Decadal Variability in the Pacific Ocean: Physics, Feedbacks and Ecosystem Impacts

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Climate Variability Studies in the Ocean
Workshops on Climate Variability in the 20th Century

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Decadal Variability in the Pacific Ocean: 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

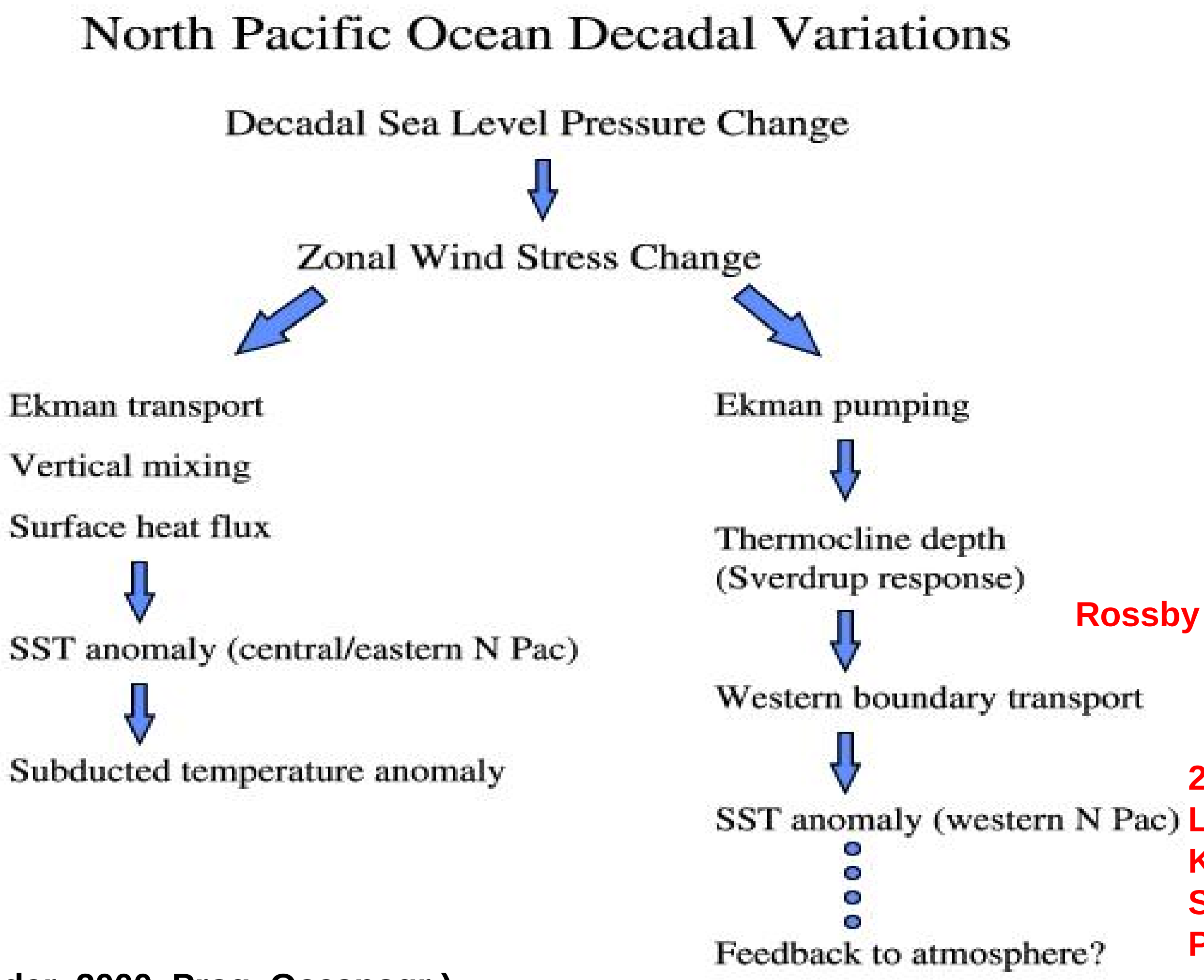
Recent Collaborators

Physics: Schneider, Di Lorenzo, Pierce, Kim, Bograd, Alexander, Capotondi, Deser, 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



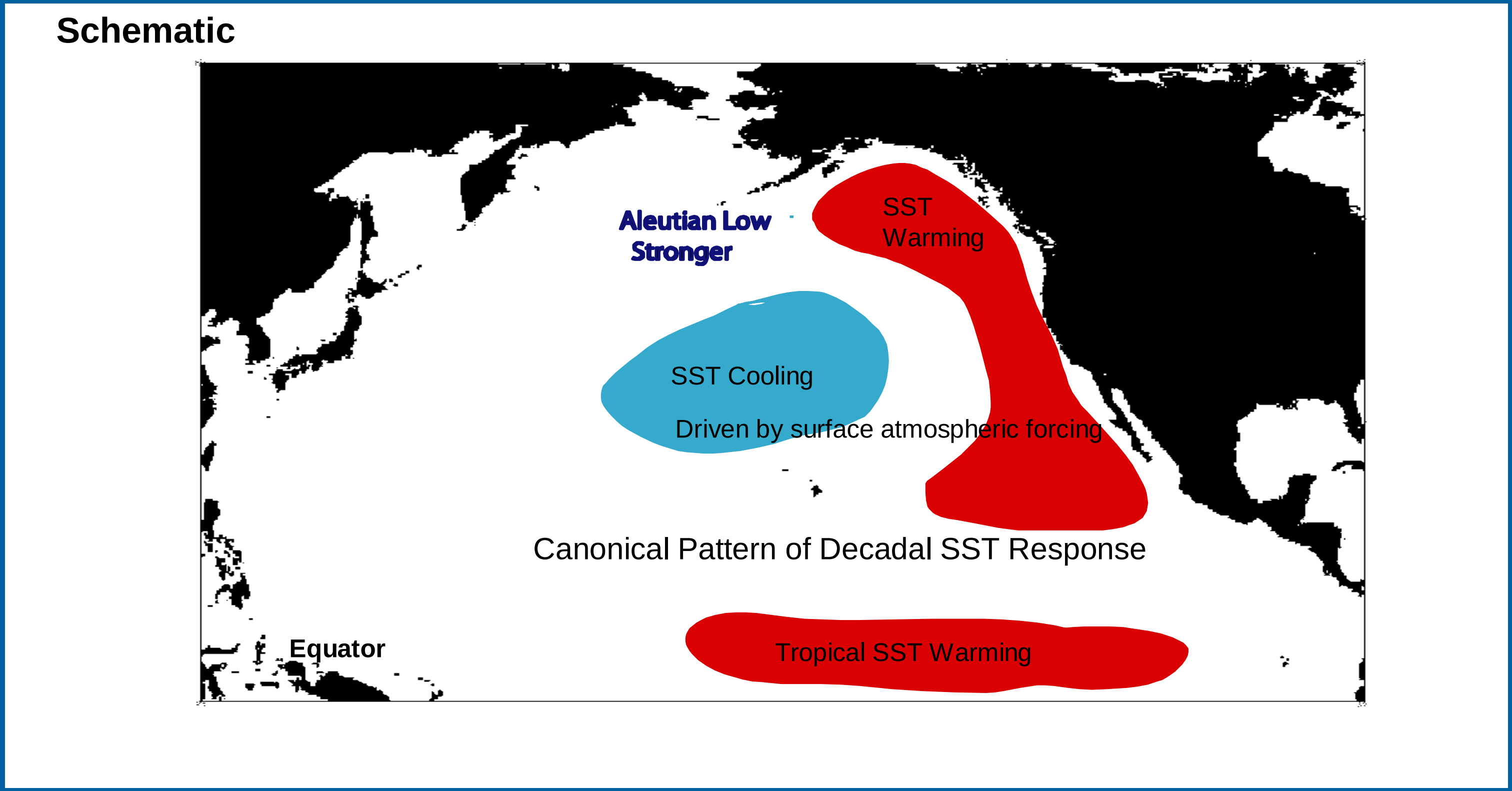
Canonical SST Pattern

Rossby waves

2 - 5 yrs Lagged KOE SST Pattern

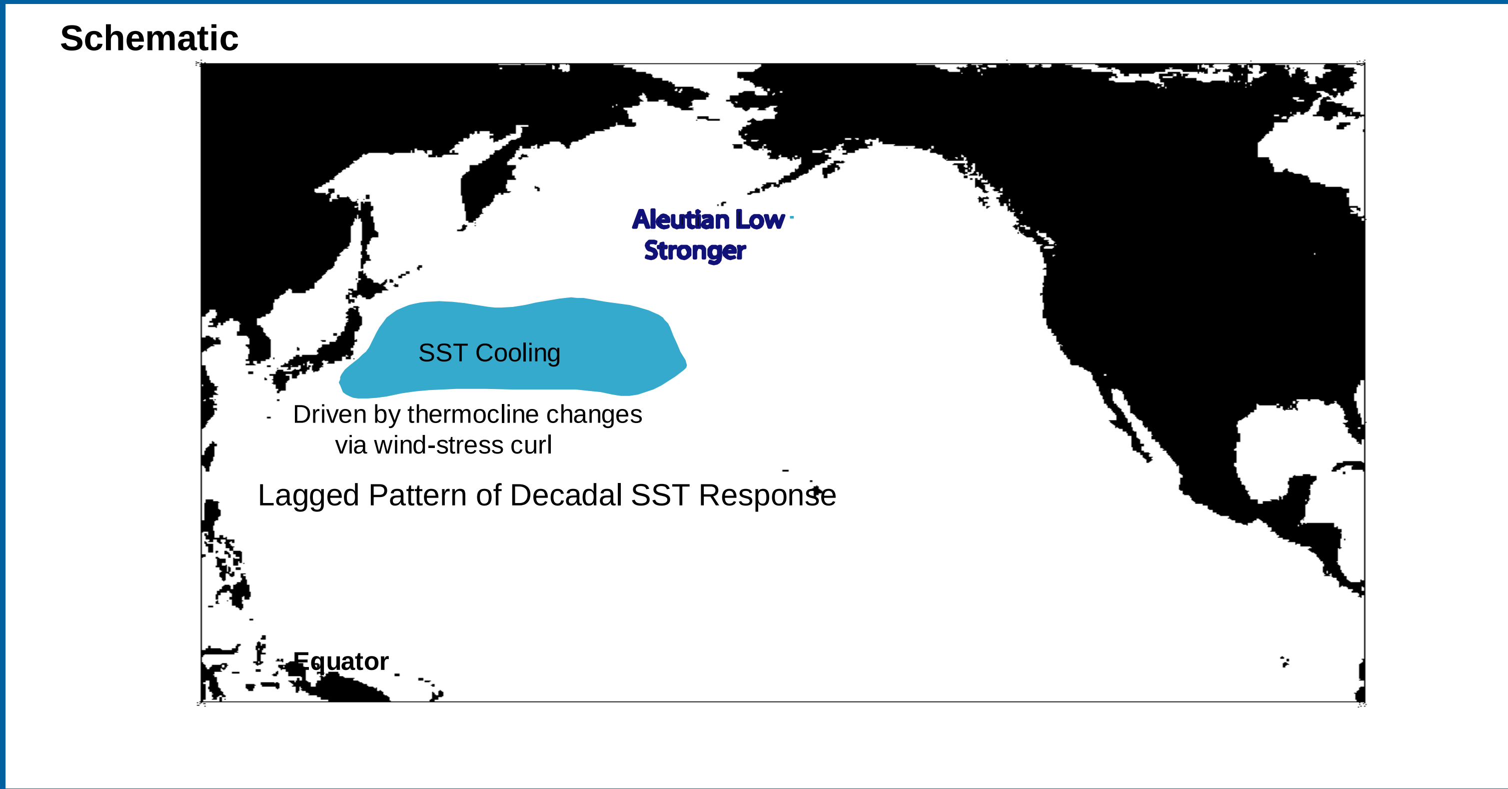
(Miller and Schneider, 2000, Prog. Oceanogr.)

Canonical Pattern of Decadal SST Response
(Aleutian Low Strengthening)



From Miller, Chai, Chiba, Moisan and Neilson (2004, J Oceanogr.)

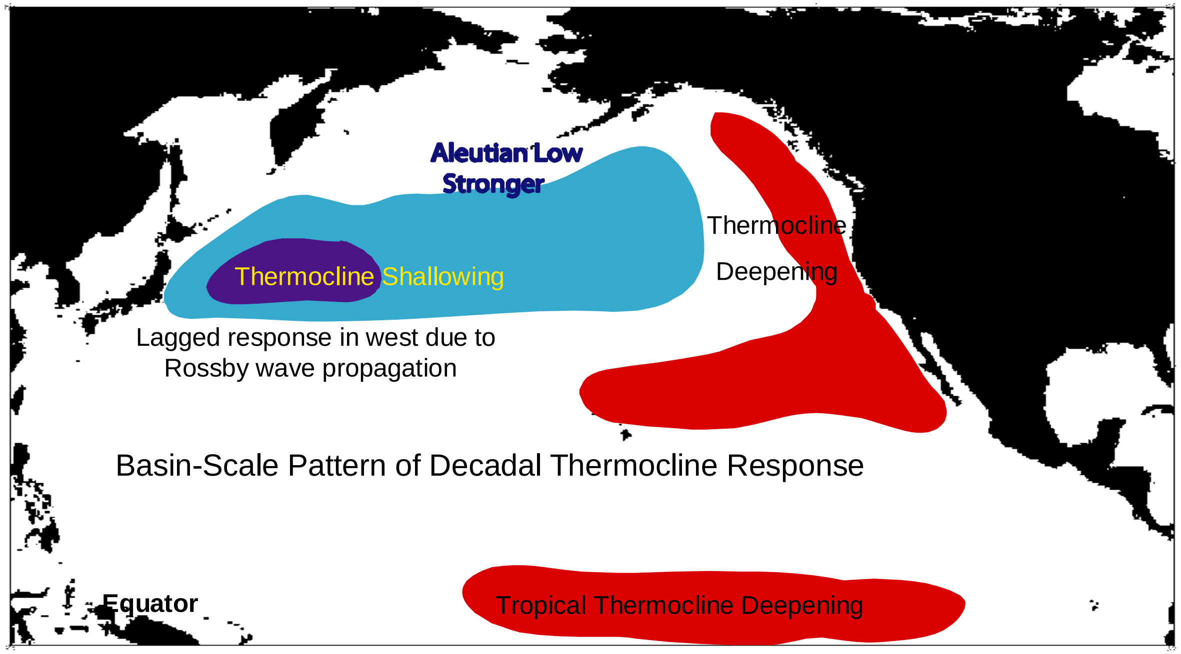
Lagged Pattern of Decadal SST Response (Aleutian Low Strengthening)



From Miller, Chai, Chiba, Moisan and Neilson (2004, J Oceanogr.)

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

Schematic



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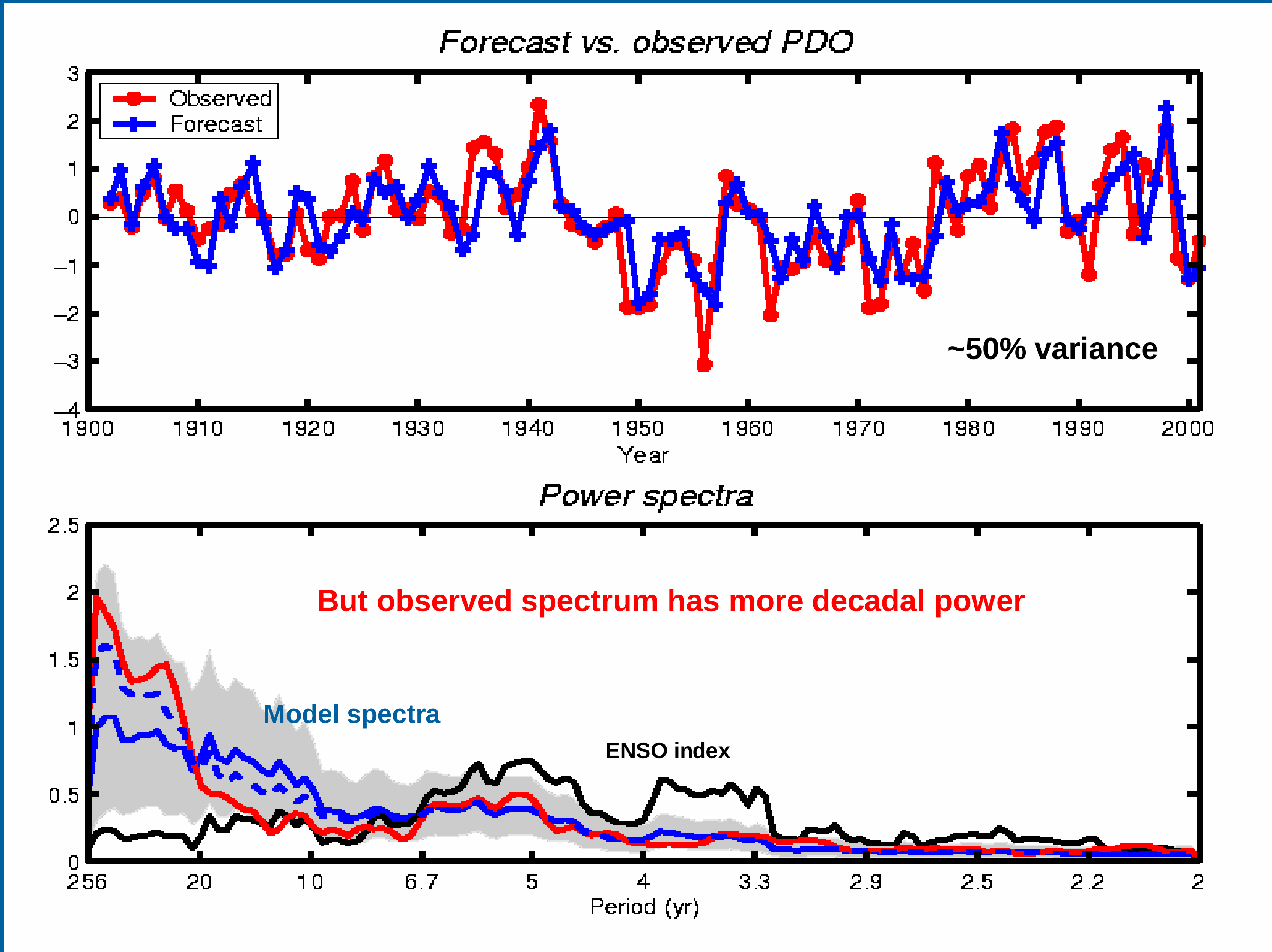
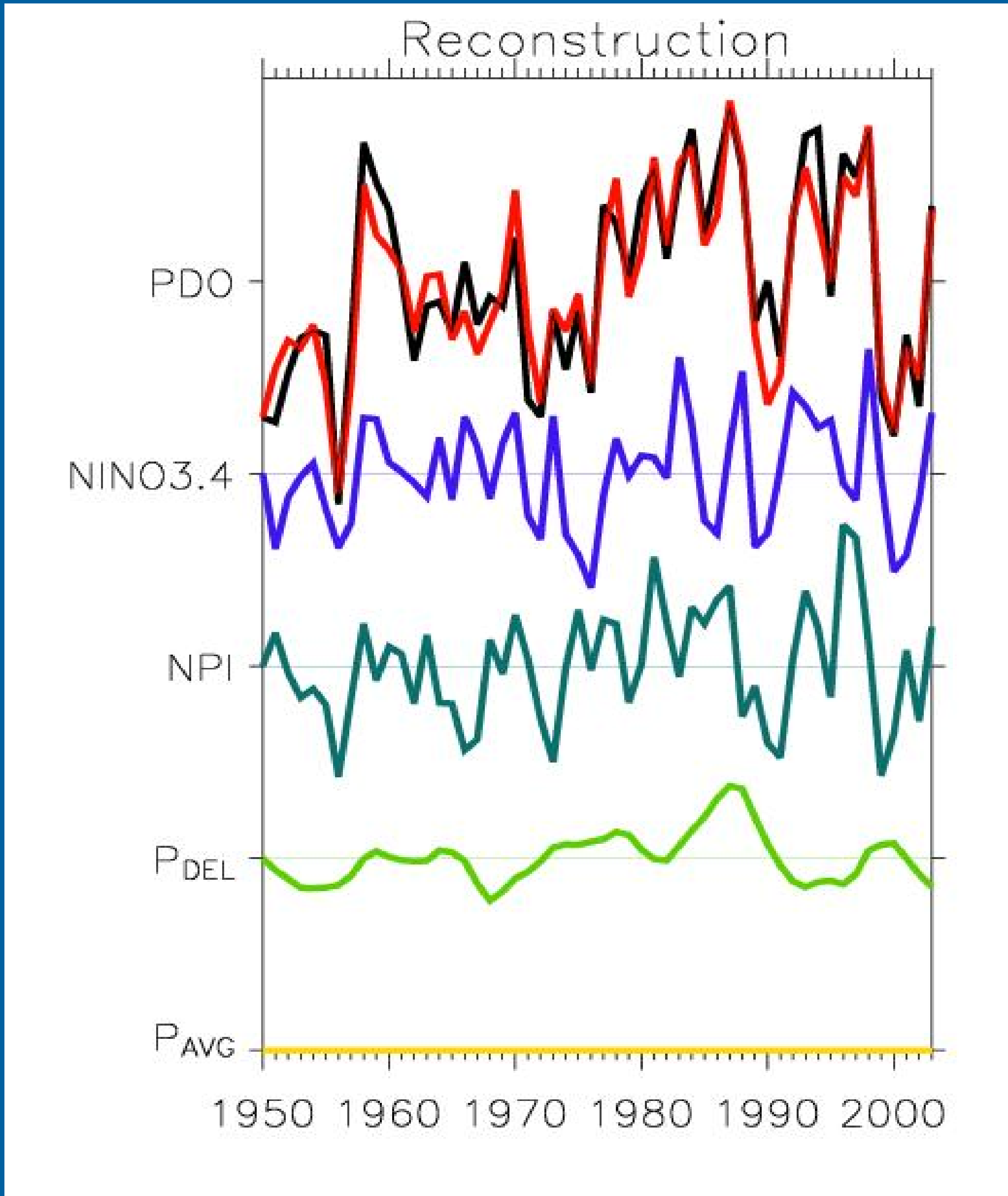
Simple ENSO-forced PDO Model (Newman et al., 2003, J Climate)

PDO Index = ENSO Index + SST Persistence + Noise





Reconstruction of PDO Index based on time integration of several index time series

		low-freq
Total	85%	75%
ENSO	36%	20%
North Pacific Index	37%	30%
KOE-1	7%	25%
KOE-2	nil	nil

(Schneider, 2004, in prep)

N Pac

Indian SST

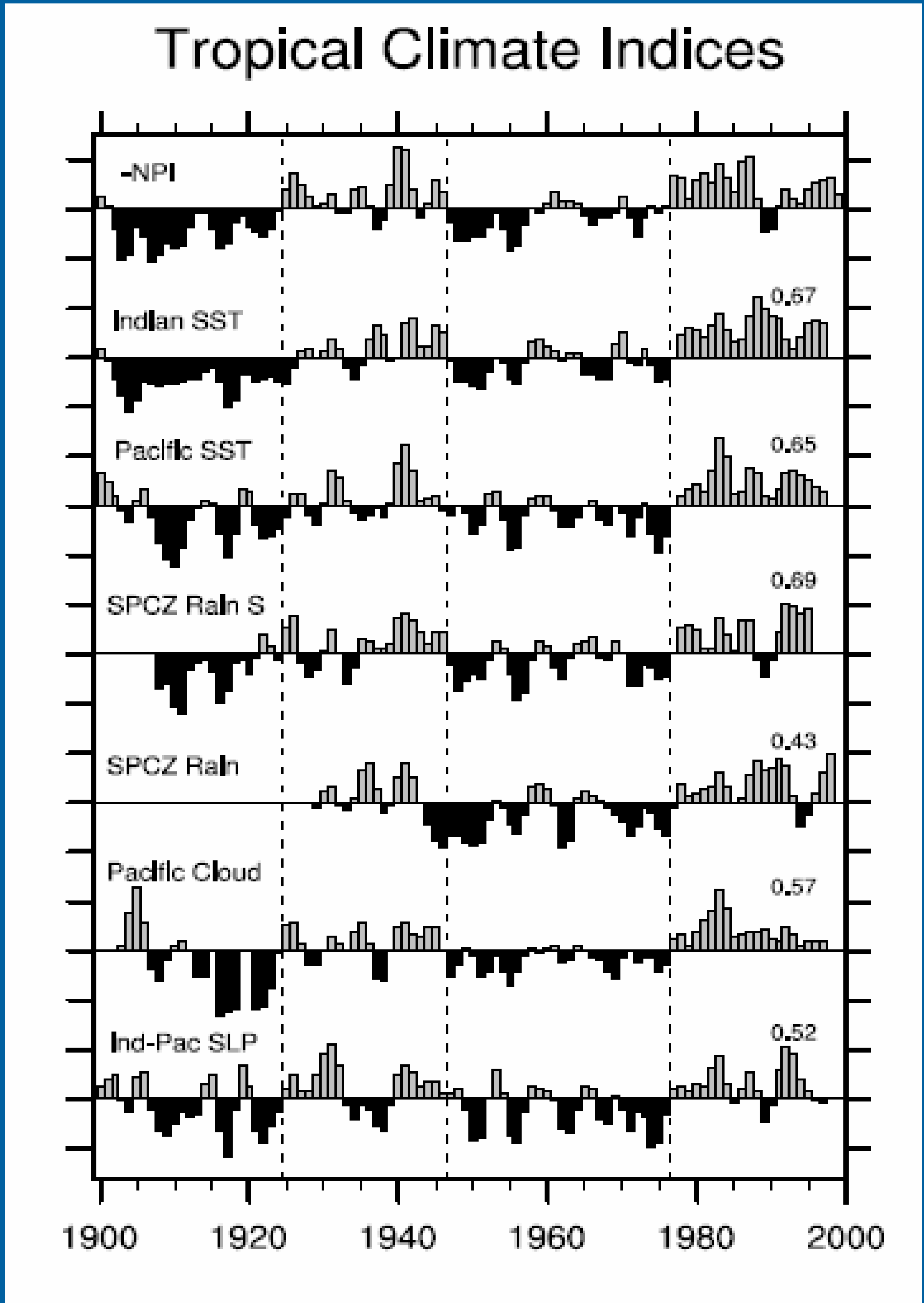
Pacific SST

SPCZ1

SPCZ2

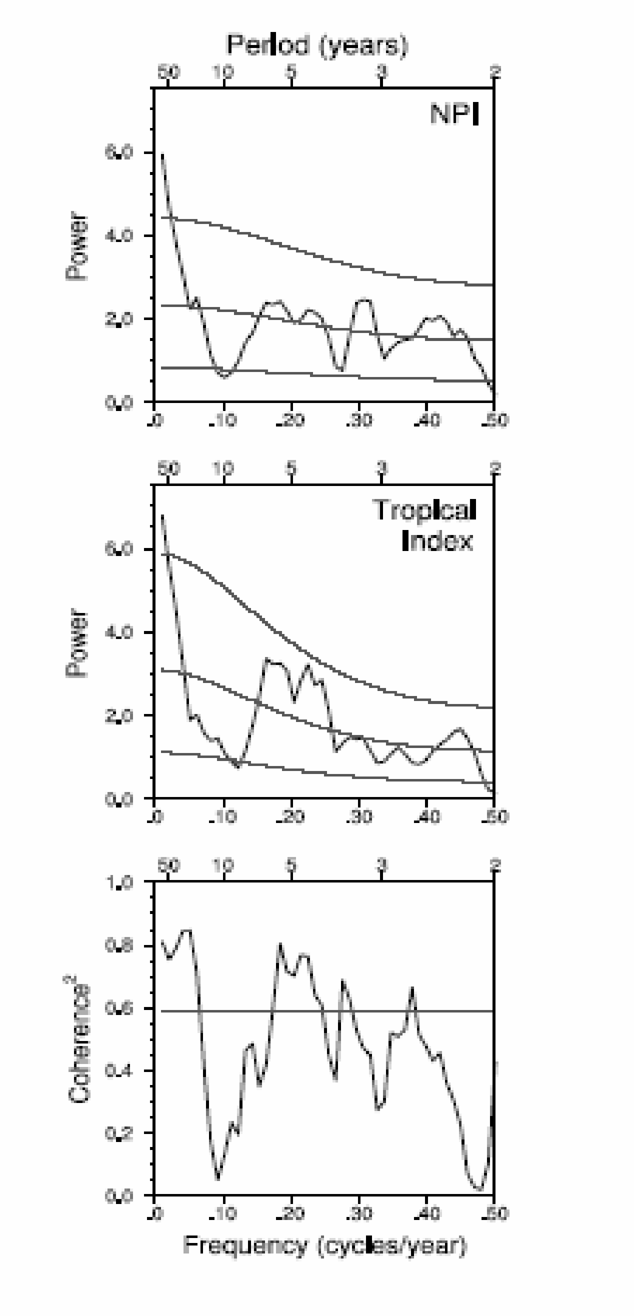
Cloud

Indo-Pac SLP



Tropics are correlated to North Pacific on decadal timescales suggesting common forcing or tropical origin of decadal signal

Deser et al., J Climate in press.



Specral content and coherence between N Pacific Index (zonal wind) and Tropical Index (composite)

Strong peaks and strong coherency in ENSO and decadal bands

Deser et al., J. Climate, in press

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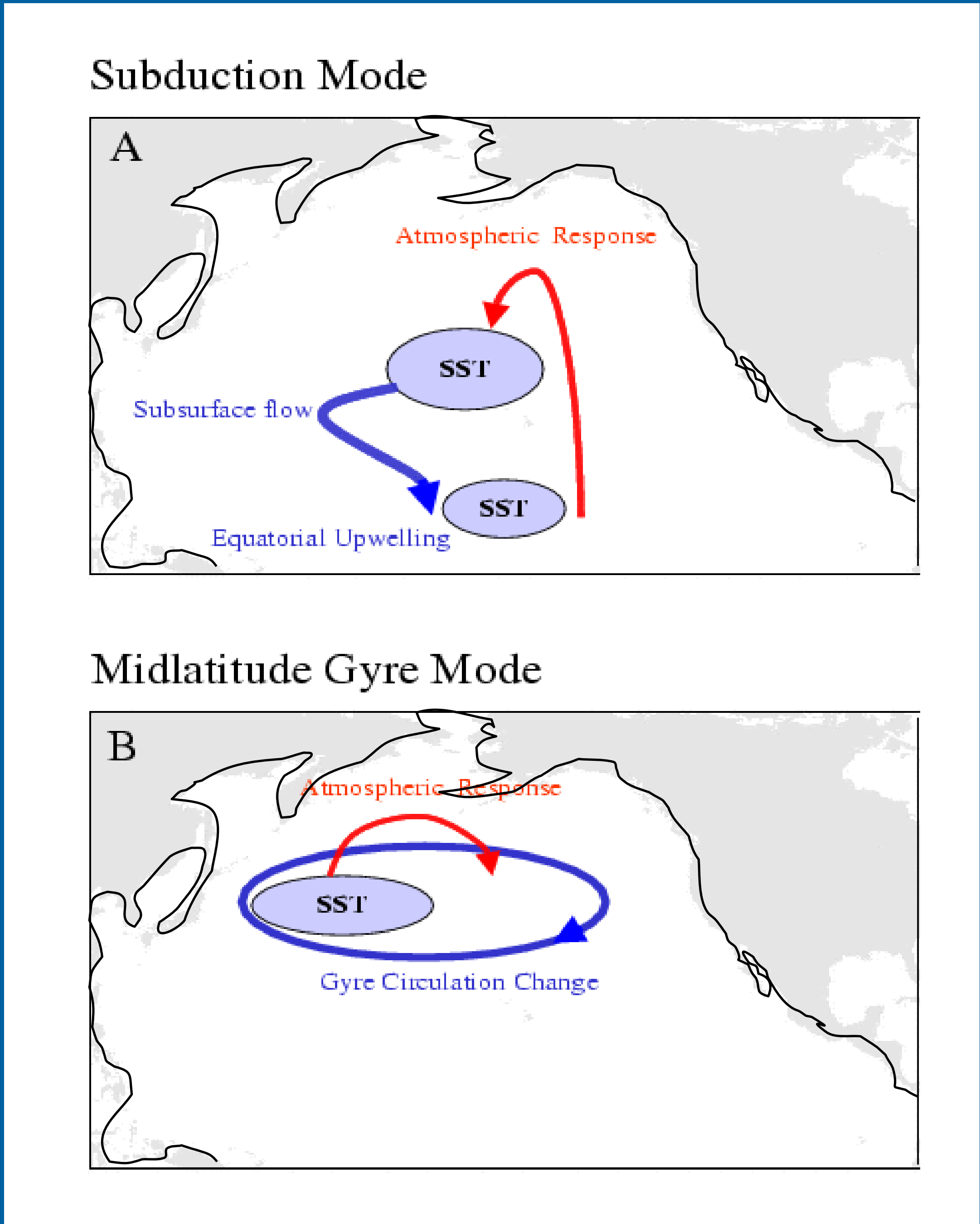
2. **Subduction Modes**

3. **Midlatitude Gyre Modes**

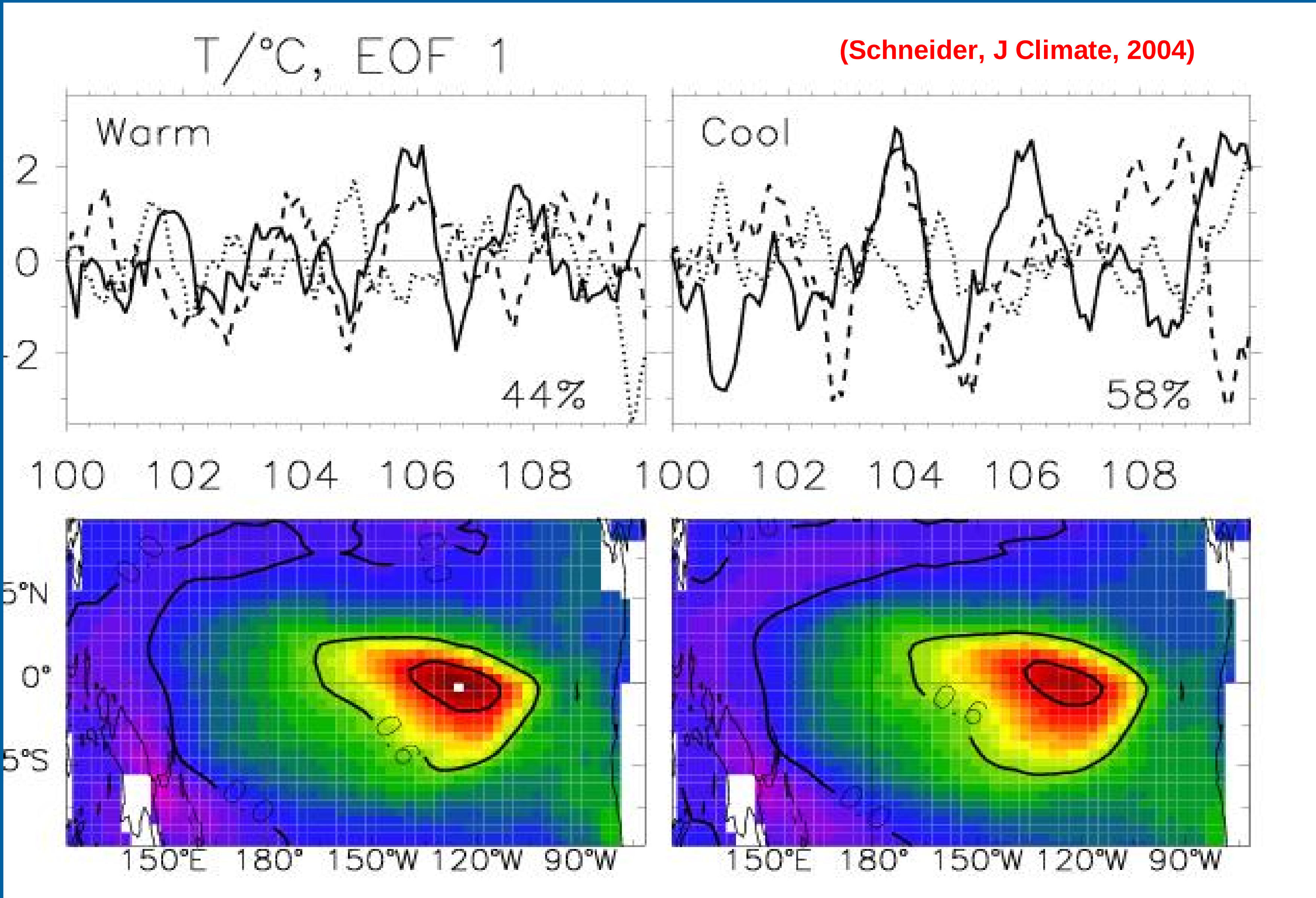


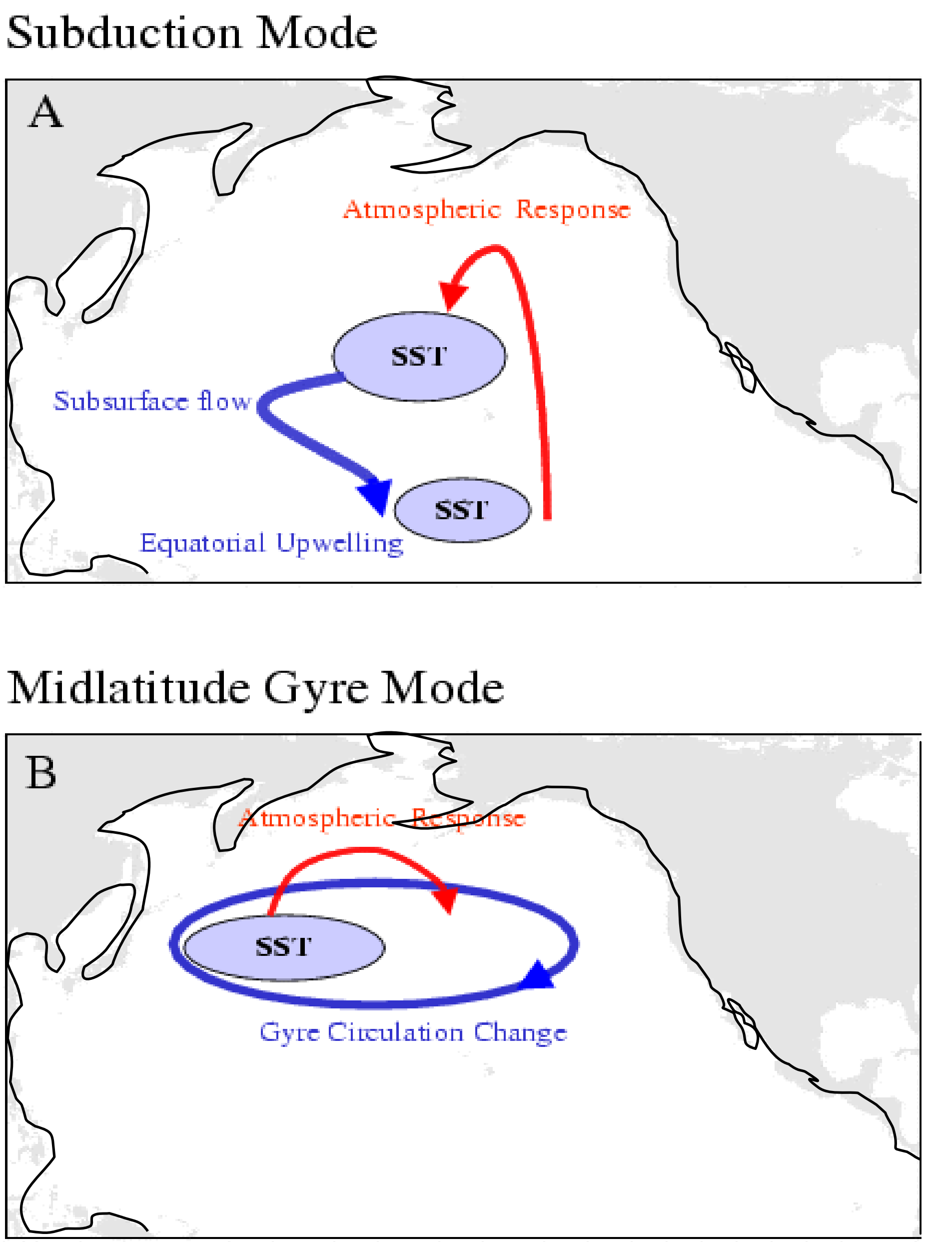
Schematic of the Gu-Philander class of decadal mode

Schematic of the Latif-Barnett class of decadal mode

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

Response of ENSO to upwelling spiciness anomalies





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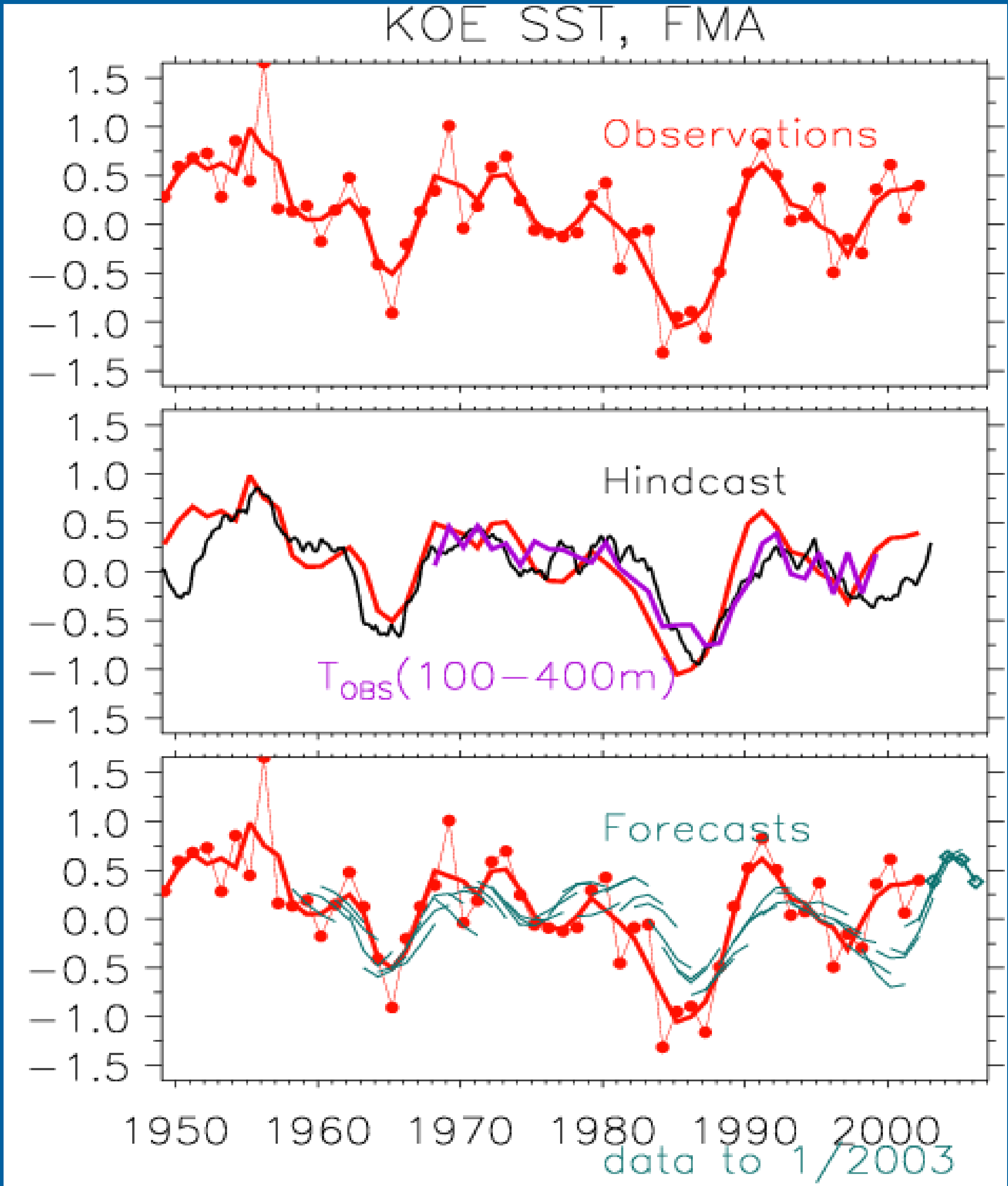


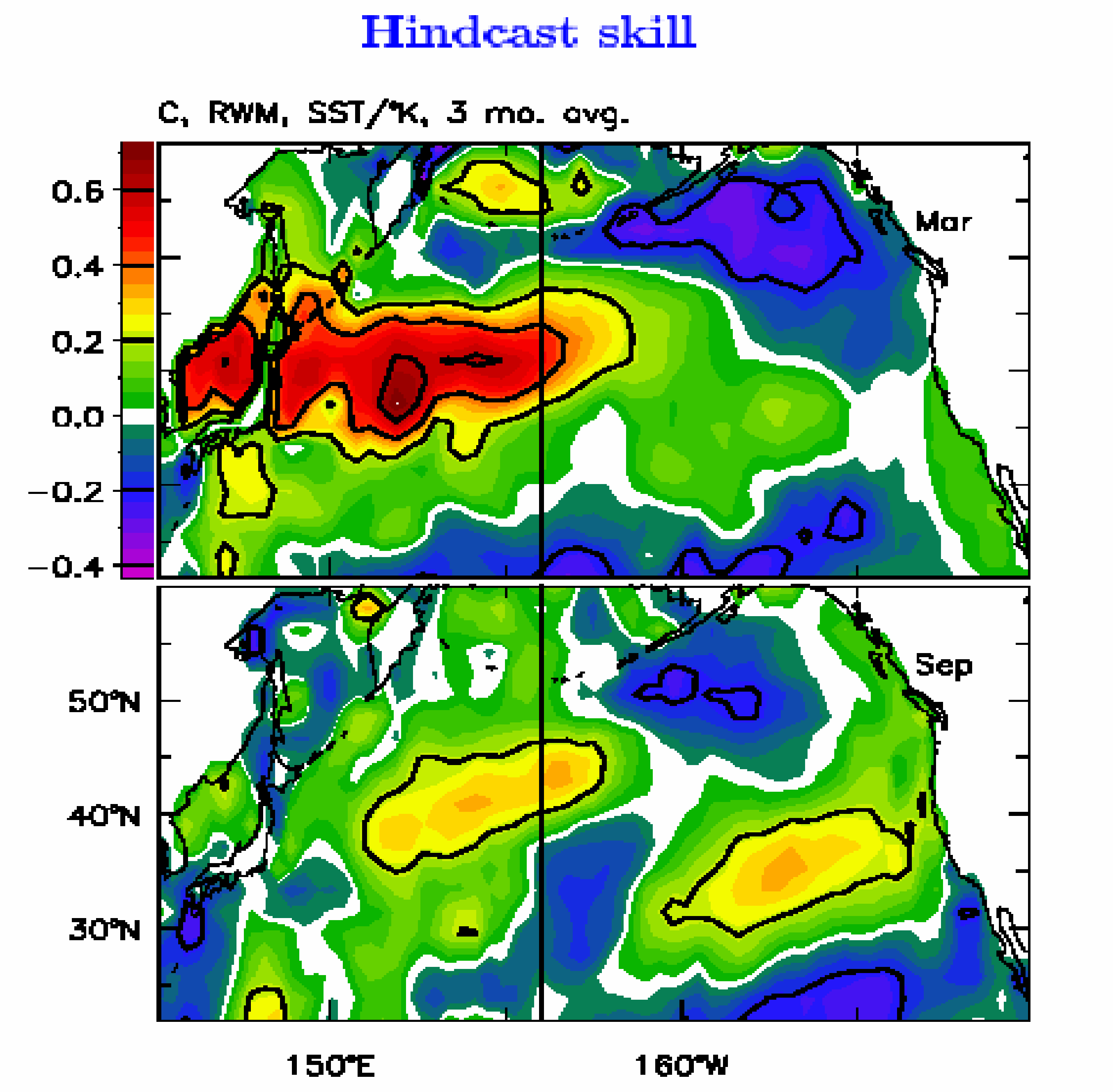
Predicting Observed SST in the Kuroshio-Oyashio Extension (KOE) Region

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

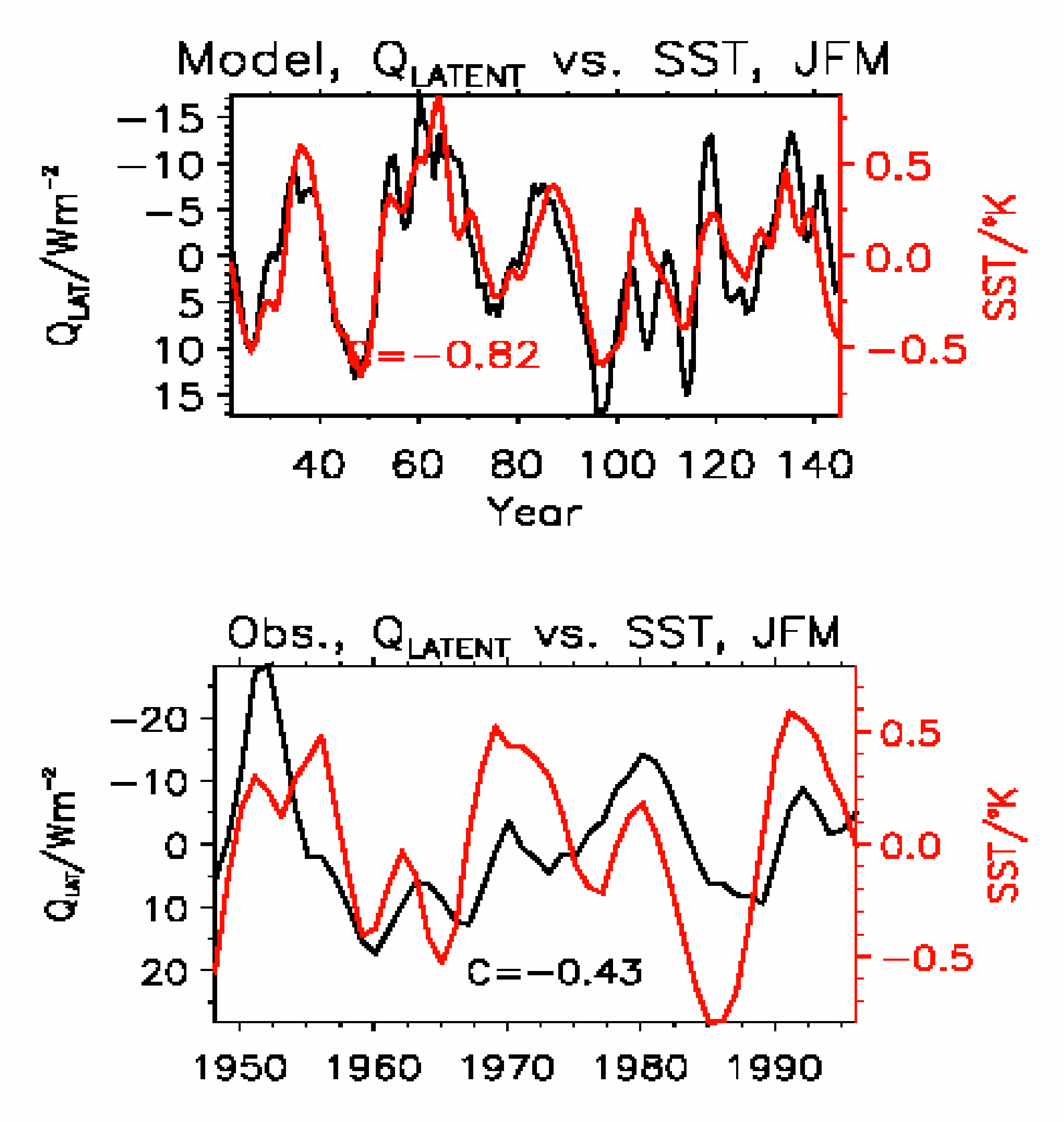
Schneider and Miller, 2001, J Climate



Hindcast skill of simple Rossby wave model predicting winter SST

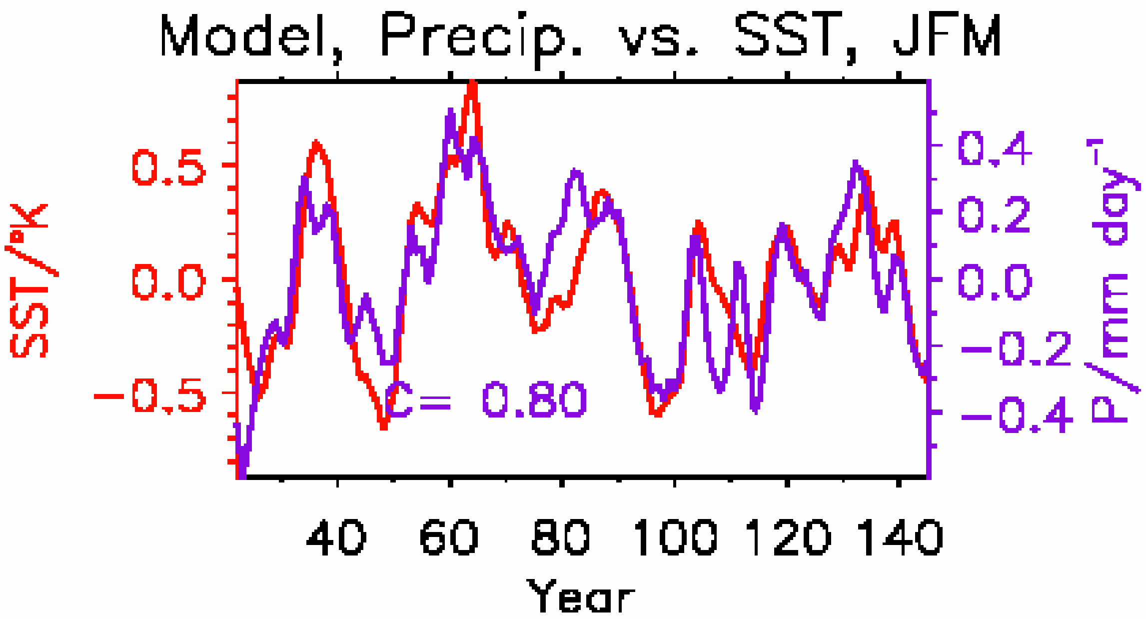
KOE Pattern is important in its feedback to the atmopsphere and potential in predicting ecosystem response in KOE

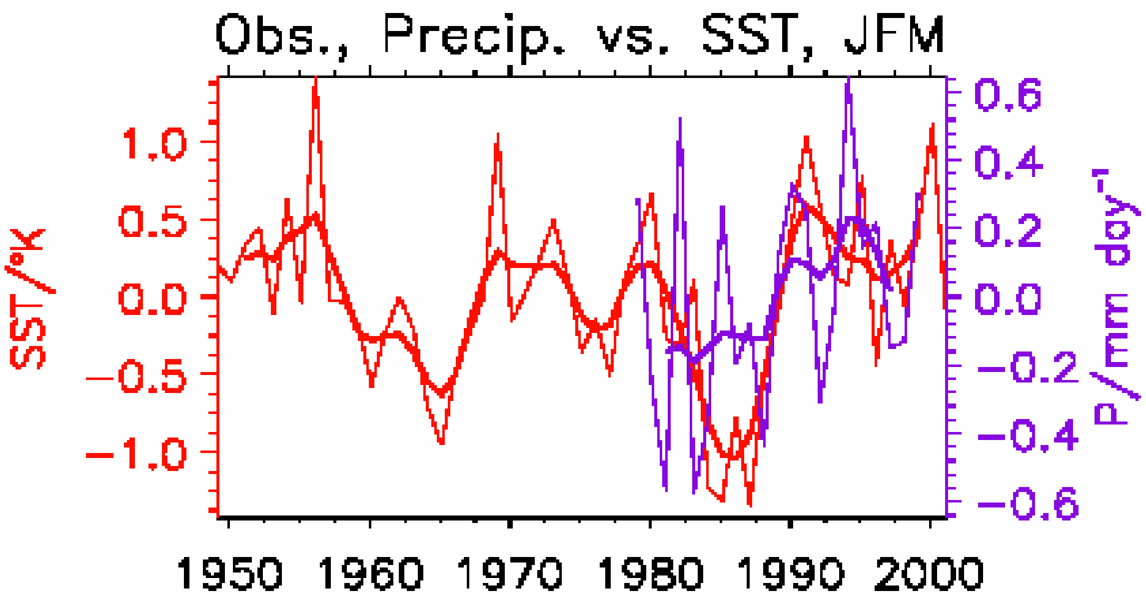
Schneider and Miller, 2001
J. Climate



Relation between SST and surface heat fluxes in KOE reveals ocean forcing atmosphere, much like in tropics

Schneider, Miller and Pierce 2002, J Climate



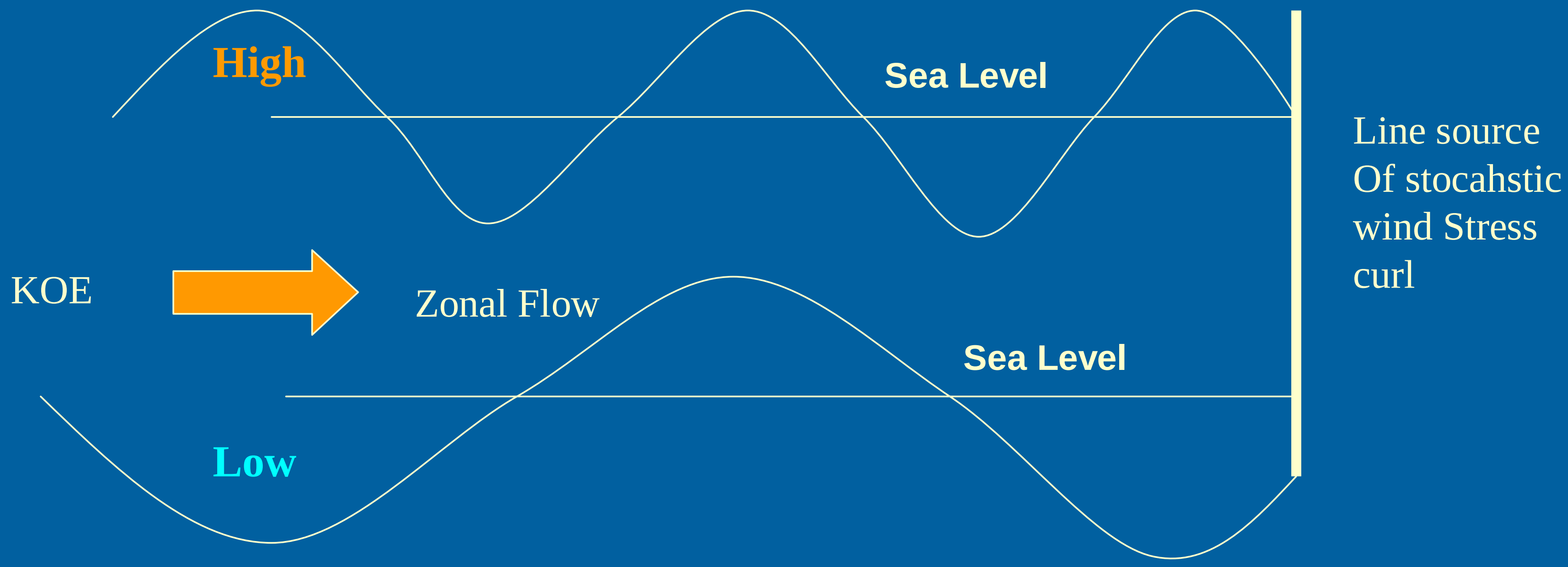


KOE SST is correlated with local regional rainfall over the ocean in this coupled model, and probably for obs.

Understanding how the downstream atmopshere behaves in response to this is vital to deterimining if decadal gyre mode feedback loops exist.

Schematic of Qiu (2004) Rossby Wave timescale selection

Rossby wave wavelength depends on latitude



For realistic parameters, strongest north-south gradient of sea level occurs for T = 10 years

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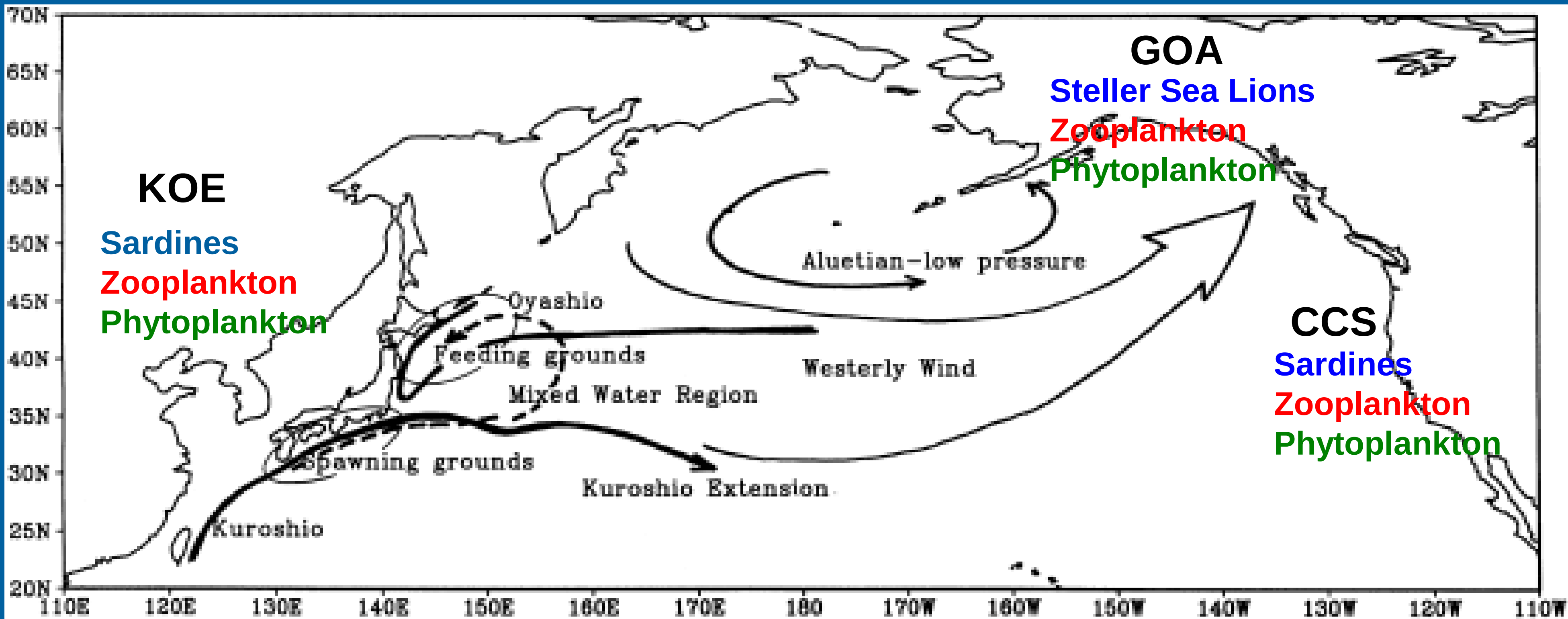
4. **Stochastic Forcing**
   - oceanic spectral peaks possible
   - predictable components possible

5. **Deterministic Forcing**
   - solar cycles, greenhouse gases

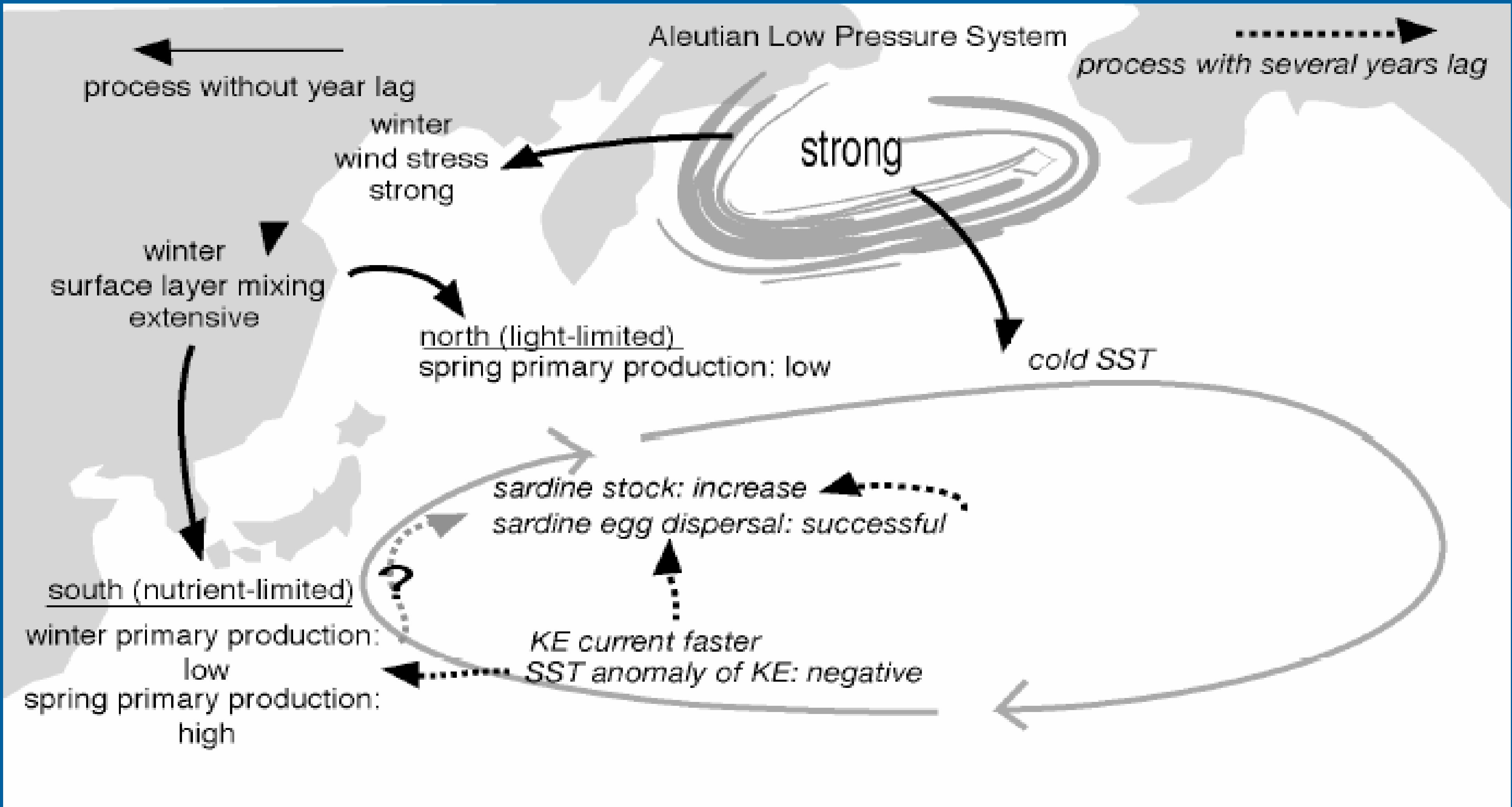
Summary of Some Regional Ecosystem Impacts Organized by Pacific Decadal Variability



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

Ecosystem response processes in KOE on long timescales

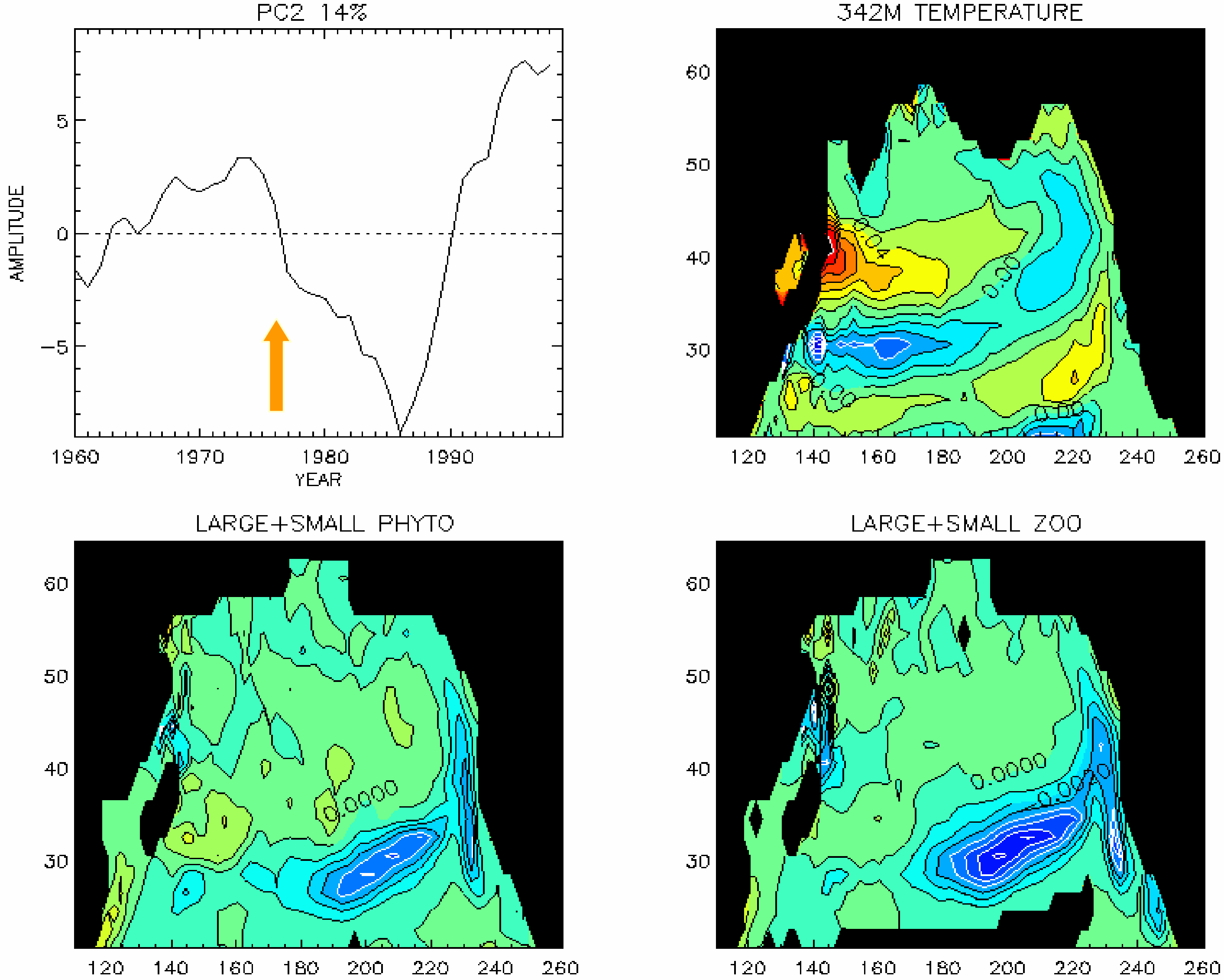
Strengthened Aleutian Low



Miller, Chai, Chiba, Moisan and Neilson, J. Oceanogr., 2004

Physical-Biological Hindcast of Pacific Ocean Decadal Variability

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



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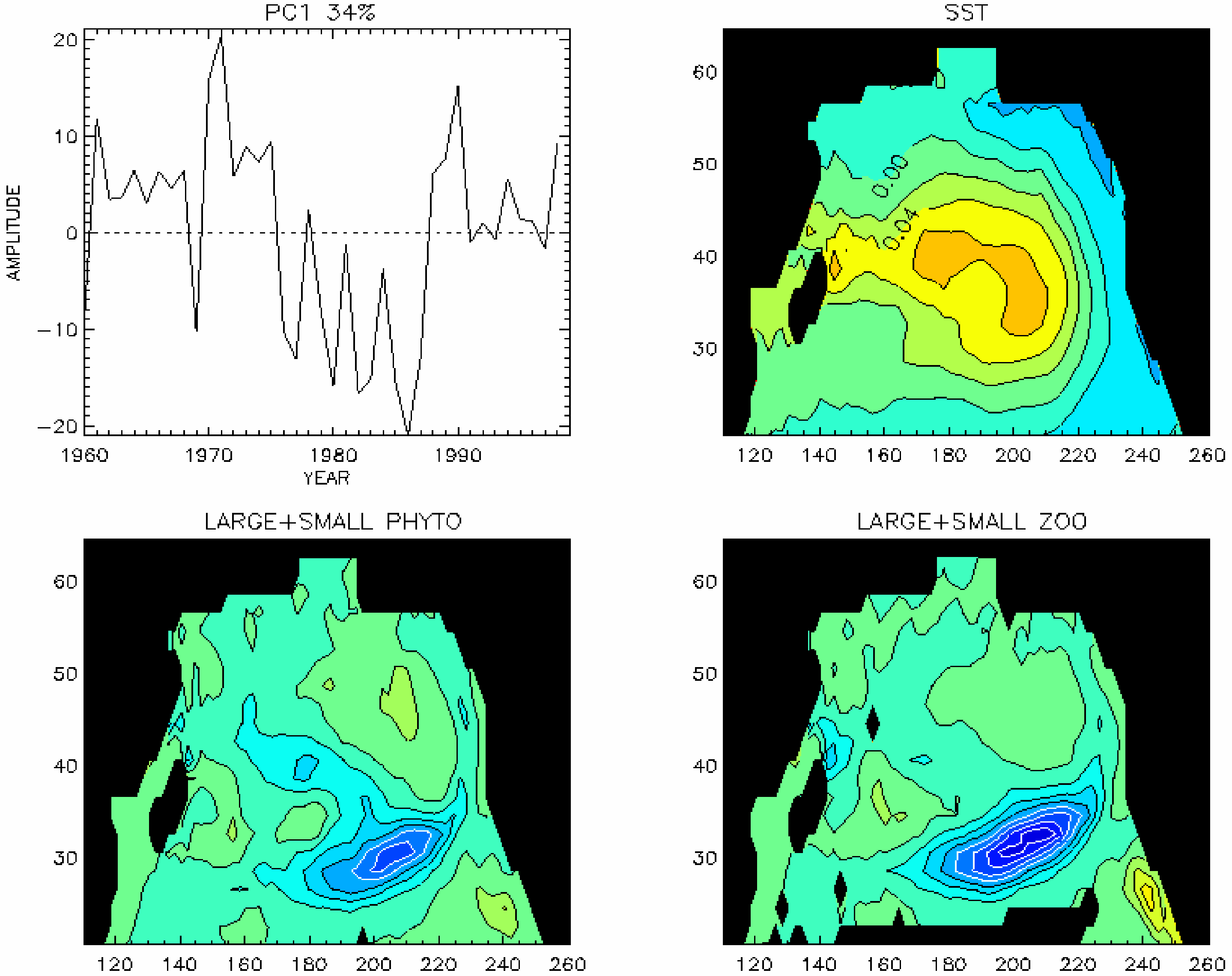

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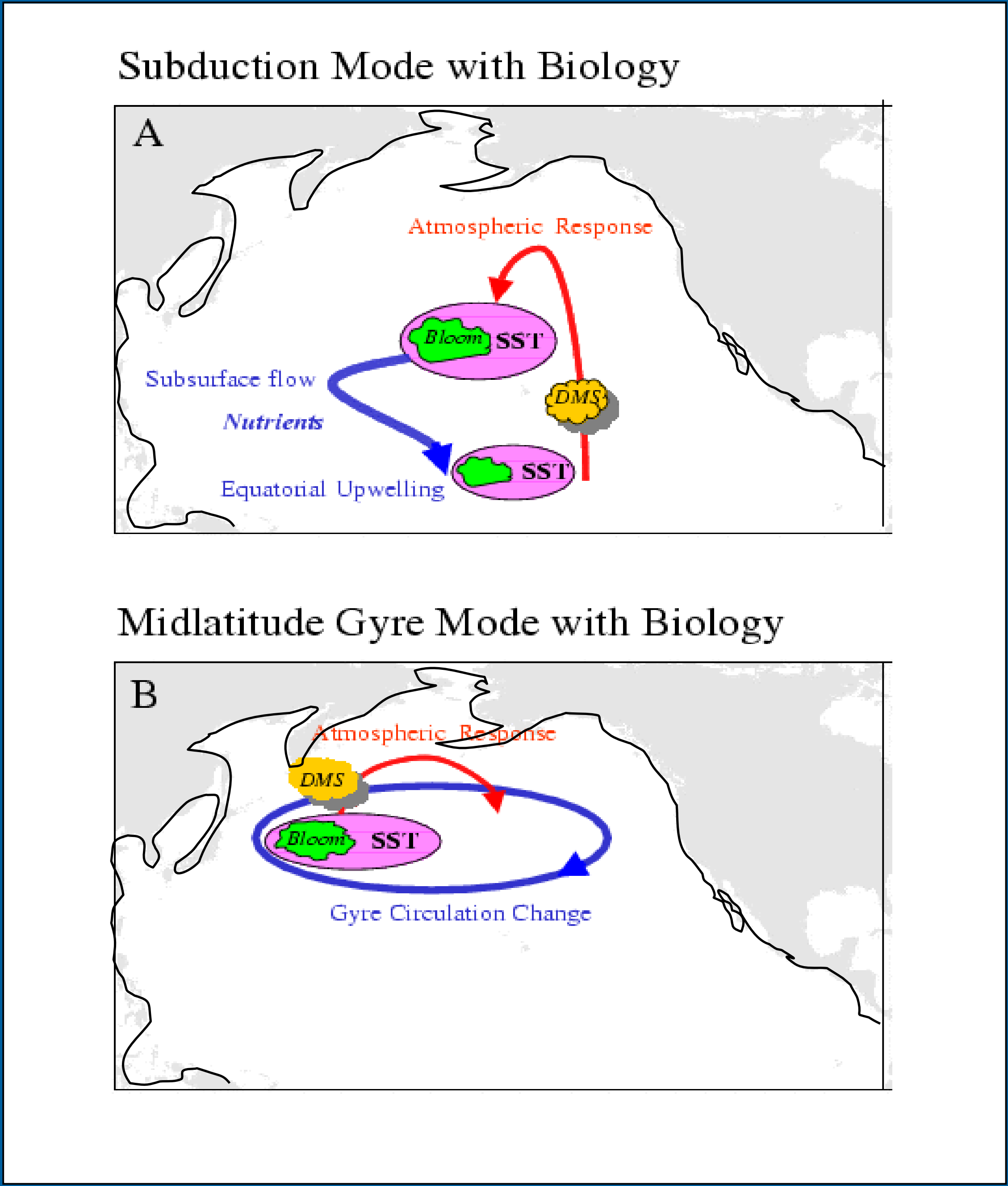

Schematic of the Gu-Philander class of decadal mode with DMS aerosols and phytoplankton heat absorbtion effects

Schematic of the Latif-Barnett class of decadal mode with DMS aerosols and phytoplankton heat absorbtion effects

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Directions….

Atmosphere

- Details of atmosphere response over KOE region
- Sensitivity to ocean biology: DMS aerosols
- Regional downscaling over mountains and coasts

Ocean

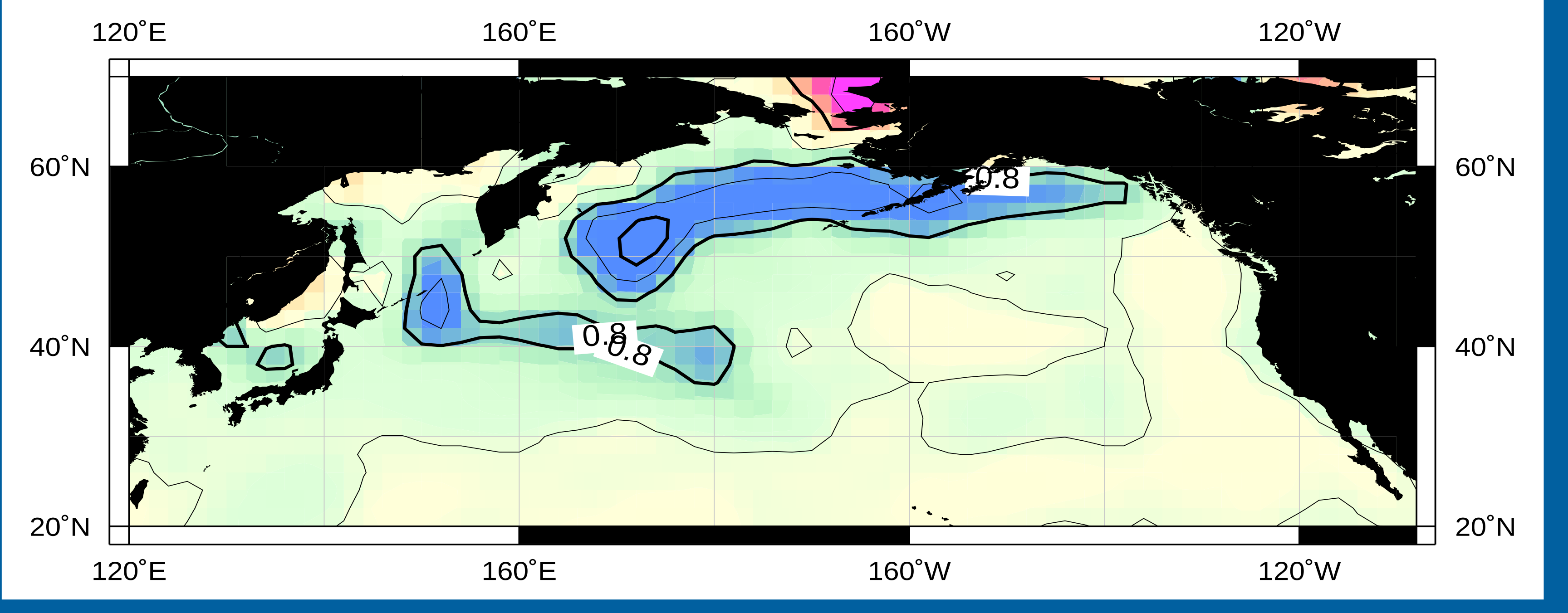
- Physical mechanisms of adjustment to forcing
- Lags and predictable compoments
- Changes in eddy statistics
- Sensitivity to ocean biology: phytoplankton absorbtion

Biology

- Organization of response by ocean patterns
- Lags and predictable components
- Distinguishing forced from intrinsic variations

…and Global Change effects on all these….

Effects of anthropogenic forcing on biological activity



Biological Model Phytoplankton [mmol C/m^3]

Ratio, Year 2100 / Year 2000

Pierce, Climate Change, 2003, submitted