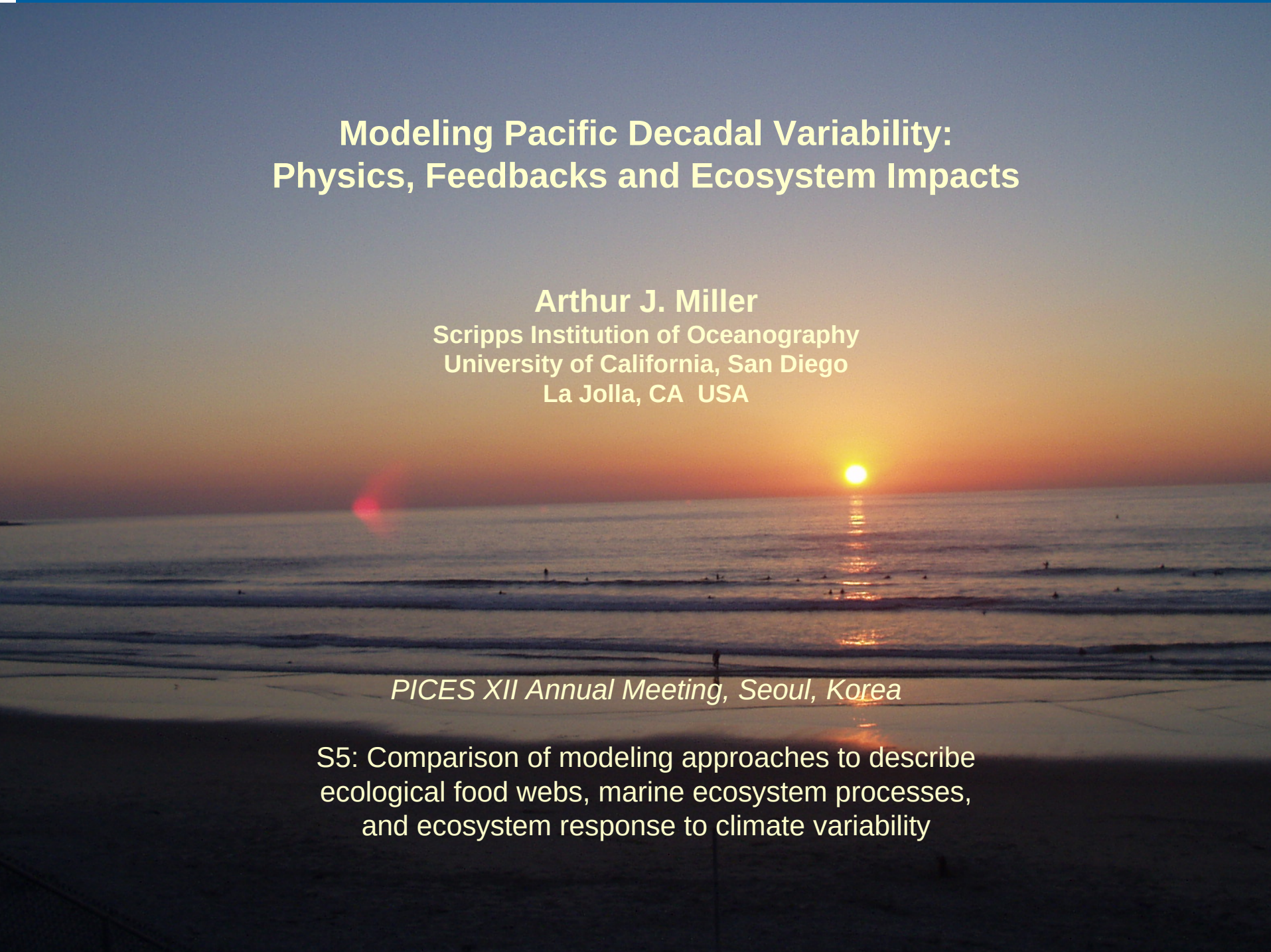


Modeling Pacific Decadal Variability: Physics, Feedbacks and Ecosystem Impacts

Arthur J. Miller
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, CA USA

PICES XII Annual Meeting, Seoul, Korea

S5: Comparison of modeling approaches to describe ecological food webs, marine ecosystem processes, and ecosystem response to climate variability

Modeling Pacific Decadal Variability: Physics, Feedbacks and Ecosystem Impacts

Outline

1. Physics that organizes the patterns of Pacific ocean decadal variability
2. Some interesting new results concerning mechanisms
3. Relations to our current research on ecosystem response

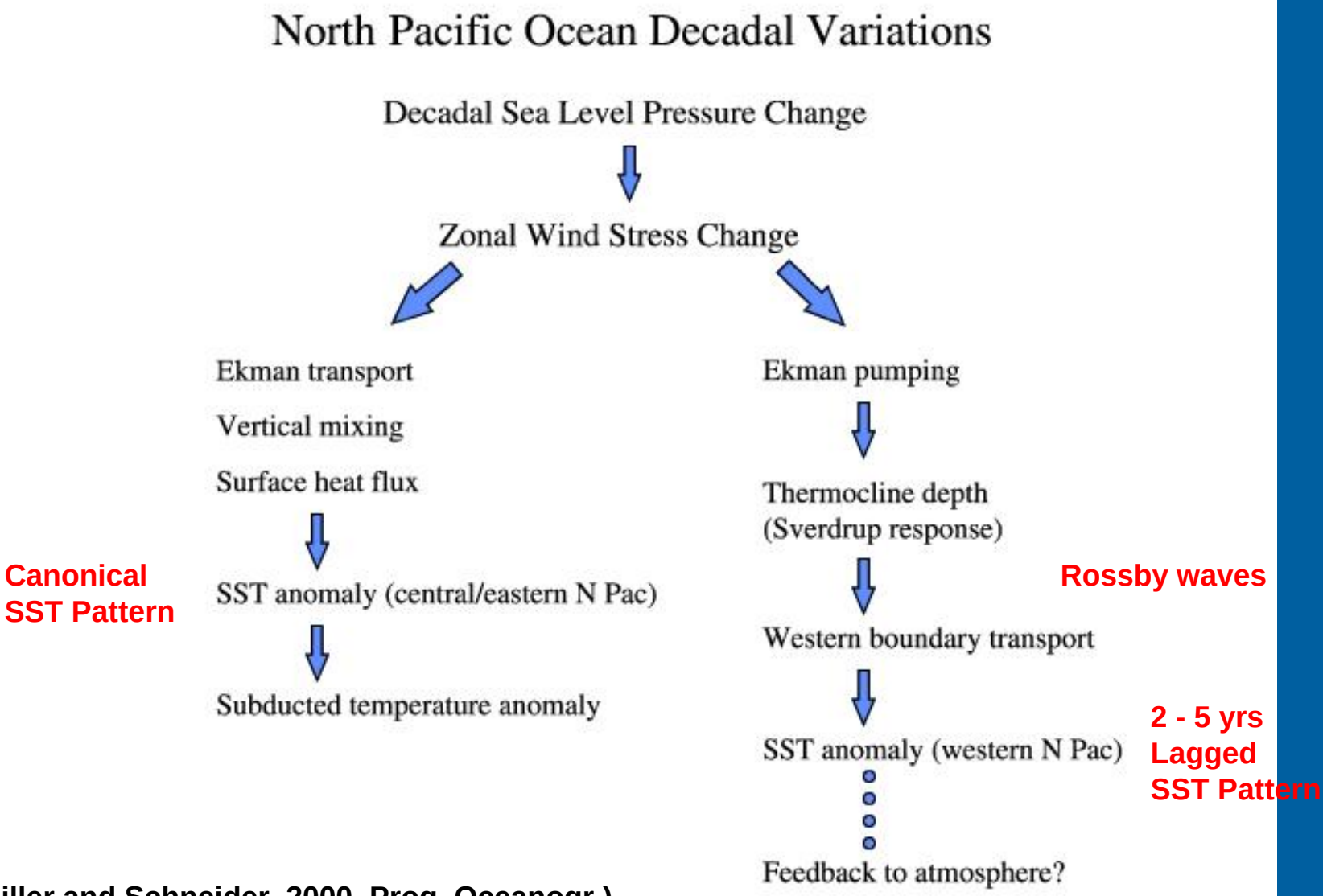
Recent Collaborators

Physics: Schneider, Di Lorenzo, Cornuelle, Pierce, Bograd, Schwing, Mendelssohn, Alexander, Capotondi, Lynn, McWilliams, Mestas-Nunez

Biology: Moisan, McGowan, Neilson, Chai, Chiba, Gabric

Funding: NSF, NASA, NOAA, DOE, ONR

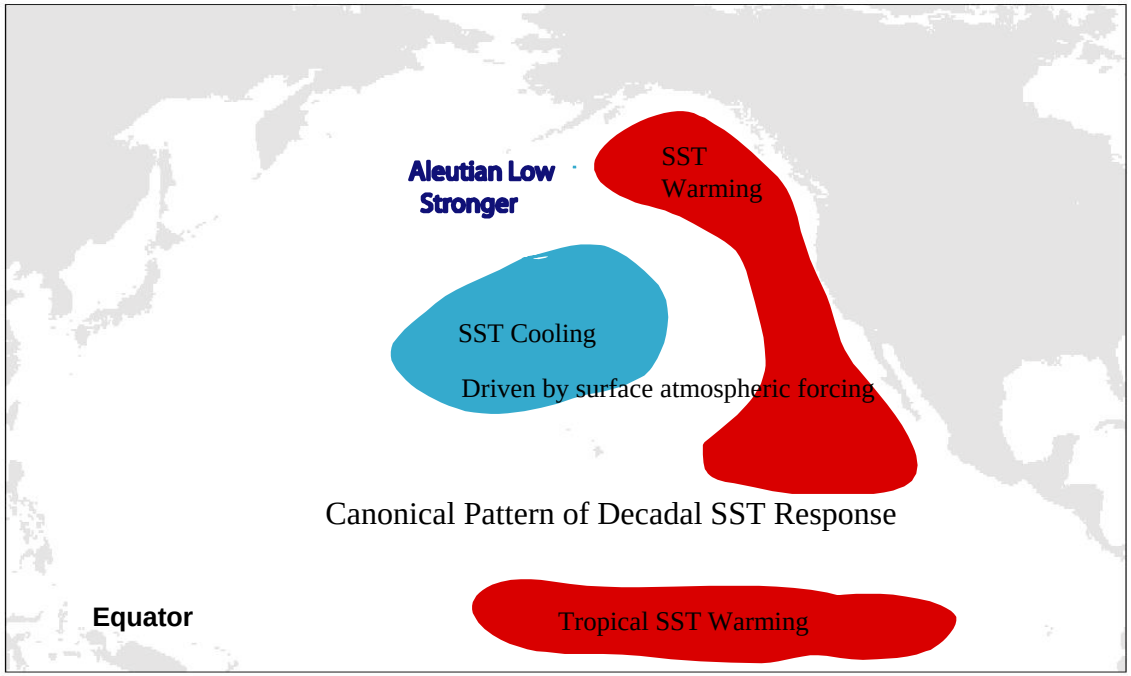
Schematic of Pacific Oceanic Response to Decadal Forcing by the Aleutian Low



(Miller and Schneider, 2000, Prog. Oceanogr.)

Canonical Pattern of Decadal SST Response (Aleutian Low Strengthening)

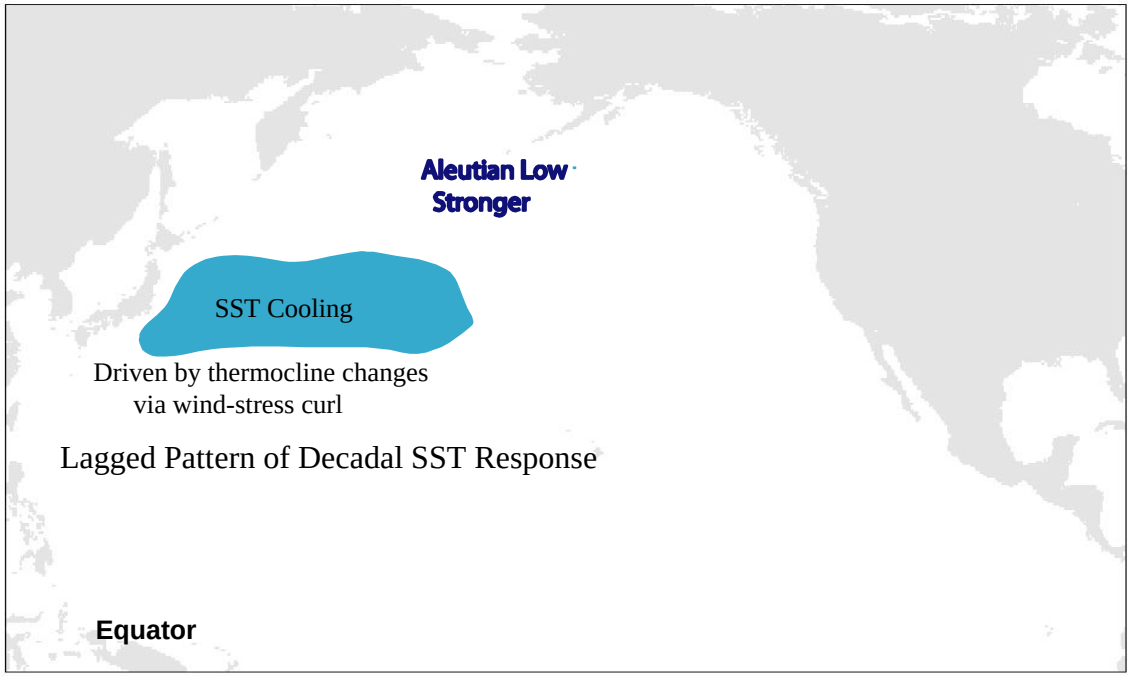
Schematic



From Miller, Chai, Chiba, Moisan and Neilson (2003, J Oceanogr.)

Lagged Pattern of Decadal SST Response (Aleutian Low Strengthening)

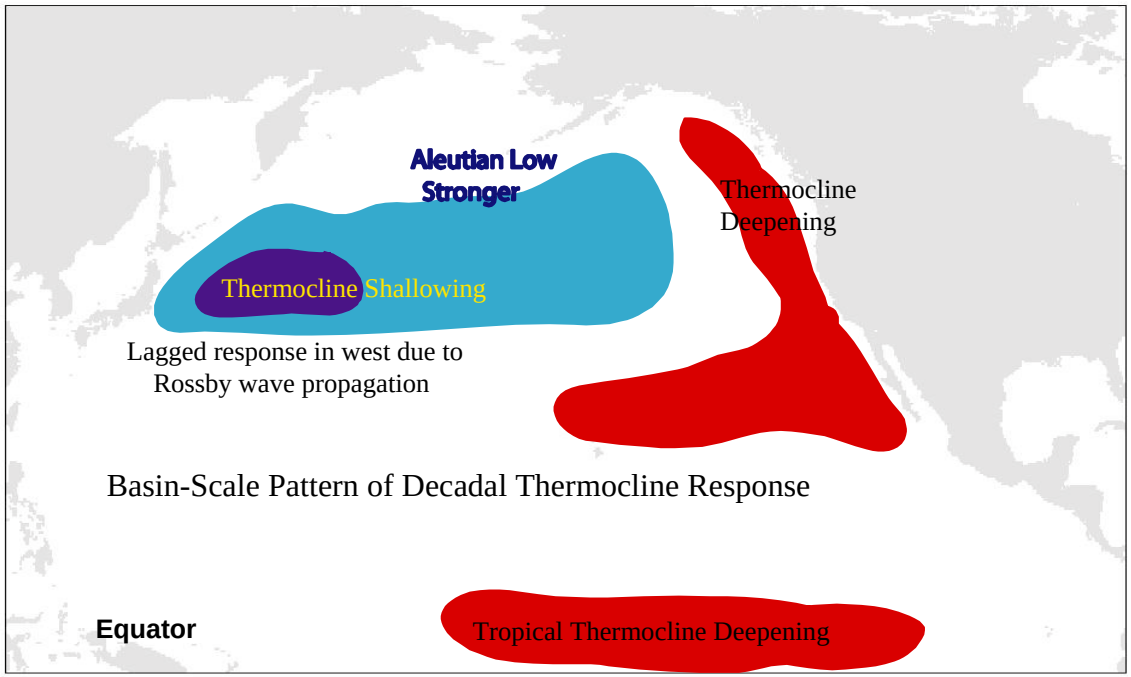
Schematic



From Miller, Chai, Chiba, Moisan and Neilson (2003, J Oceanogr.)

Basin-Scale Pattern of Decadal Thermocline Response (Aleutian Low Strengtherning)

Schematic



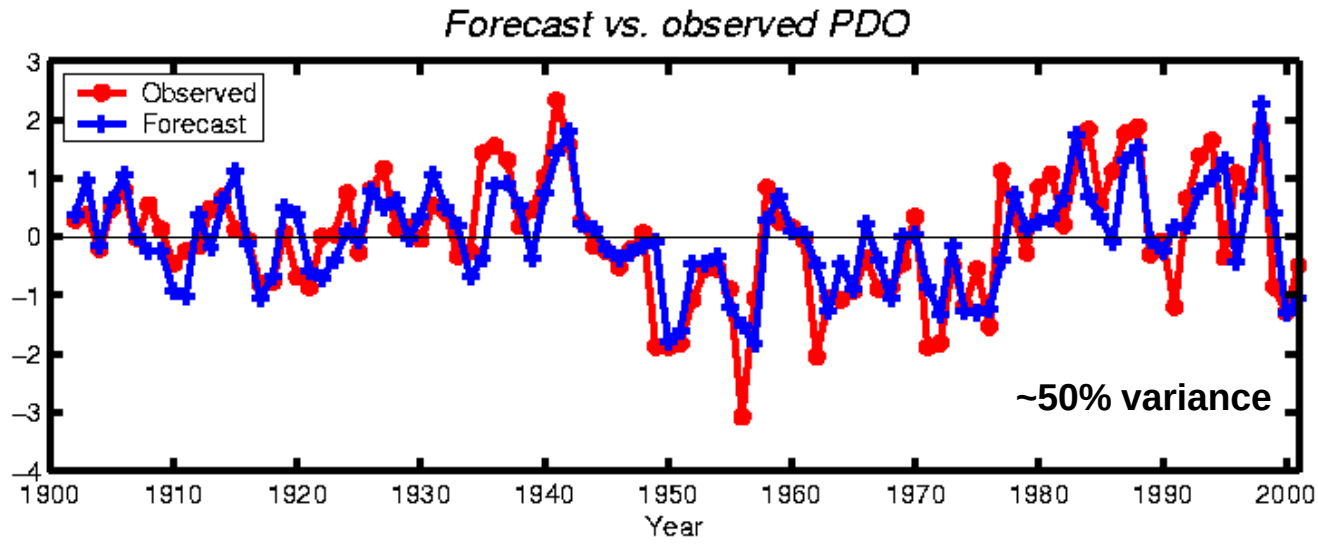
From Miller, Chai, Chiba, Moisan and Neilson (2003, J Oceanogr.)

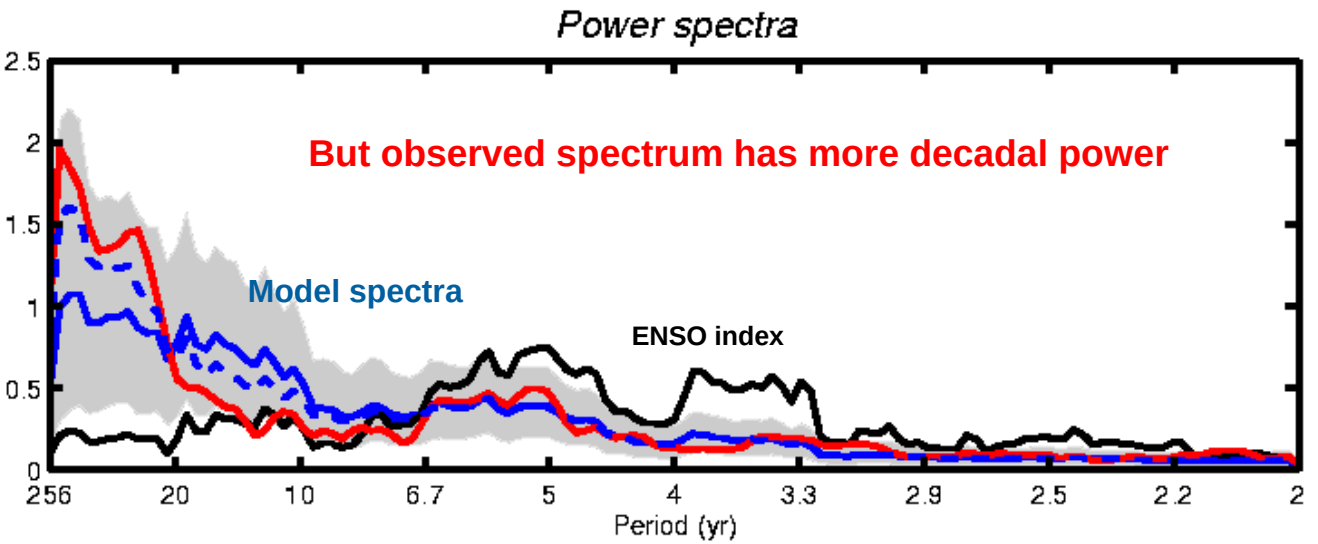
Sources of North Pacific Decadal Variability

1. **Tropical Teleconnections (requires tropical decadal mechanism)**
   - **a. Atmospheric (ENSO-like)**
     - **canonical SST pattern**
     - **basin-scale thermocline response**
   - **b. Oceanic (ENSO-like)**
     - **eastern boundary thermocline response**

Simple ENSO-forced PDO Model (Newman et al., 2003, J Climate)

PDO Index = ENSO Index + SST Persistence + Noise





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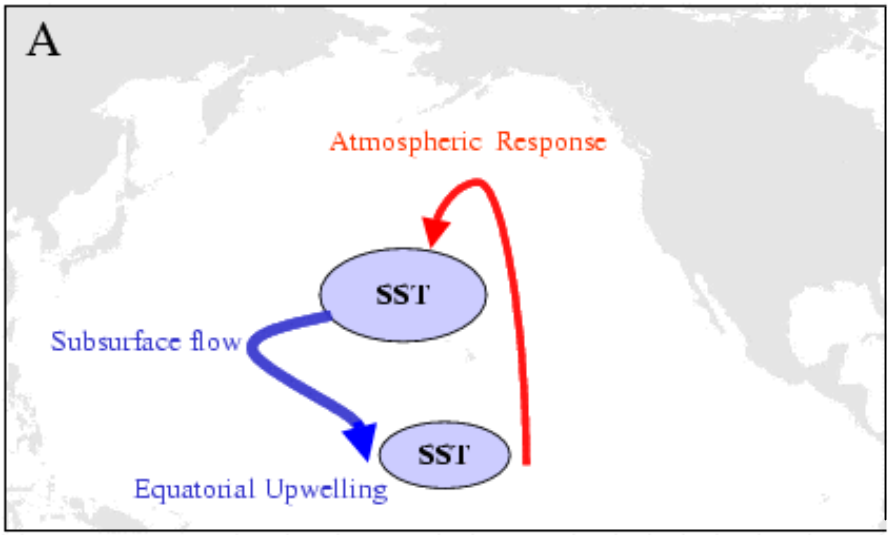
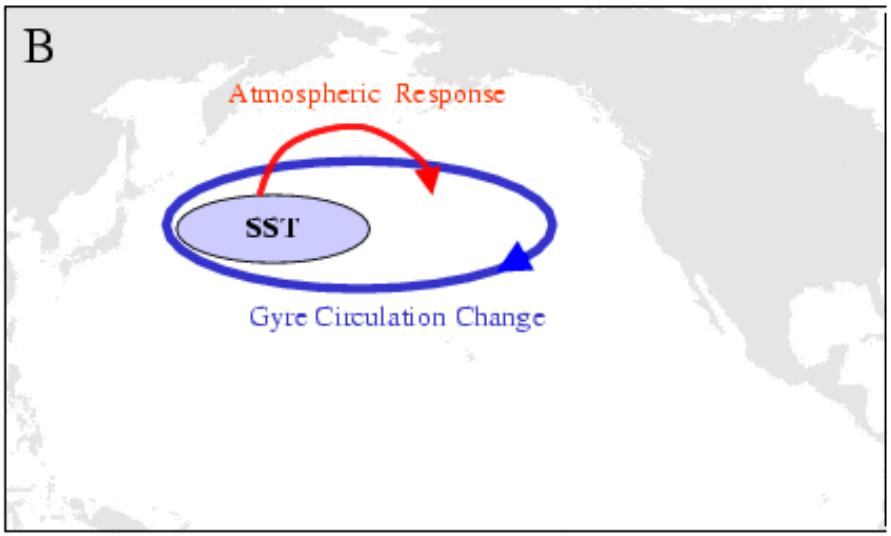
2. **Subduction Modes**

3. **Midlatitude Gyre Modes**

Subduction Mode



Midlatitude Gyre Mode

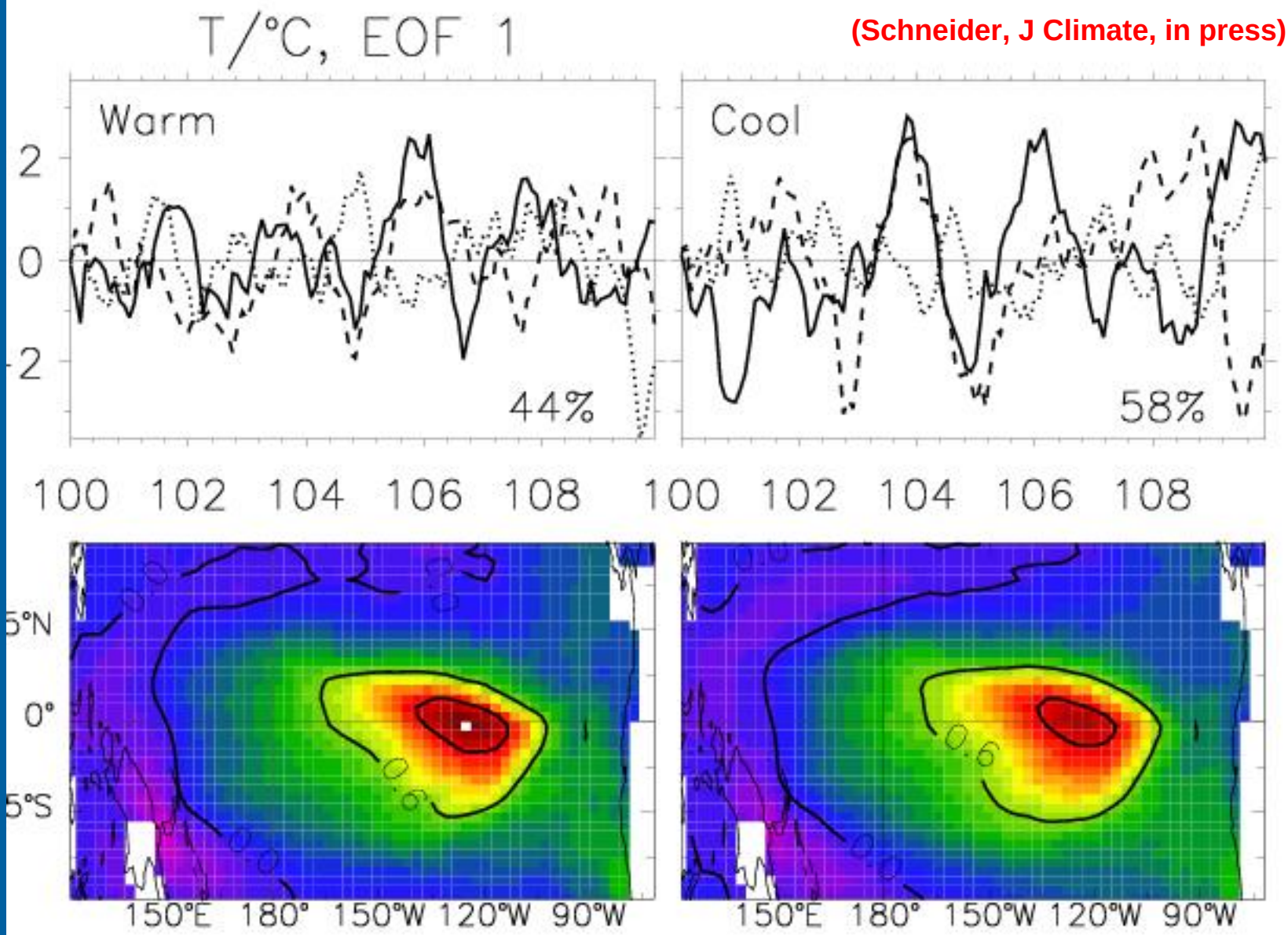


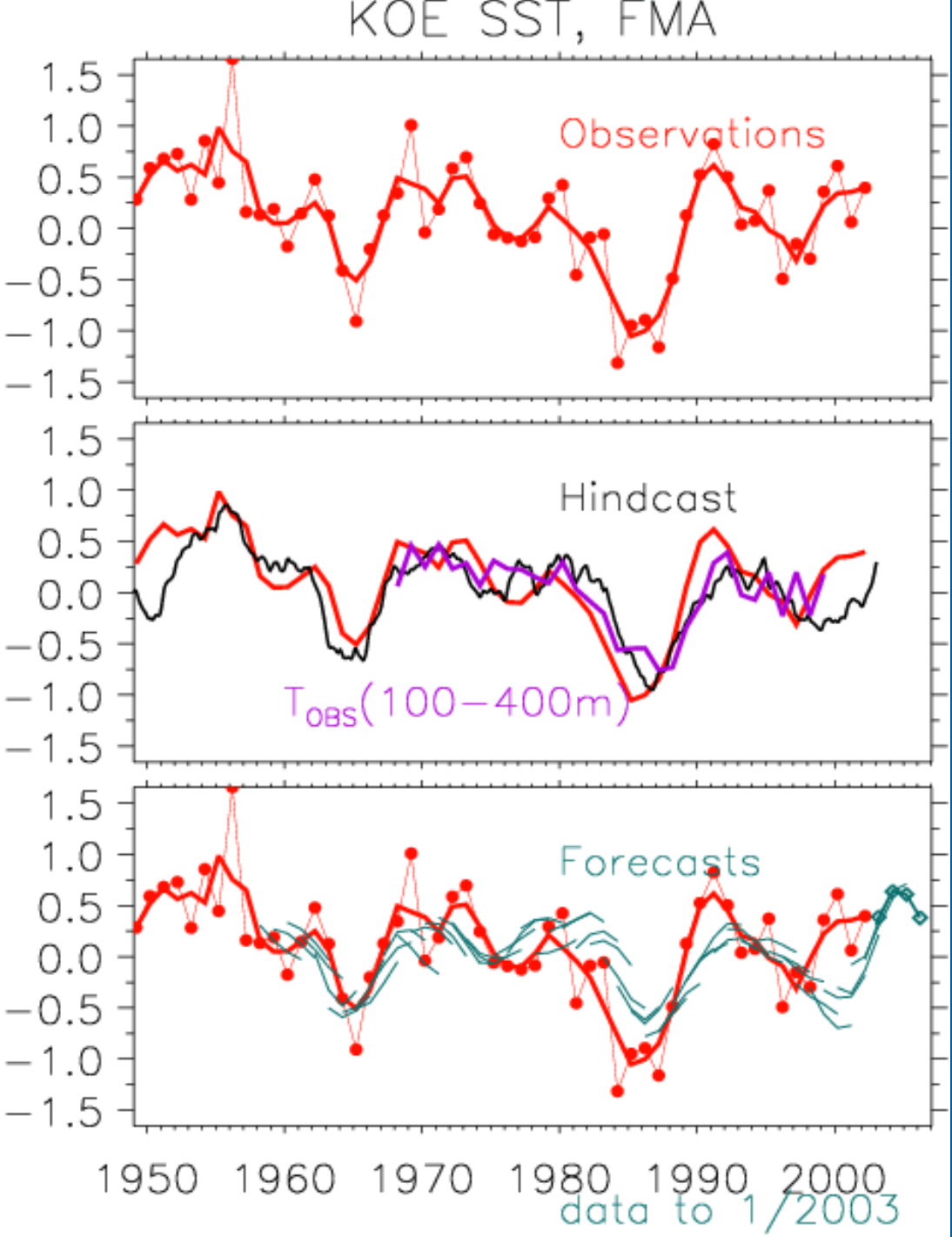
Schematic of the Gu-Philander class of decadal mode

Schematic of the Latif-Barnett class of decadal mode

Miller et al., 2003, Bull. Am. Meteorol. Soc.

Response of ENSO to upwelling spiciness anomalies





Predicting Observed SST in the Kuroshio-Oyashio Extension (KOE) Region

Basin-wide wind stress curl drives Rossby wave model

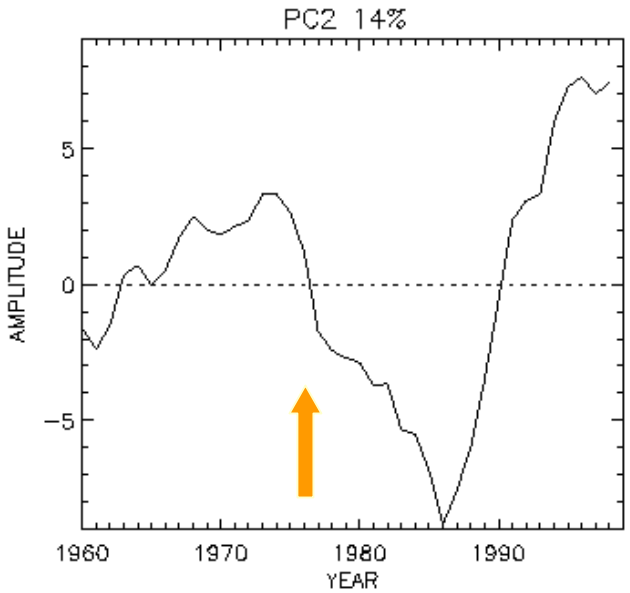
Rossby waves change the upwelling and currents (Qiu, 2003) in the KOE during winter

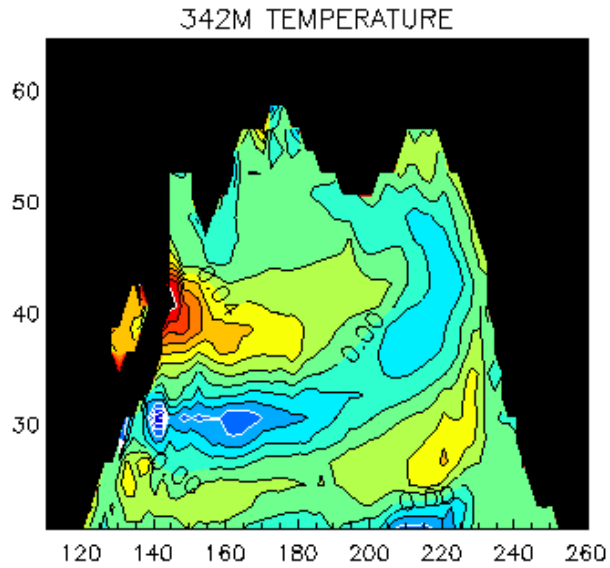
Quantified forecast skill up to 3 years in advance

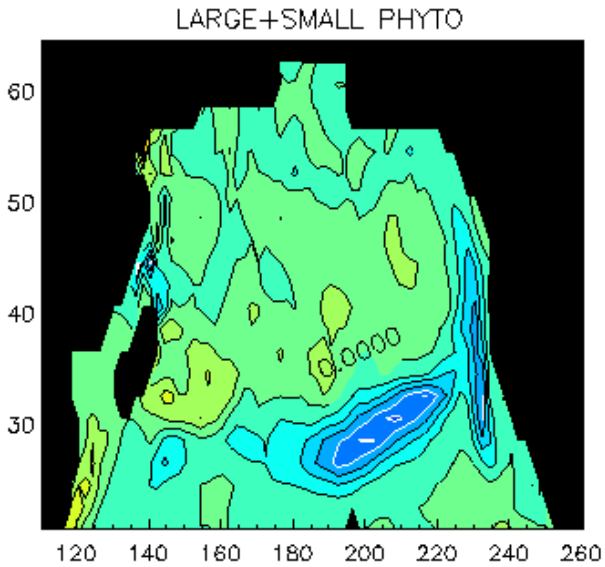
Schneider and Miller, 2001, J Climate

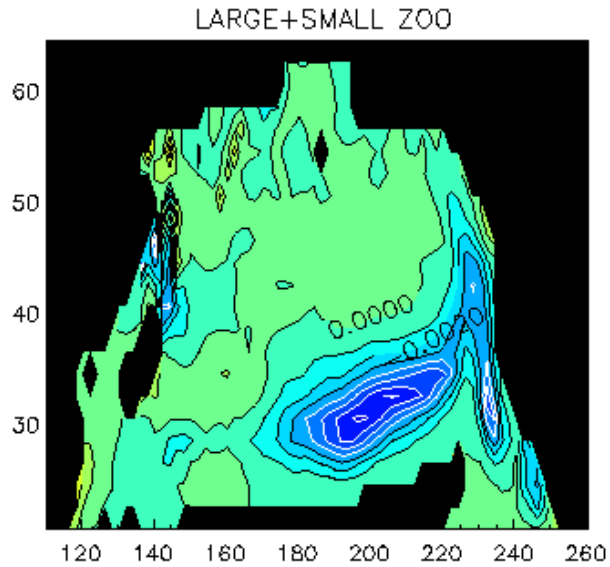
Physical-Biological Hindcast of Pacific Ocean Decadal Variability

First EOF of Combined Thermocline, Phyto-, and Zooplankton fields









Miller, Chai, Chiba, Moisan, and Neilson, J. Oceanogr., submitted

Physical-Biological Hindcast of Pacific Ocean Decadal Variability

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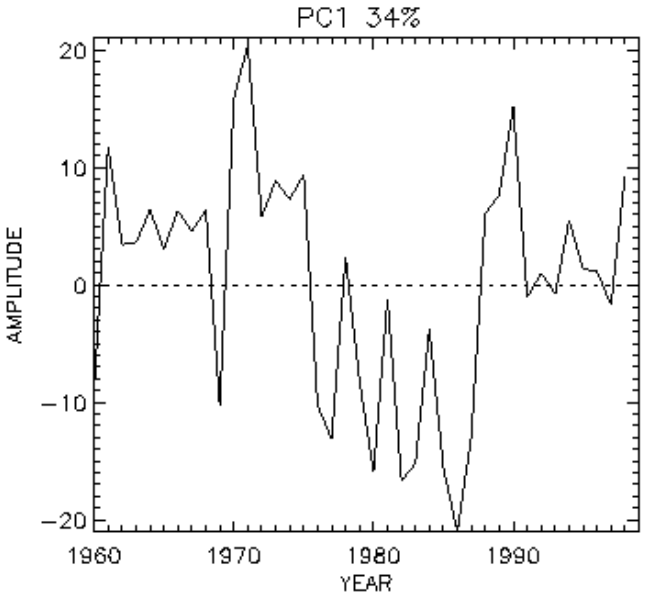

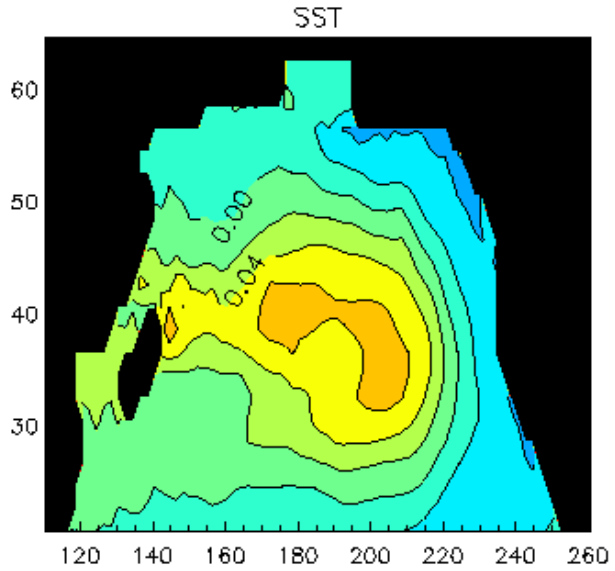

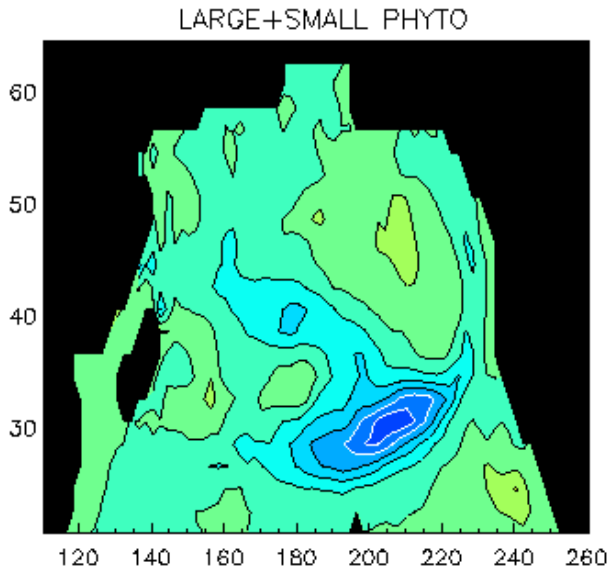

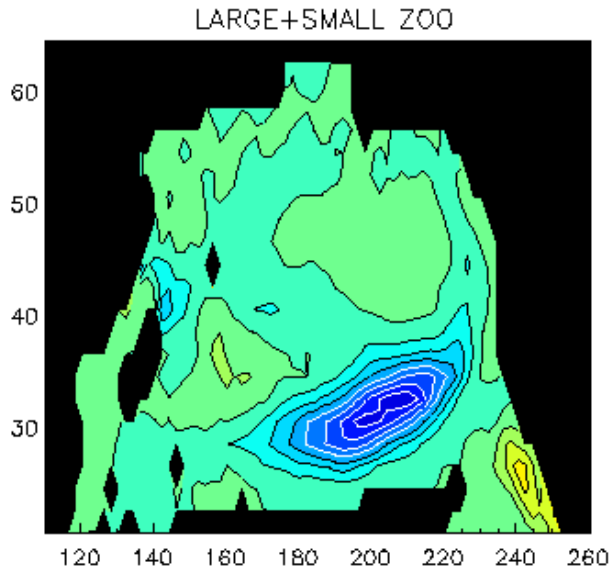

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      - eastern boundary thermocline response

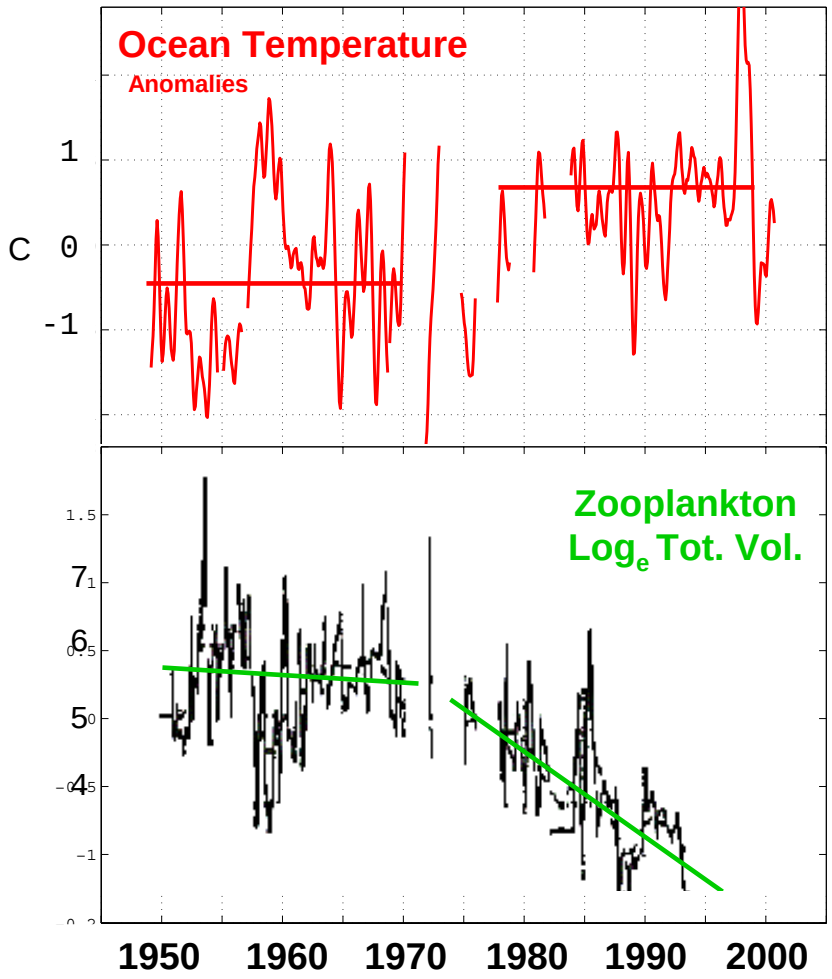
2. Subduction Modes

3. Midlatitude Gyre Modes

4. Stochastic Forcing
      - oceanic spectral peaks possible
      - predictable components possible

5. Deterministic Forcing
      - solar cycles, greenhouse gases

CalCOFI Observations along the Southern California Coast



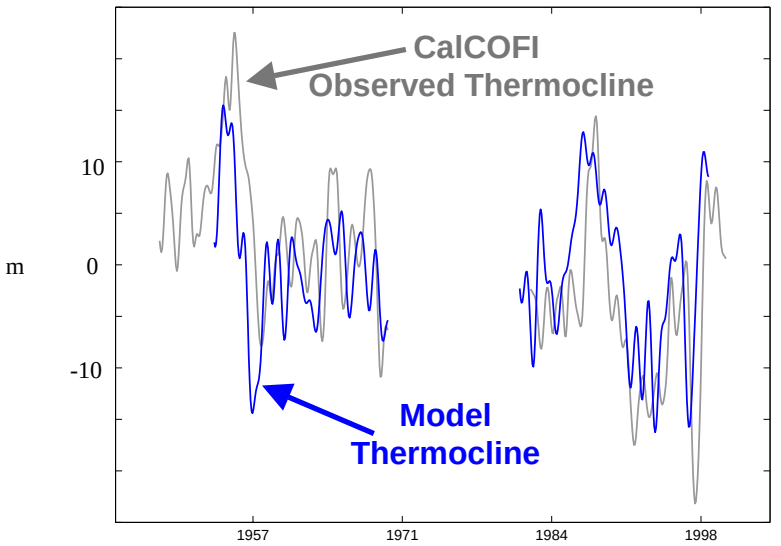
Over 50 yrs…

1 deg C warming of SST…

…70% decline in macro zooplankton

An eddy-permitting ocean model hindcast captures the observed SST and thermocline variations

Interannual and Decadal physical variations



Thermocline depth over the last 50 yrs shows an overall deepening of 20 m

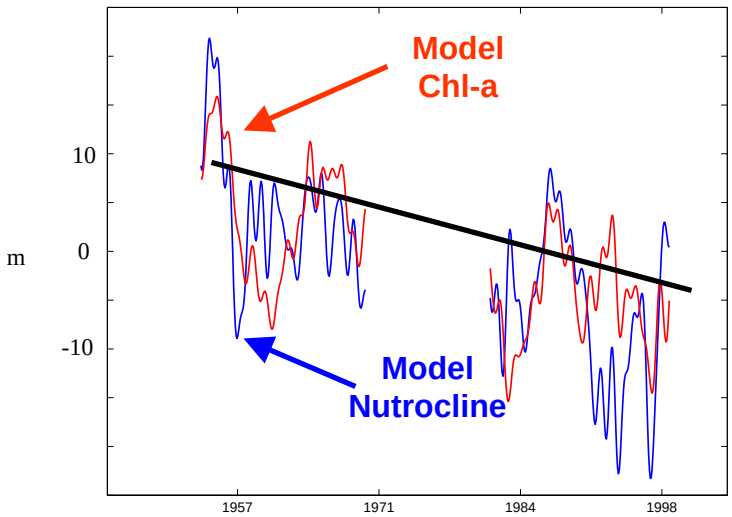
Warming is due to large-scale decadal surface heat fluxes combined with southward advection of concomitantly warmed water

Increase in upwelling favorable winds partially cools water column

Di Lorenzo, Miller, Schneider and McWilliams, JPO, in press.

Biological response to these physical changes

NPZD-type 7-component model hindcast



Decline in Chl-a linked to thermocline deepening in the model simulation.

This is consistent with the zooplankton decline.

Di Lorenzo et al., in preparation, 2003

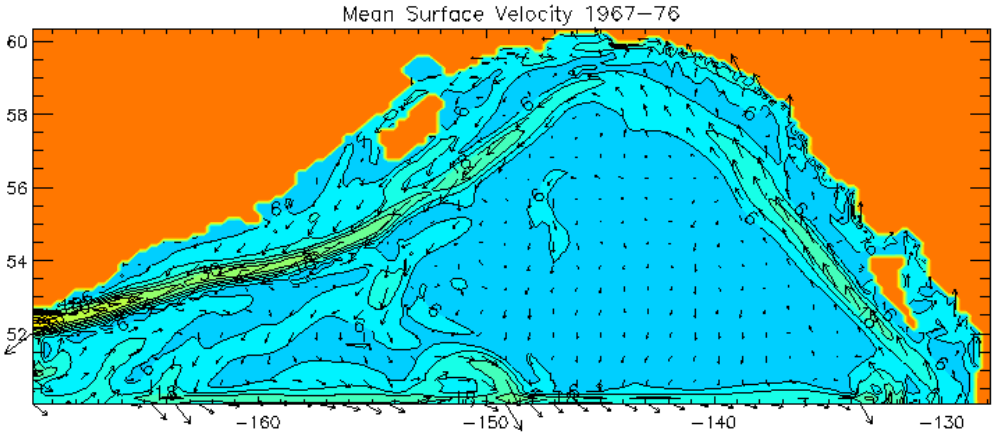
Circulation Changes in the Gulf of Alaska associated with the Decline of the Steller Sea Lion Population

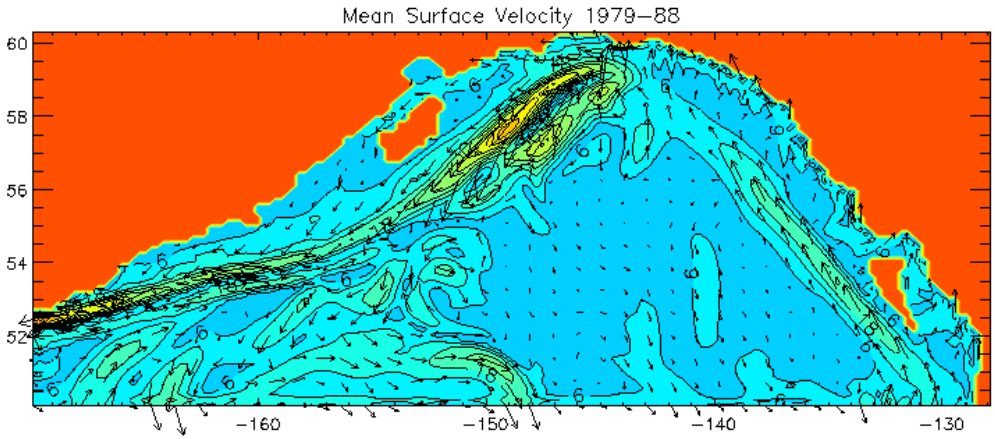
- After the 1976-77 Climate Shift, sea lions reduced 80%
- Post 1976-77, eddy-resolving model hindcast reveals:

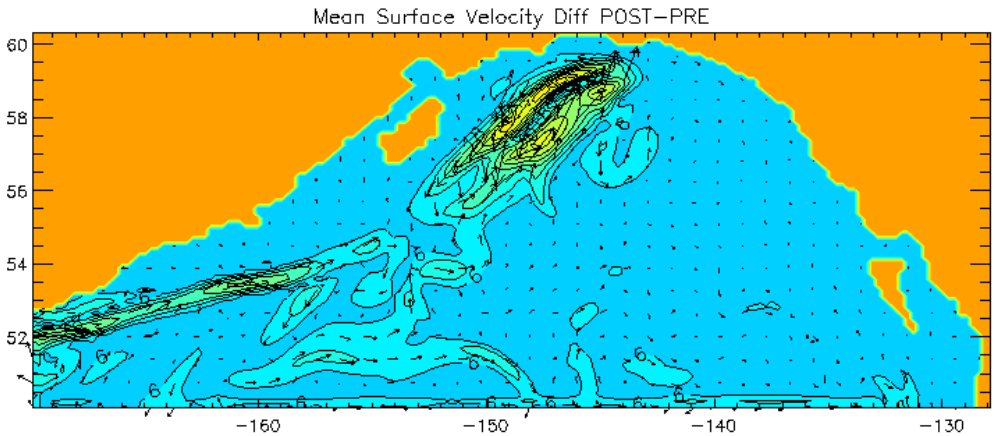
  Stronger Alaska Stream north of Kodak Island

  Reduced eddy variance south of Kodiak Island
- Ecosystem model response to physical changes in progress

Miller, Di Lorenzo, Neilson, Alexander, Capotondi, Bograd, Schwing, Musgrave, and Hedstrom, in prep, 2003







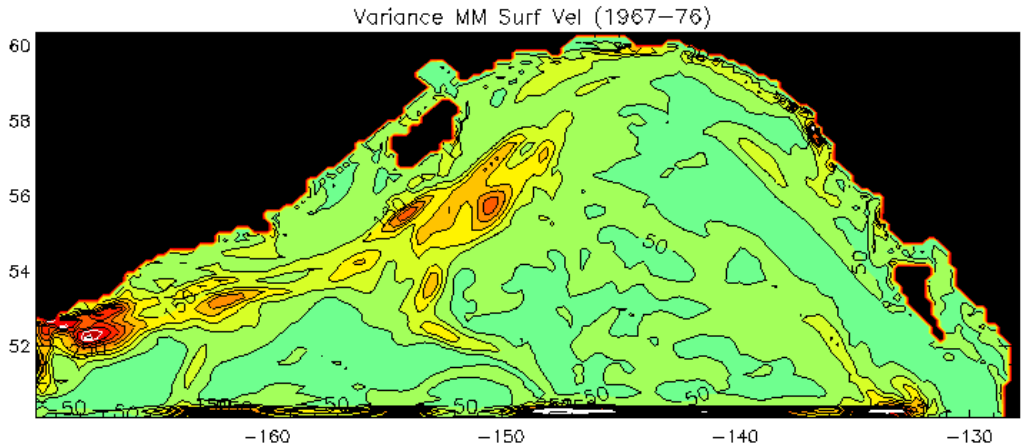
Eddy-Permitting Model
Mean Surface Currents

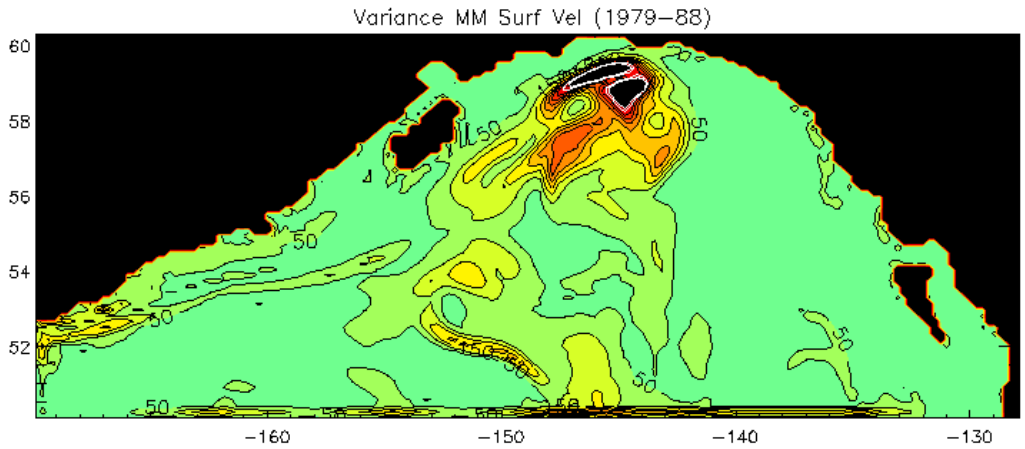
Before 76-77 Shift

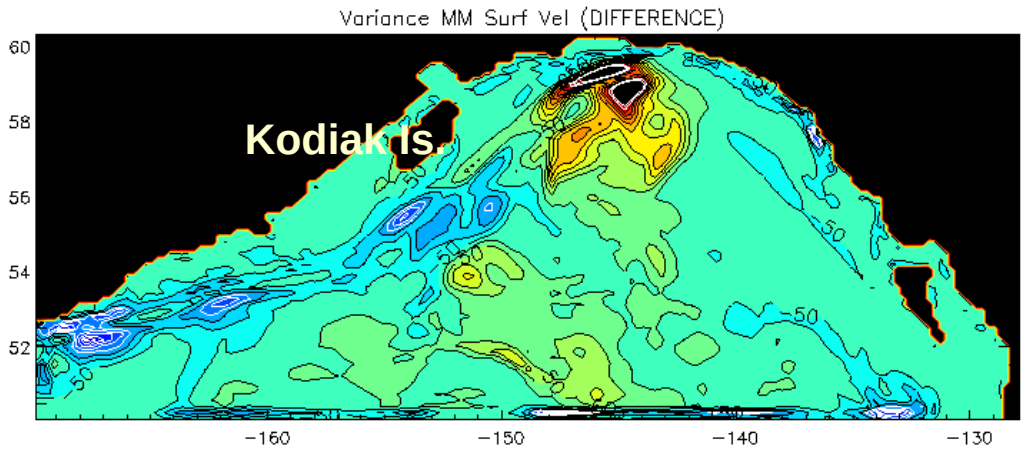
After 76-77 Shift

Difference

Large in western gulf
Little change in east







Eddy-Permitting Model
Eddy Surface Currents

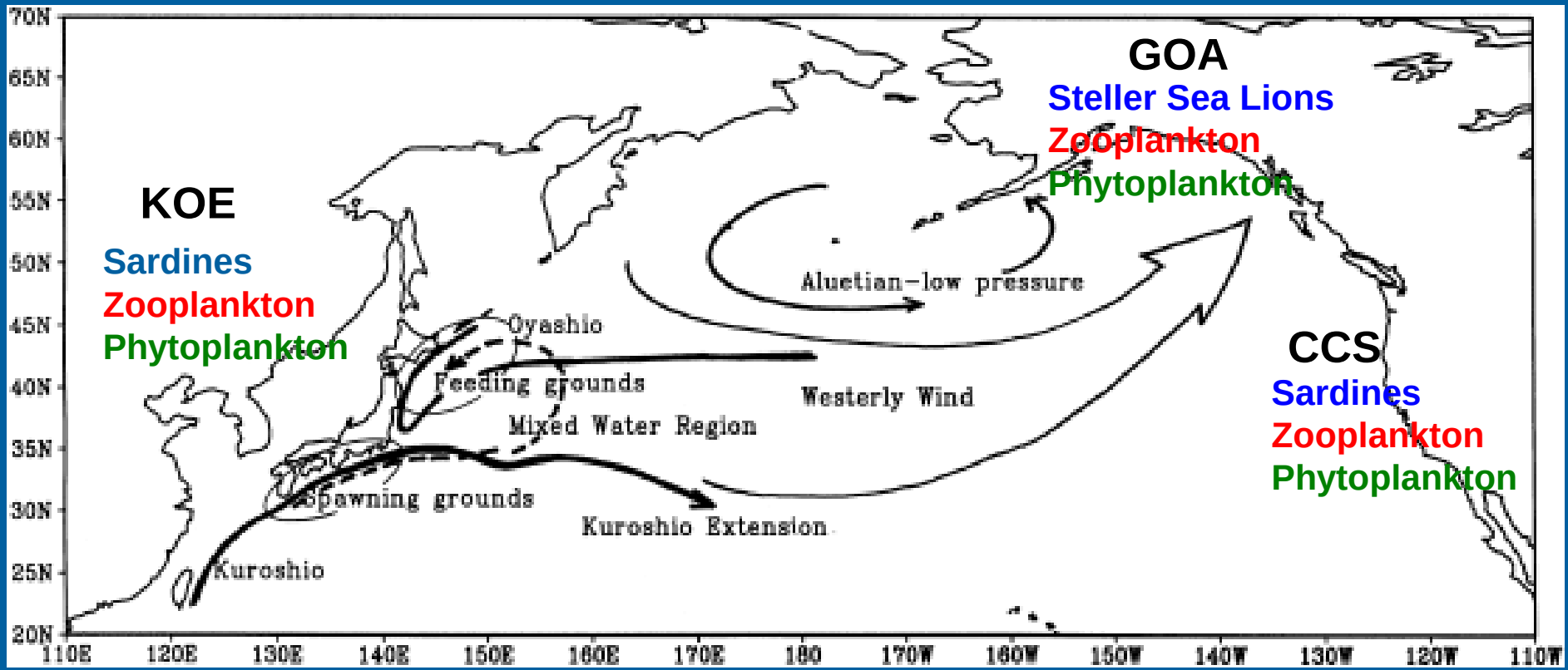
Before 76-77 Shift

After 76-77 Shift

Difference

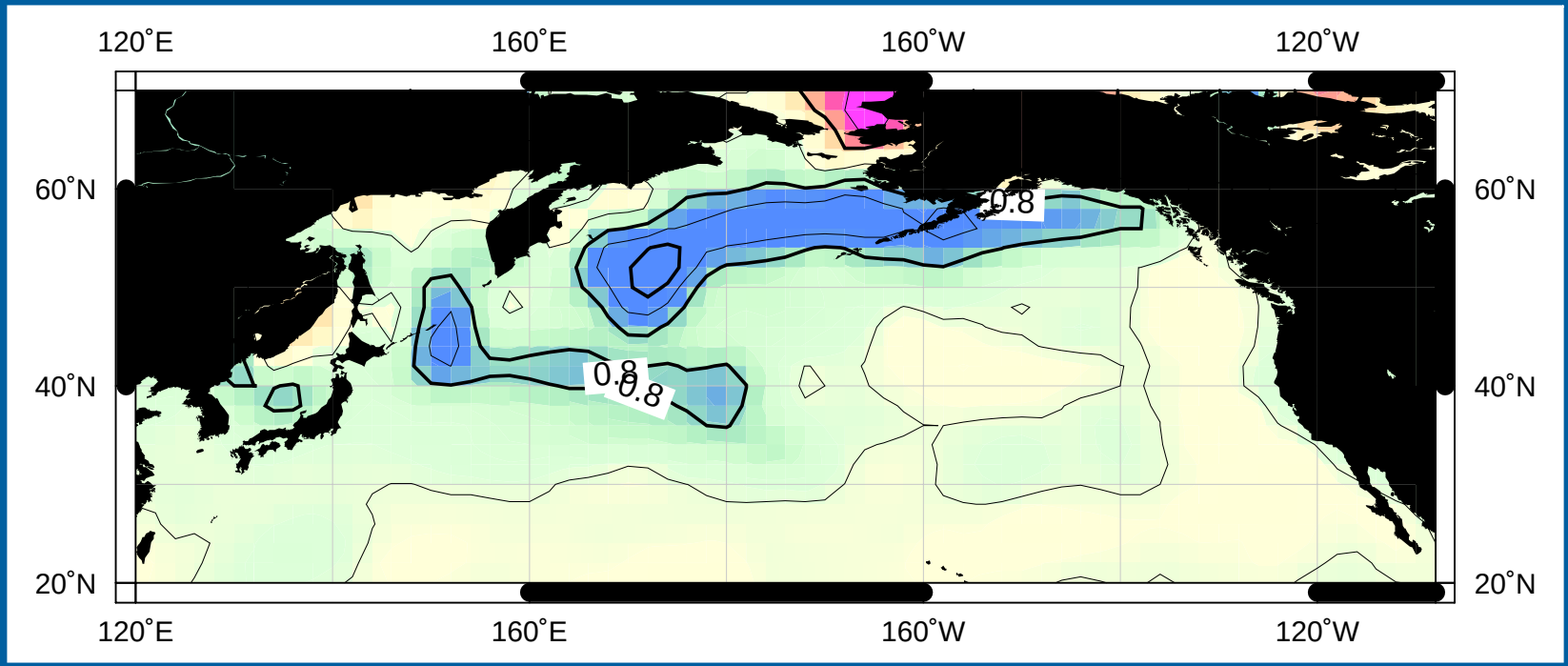
More eddies north of Kodiak
Fewer eddies southwards

Summary of Some Regional Ecosystem Impacts Organized by Pacific Decadal Variability



Adapted from Yasuda et al., 1999, Fish. Oceanogr.

Effects of anthropogenic forcing on biological activity



Biological Model Phytoplankton [mmol C/m³]

Ratio, Year 2100 / Year 2000

Pierce, Climate Change, 2003, submitted