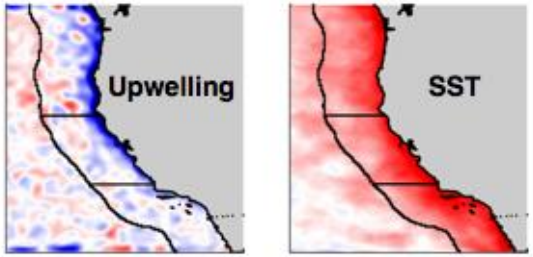
Hazen et al., in review
Welch et al., in review

EcoCast
An Eco-informatic Tool for Fisheries Sustainability

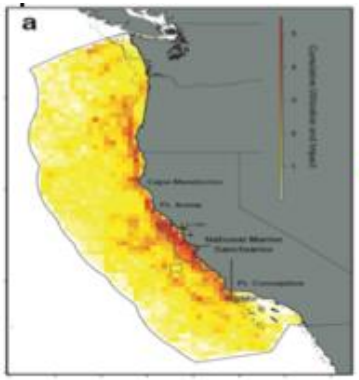
Global Climate Forecast



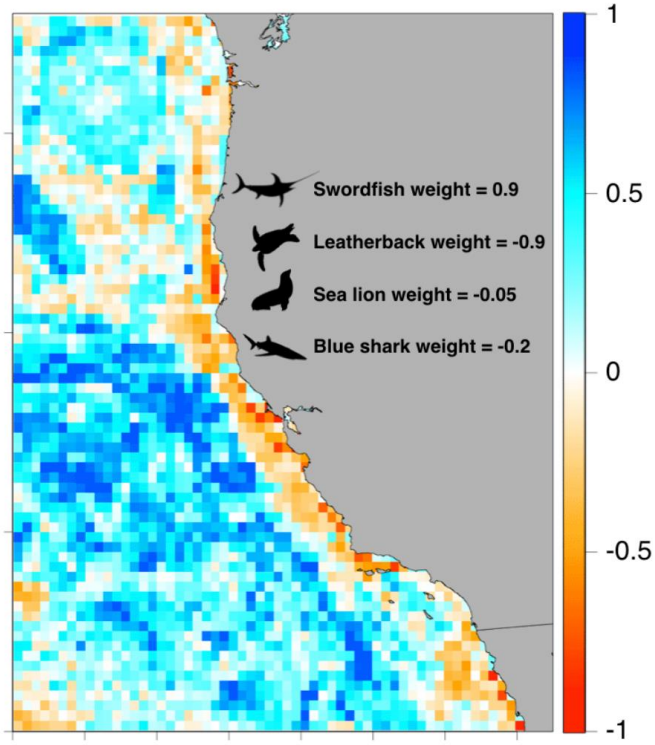
Regional Ocean Forecast



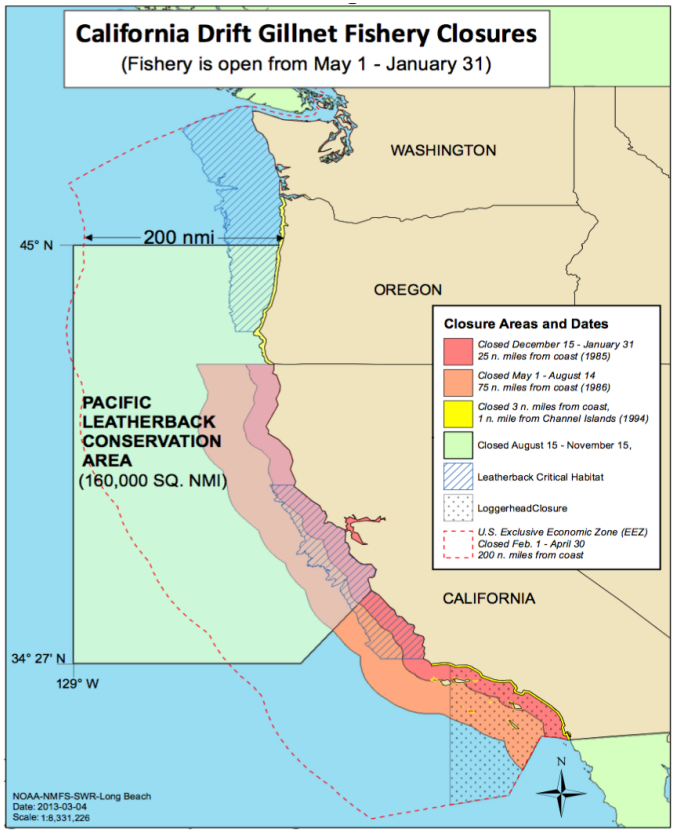
Species Distribution Models



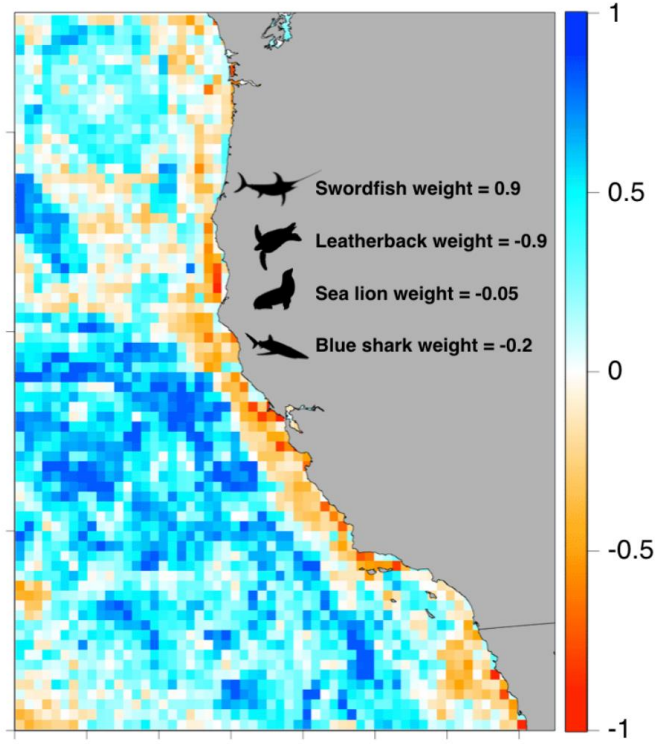
EcoCast Product



EcoCast
An Eco-informatic Tool for Fisheries Sustainability



EcoCast Product



EcoCast
An Eco-informatic Tool for Fisheries Sustainability

Key Messages: Seasonal Ocean Forecasts

Opportunities and Benefits

- Manage fisheries based on dynamic rather than static ecological assessments
- Inform fisheries management with environmental information
- Exploit predictable climatic forcing on seasonal timescales
- Collaborate with industry and managers, and leverage a real-time observational network

Technical Aspects

- Builds on seasonal weather forecasting
- Applications of ensembles of seasonal climate forcing
- Detailed skill assessment
- Understanding of mechanisms of predictability (e.g., persistence, ENSO variability)

OUTLINE

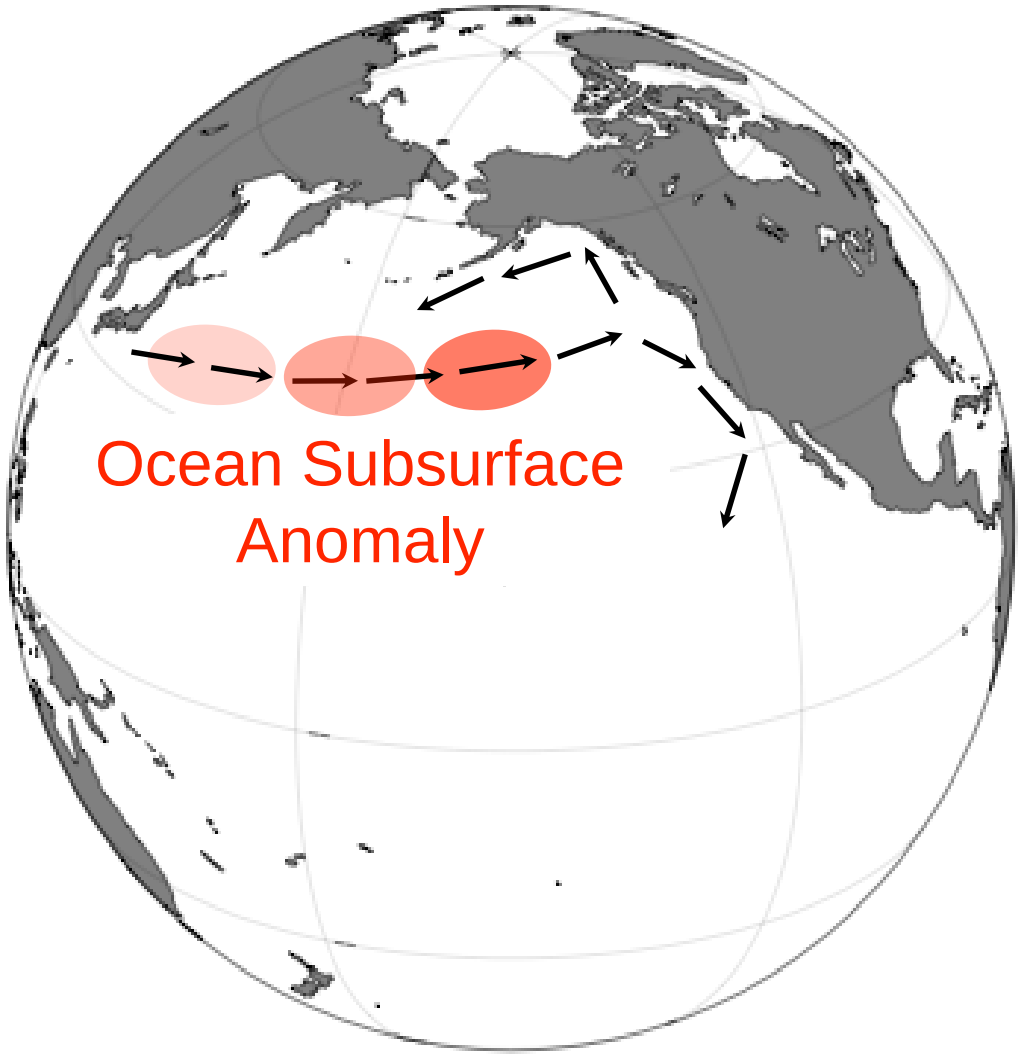
Introduction: The forecasting toolbox

Part 1: Short-term forecasts: ‘real-time’ to 1 month

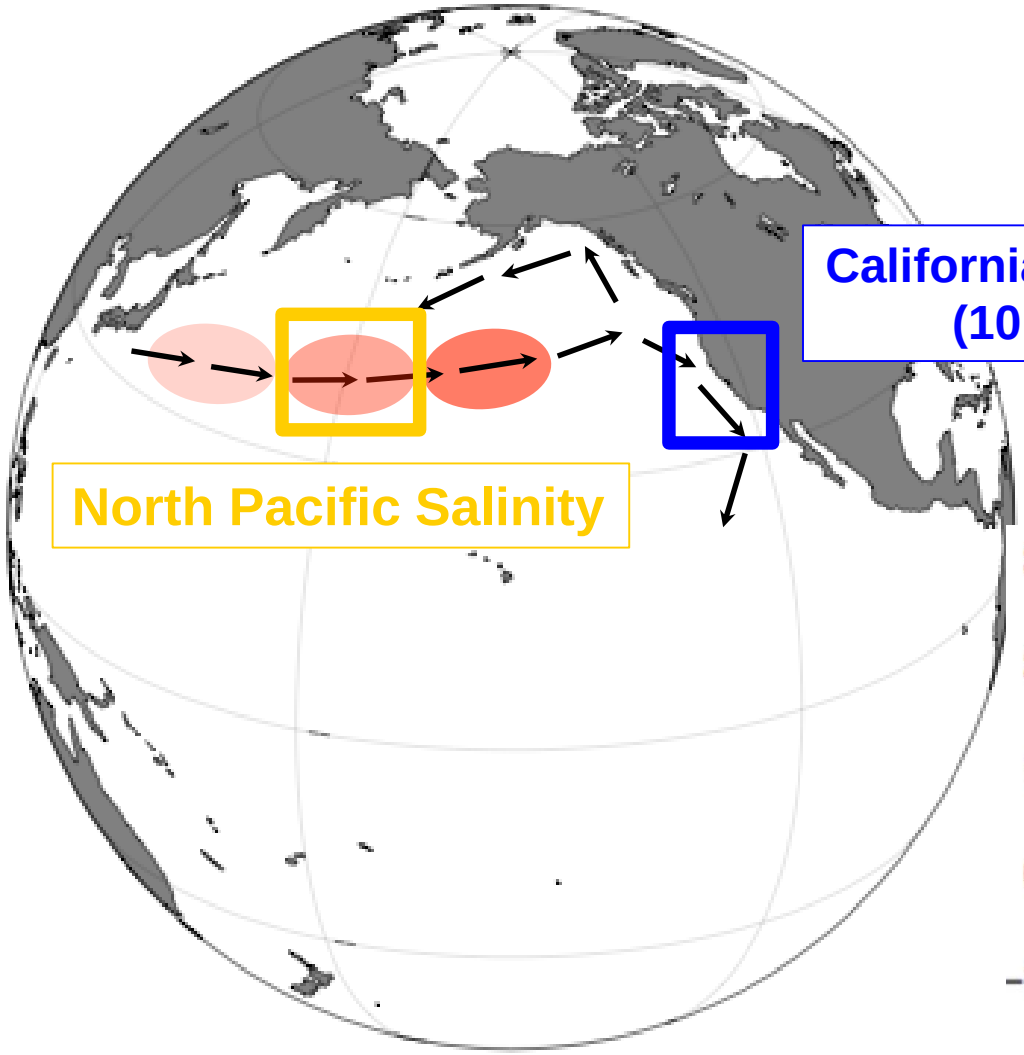
Part 2: Seasonal ocean forecasts: 1-12 months

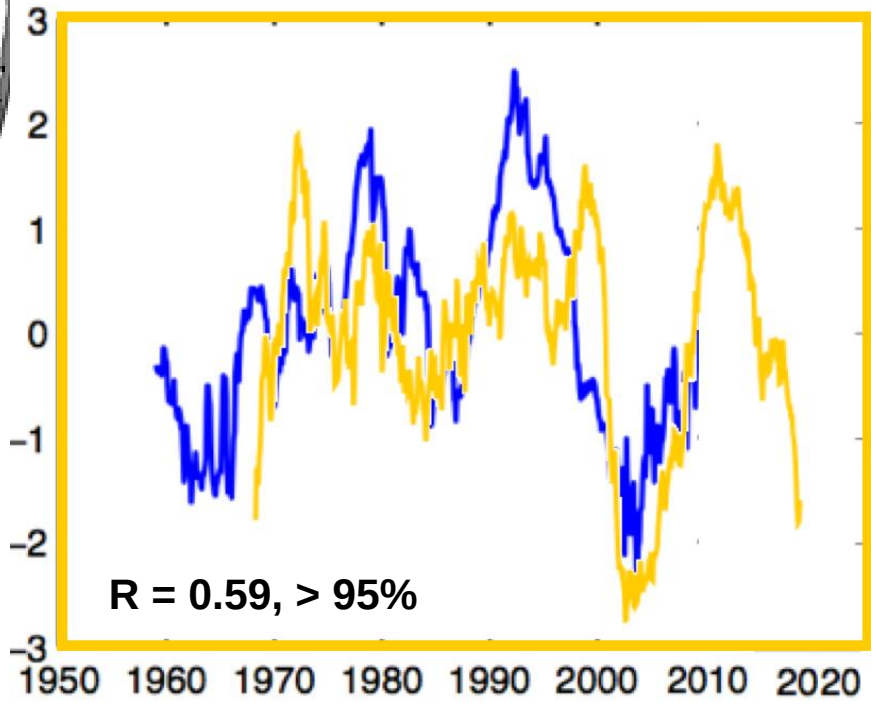
Part 3: Medium-term forecasts: 1-20 years

Part 4: Long-term forecasts: Decades



Pozo Buil and Di Lorenzo (2017)





Pozo Buil and Di Lorenzo (2017)

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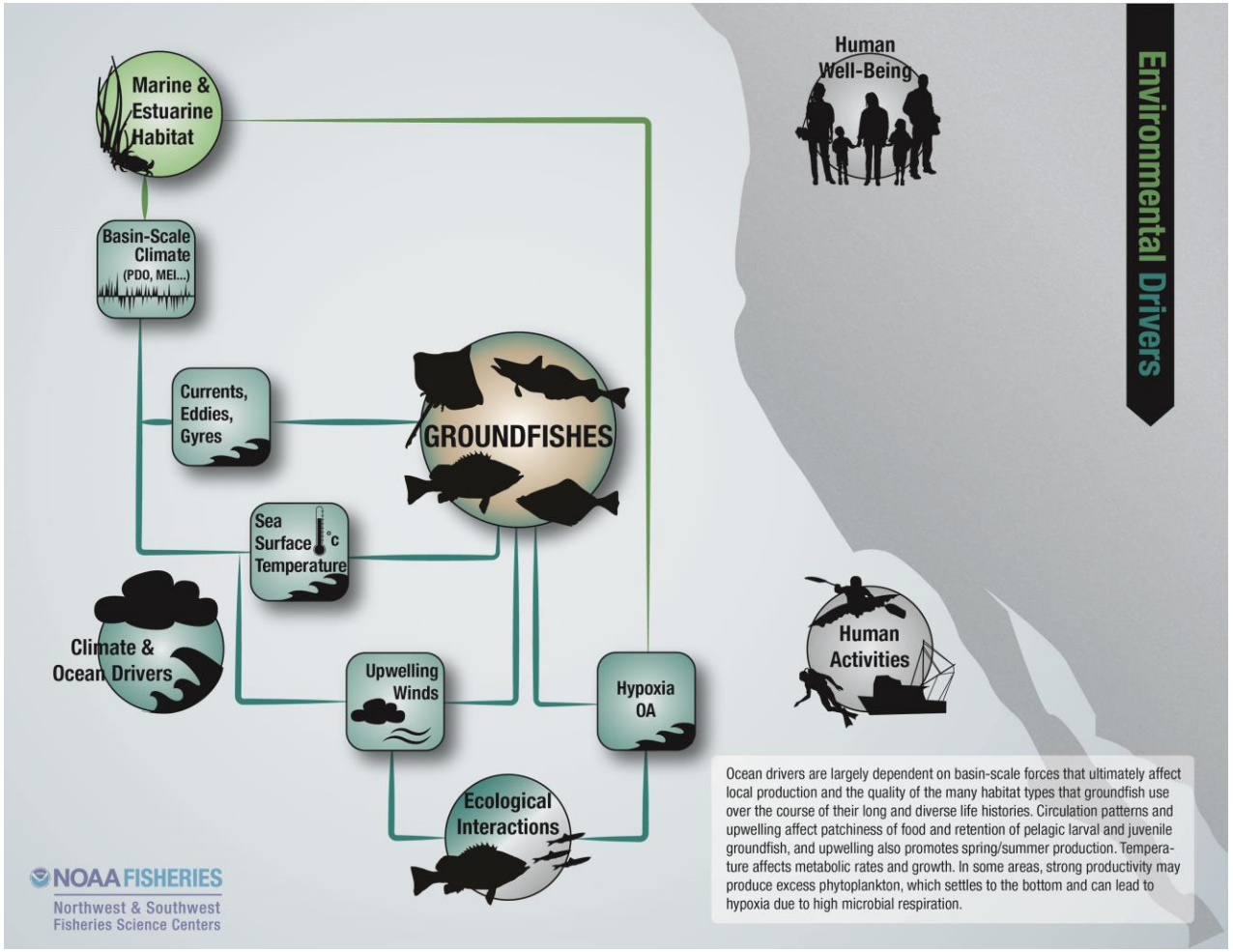
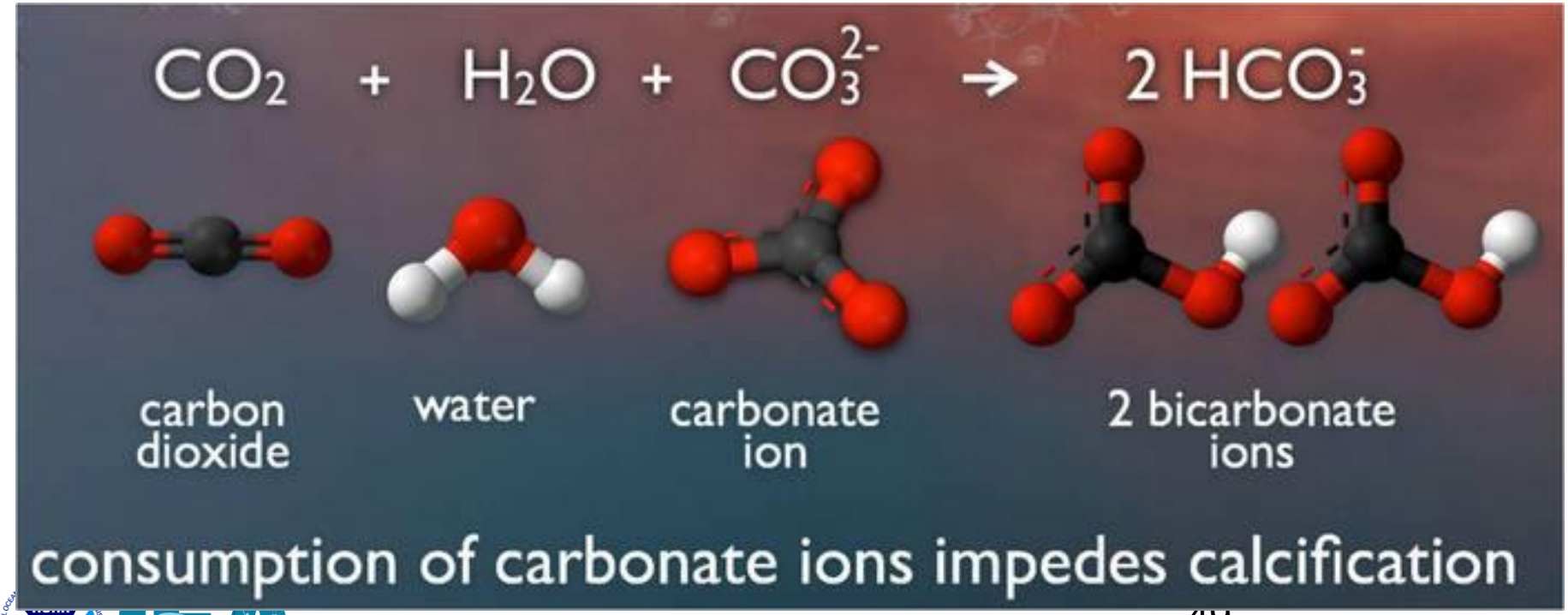
Long-term forecasts: Potential effects of ocean acidification on the California Current food web and fisheries



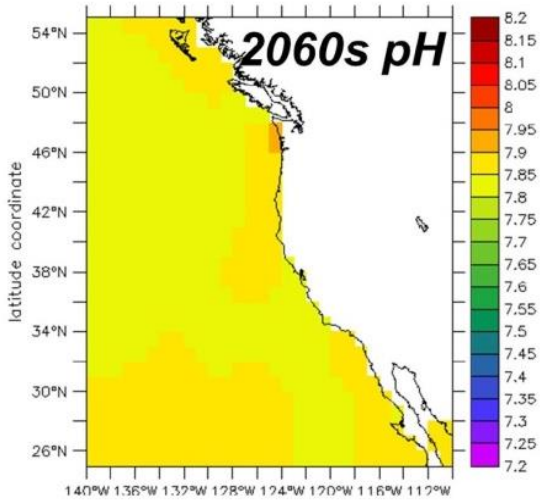
Ocean Acidification

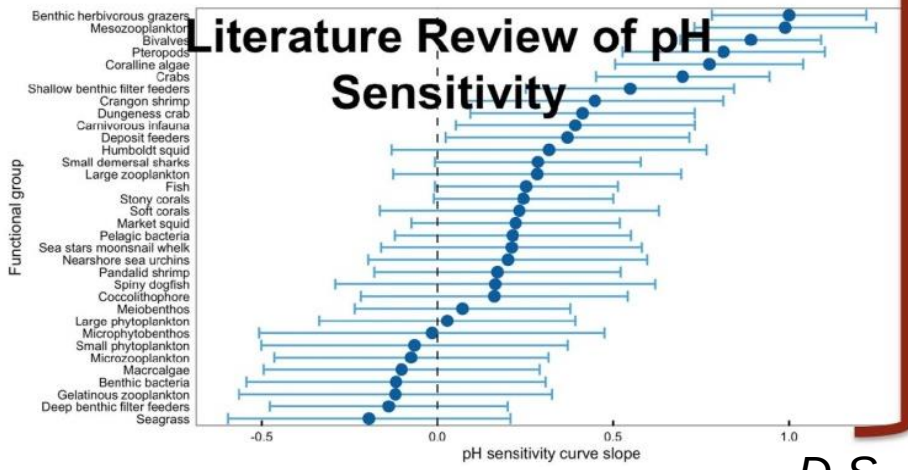


Graphic: NOAA PMEL

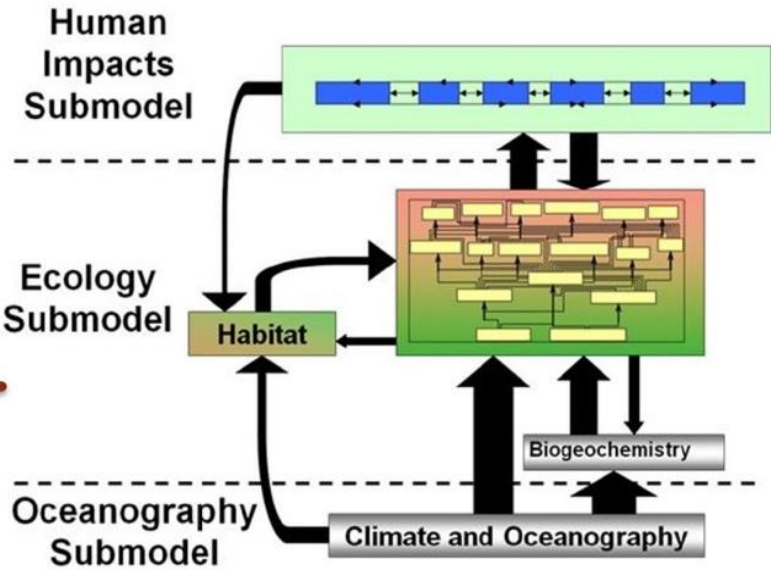
Approach: Ecosystem projections under scenarios for oceanography and pH sensitivity

Oceanographic Model





Atlantis Ecosystem Model



D.S. Busch and P. McElhany 2016 PLoS One
K.N. Marshall et al. (2017) Global Change Bio

Questions

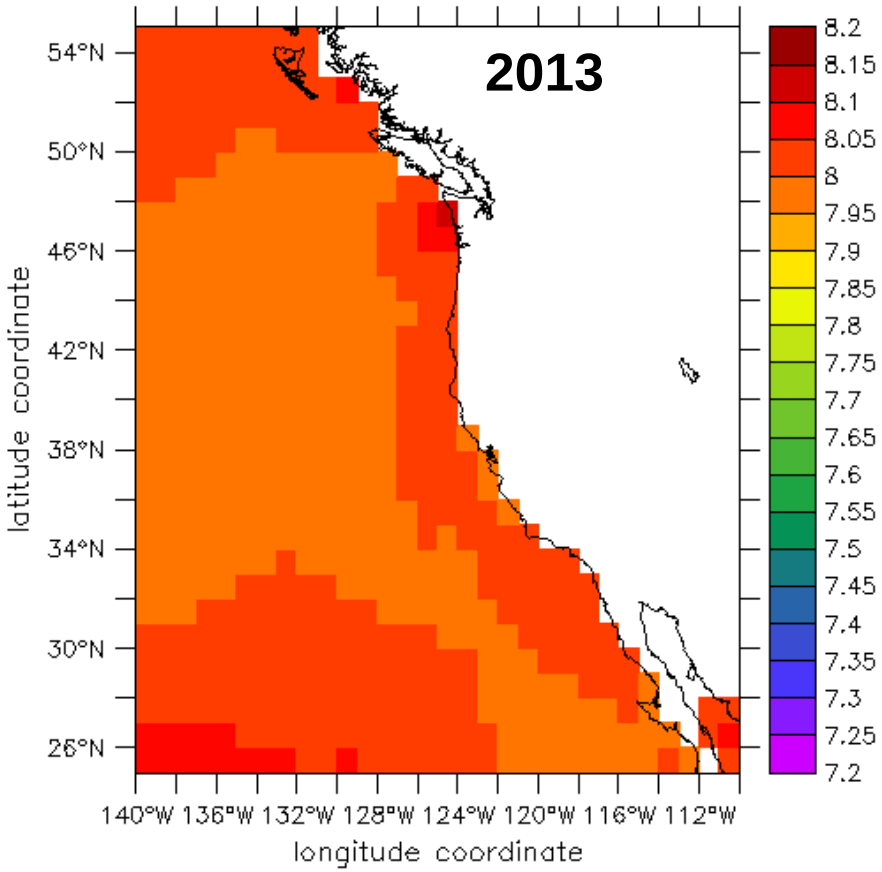
What are the effects of forecasted 2060 pH levels on:

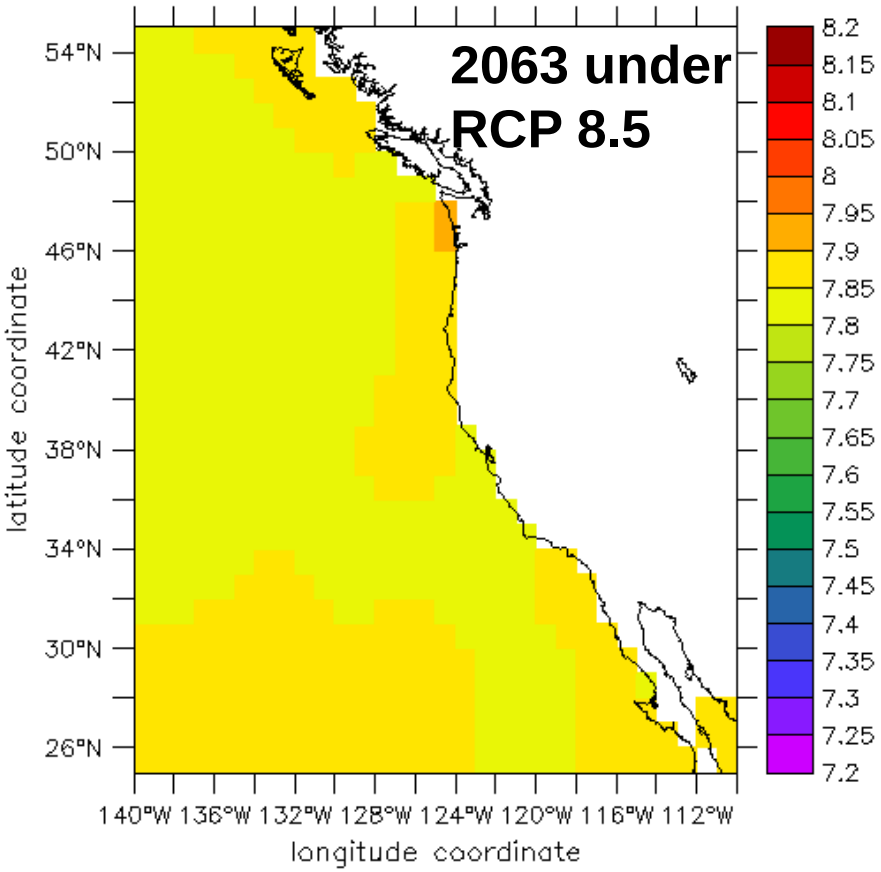
a. Biomass of organisms directly sensitive to pH?

b. Indirect effect on biomass of their predators/prey?

c. Effects on fisheries revenue?

Scenarios for ocean conditions: continuation of present conditions, or IPCC scenario RCP8.5 in 2063



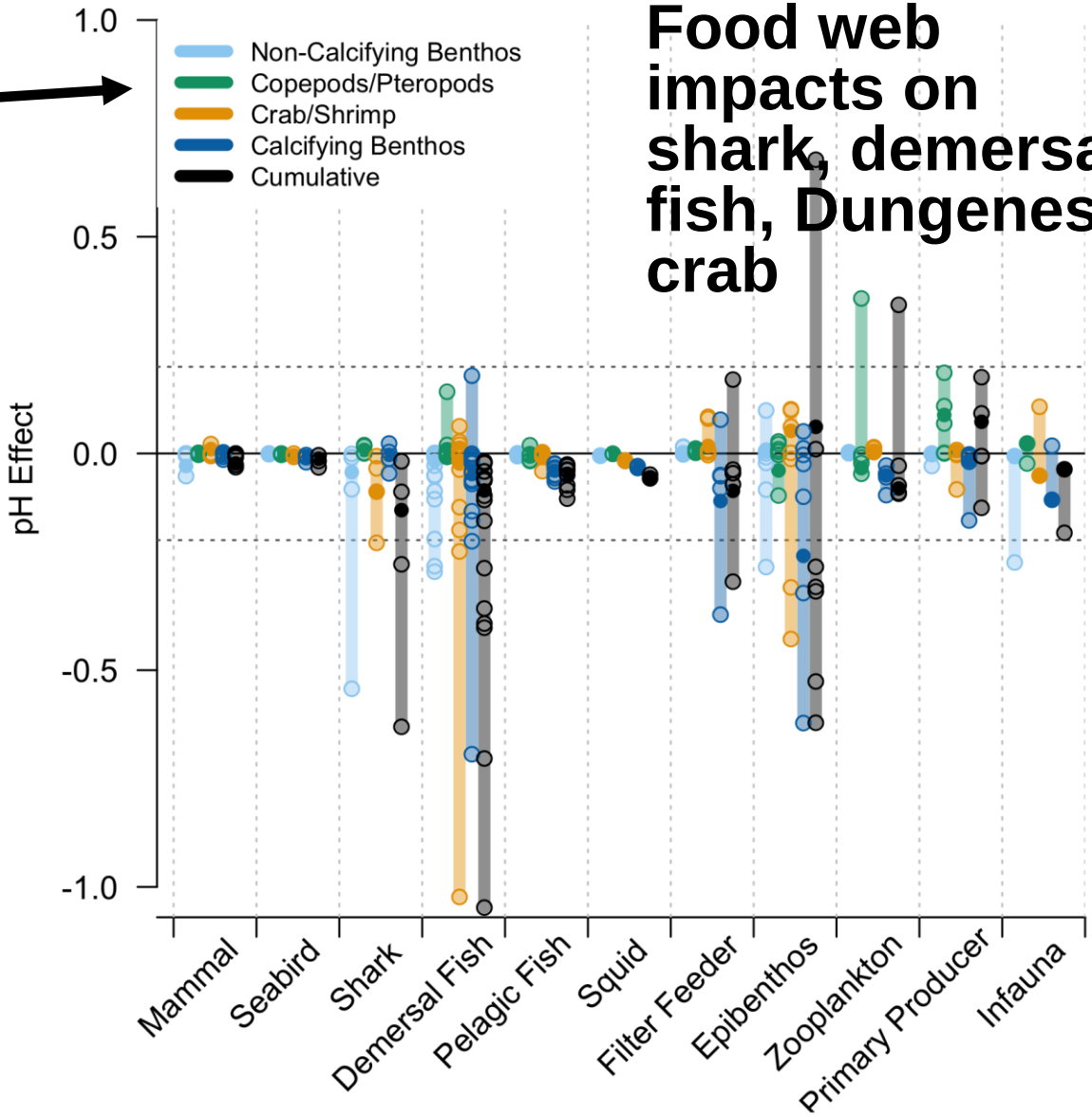


August surface pH, GFDL ESM2M

Scenarios for biological sensitivity to pH

Biomass responses of guilds to 2060s pH

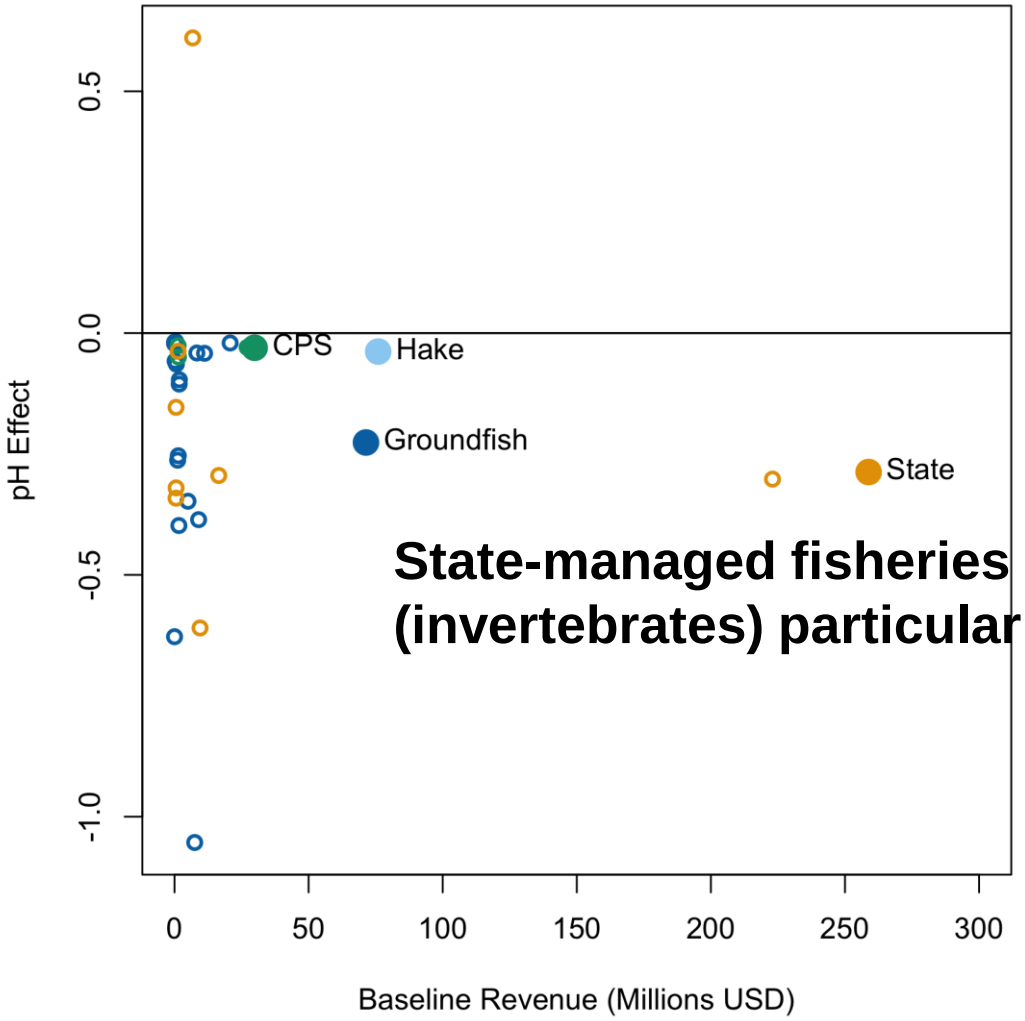
Food web impacts on shark, demersal fish, Dungeness crab



K.N. Marshall et al. (2017) Global Change Biology

Economic responses to pH sensitivity

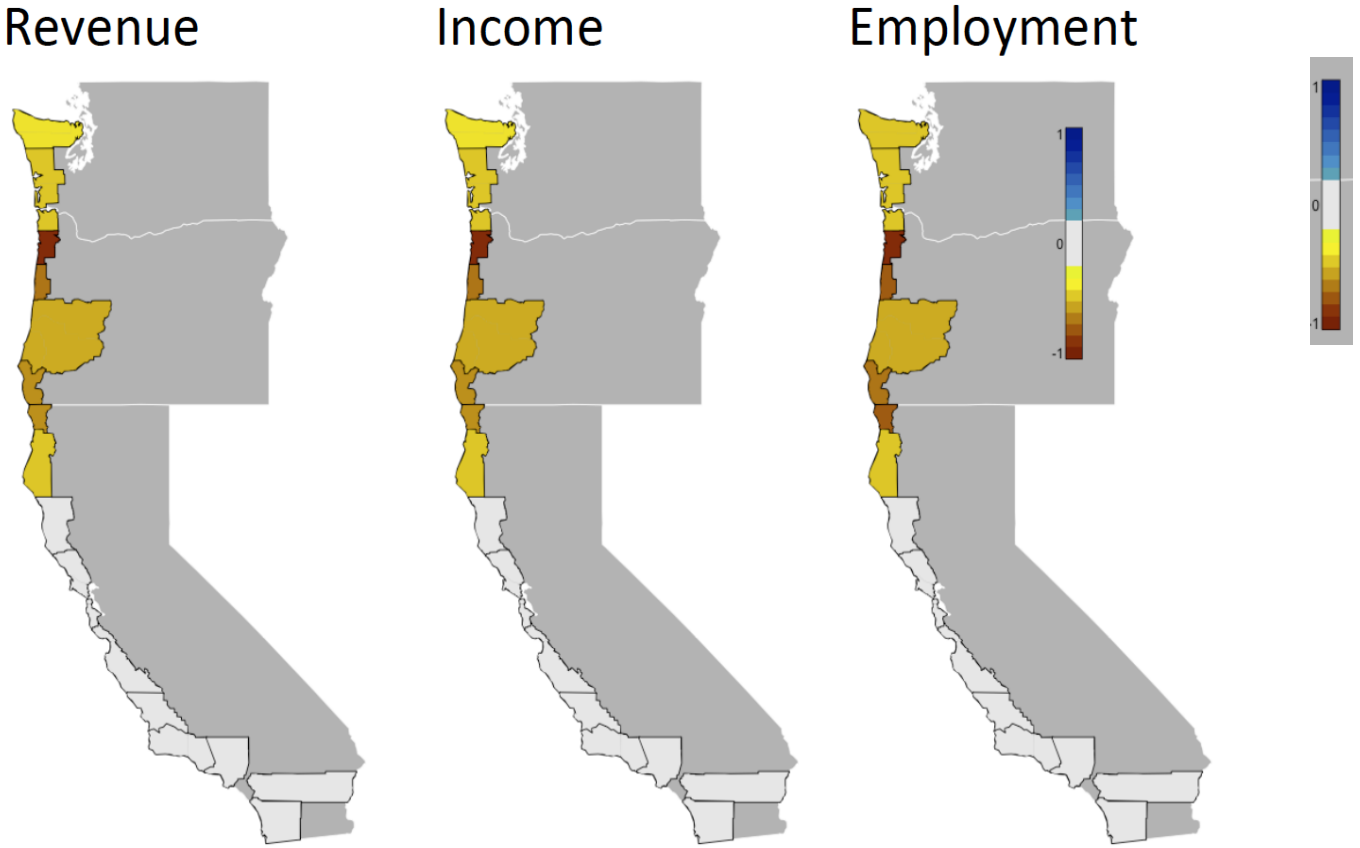
Catch or Biomass responses to 2060s pH



State-managed fisheries (invertebrates) particularly at risk

K.N. Marshall et al. (2017) Global Change Biology

Economic responses to pH sensitivity (via IOPAC model)

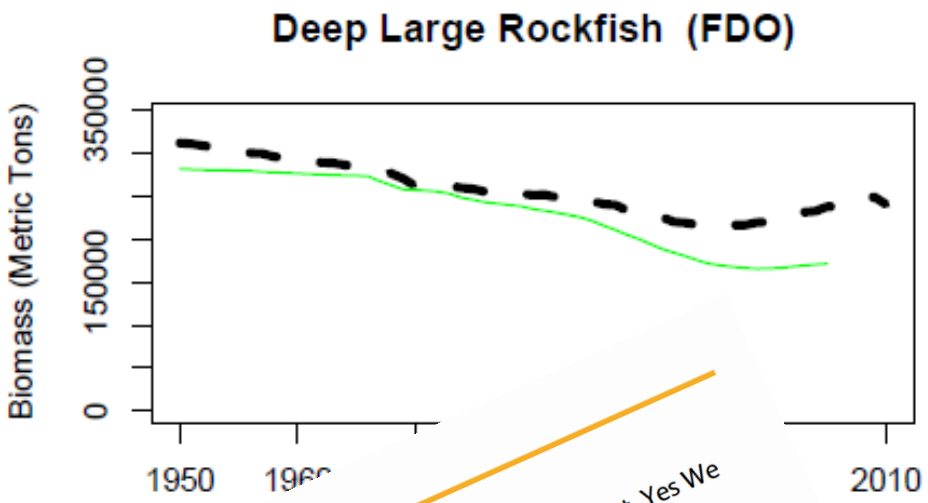


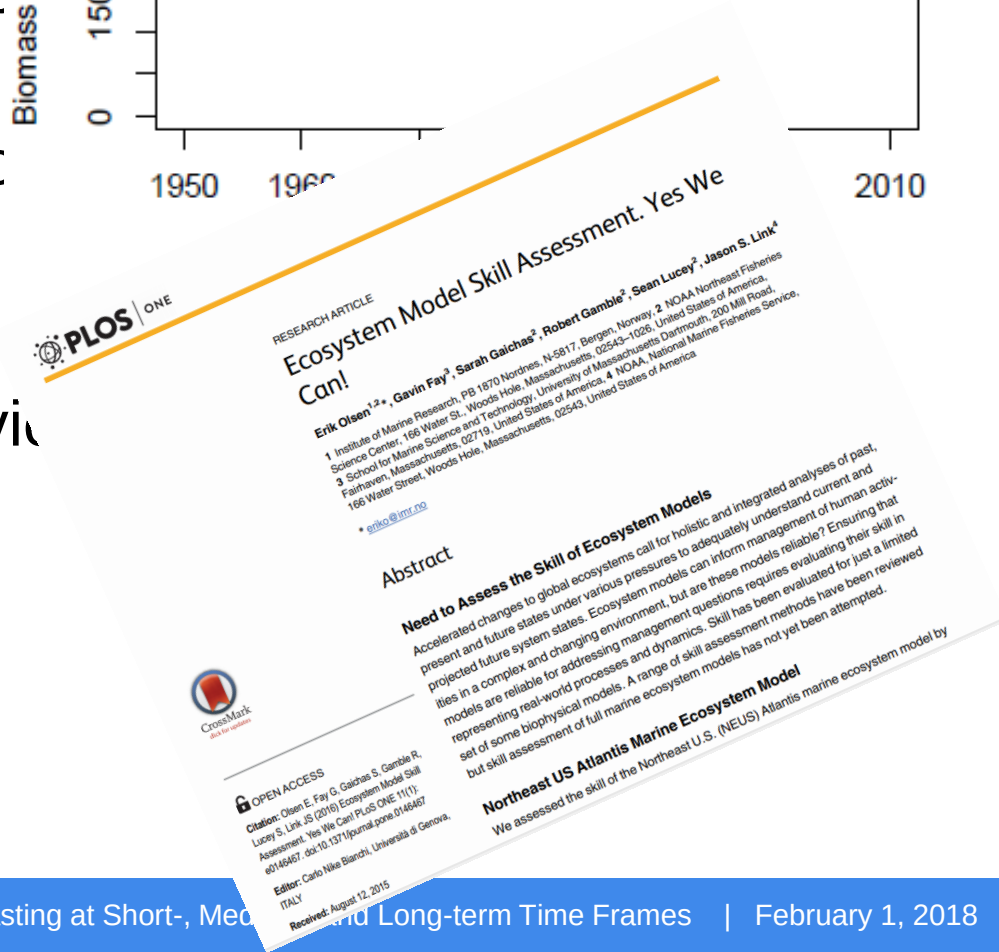
Strongest economic impacts in US northern ports (reliance on Dungeness crab), though biological impacts stronger in south.

E.E. Hodgson et al. (in review)

Skill Assessment is a work in progress

- Methodology Review (3 day
- Terms of Reference: Metho
  for Groundfish and Coastal
- 7 SSC members, 3 CIE revi
  ecosystem modeler




PLOS ONE

RESEARCH ARTICLE

Ecosystem Model Skill Assessment. Yes We Can!

Erik Olsen[1,2]*, Gavin Fay[3], Sarah Gaichas[2], Robert Gamble[2], Sean Lucey[2], Jason S. Link[4]

1 Institute of Marine Research, PB 1870 Nordnes, N-5817, Bergen, Norway, 2 NOAA Northeast Fisheries Science Center, 166 Water St., Woods Hole, Massachusetts, 02543–1026, United States of America, 3 School for Marine Science and Technology, University of Massachusetts Dartmouth, 200 Mill Road, Fairhaven, Massachusetts, 02719, United States of America, 4 NOAA, National Marine Fisheries Service, 166 Water Street, Woods Hole, Massachusetts, 02543, United States of America

* erik.o@imr.no

Abstract

Need to Assess the Skill of Ecosystem Models

Accelerated changes to global ecosystems call for holistic and integrated analyses of past, present and future states under various pressures to adequately understand current and projected future system states. Ecosystem models can inform management of human activities in a complex and changing environment, but are these models reliable? Ensuring that models are reliable for addressing management questions requires evaluating their skill in representing real-world processes and dynamics. Skill has been evaluated for just a limited set of some biophysical models. A range of skill assessment methods have been reviewed but skill assessment of full marine ecosystem models has not yet been attempted.

Northeast US Atlantis Marine Ecosystem Model

We assessed the skill of the Northeast U.S. (NEUS) Atlantis marine ecosystem model by

OPEN ACCESS

Citation: Olsen E, Fay G, Gaichas S, Gamble R, Lucey S, Link JS (2016) Ecosystem Model Skill Assessment. Yes We Can! PLOS ONE 11(1): e0146467. doi:10.1371/journal.pone.0146467

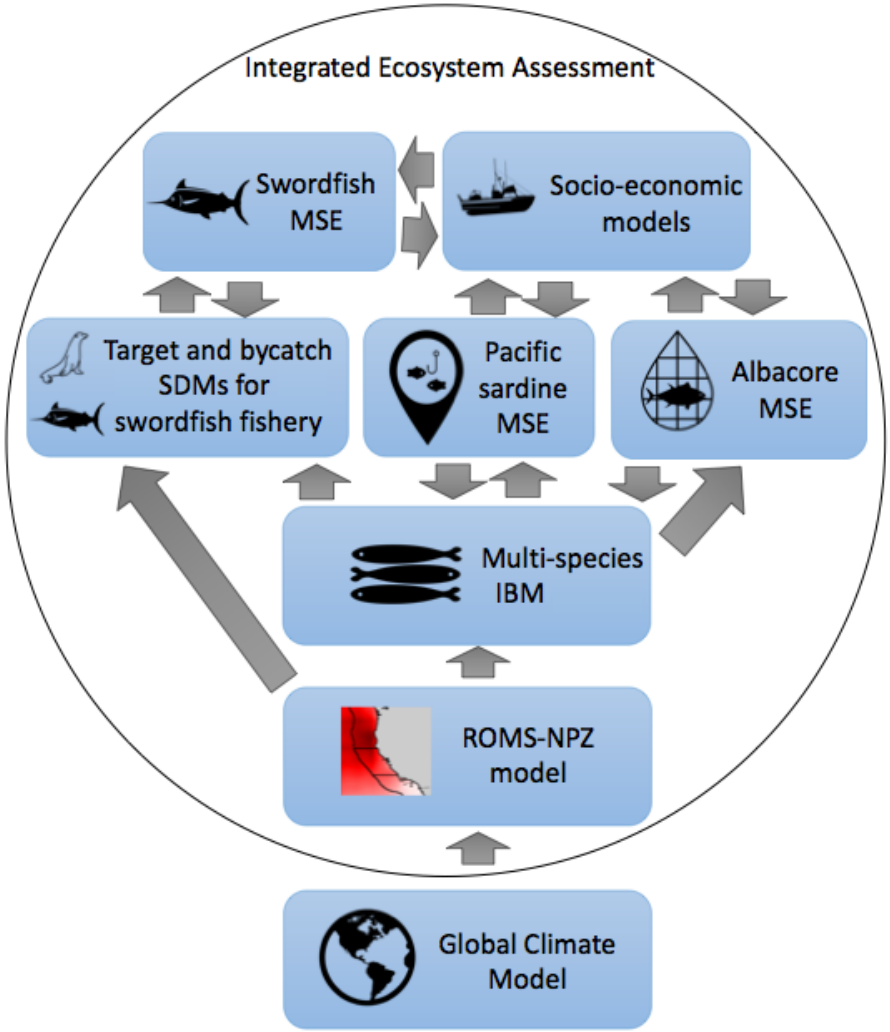
Editor: Carlo Nike Bianchi, Università di Genova, ITALY

Received: August 12, 2015

Key Messages
Long-term forecasts: Potential effects of ocean acidification

- Direct effects of acidification on invertebrates
- Strong indirect effects expected on demersal fish, sharks, and epibenthic invertebrates (including Dungeness crab)
- Strong effects on nearshore state-managed invertebrate fisheries and the groundfish fishery.
- Strongest effects in the north (due to dependence on Dungeness crab)
- Pelagic community was much less influenced by future pH
- Scenarios for long-term projections, and steps toward skill assessment

From Physics to Fisheries: A Social-Ecological Management Strategy Evaluation for the California Current Large Marine Ecosystem



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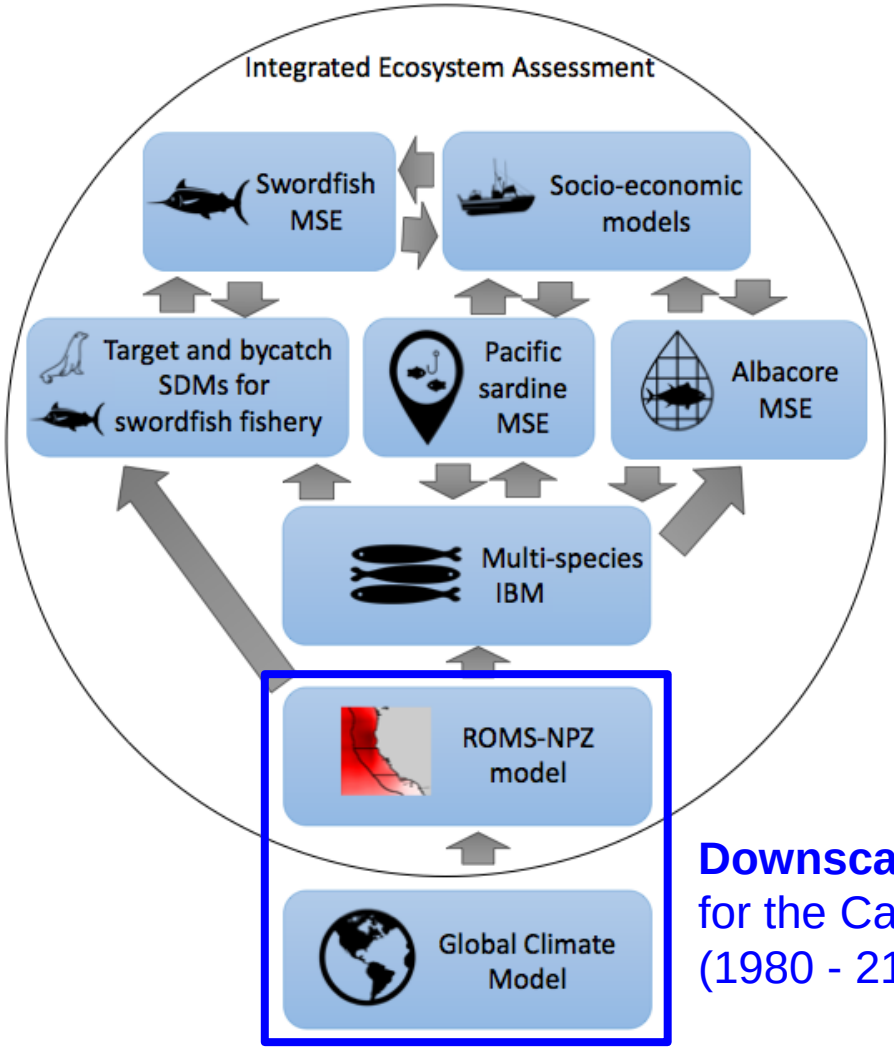

Downscaled Ocean Projections
for the California Current System
(1980 - 2100)

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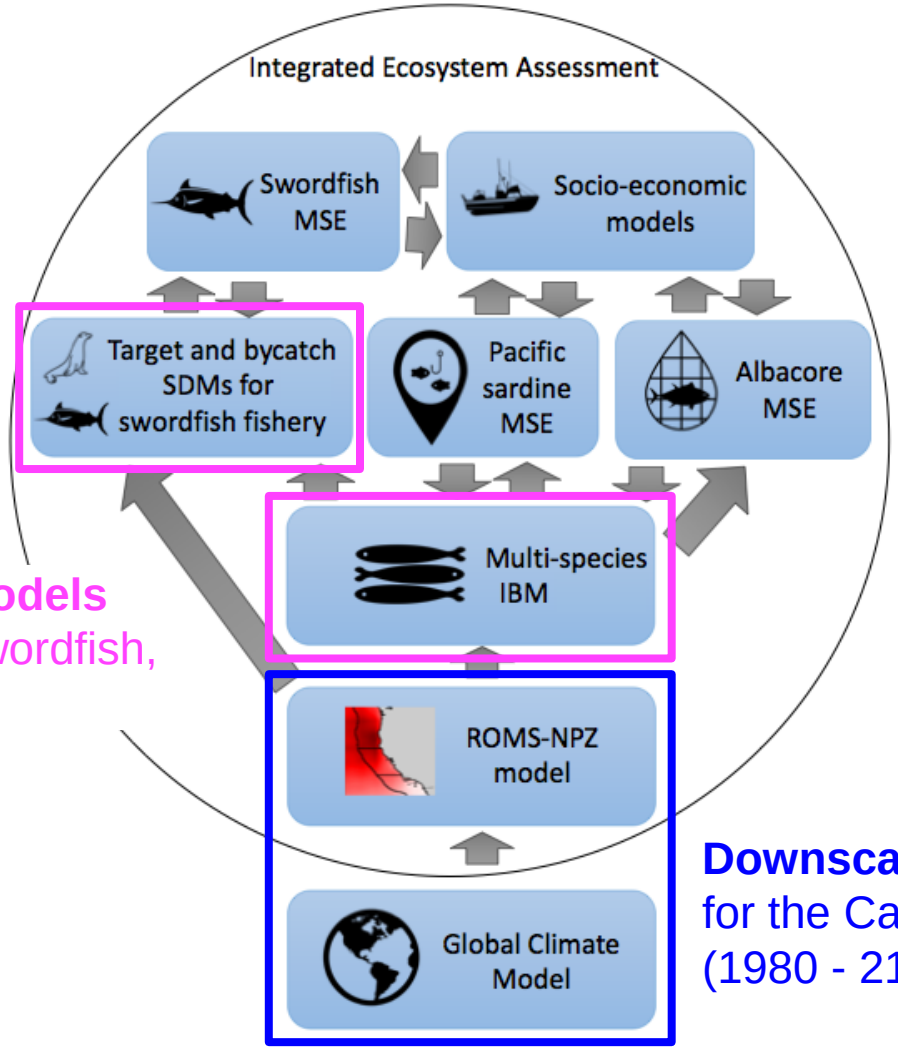

Multiple Ecosystem Models
for sardine, albacore, swordfish, and bycatch species

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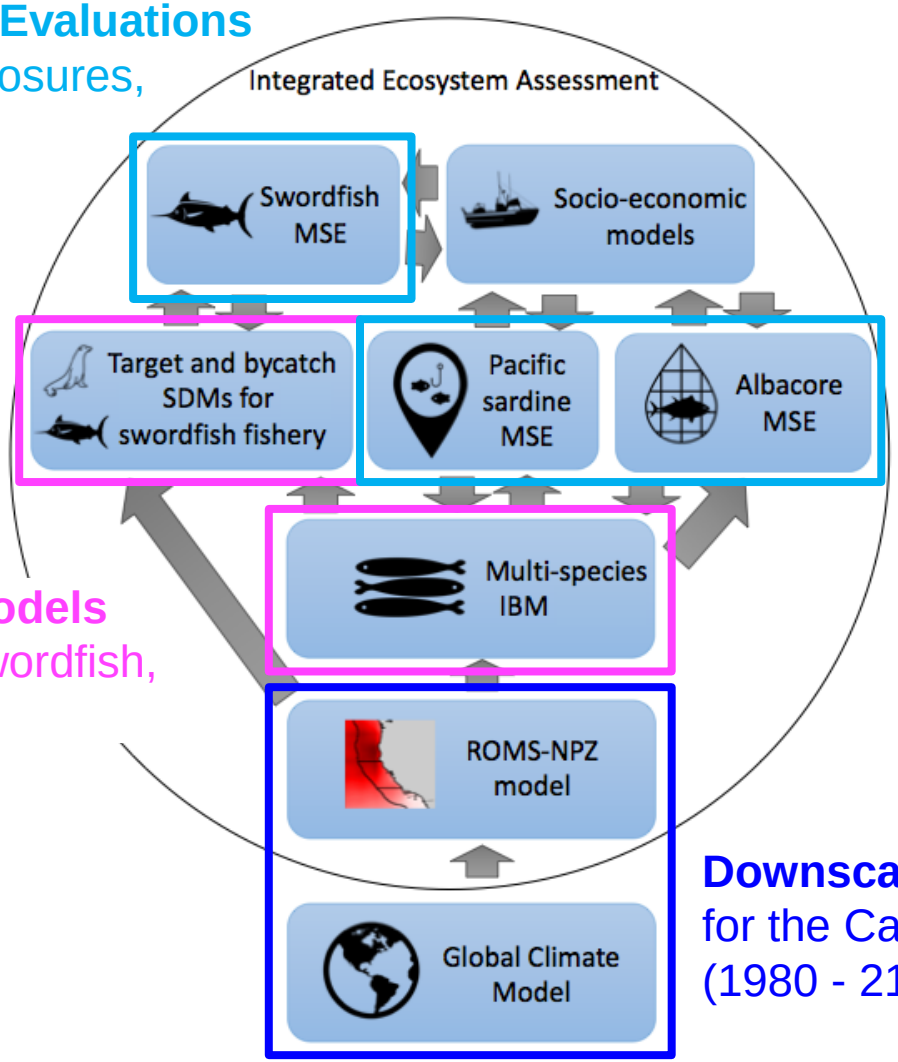
Management Strategy Evaluations
(e.g., spatial/temporal closures, harvest guidelines)



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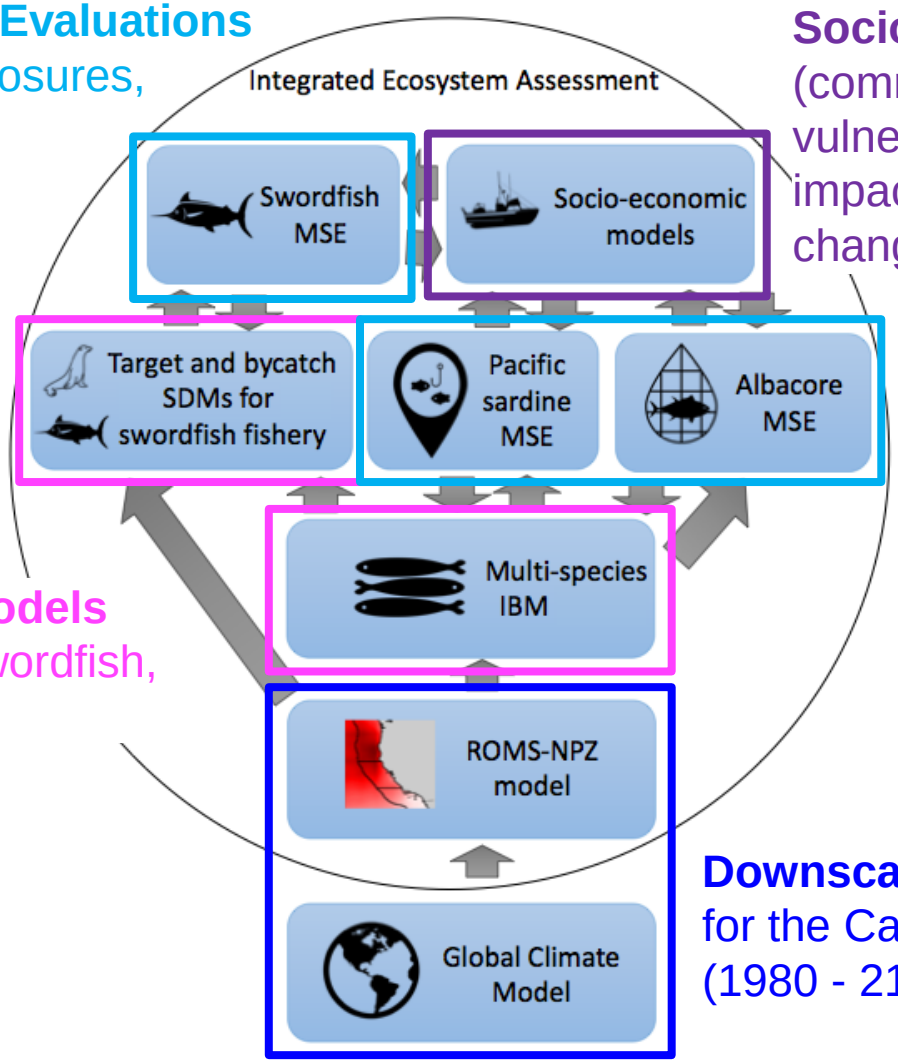
Management Strategy Evaluations
(e.g., spatial/temporal closures, harvest guidelines)

Socio-economic Analyses
(community reliance and vulnerability, economic impacts of distributions shifts, changing abundance, etc.)



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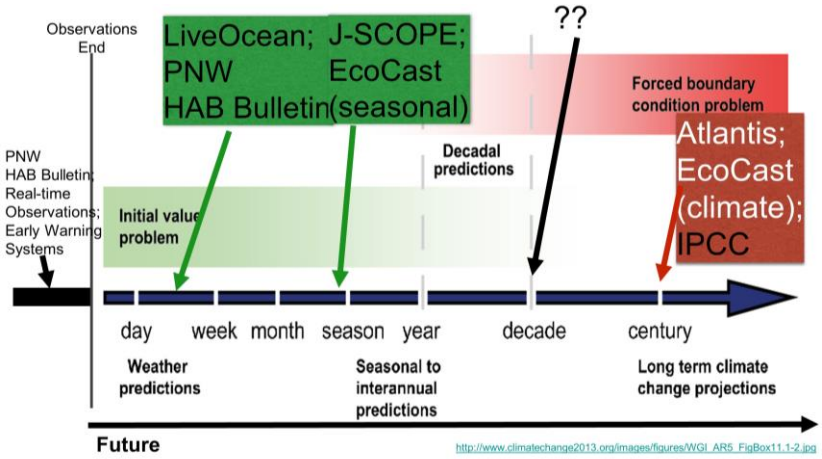
Downscaled Ocean Projections
for the California Current System (1980 - 2100)

Summary

We are entering an era of rapid ocean change, and forecasts help us see what is on the horizon

- Short-term forecasts, e.g. *Pseudo-nitzschia* blooms: *should I harvest next week?*
- Seasonal ocean forecasts: *Will hake migration reach Canada? Will crab season be delayed? What is turtle bycatch risk off Central California?*
- Long-term forecasts (decades): *What are the risks of global change to the ecosystem and particular fisheries and ports?*



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Gaps

- Mid-term forecasts from 1-10 years.

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Gaps

- Mid-term forecasts from 1-20 years.

Next steps

- Tailored forecasts for PFMC and other partners
- Skill assessment
- Scenarios (e.g., “Physics to Fisheries”) and ensembles (e.g., EcoCast, J-SCOPE)

Questions?

Questions for you!

- What ocean conditions matter most for your fisheries and species?

- What are PFMC needs for short-term, seasonal, and long-term forecasts?