Enrique Curchitser

Department of Environmental Sciences
Rutgers University

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Collaborators

- Raphael Dussin (Rutgers University)
- Charles Stock (NOAA-GFDL)
- Nicolas van Oostende (Princeton University)

Background (The very big picture)

Background (The very big picture)

- Motivation: Make projections of marine ecosystem response to climate perturbations

Background (The very big picture)

- Motivation: Make projections of marine ecosystem response to climate perturbations

- Challenge: Interacting components on a wide-range of scales in the dynamics of both the physics and the biology

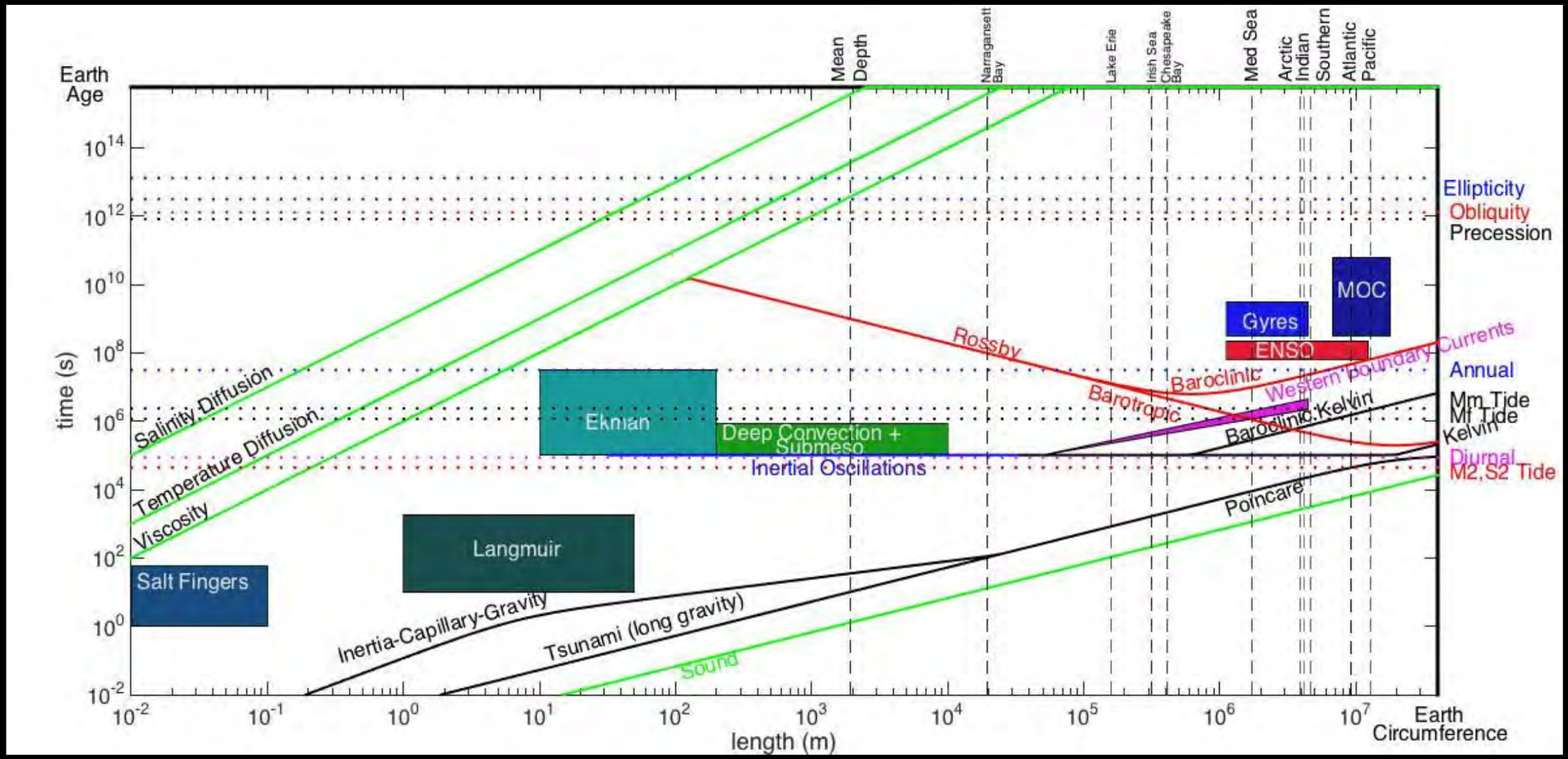
Background (The very big picture)

- Motivation: Make projections of marine ecosystem response to climate perturbations

- Challenge: Interacting components on a wide-range of scales in the dynamics of both the physics and the biology

- Approach: Develop and use a multi-scale model framework to explore possible drivers of marine ecosystem variability on a range of scales

Space-time scales for some oceanic processes

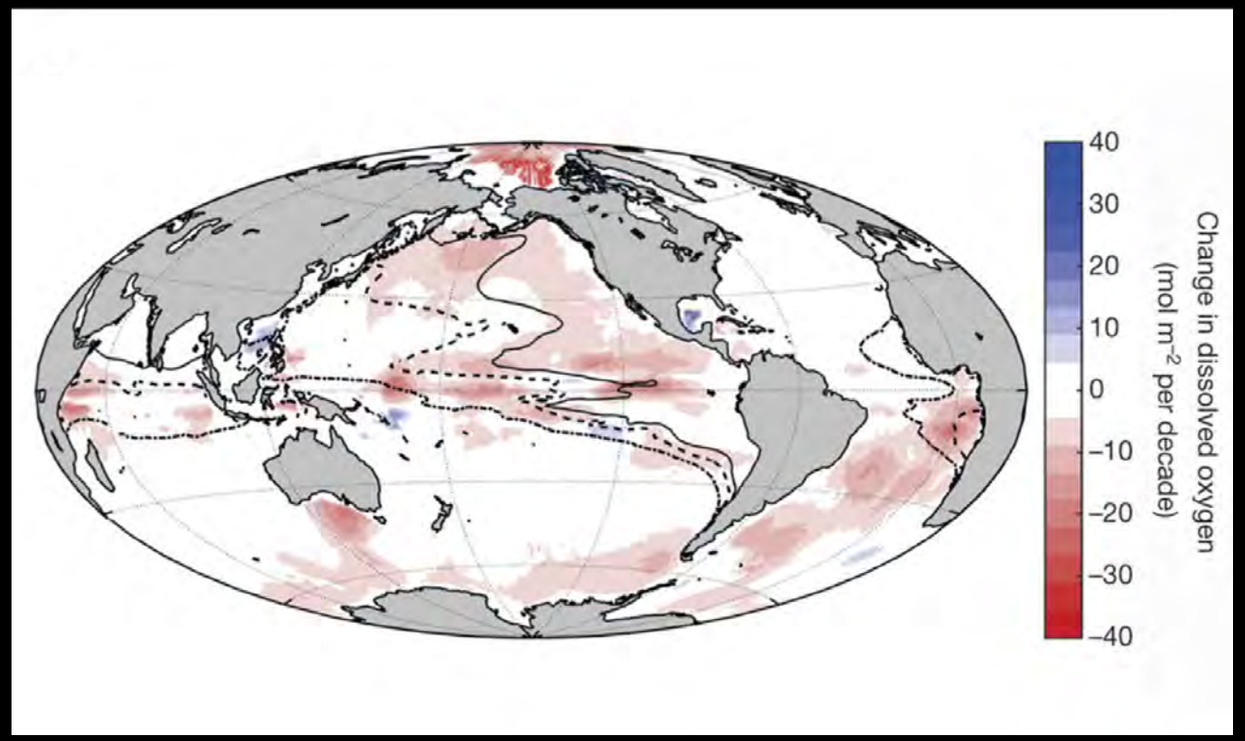


Haidvogel, Curchitser, Danilov and Fox-Kemper (2018). Numerical Modelling in a Multi-Scale Ocean. *The Sea* Vol. ??

Motivation: Observed deoxygenation of the ocean

Observed decline in Dissolved Oxygen (DO) over the past 50 years of 2% = 77 billion metric tons (Schmidtko, Nature, 2017)

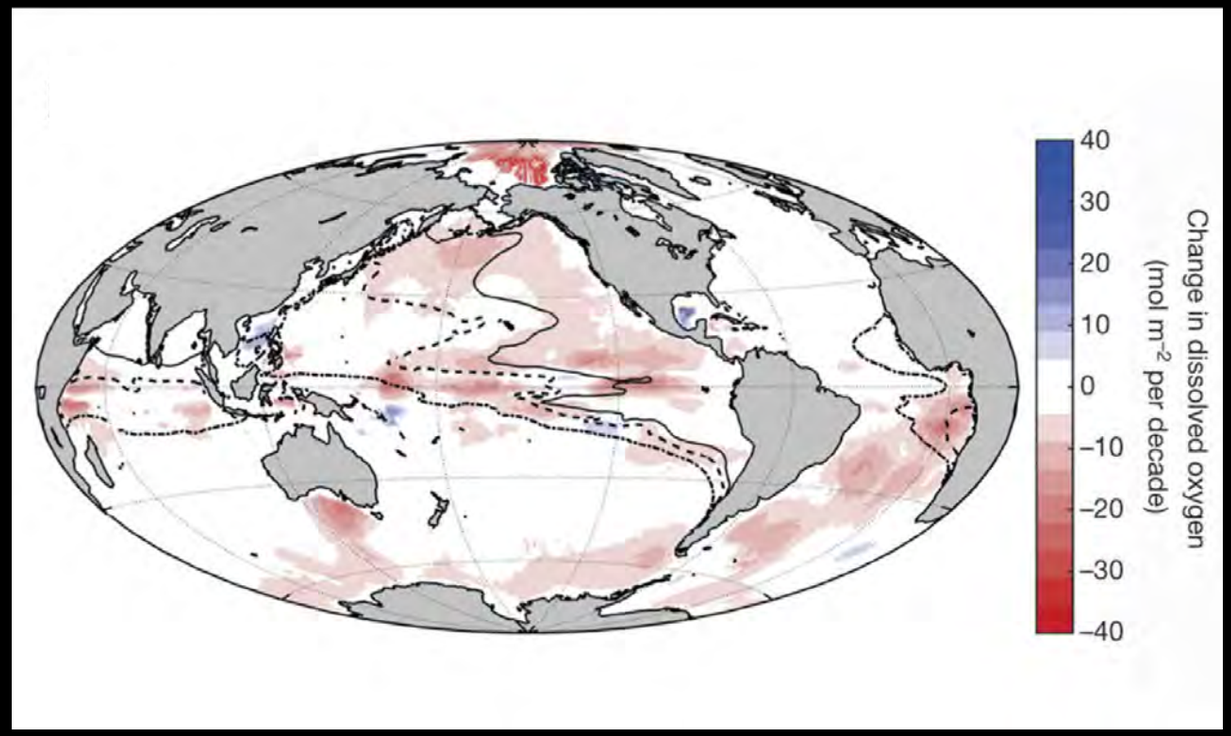
Reduced ventilation due to decrease in DO solubility and stronger stratification (Helm, GRL, 2011)



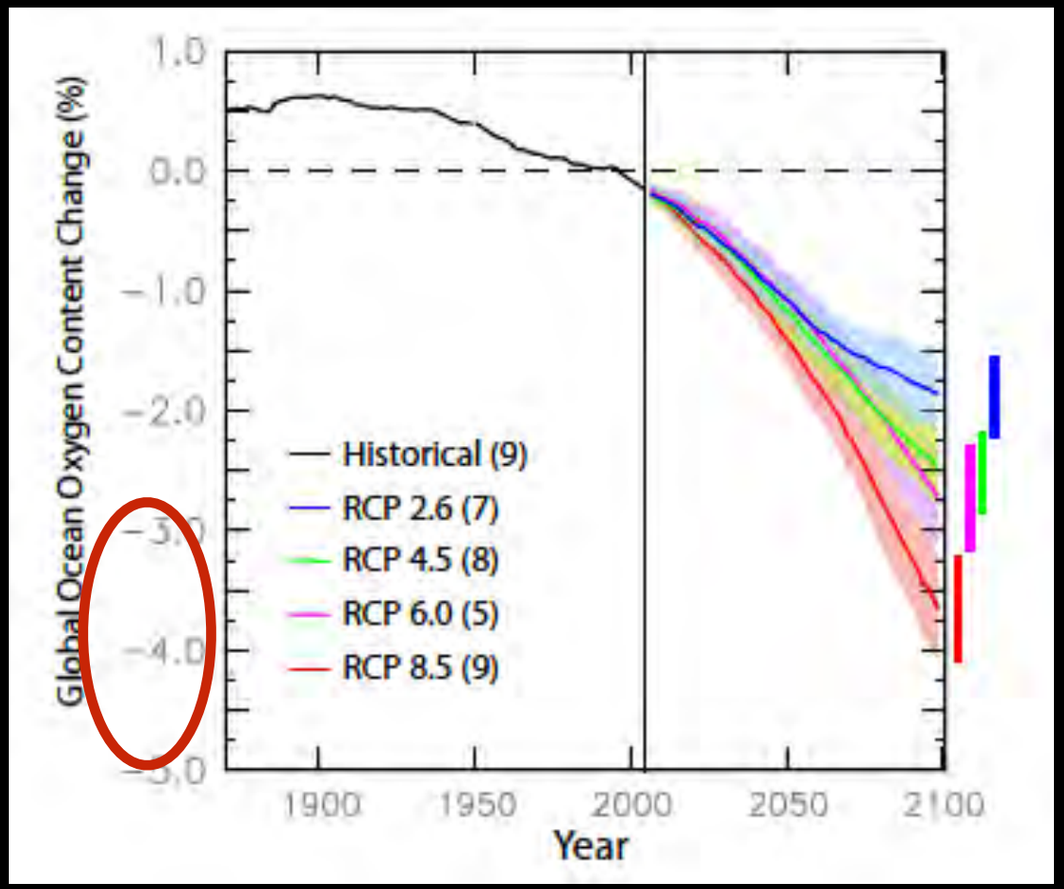
Motivation: Observed deoxygenation of the ocean

Observed decline in Dissolved Oxygen (DO) over the past 50 years of 2% = 77 billion metric tons(Schmidtko, Nature, 2017)

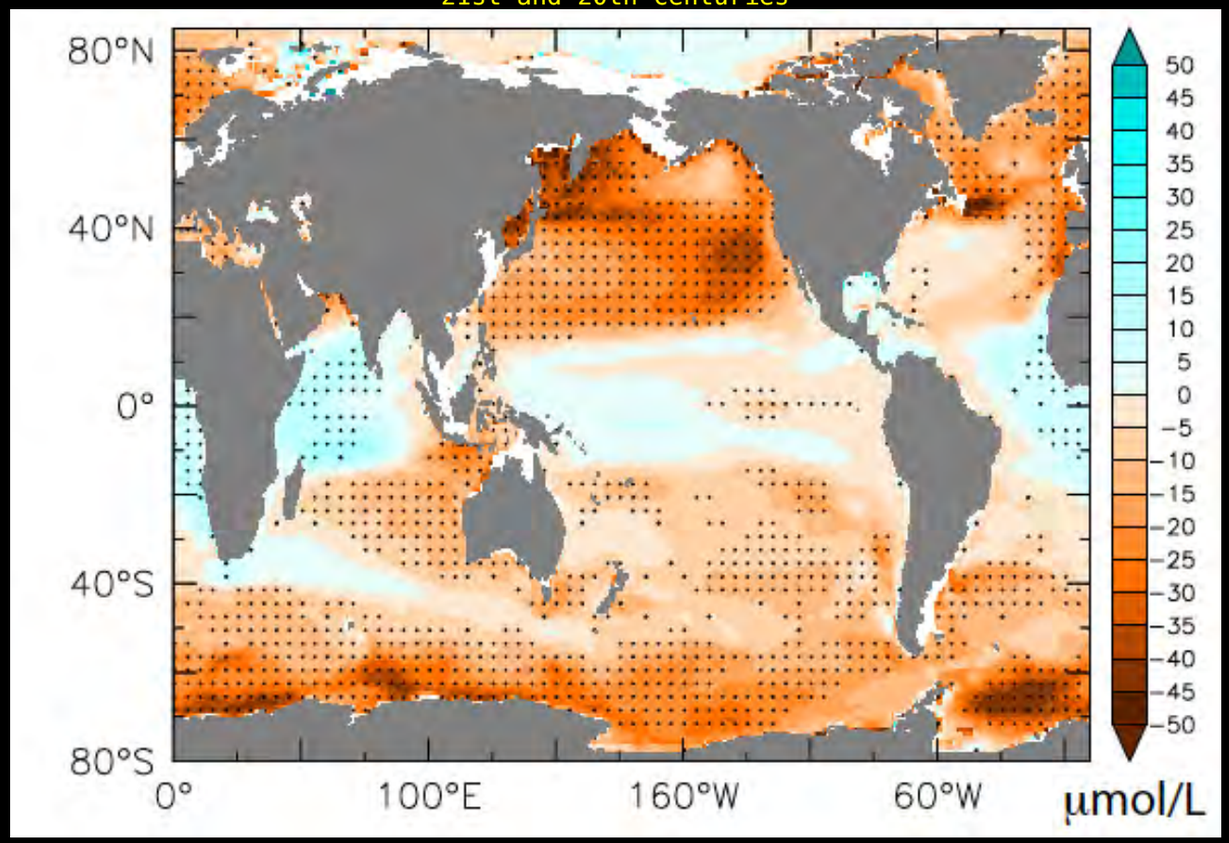
Reduced ventilation due to decrease in DO solubility and stronger stratification (Helm, GRL, 2011)



Trend is projected to continue over the 21st century in CMIP5 models (Bopp 2013, Cocco 2013)



subsurface (200–600m) DO change between last decade of 21st and 20th centuries



Motivation: Coastal Hypoxia on the rise

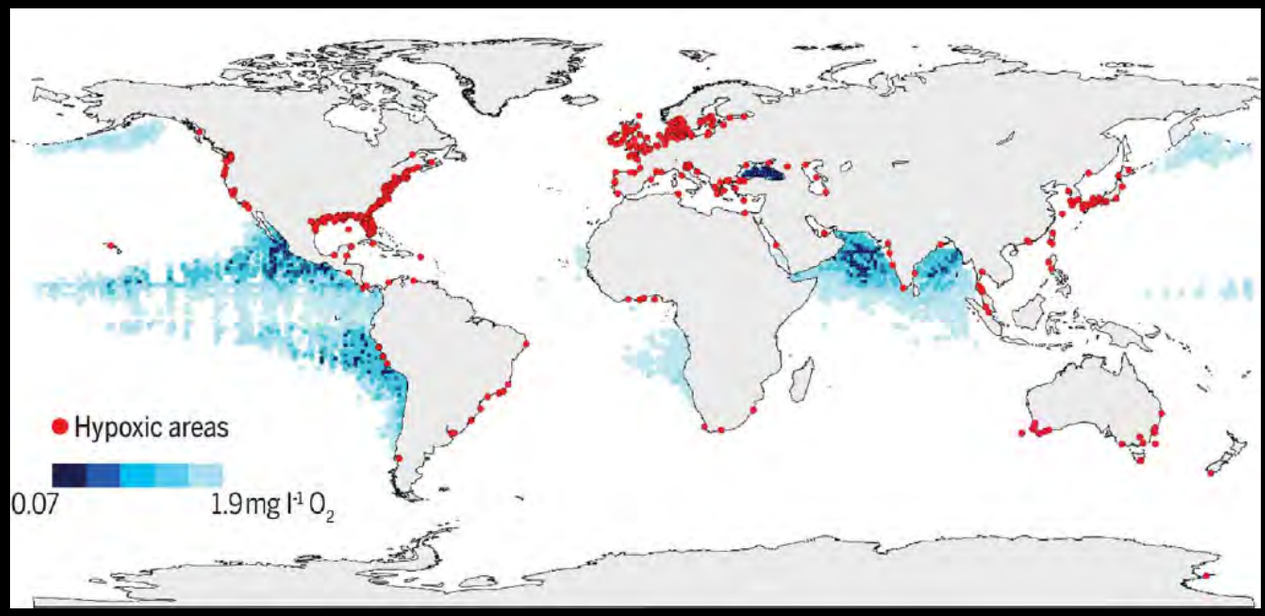
As DO declines, more hypoxia is reported worldwide
(Diaz & Rosenberg, Science, 2008 - Breitburg, Science, 2018)

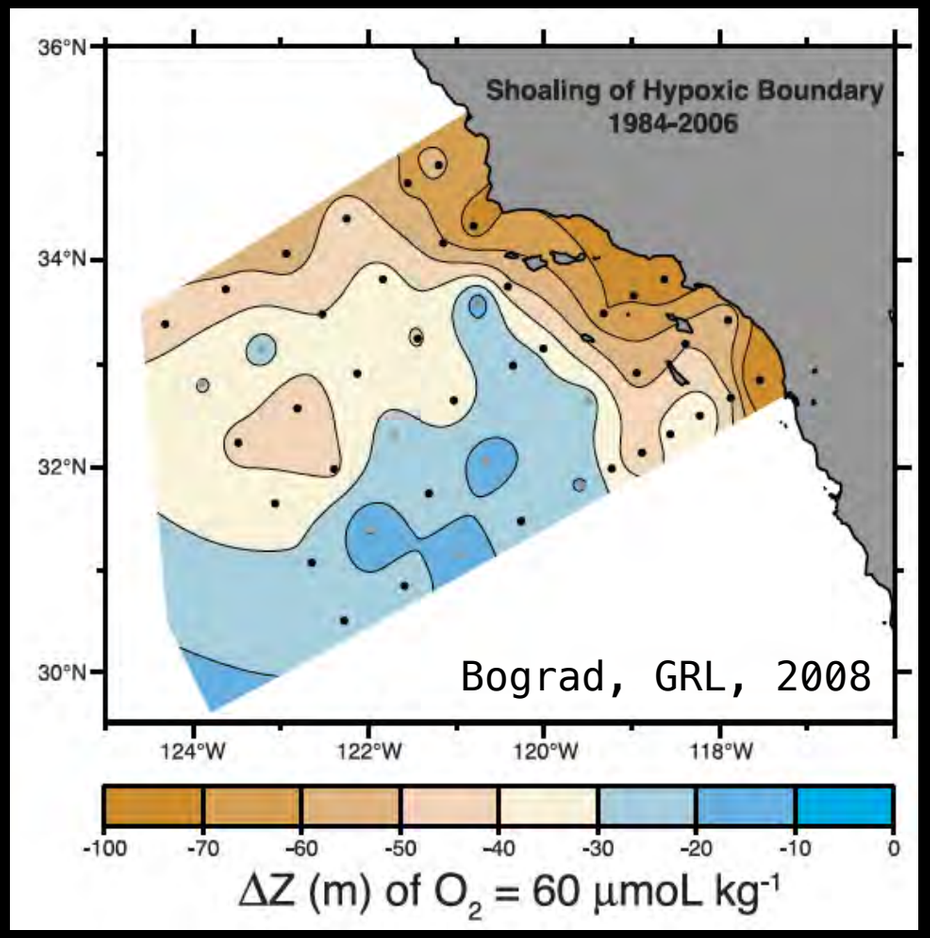
Drivers:

- Global: Deoxygenation of the oceans
- Local:
  - Eutrophication
  - Changes in Solubility
  - Changes in Circulation

Question: What is the relative contribution of ocean deoxygenation versus local processes?

Our approach: using a climate projection to produce perturbations and downscale to a region of interest.

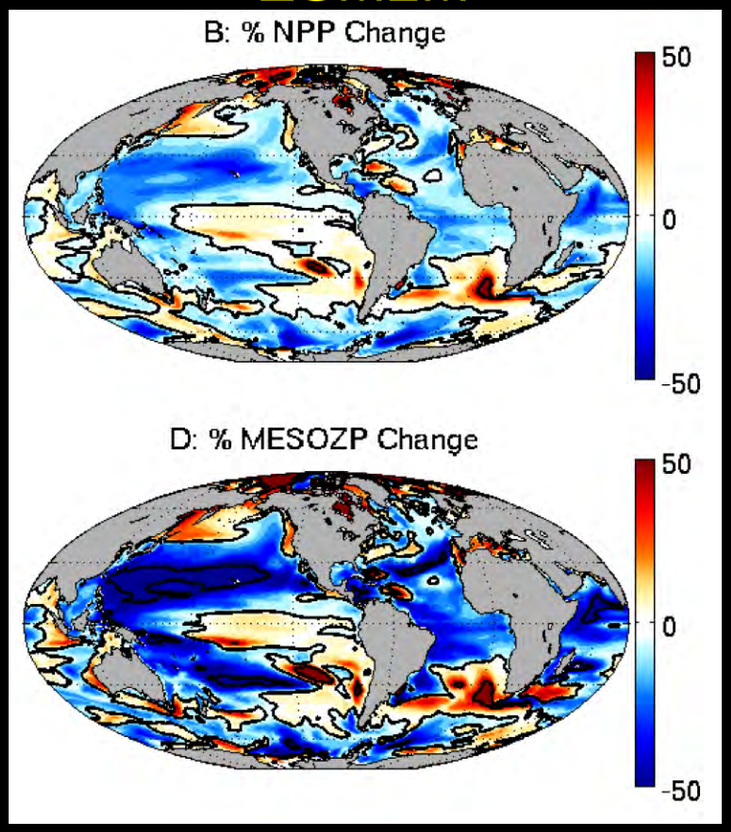




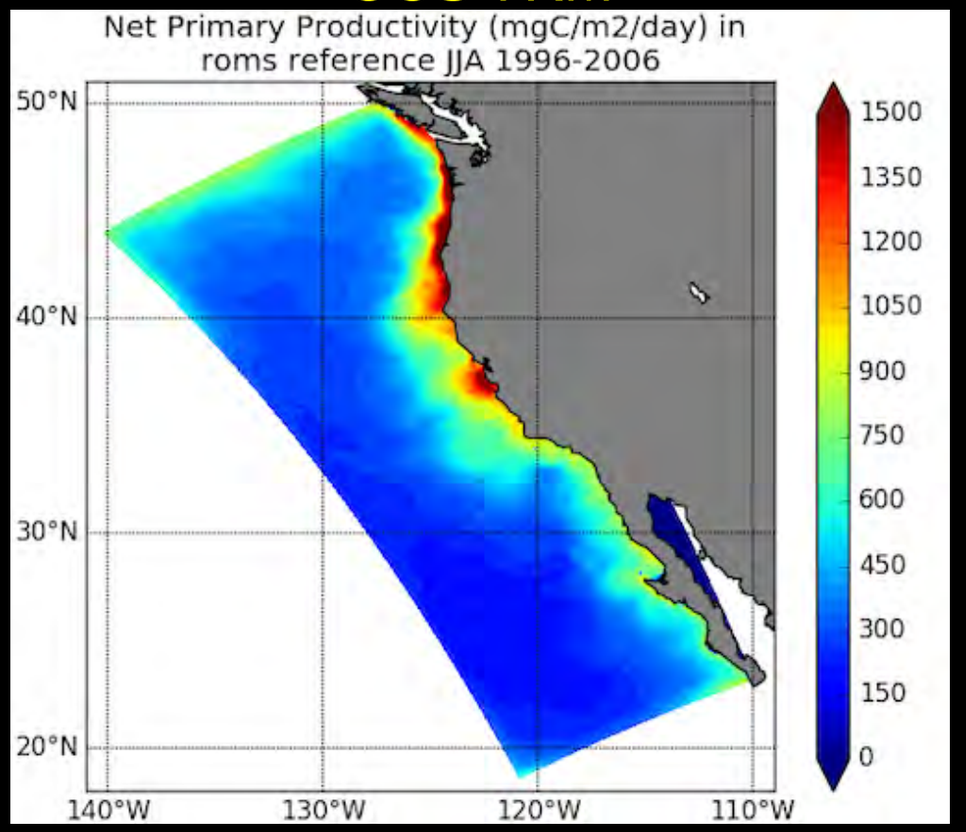
EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Approach:
Downscale couples models

GFDL
ESM2M

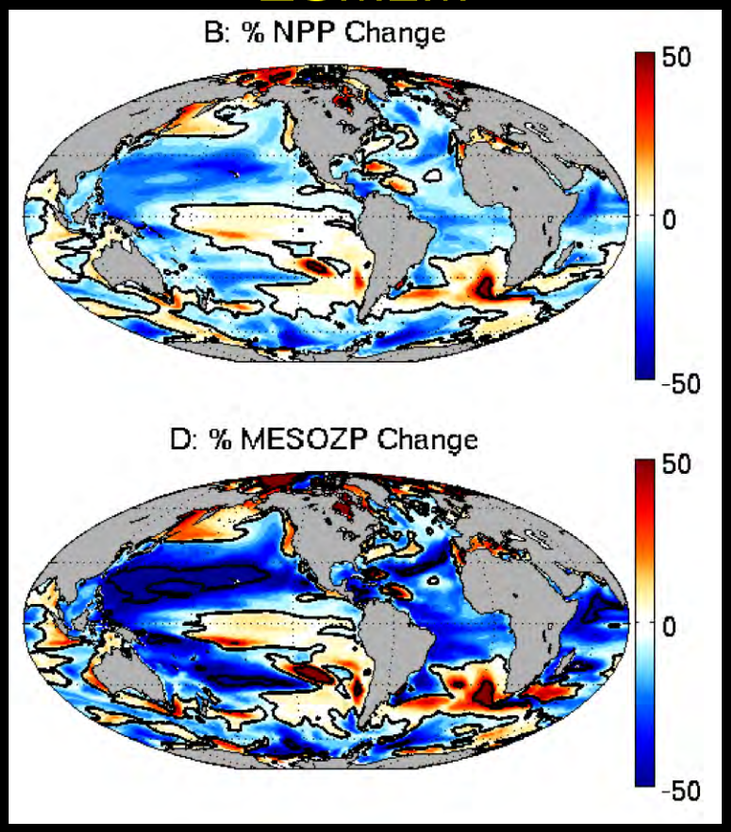


ROMS
CCS 7KM



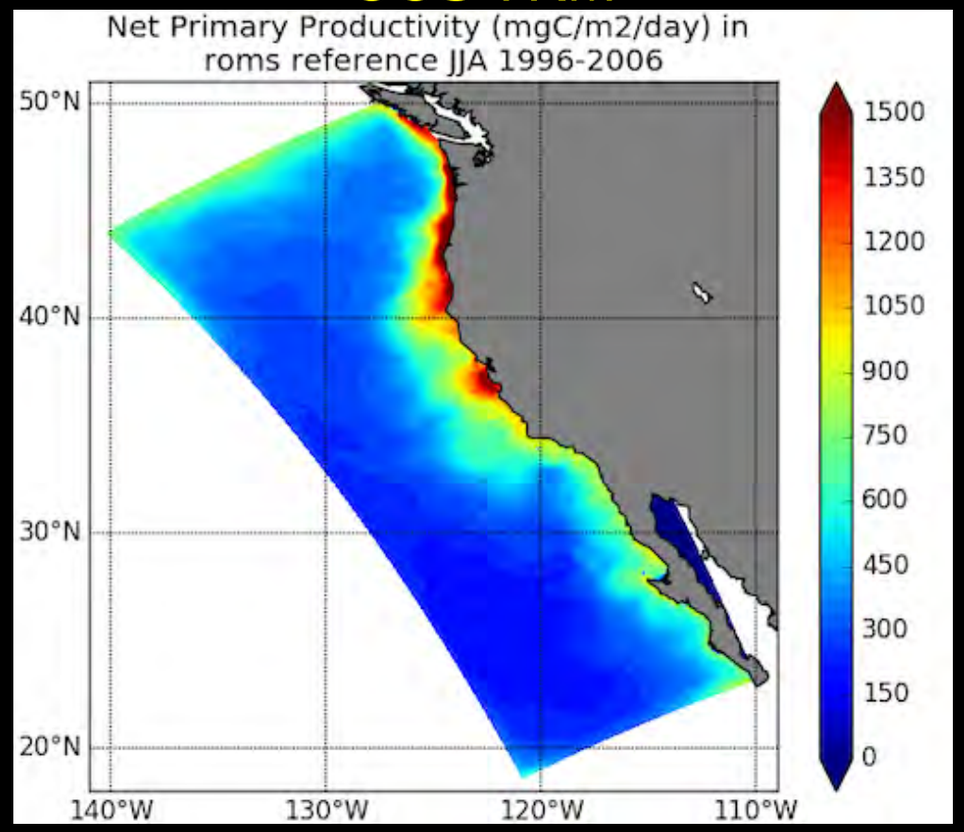
Approach:
Downscale couples models

GFDL
ESM2M



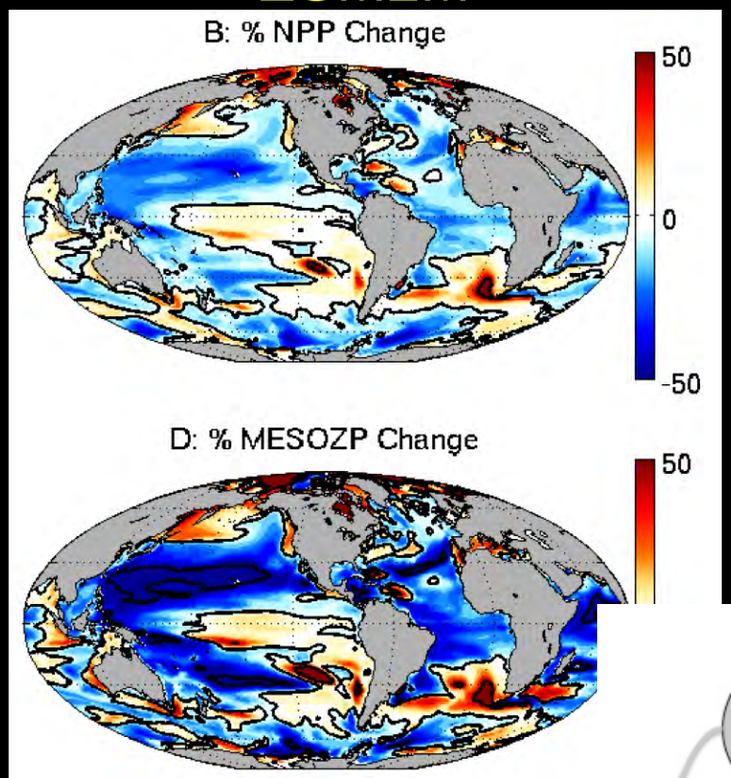
Dynamical downscaling of
Physics and BGC

ROMS
CCS 7KM



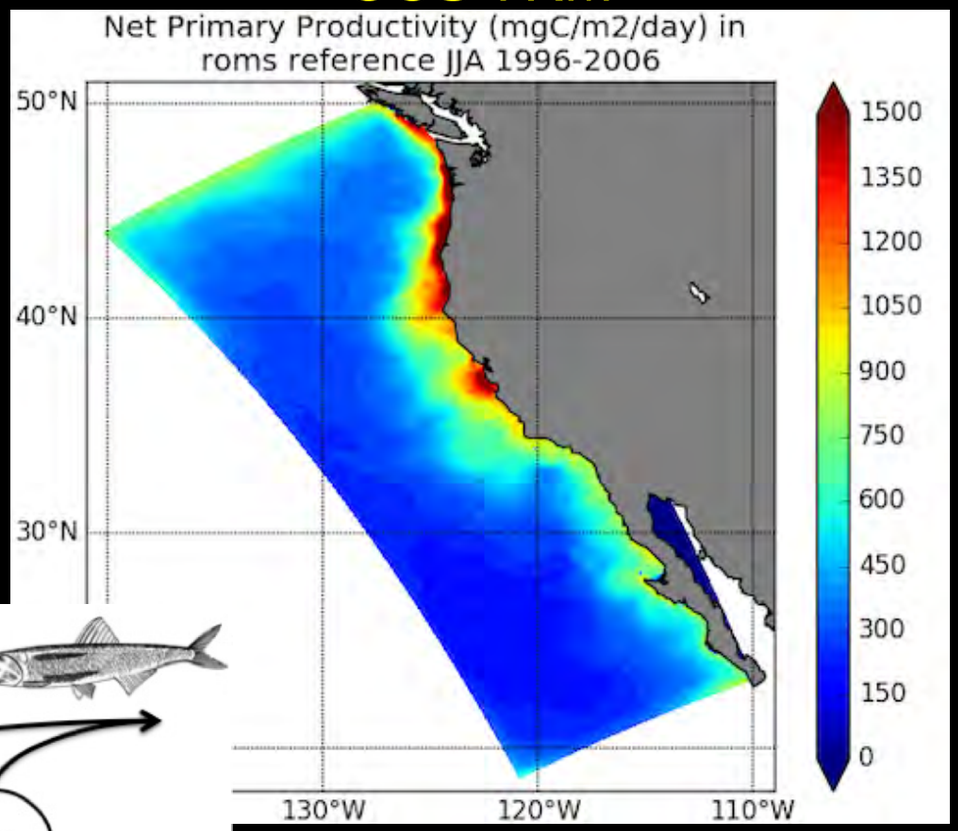
Approach:
Downscale couples models

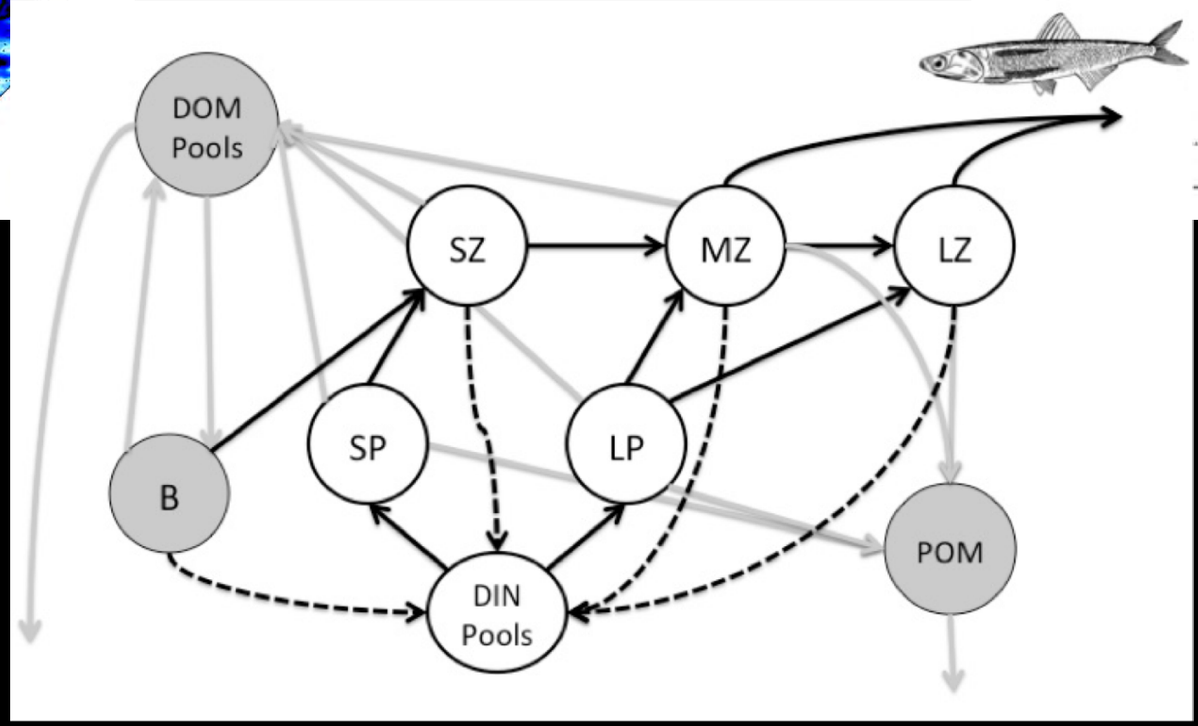
GFDL
ESM2M



Dynamical downscaling of
Physics and BGC

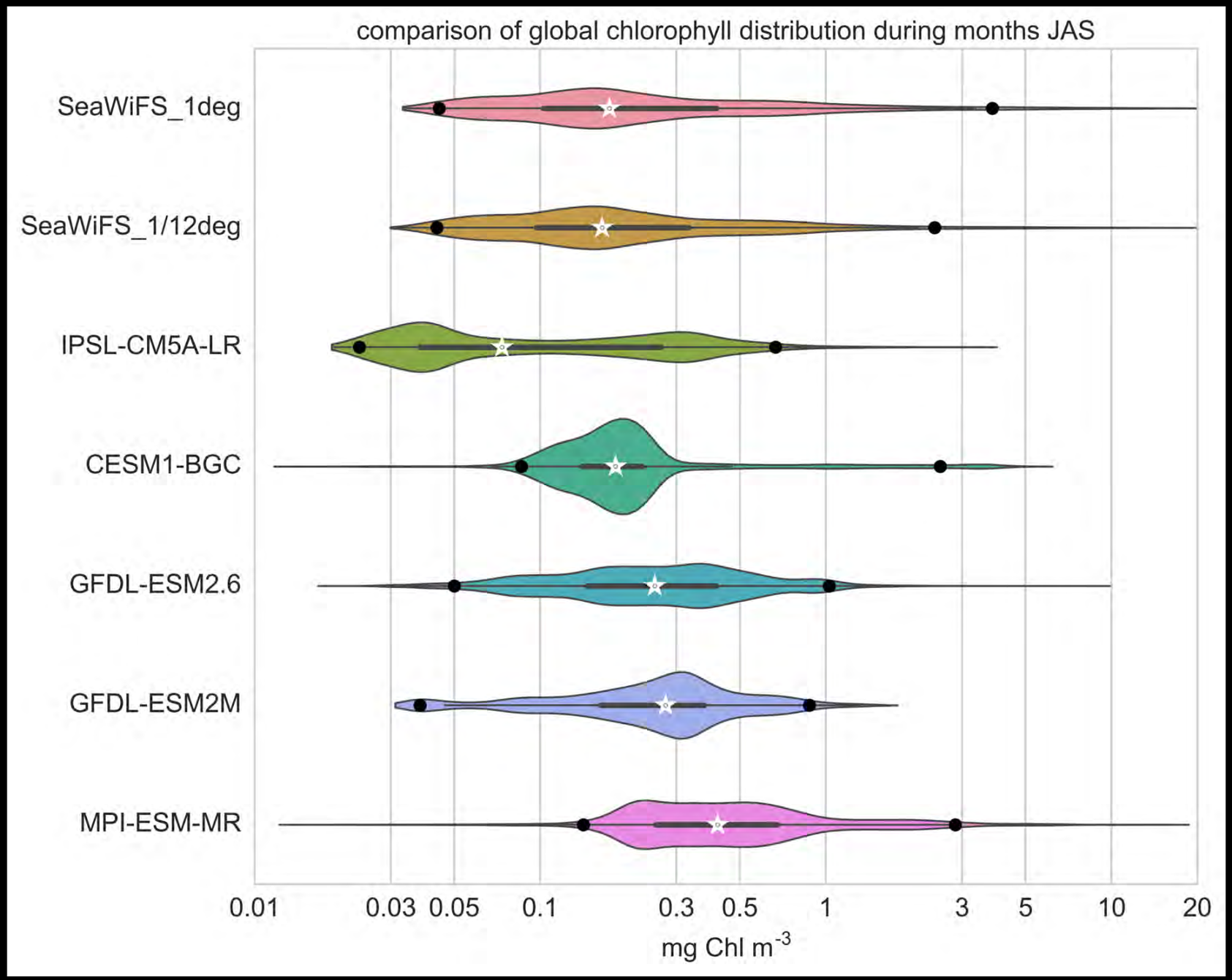
ROMS
CCS 7KM





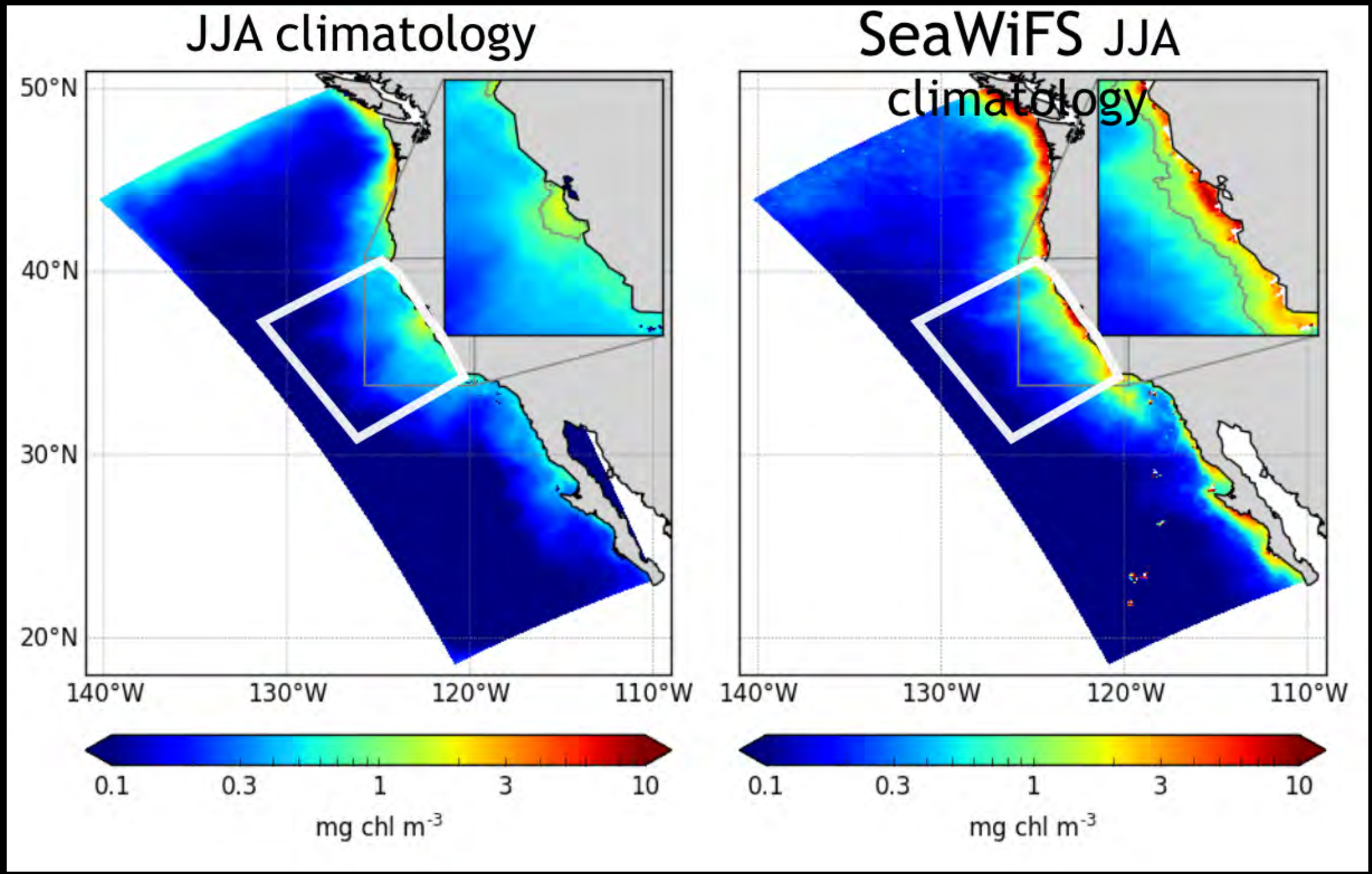
COBALT

Climate model biases: Chlorophyll

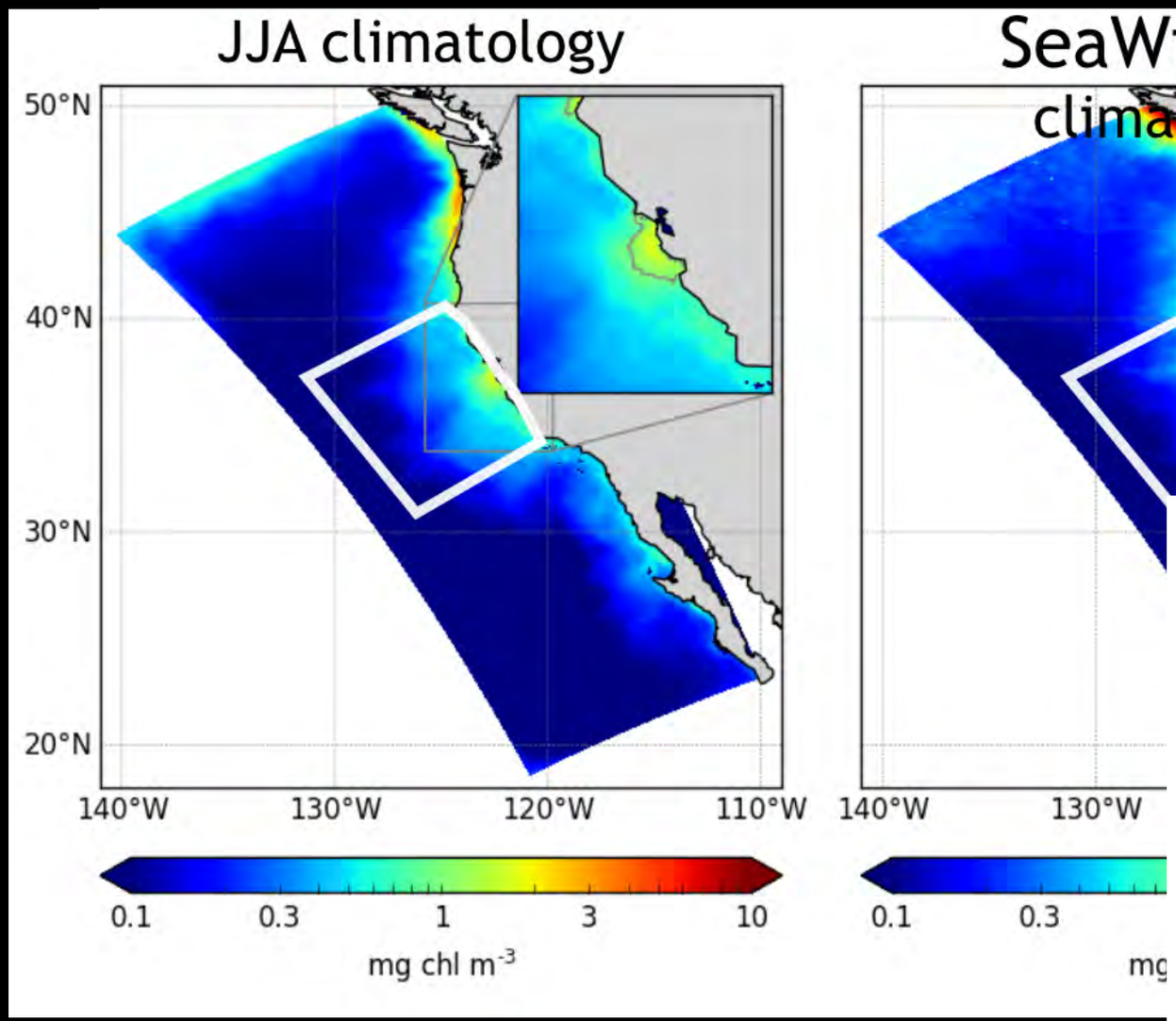


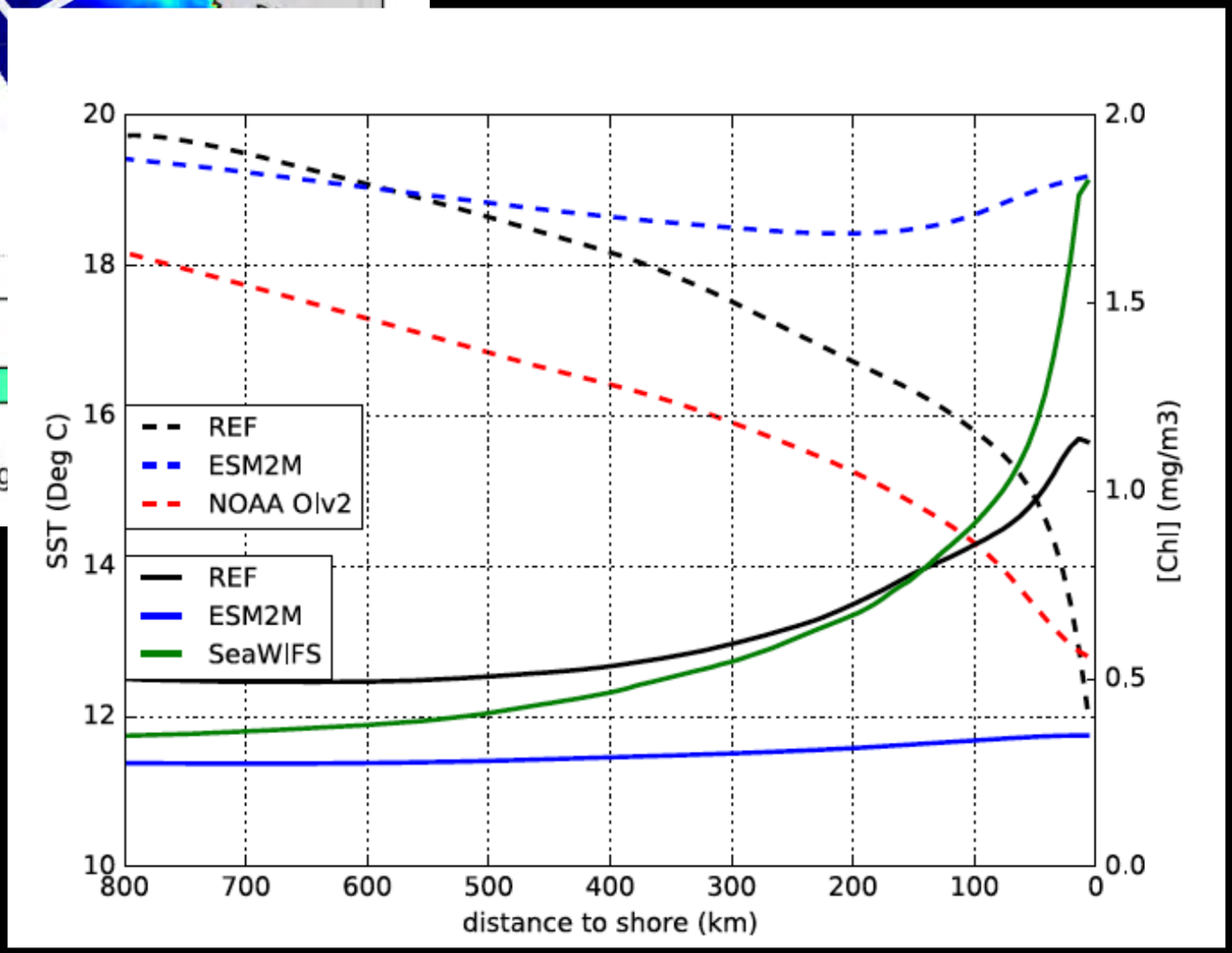
Van Oostende et al., (2018). Prog. Oce. *Sub Judice*

Implementation in the California Current



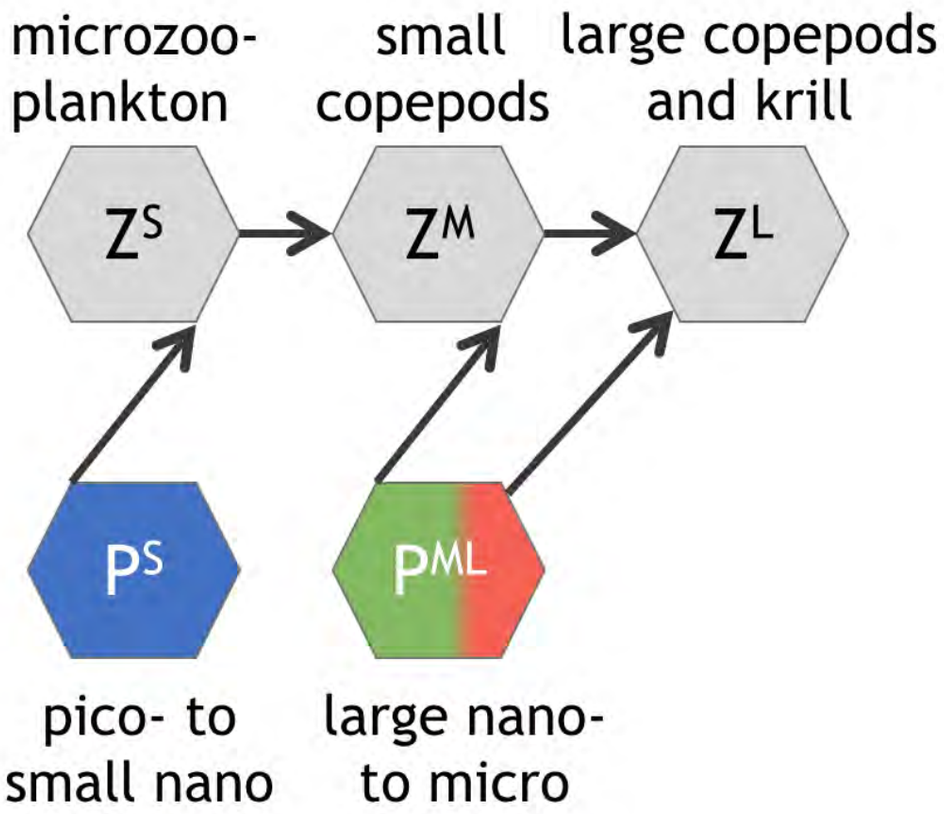
Implementation in the California Current





Adding coastal diatoms

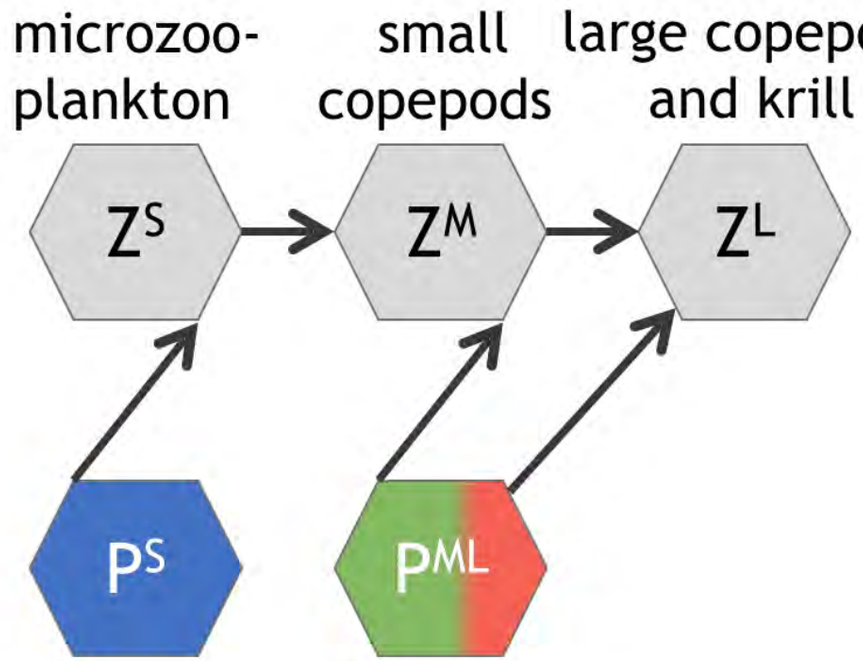
original COBALT 2PS model configuration



2 phytoplankton size classes

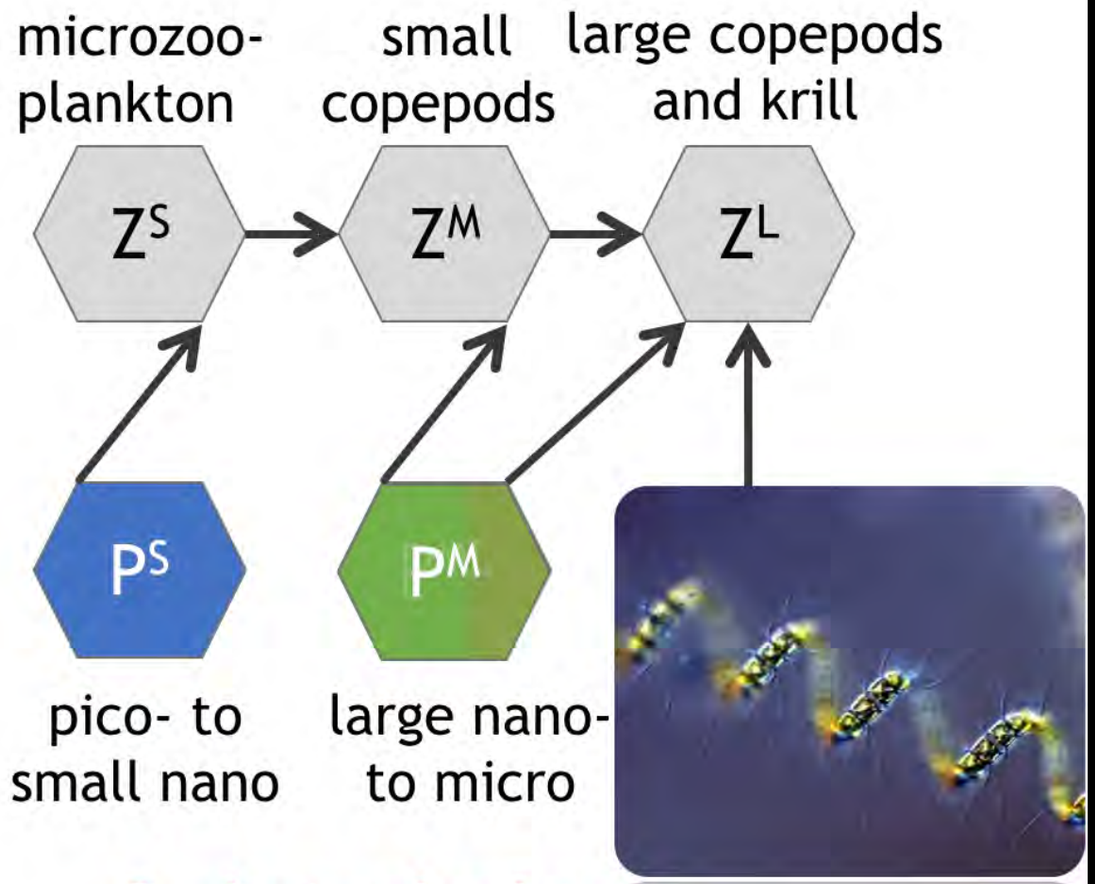
Adding coastal diatoms

original COBALT 2PS model configuration



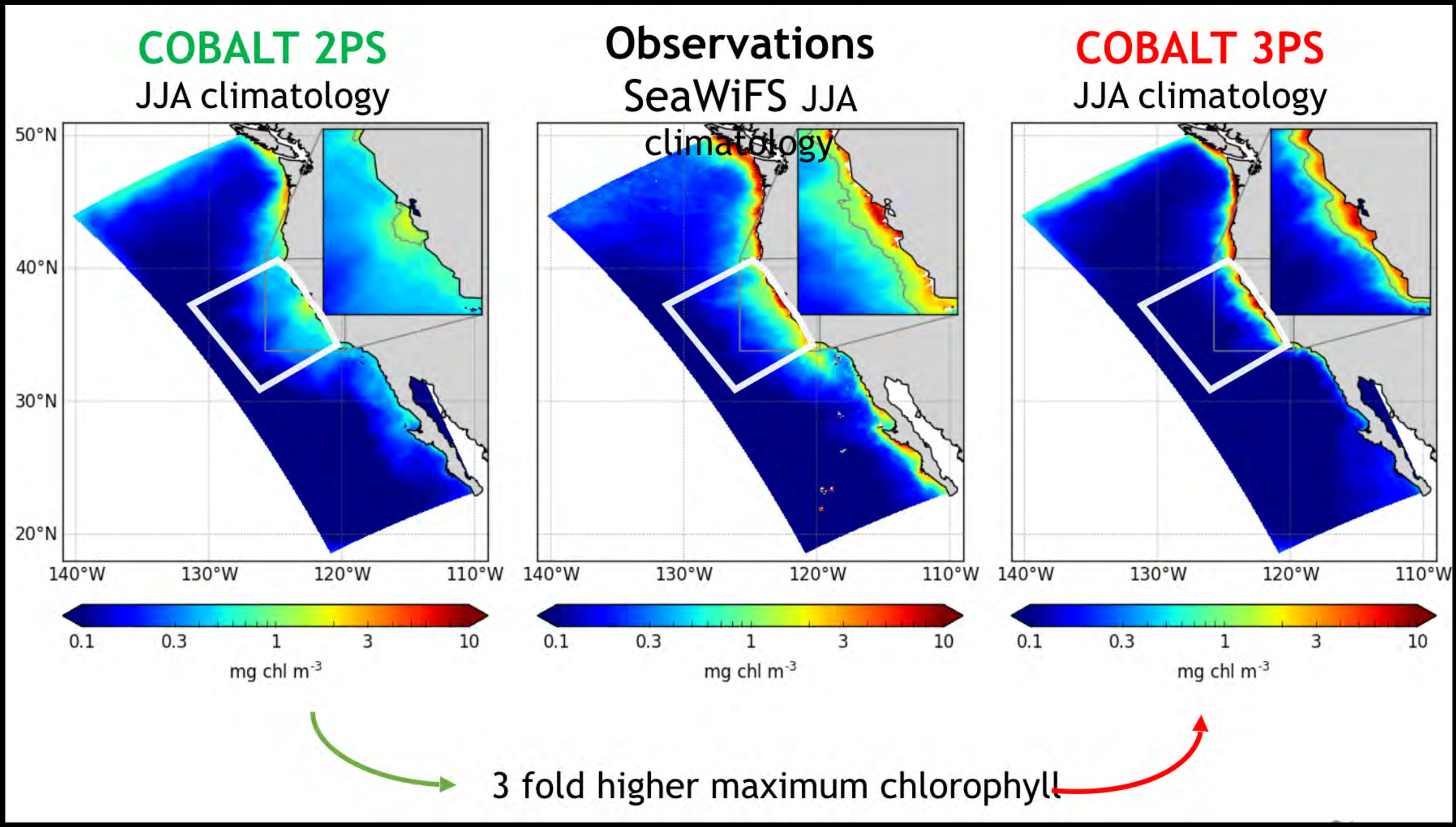
2 phytoplankton size classes

augmented COBALT 3PS model configuration



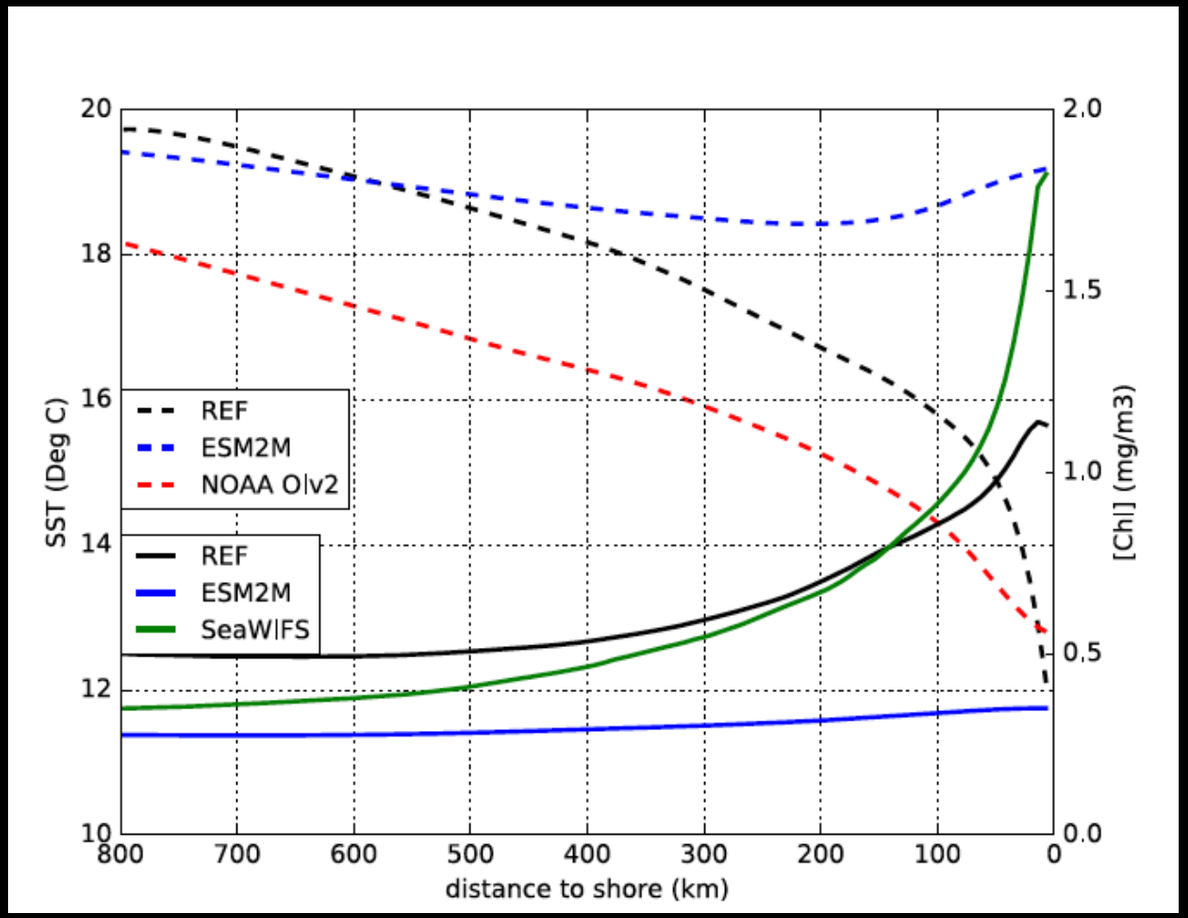
3 phytoplankton size classes

Implementation in the California Current

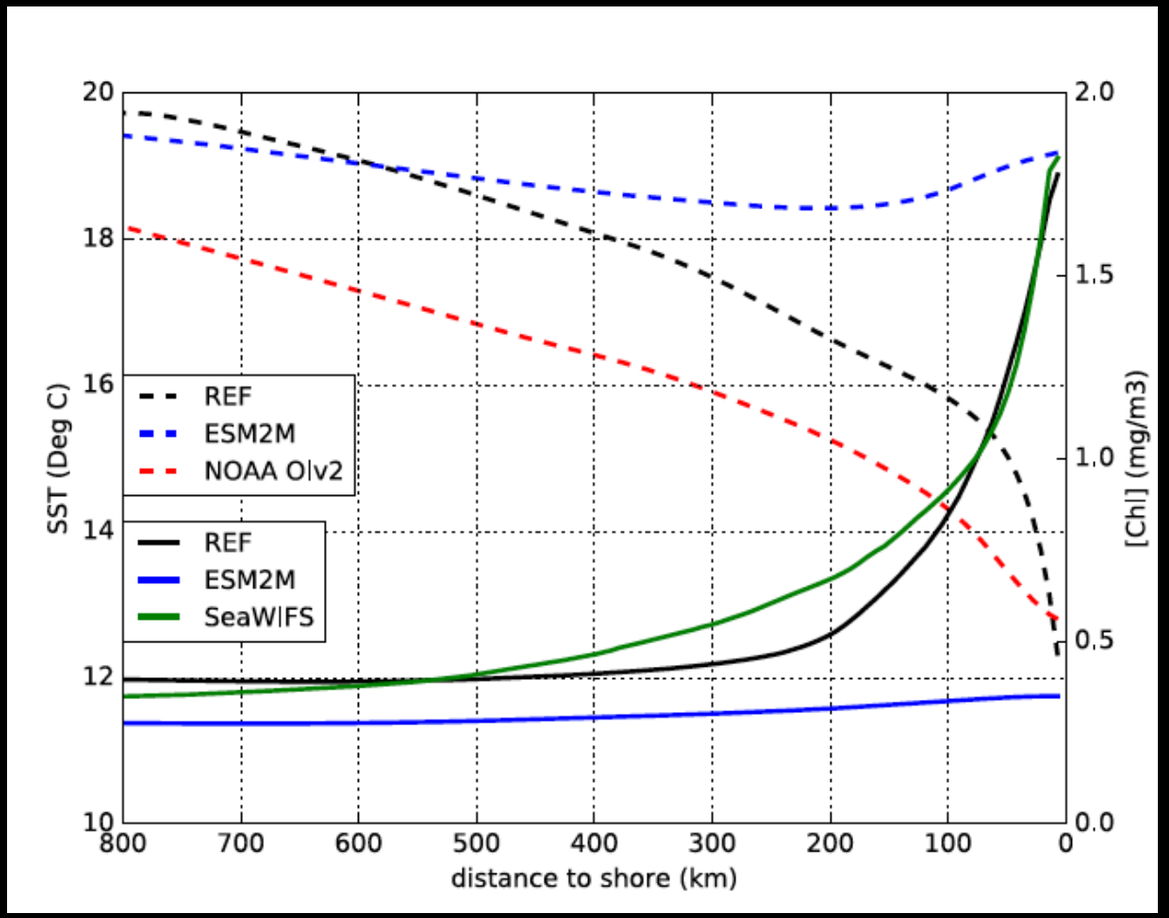


Impact of improved physics and BGC

COBALT-2P

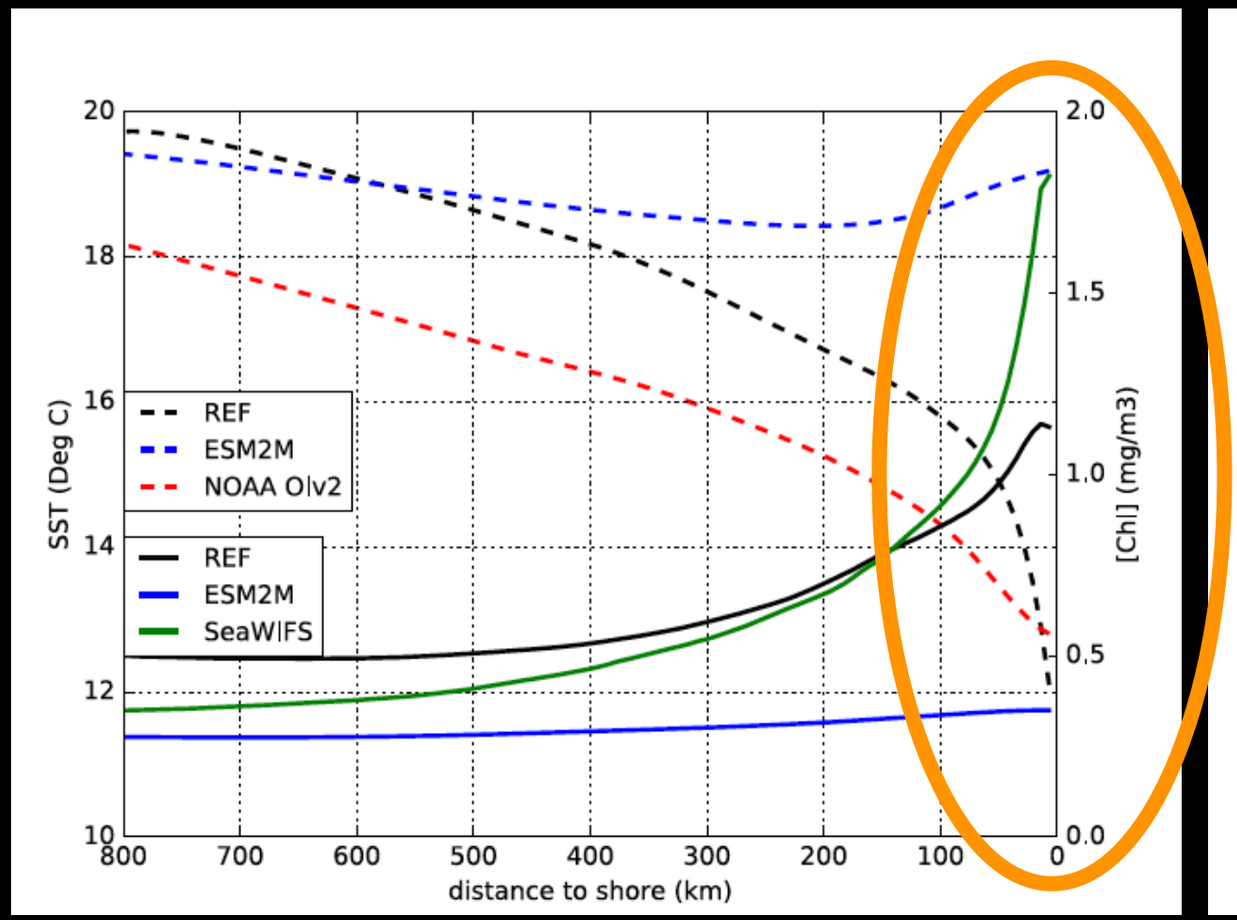


COBALT-3P

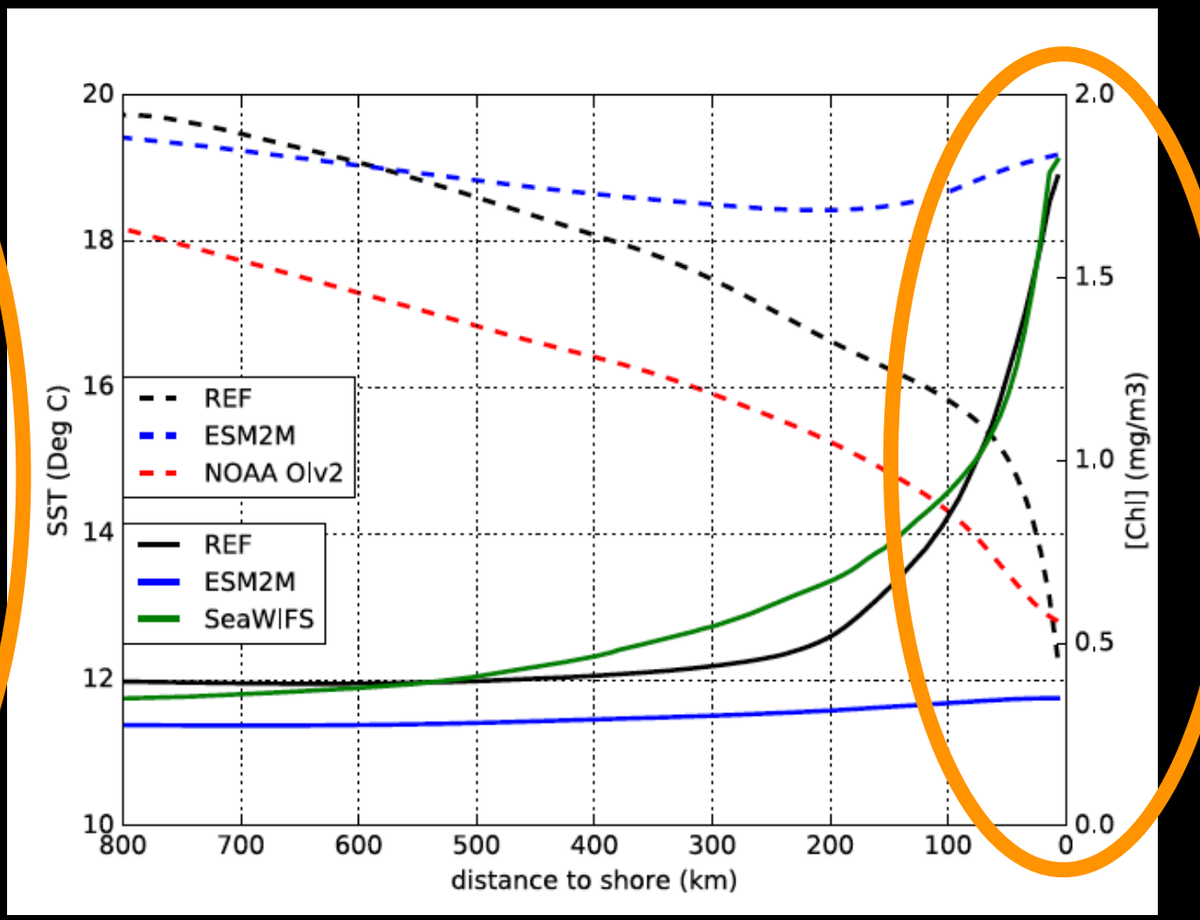


Impact of improved physics and BGC

COBALT-2P

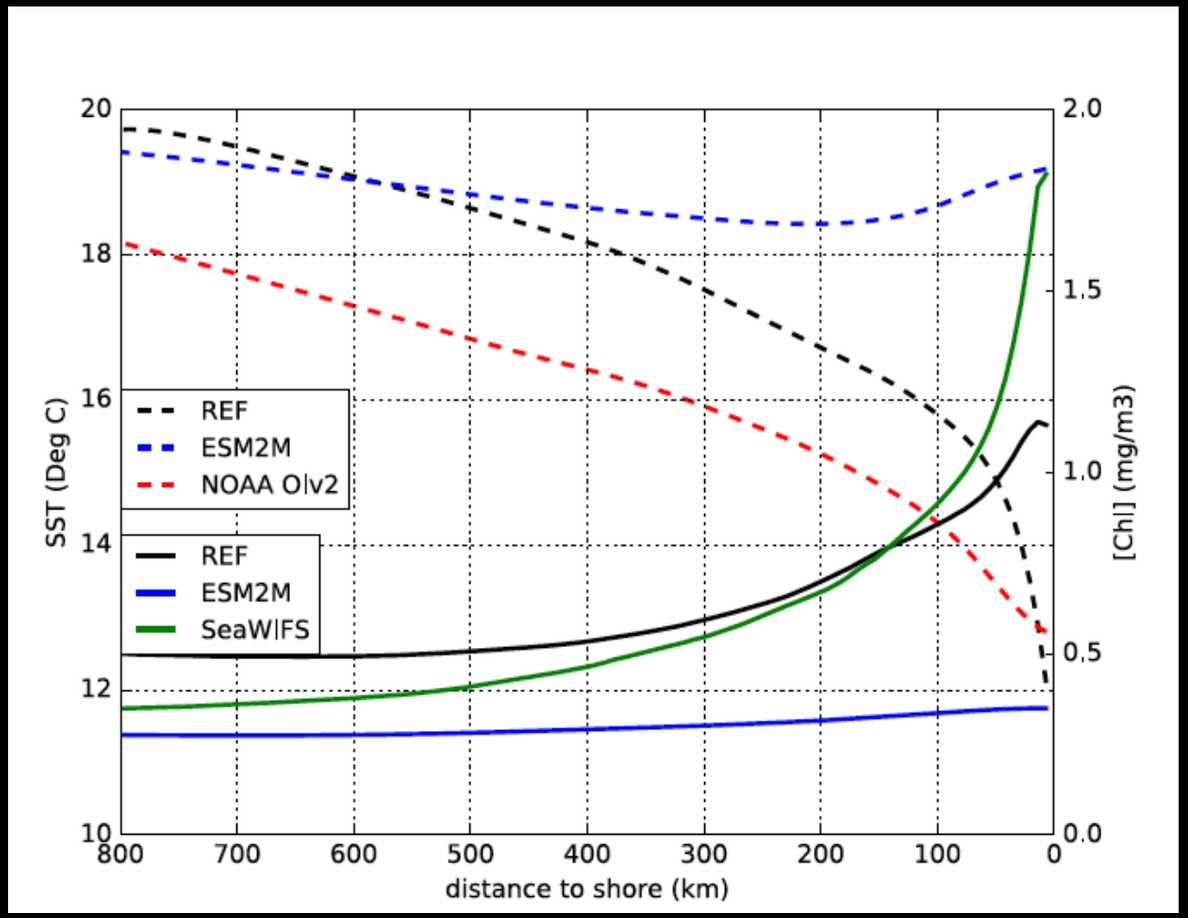


COBALT-3P

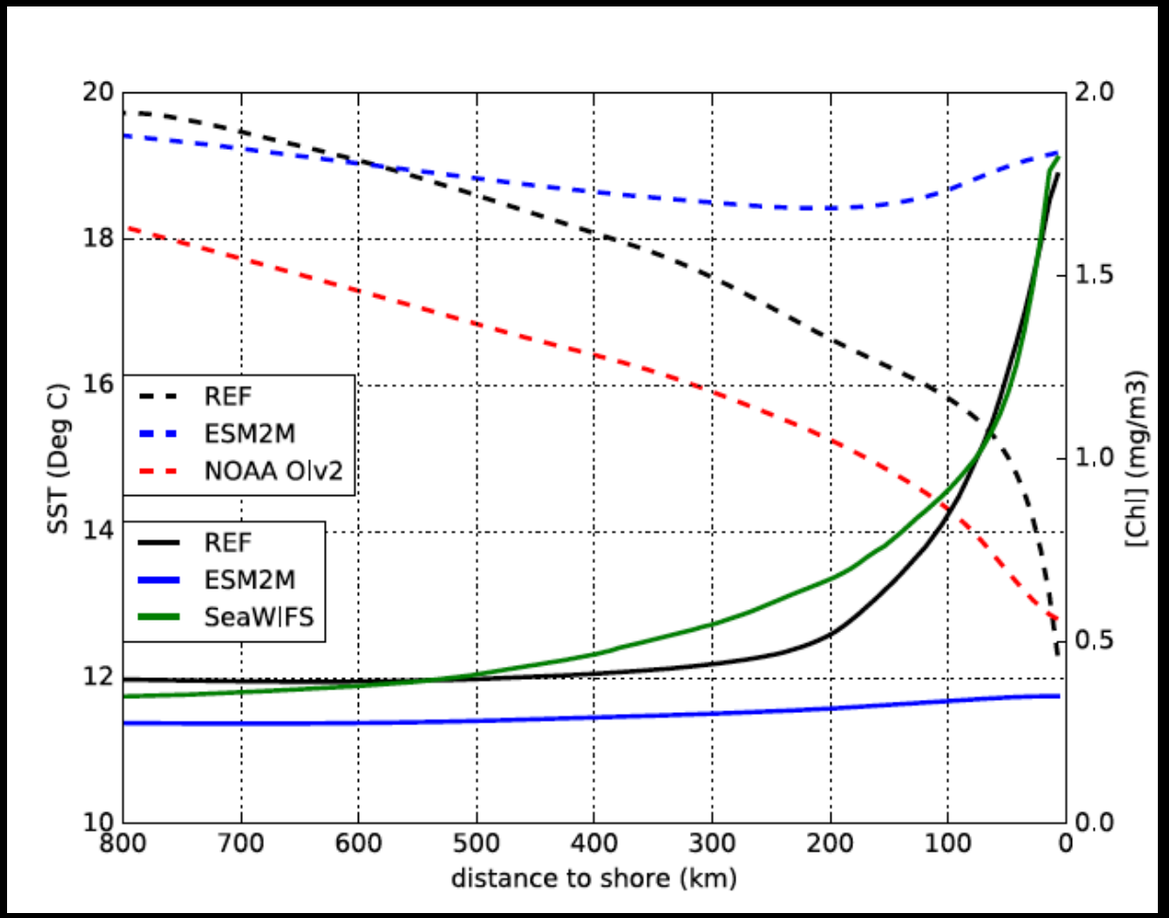


Impact of improved physics and BGC

COBALT-2P

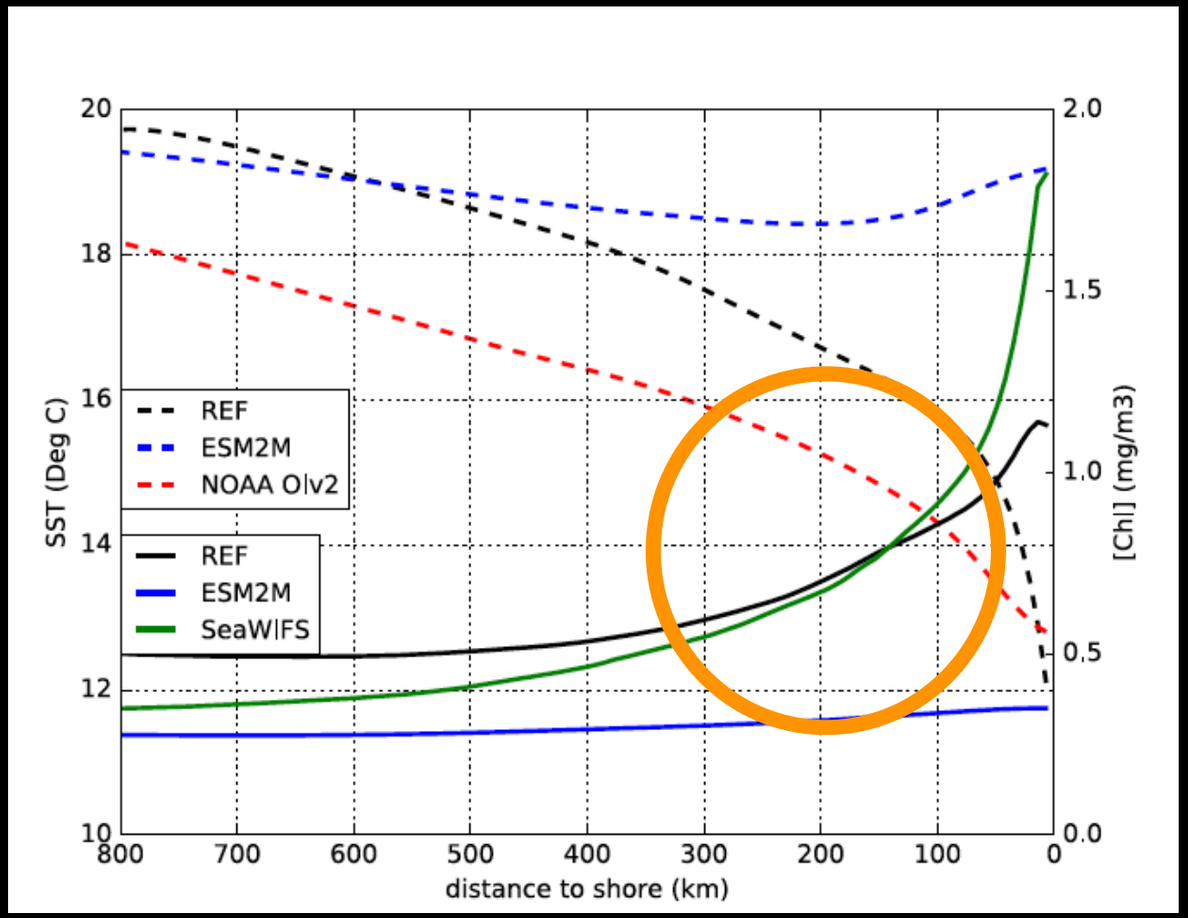


COBALT-3P

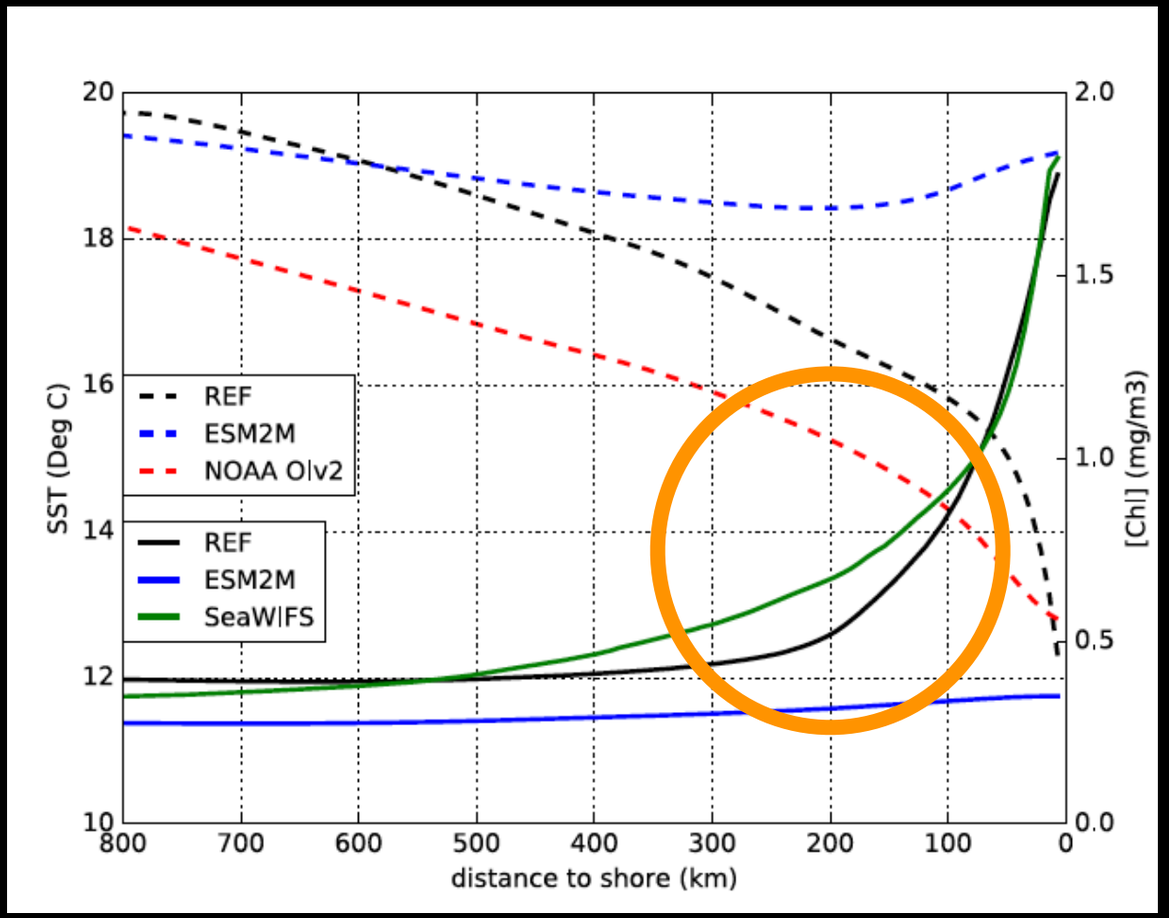


Impact of improved physics and BGC

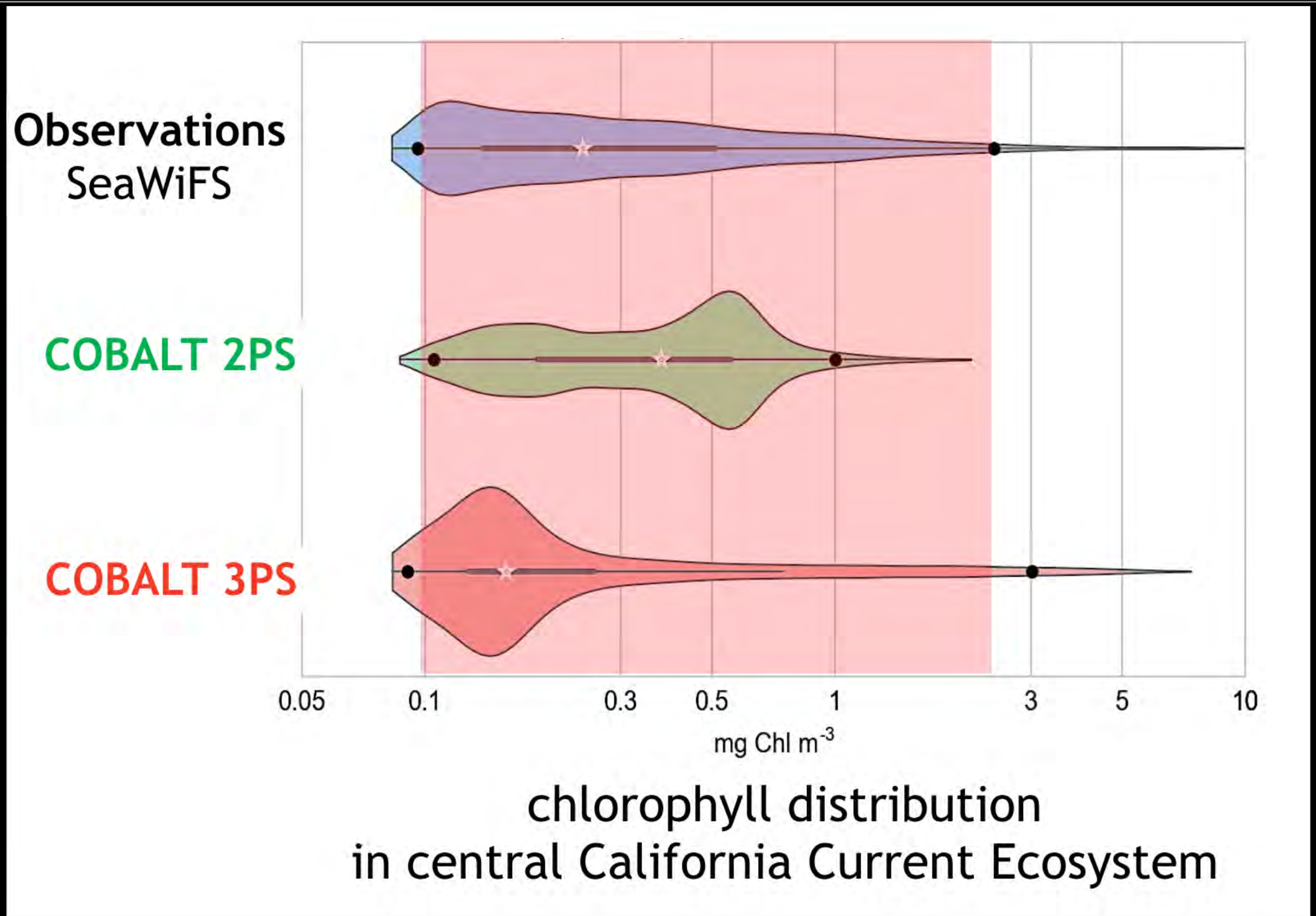
COBALT-2P



COBALT-3P

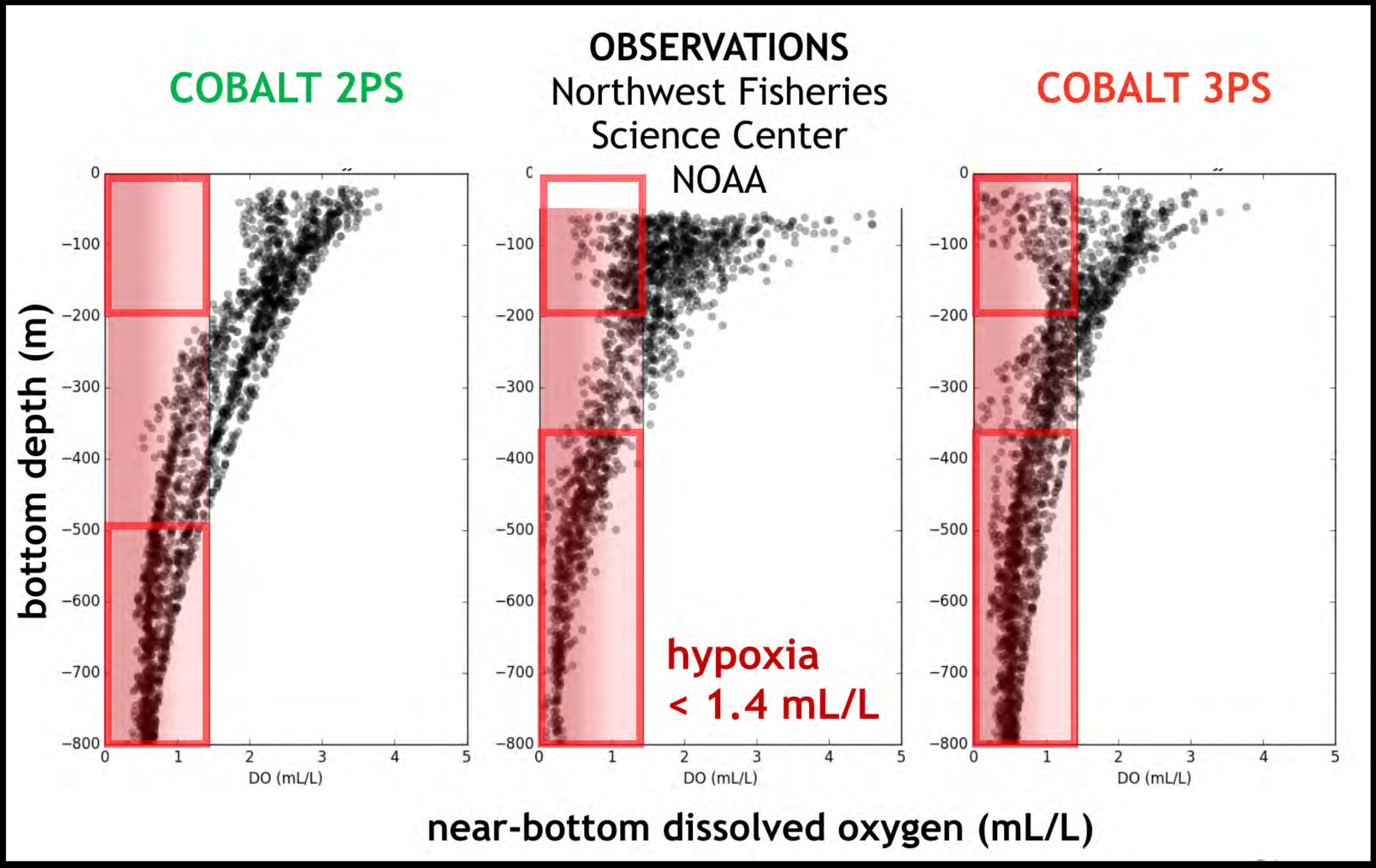


Chlorophyll distributions



chlorophyll distribution
in central California Current Ecosystem

Impact on oxygen concentrations

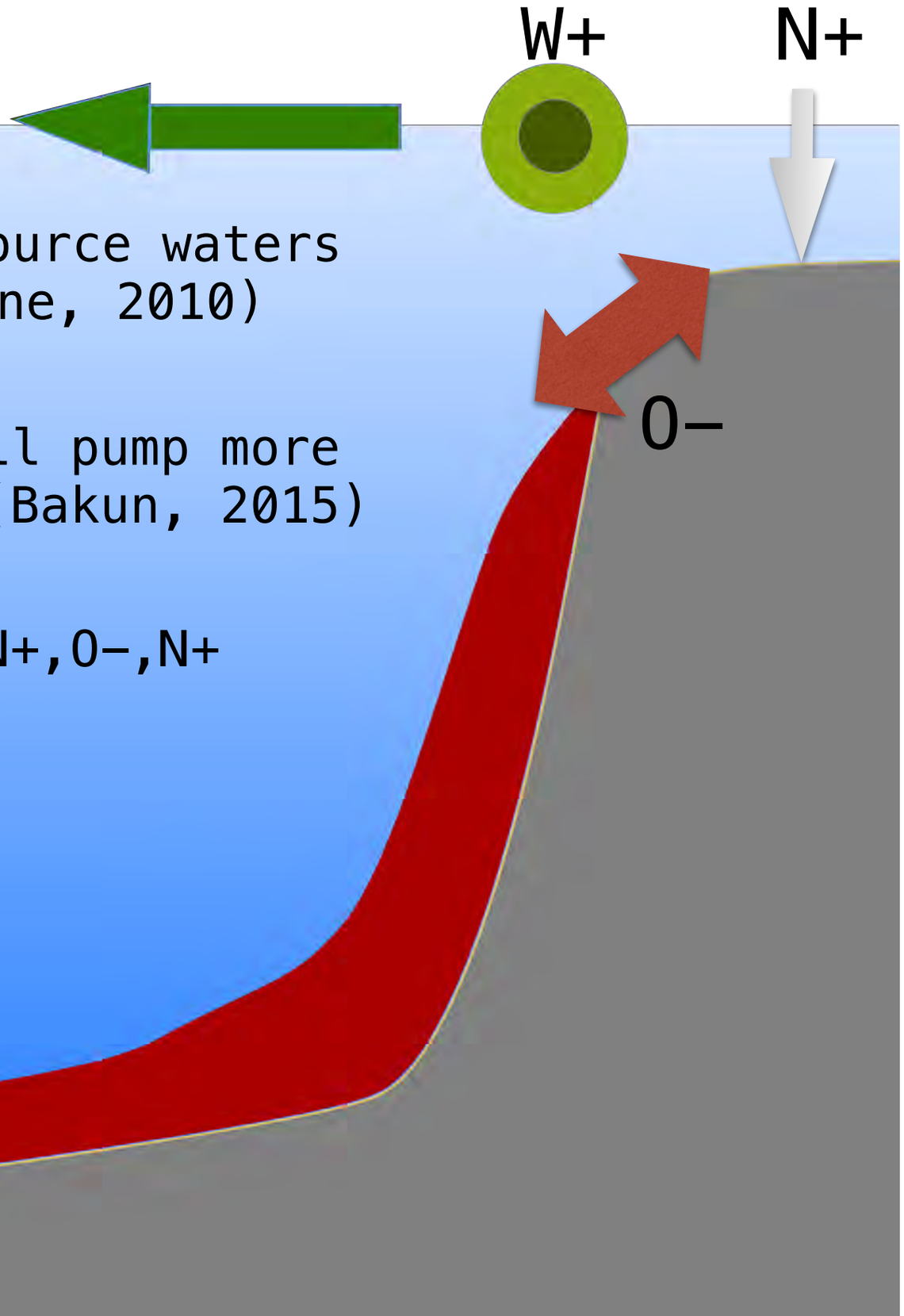


Testing drivers of coastal hypoxia

Projected nutrient enrichment from source waters will increase NPP (Rykaczewski & Dunne, 2010)

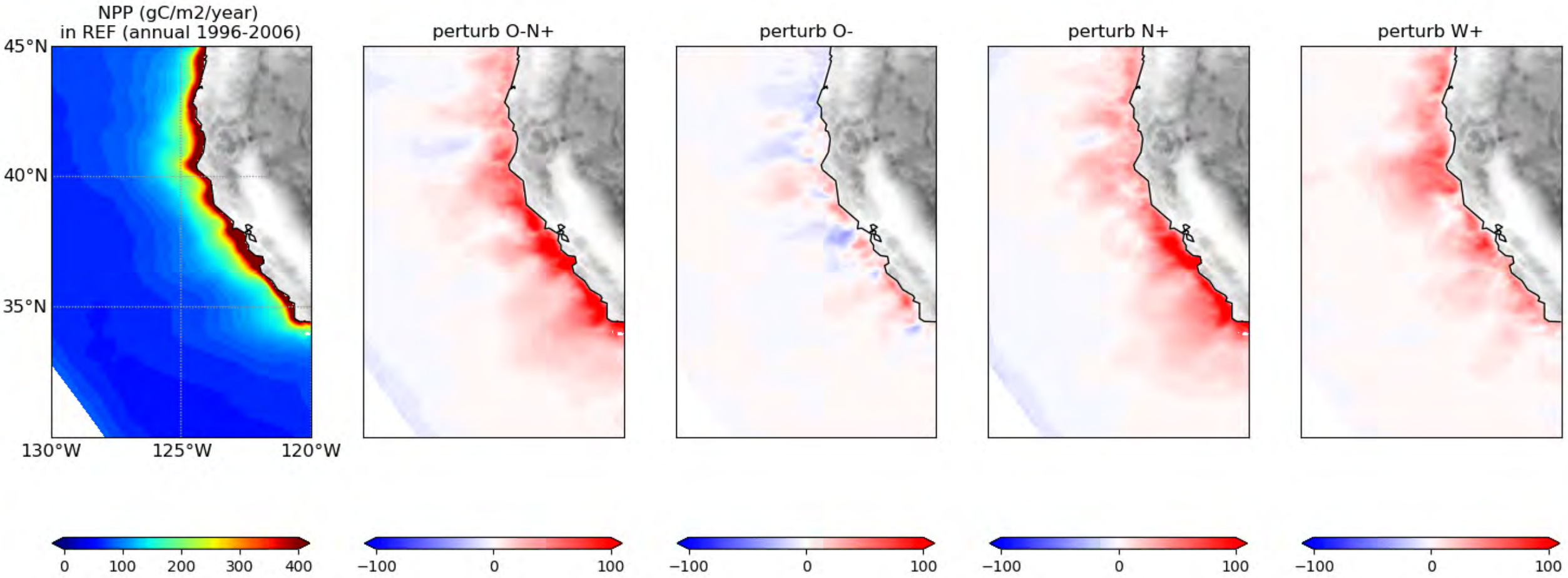
Upwelling favorable wind increase will pump more nutrients, increase NPP and hypoxia (Bakun, 2015)

Perturbations from ESM2M-COBALT : O-N+,O-,N+
+10% on southward wind in JJAS : W+



EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

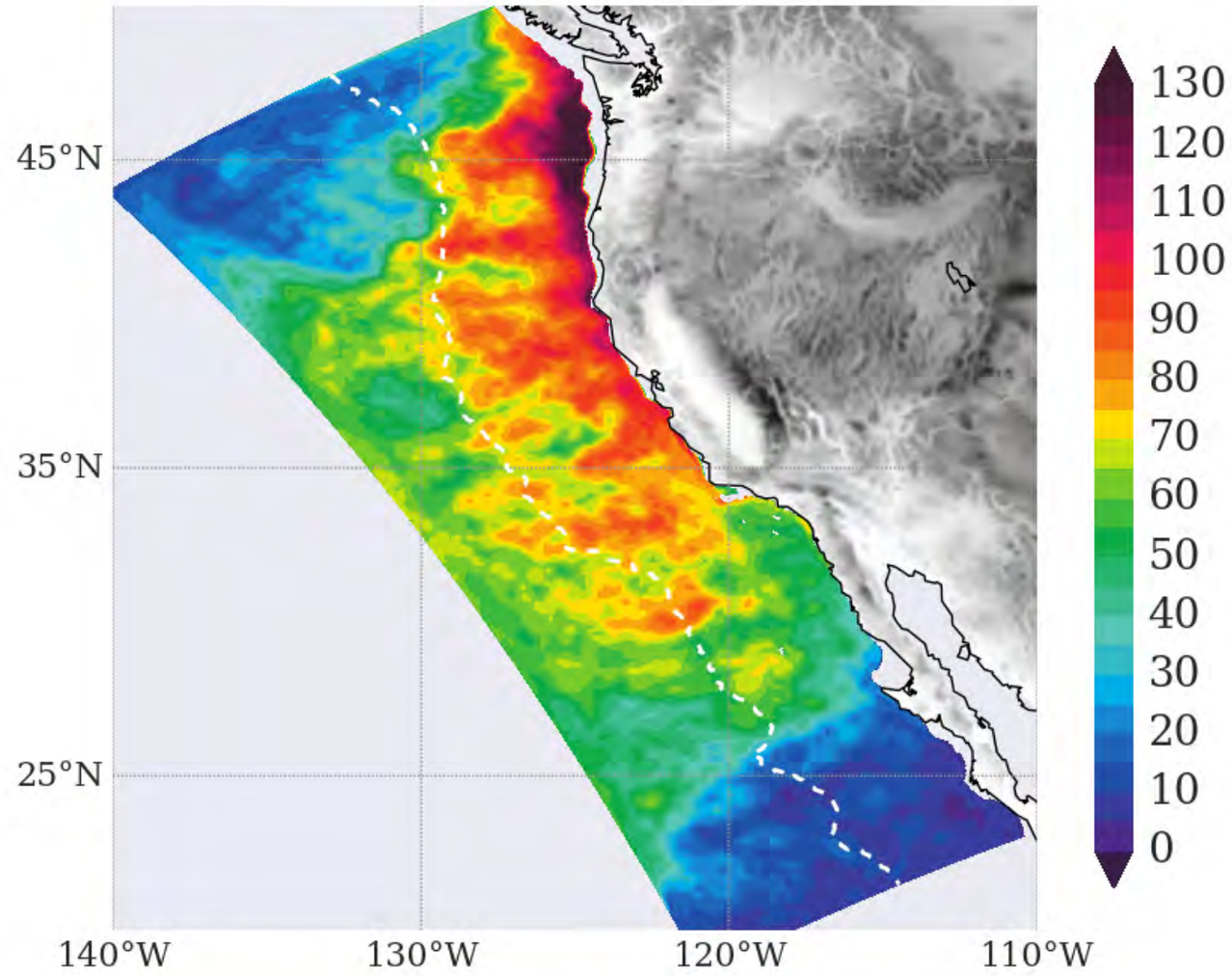
A more productive coastal ocean

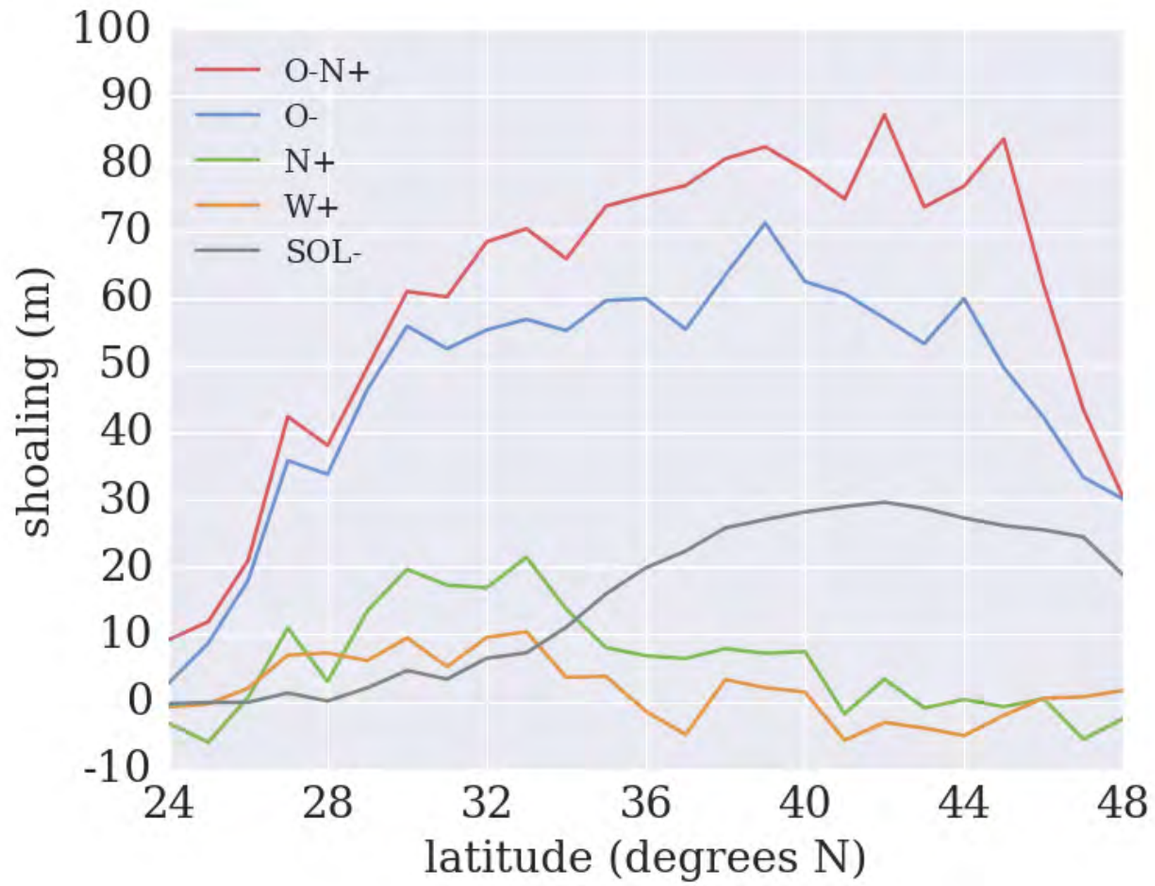


- Results consistent with ESM2M
- The BGC perturbations capture trend of RCP 8.5
- Most of NPP increase in O-N+ comes from N+
- Increase upwelling wind produces a lesser amount of NPP

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Hypoxic Boundary respond mainly to DO perturbation





- Depth of hypoxic boundary = 200–500 meters
- Major changes to available habitat = –20 to –35%
- Driven by perturbation in DO profile
- Change in export fluxes limited to first 200km

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Summary

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Summary

- Resolution is important…but not the only concern

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Summary

- Resolution is important…but not the only concern
- Eutrophication is most effective in driving coastal NPP

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY

Summary

- Resolution is important…but not the only concern
- Eutrophication is most effective in driving coastal NPP
- Global decrease in ocean DO is main source for coastal hypoxia in the CCS

EARTH SYSTEM MODELING
at RUTGERS UNIVERSITY