OUR GOAL IS NOT REGIME CHANGE.
OURS IS!
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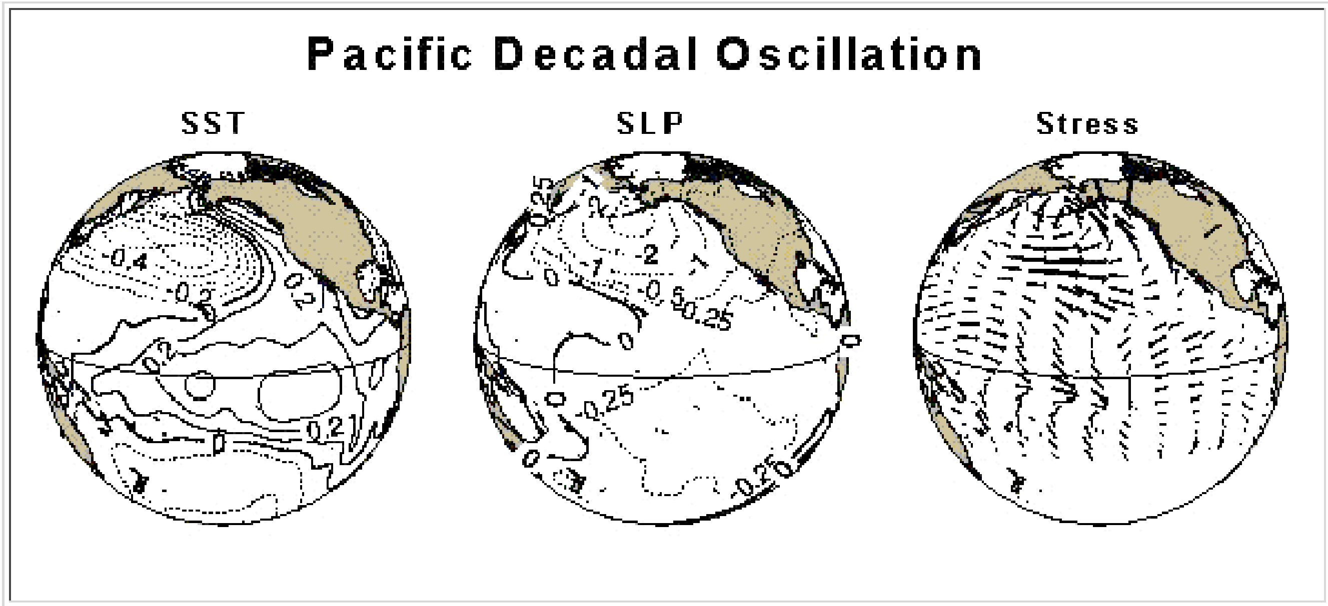
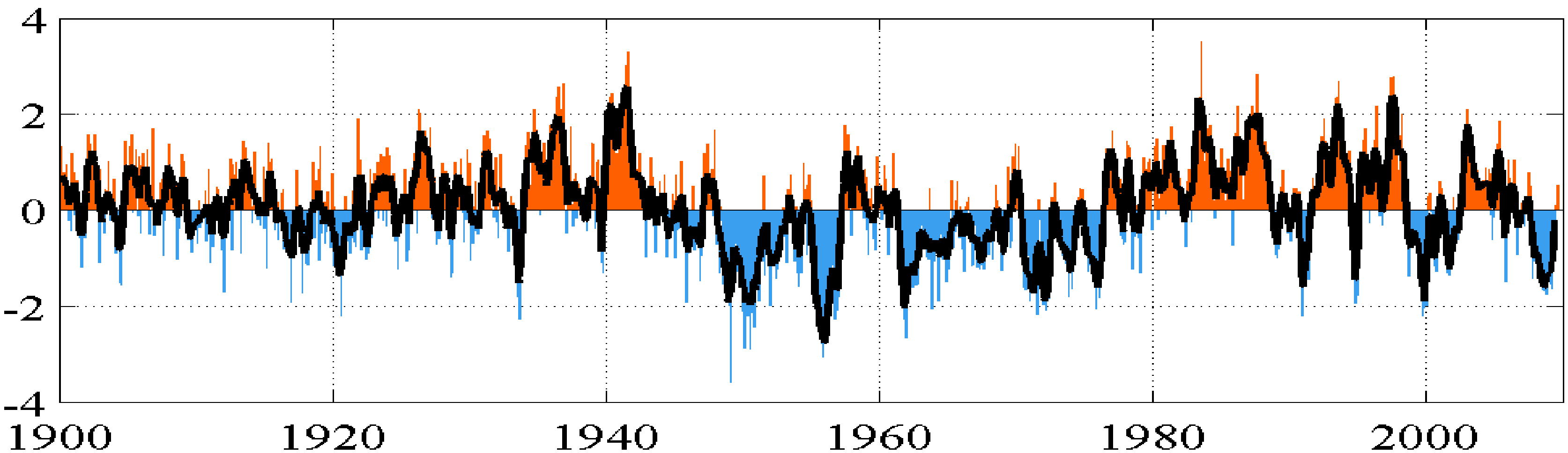
Past and Future Regime Shifts in the North Pacific from Physical and Biochemical Perspectives

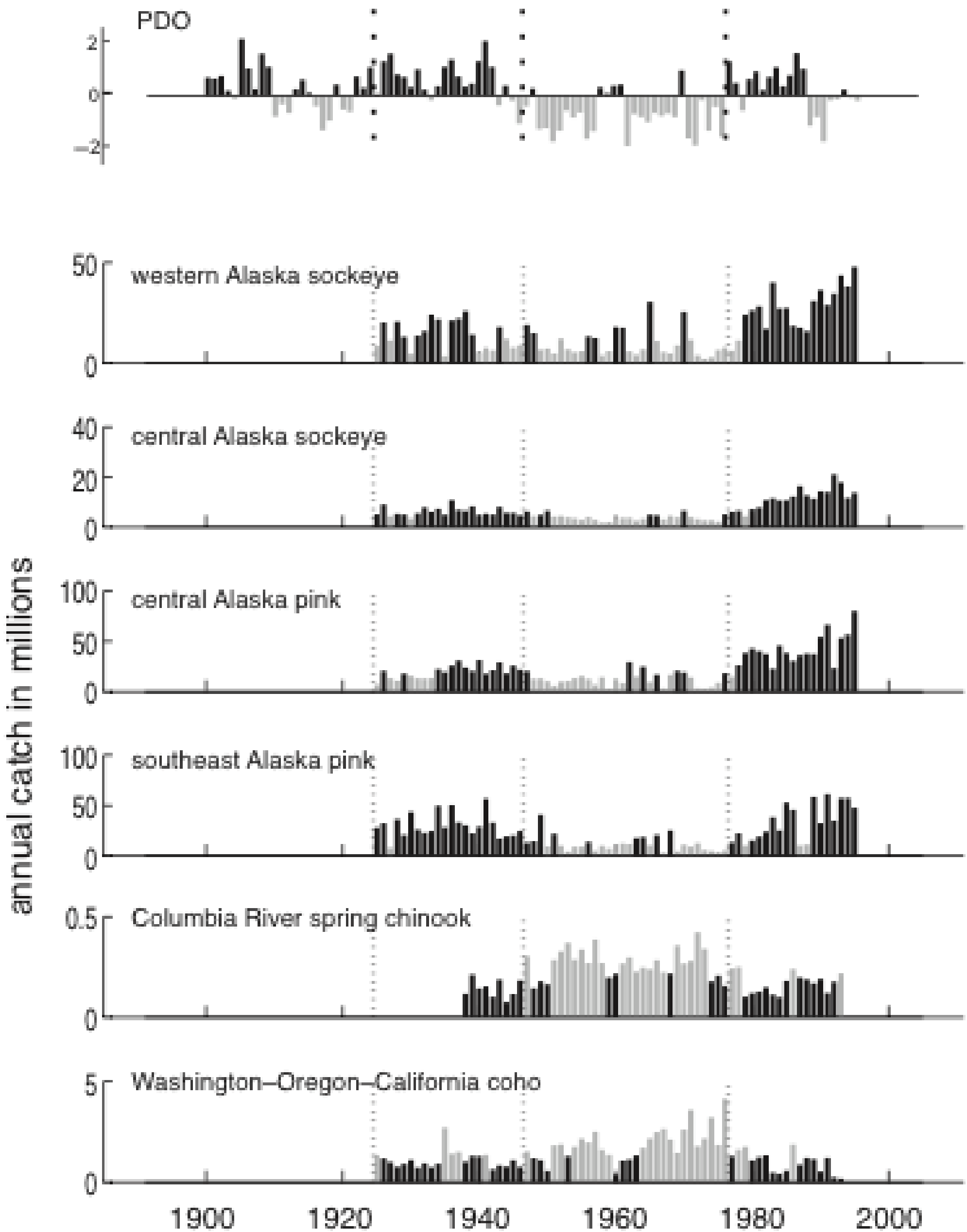
- Past Fluctuations – Physics vs. Biochemistry
- Future Variability from Global Climate Models
- Philosophical Musings

N. Mantua UW
S. Hare IPHC

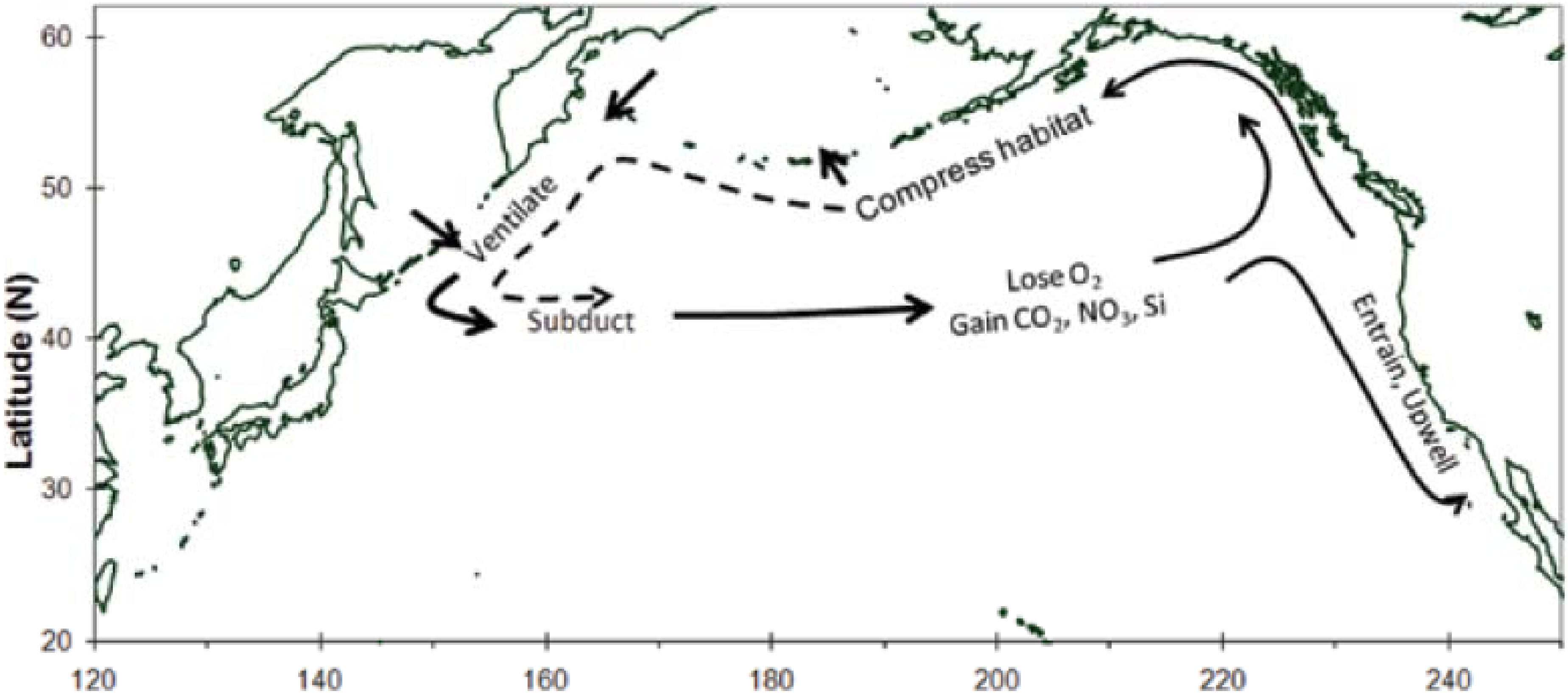


monthly values for the PDO index: 1900-September 2009

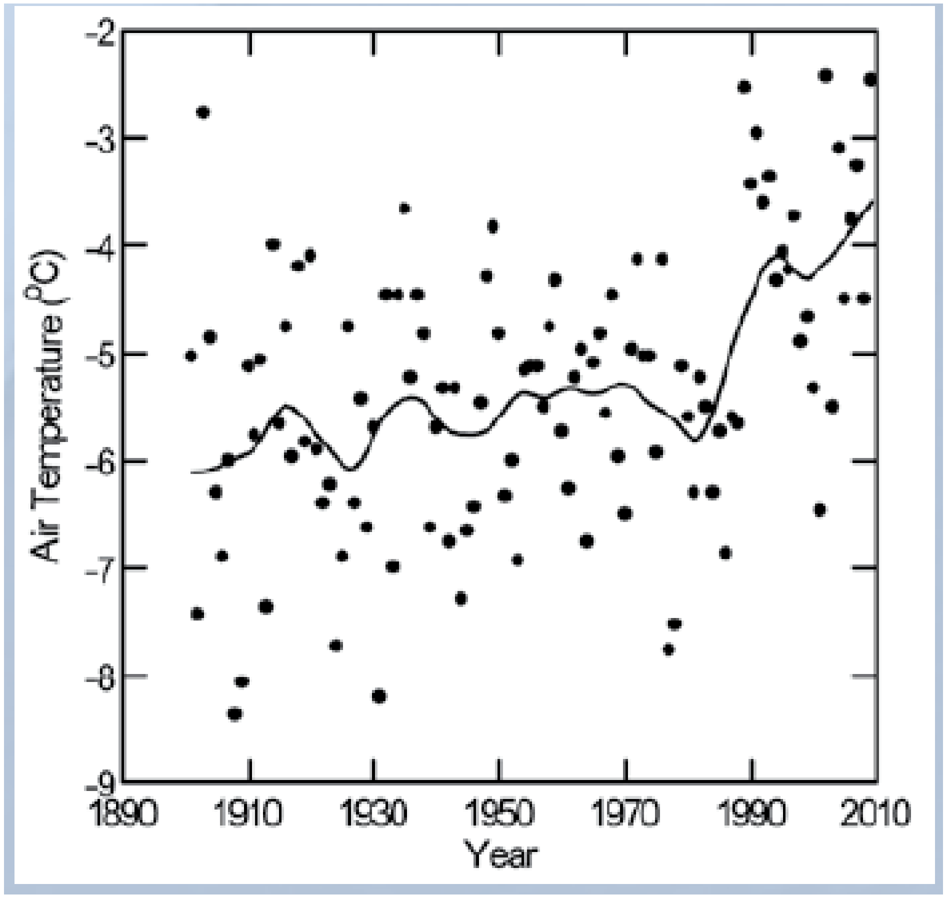




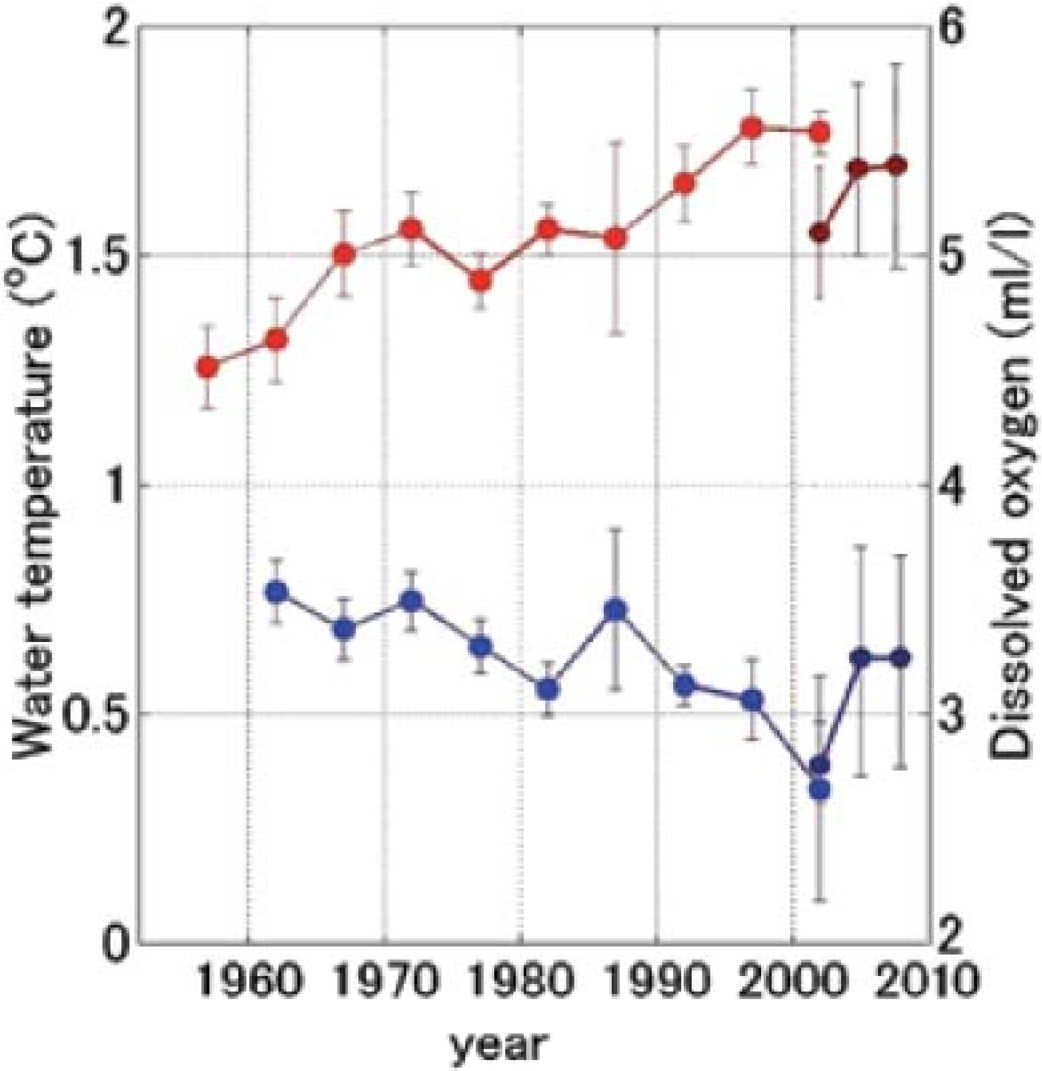
Mantua et al. (BAMS, 1996)



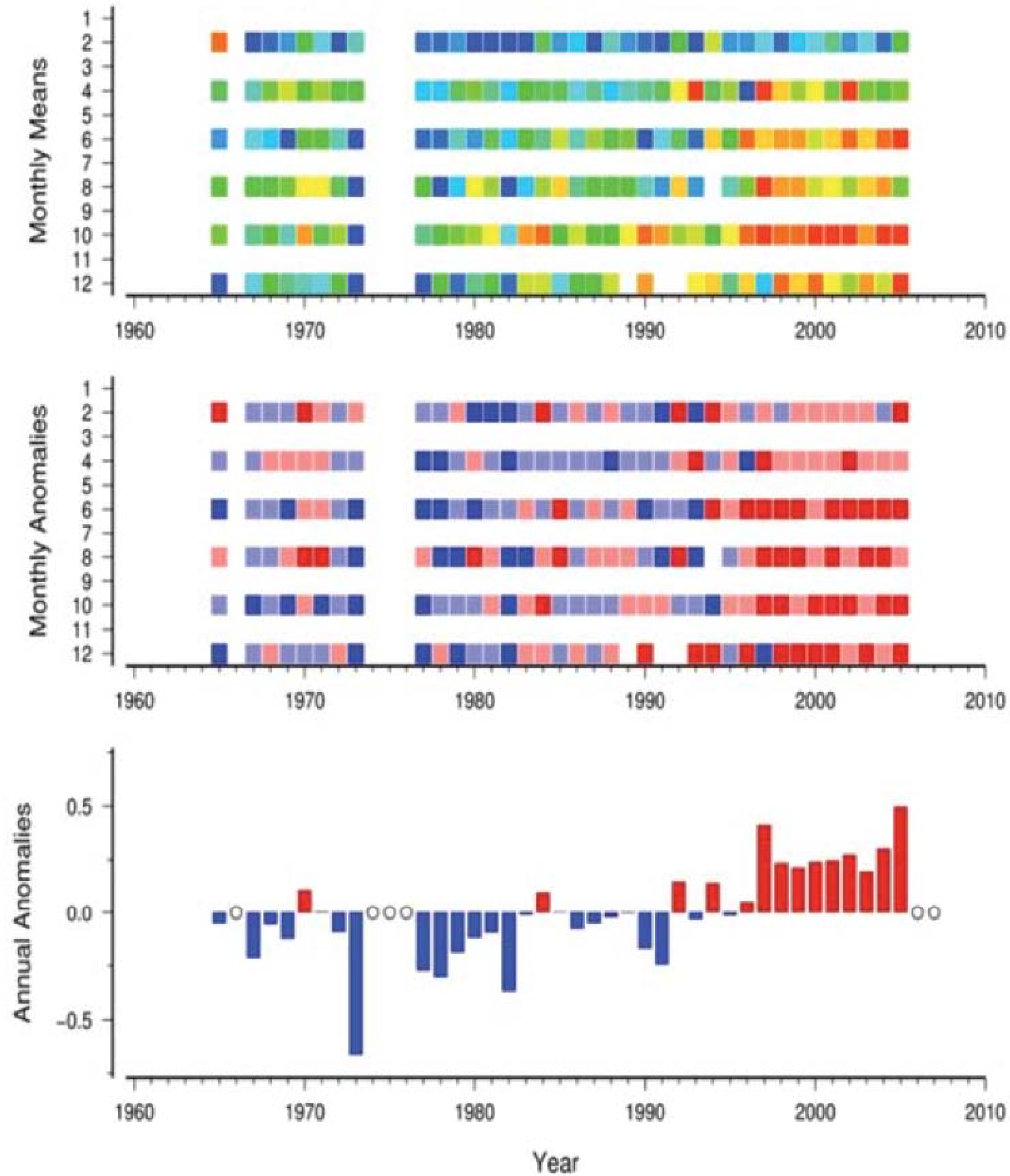
Marine Ecosystems of the North Pacific Ocean 2003-2008, PICES Special Pub. 4



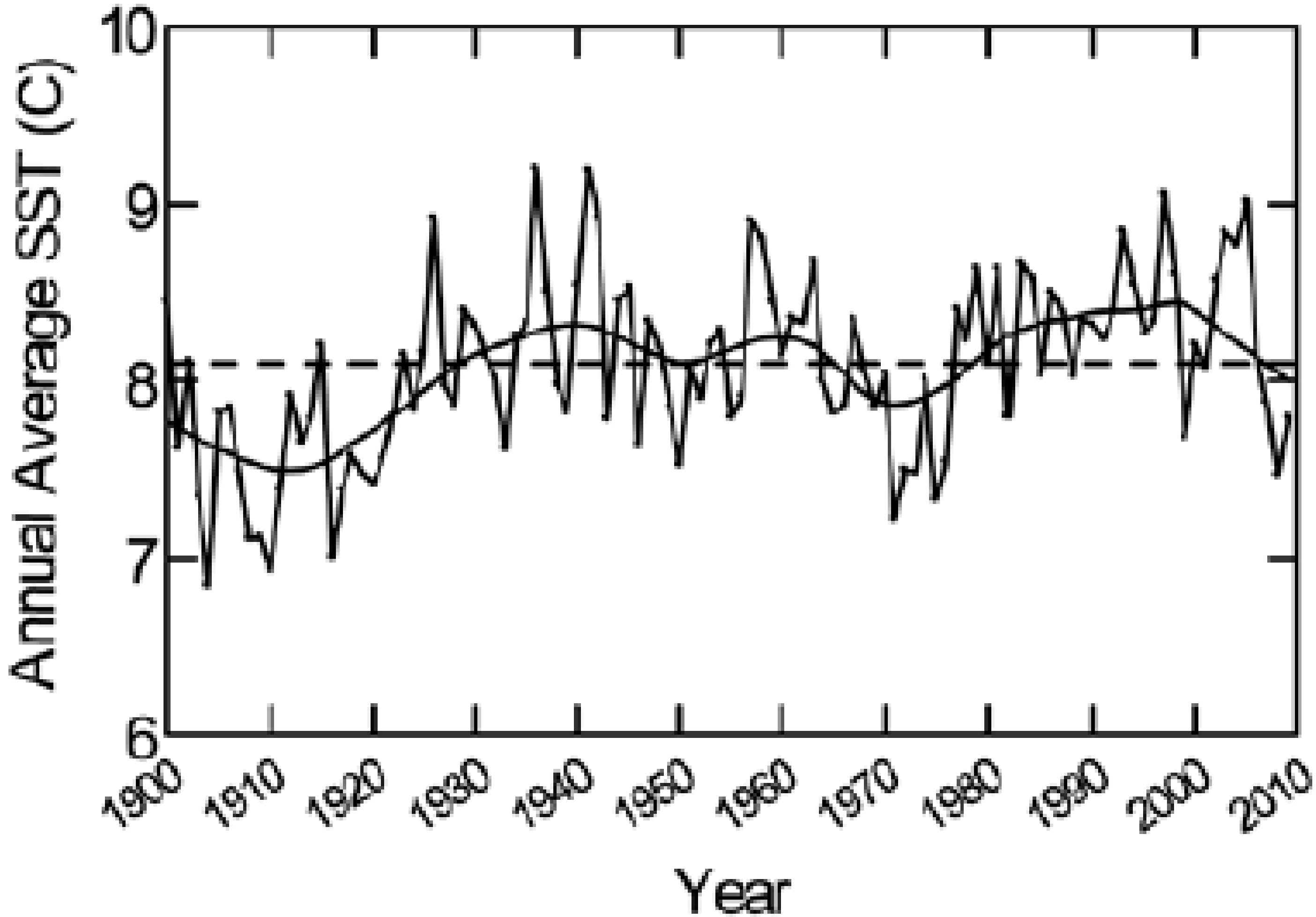
Mean Jan-Mar Air Temperatures at Abashiri, Japan near southwest corner of the Sea of Okhotsk



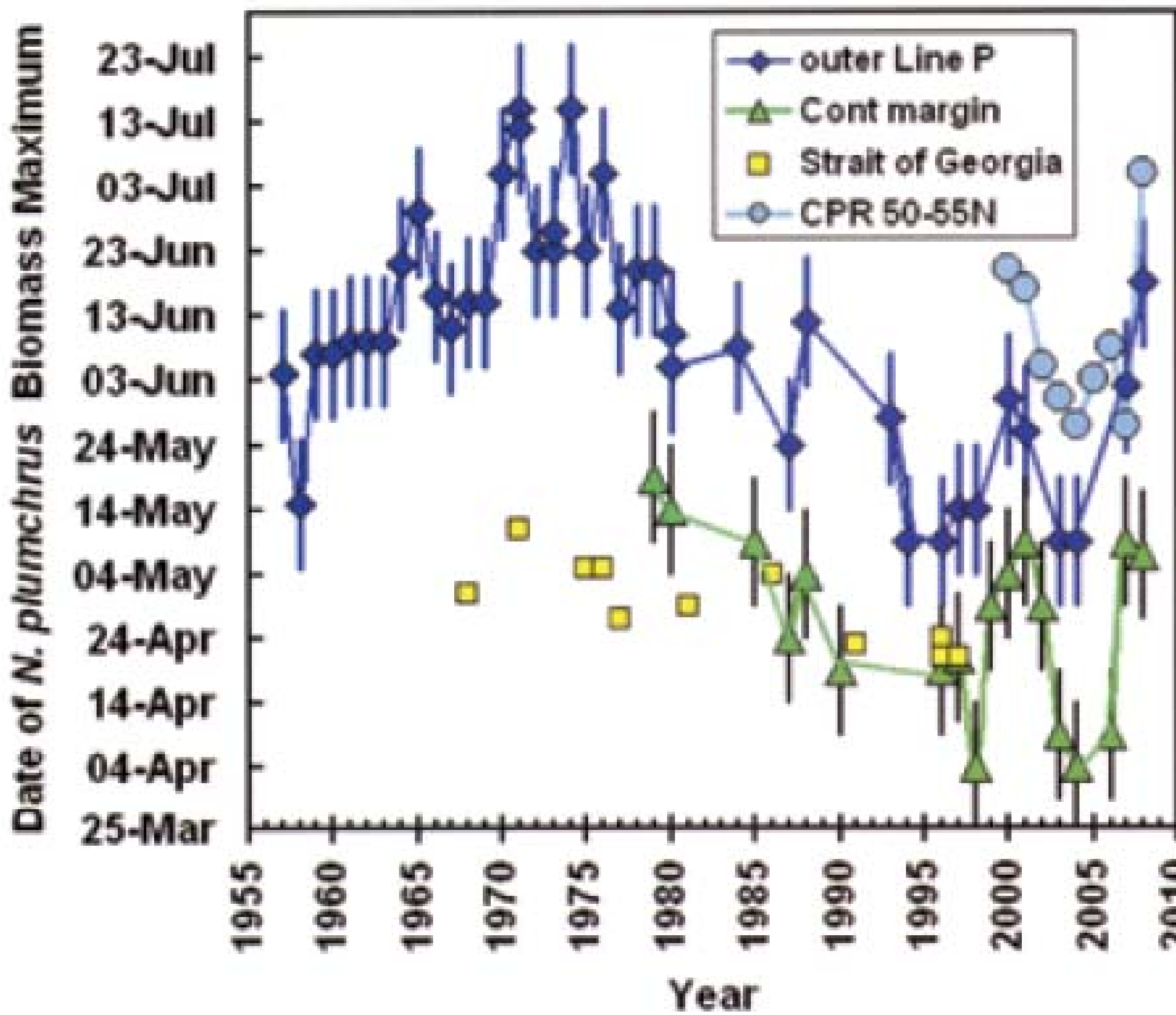
Temperature (Red) and Dissolved Oxygen (Blue) on σ 27.0 Surface (~400 m) in Sea of Okhotsk



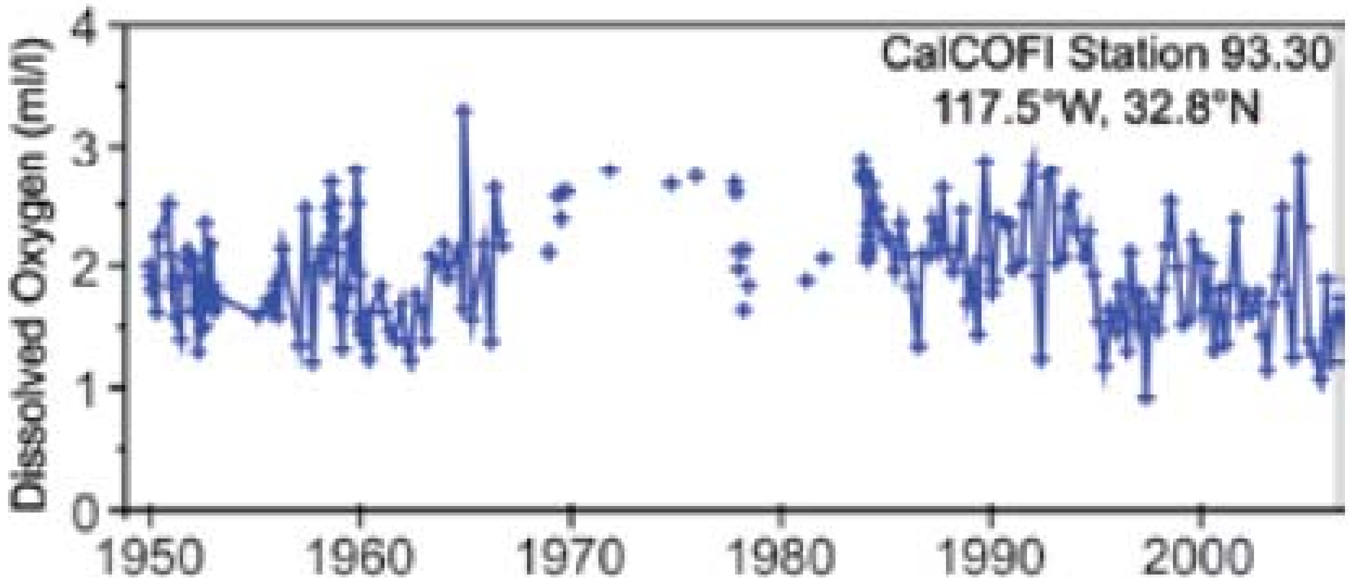
Zooplankton Biomass in northern East China Sea (Kang et al. 2009)



SST in Gulf of Alaska (Smith et al. 2007)



Timing of Zooplankton Biomass Maxima along Line-P (Mackas)

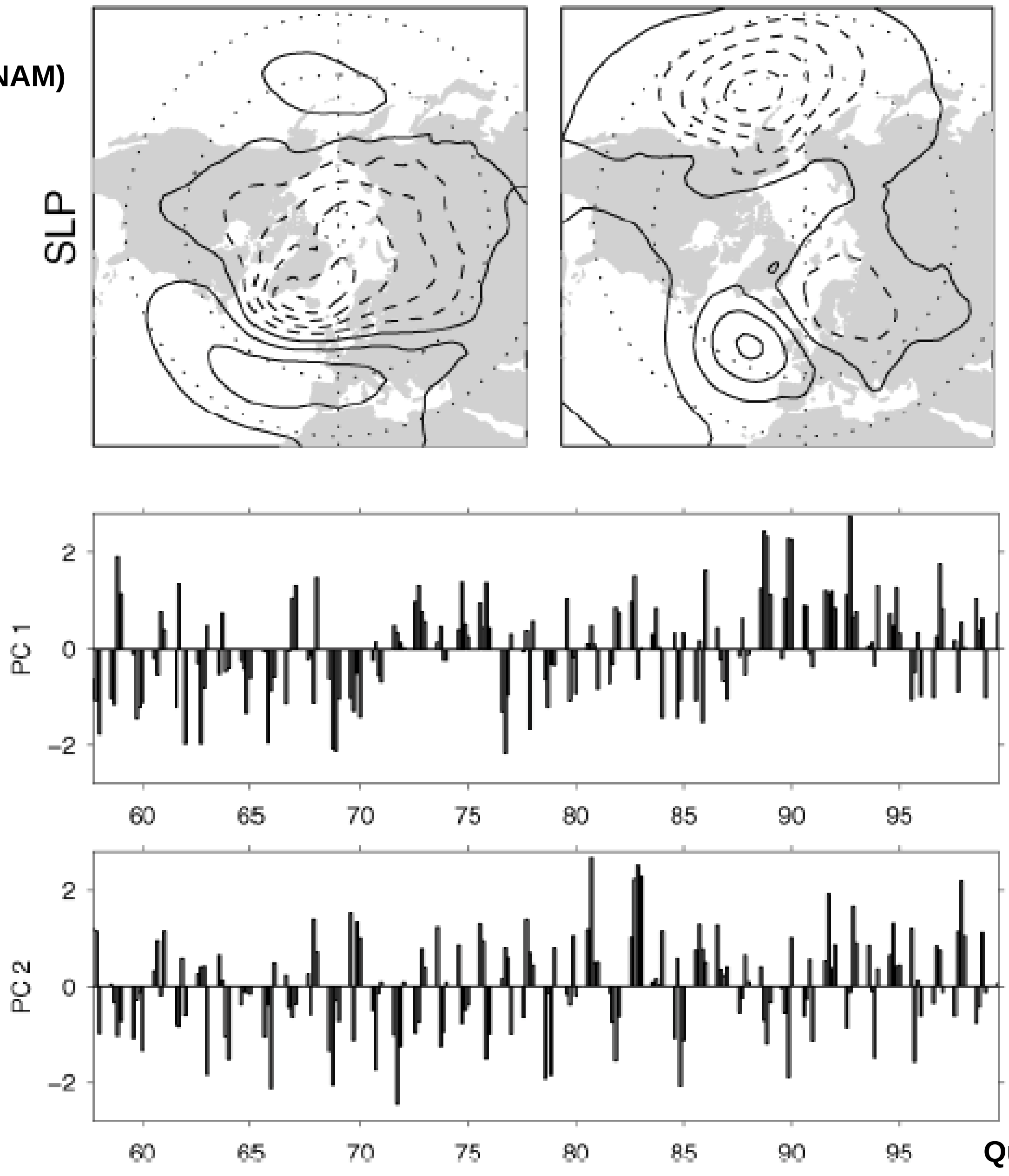


Dissolved Oxygen at 200 m near San Diego, CA

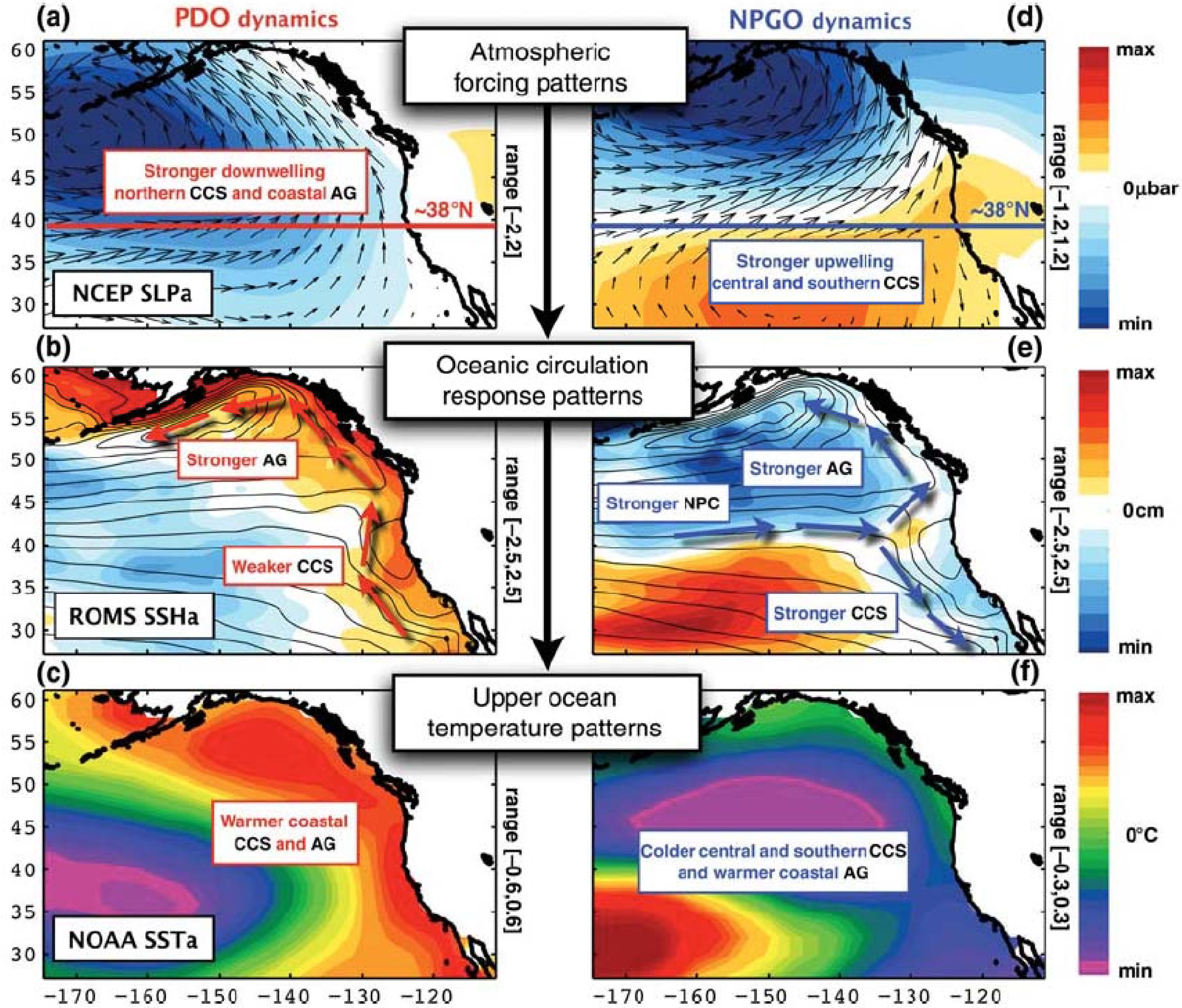
N. Hemisphere has Two Robust Climate Patterns

Northern Annular Mode (NAM) or Arctic Oscillation (AO)

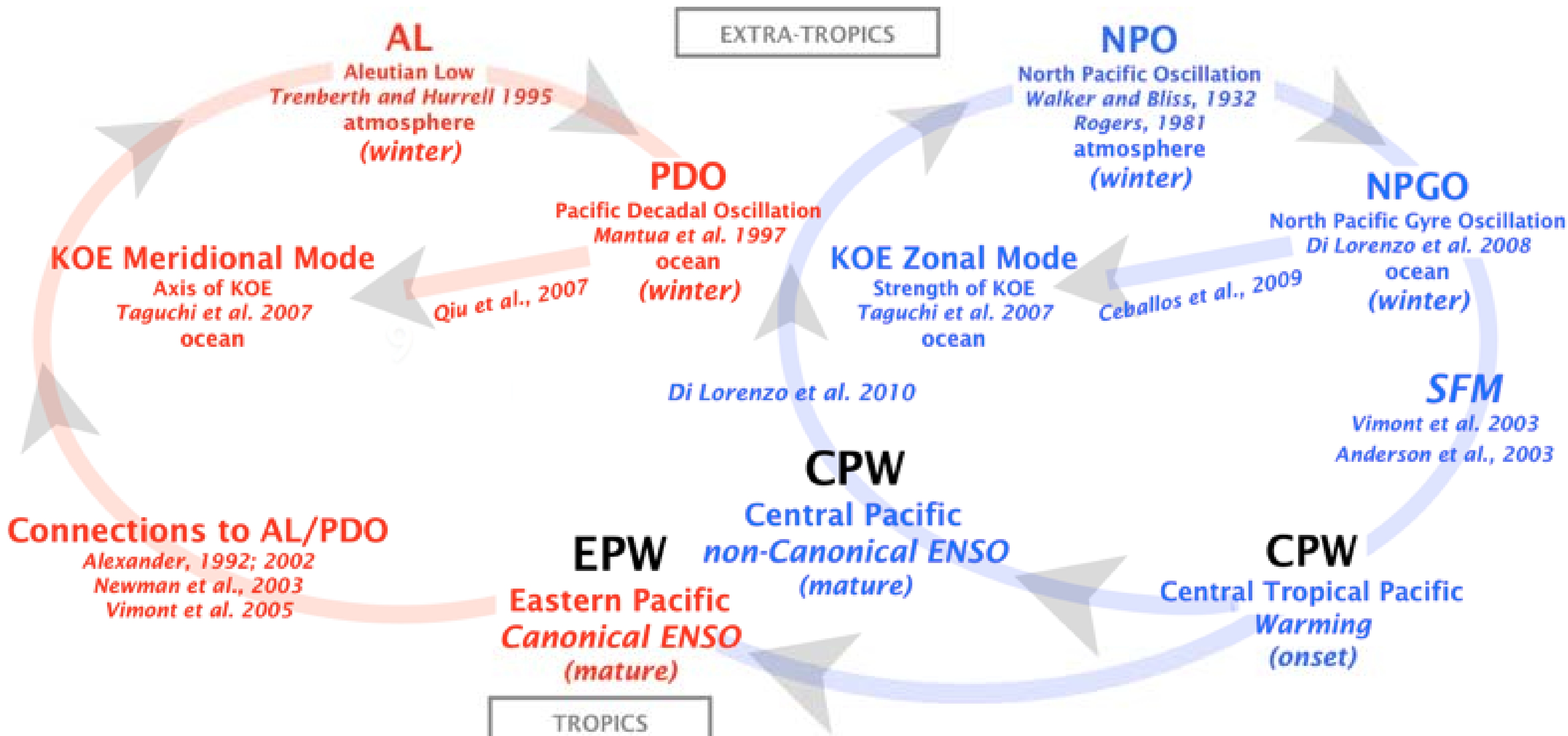
Pacific- North American Pattern (PNA)



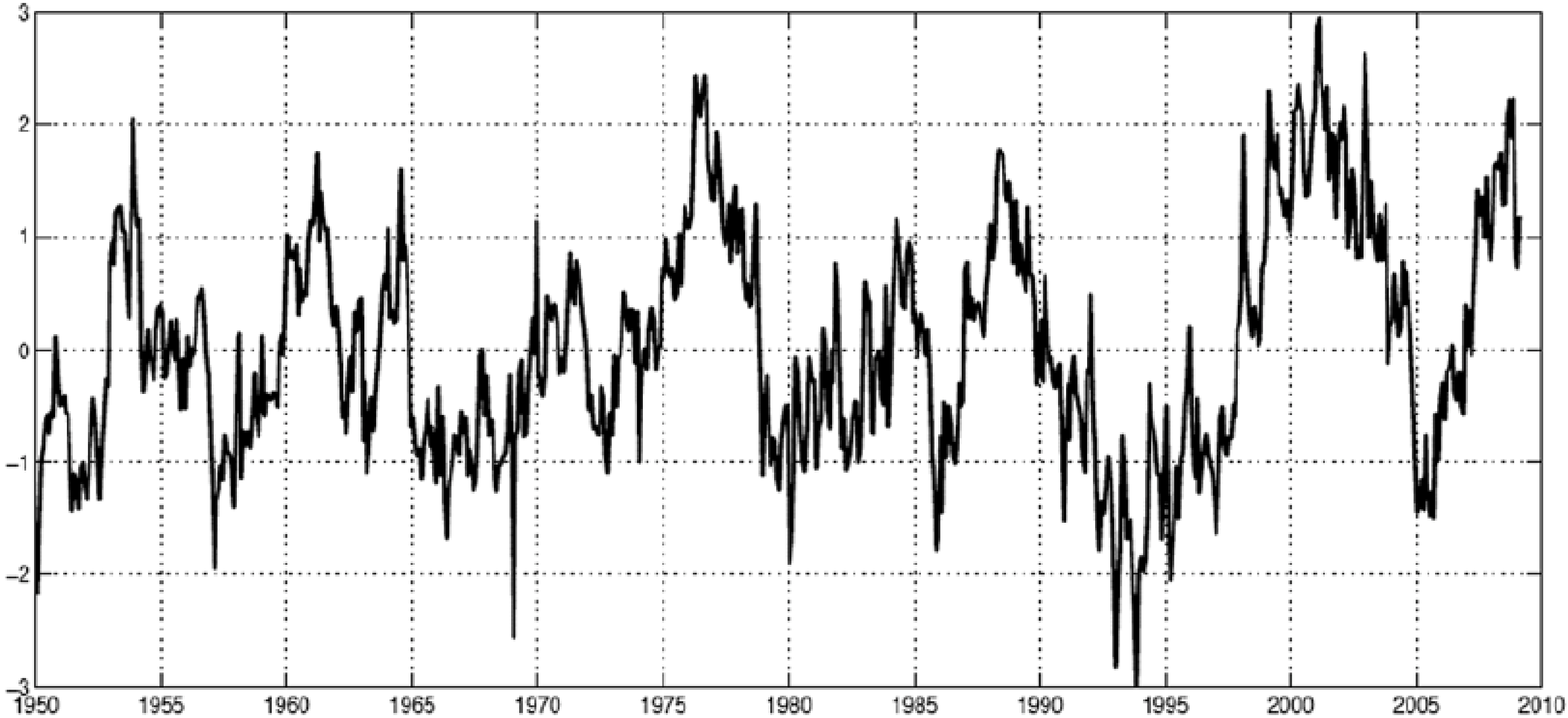
Quadrelli and Wallace (2004)



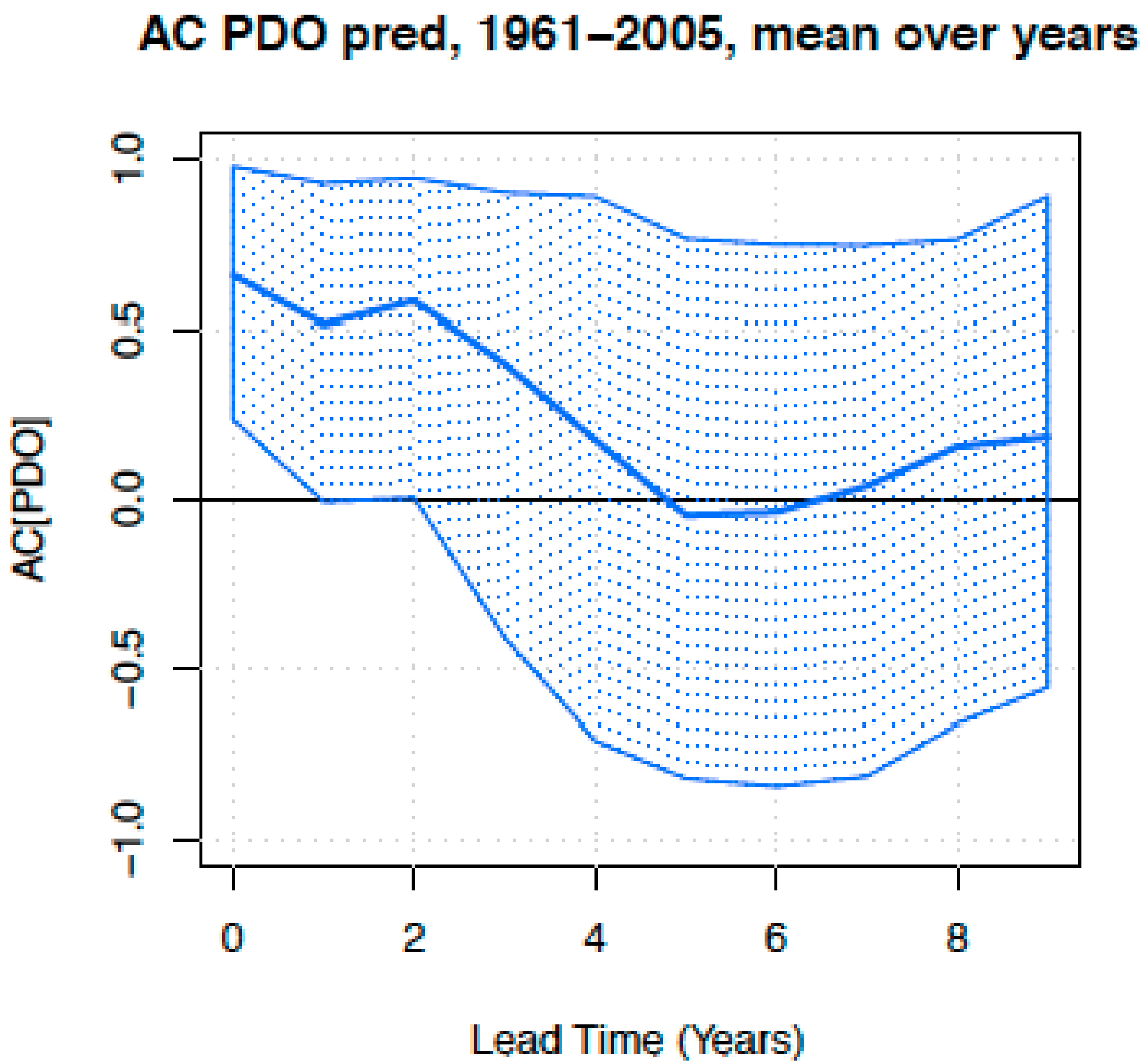
(a)
PDO dynamics
(d)
NPGO dynamics
Atmospheric forcing patterns
Stronger downwelling northern CCS and coastal AG
~38°N
NCEP SLPa
range [−2,2]
Stronger upwelling central and southern CCS
~38°N
range [−1.2,1.2]
max
0μbar
min
(b)
Oceanic circulation response patterns
(e)
Stronger AG
Weaker CCS
ROMS SSHa
range [−2.5,2.5]
Stronger AG
Stronger NPC
Stronger CCS
range [−2.5,2.5]
max
0cm
min
(c)
Upper ocean temperature patterns
(f)
Warmer coastal CCS and AG
NOAA SSTa
range [−0.6,0.6]
Colder central and southern CCS and warmer coastal AG
range [−0.3,0.3]
max
0°C
min
60
55
50
45
40
35
30
−170
−160
−150
−140
−130
−120



M. DiLorenzo and Collaborators



North Pacific Gyre Oscillation (DiLorenzo et al. 2008)

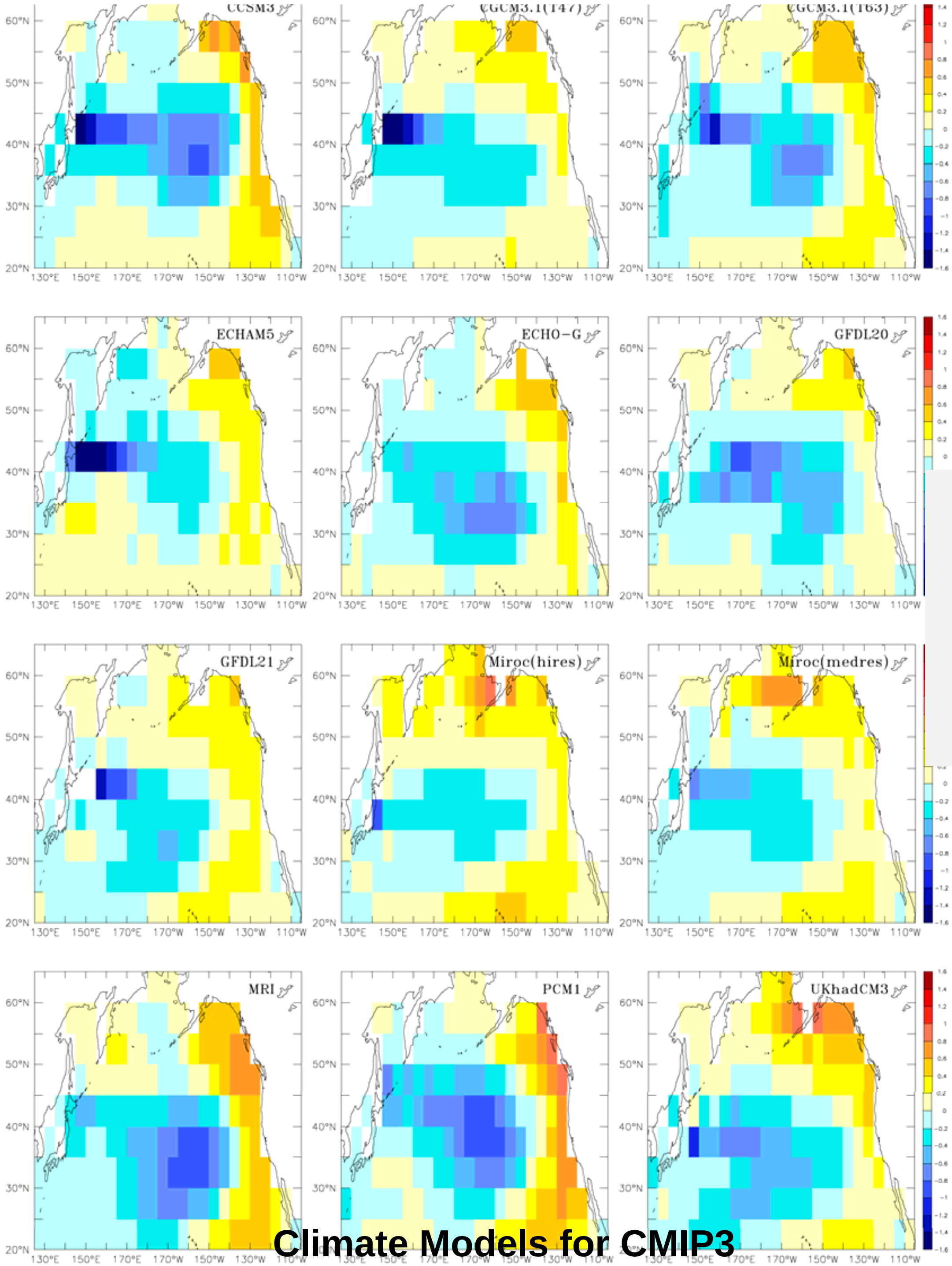


Skill of Global Climate Model (DHFP1) for PDO Prediction
Lienert (Ph.D., 2011)

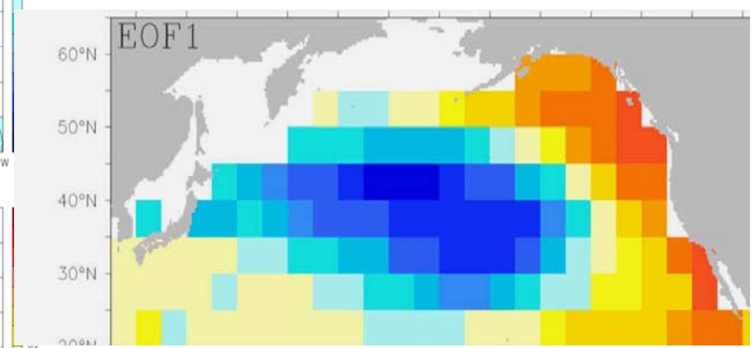
Notable Examples:

- Early 20th century warmth in North Atlantic
- Mid-1970s regime shift in North Pacific
- Recent switch from very warm to cold in the Bering Sea

Appear to be large, random events
(not regular oscillations)
due to natural variability

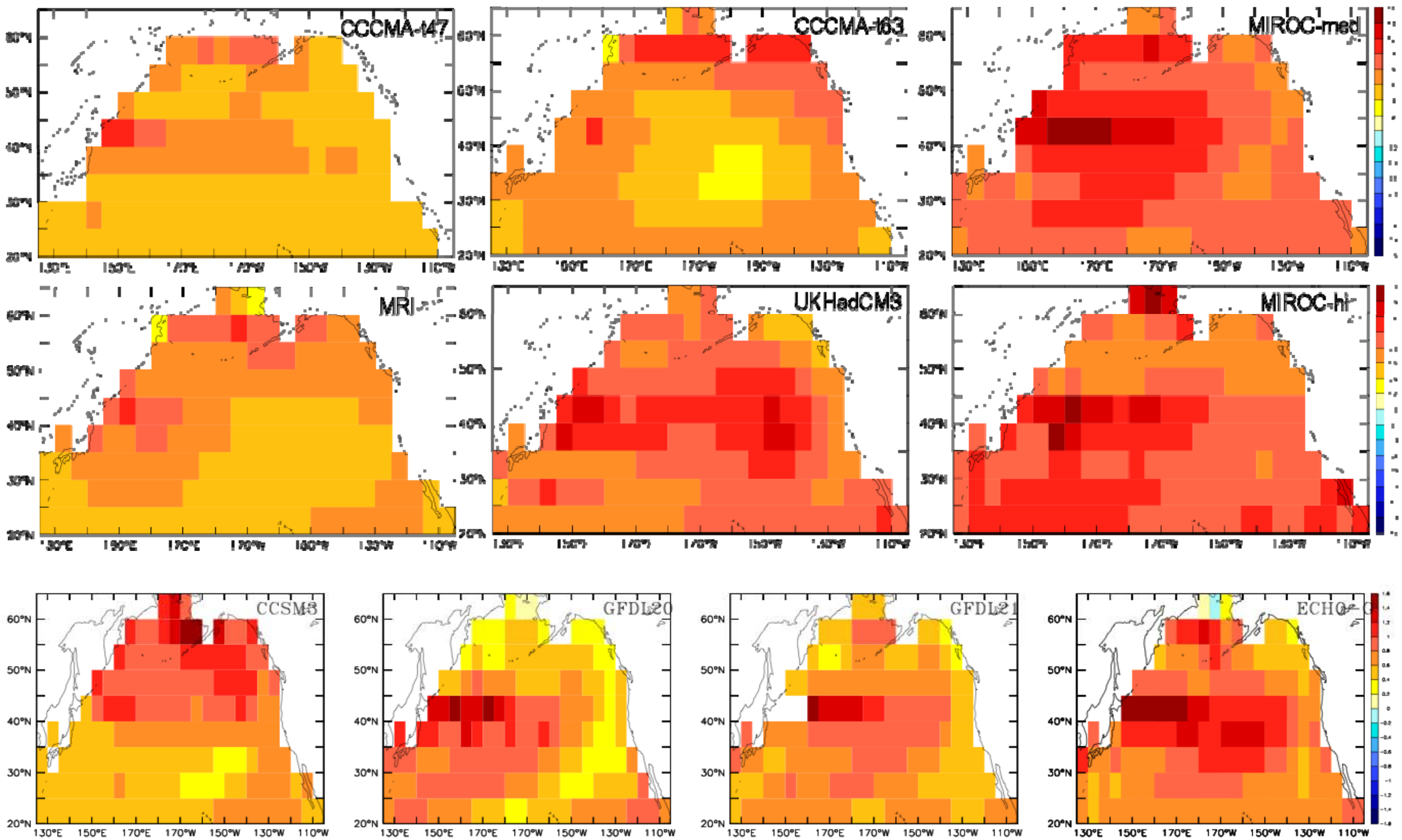


Climate Models for CMIP3

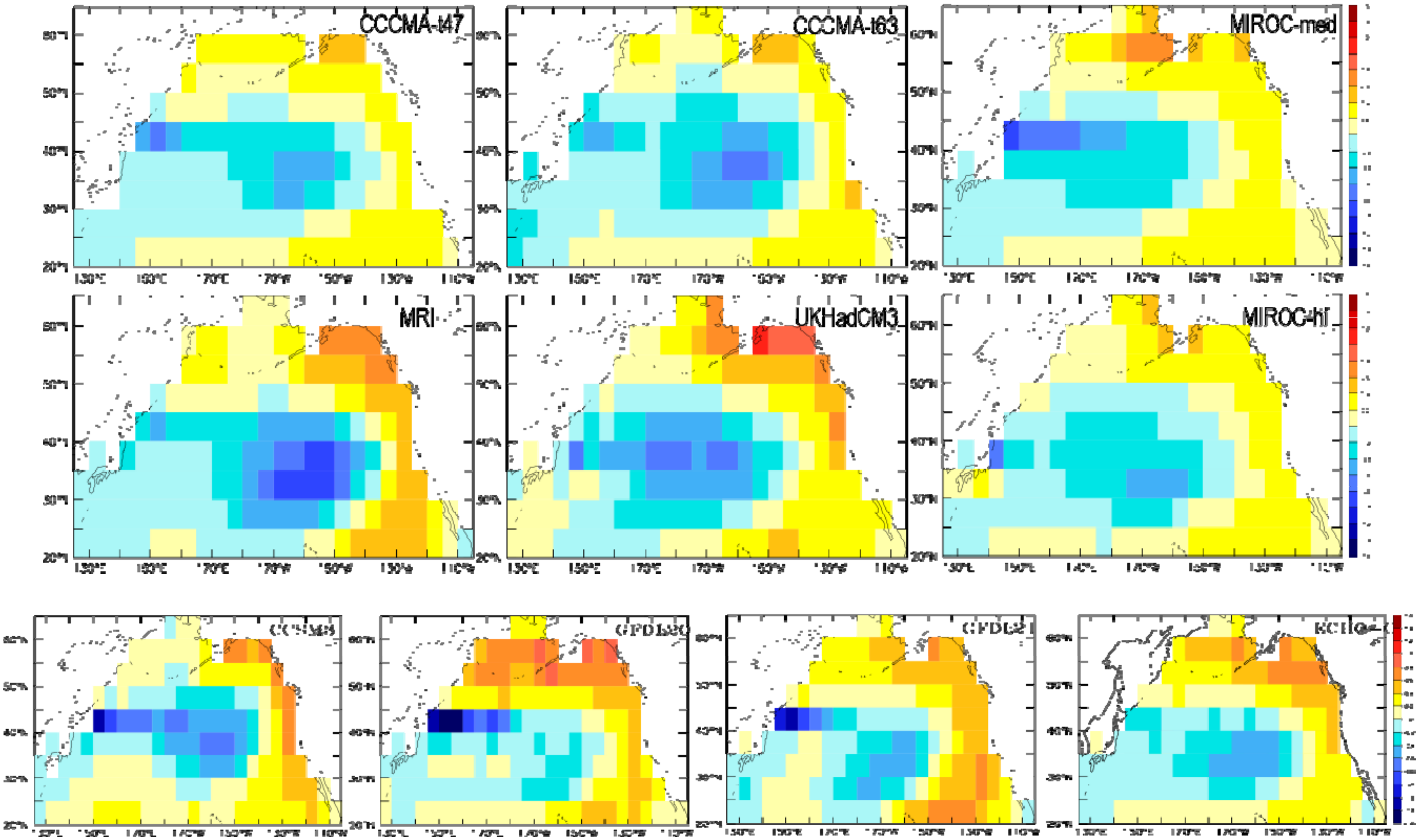


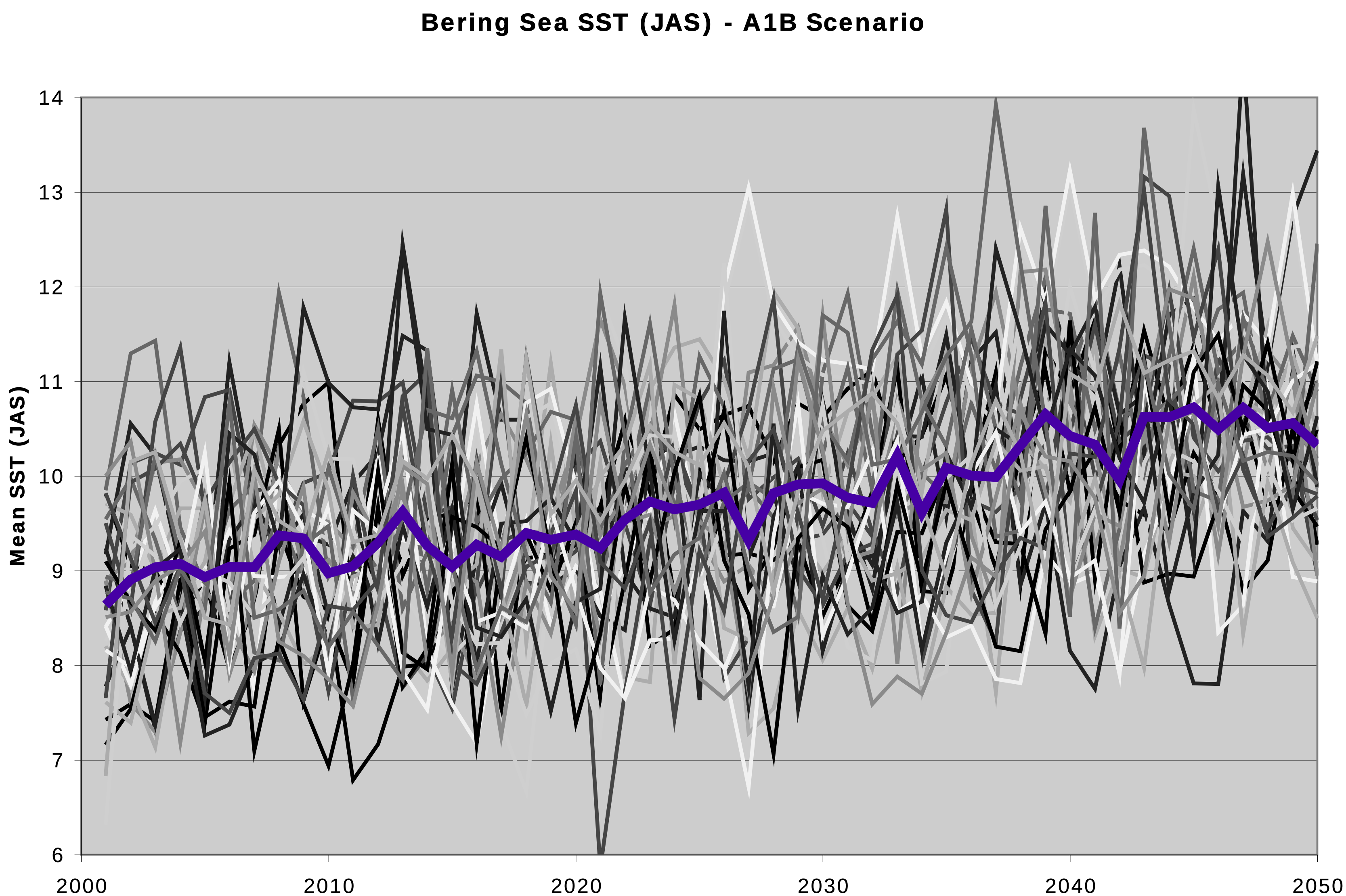
Leading Mode of North Pacific SST Variability (Observations)

EOF1 of SST for 2001-2099 in A1B

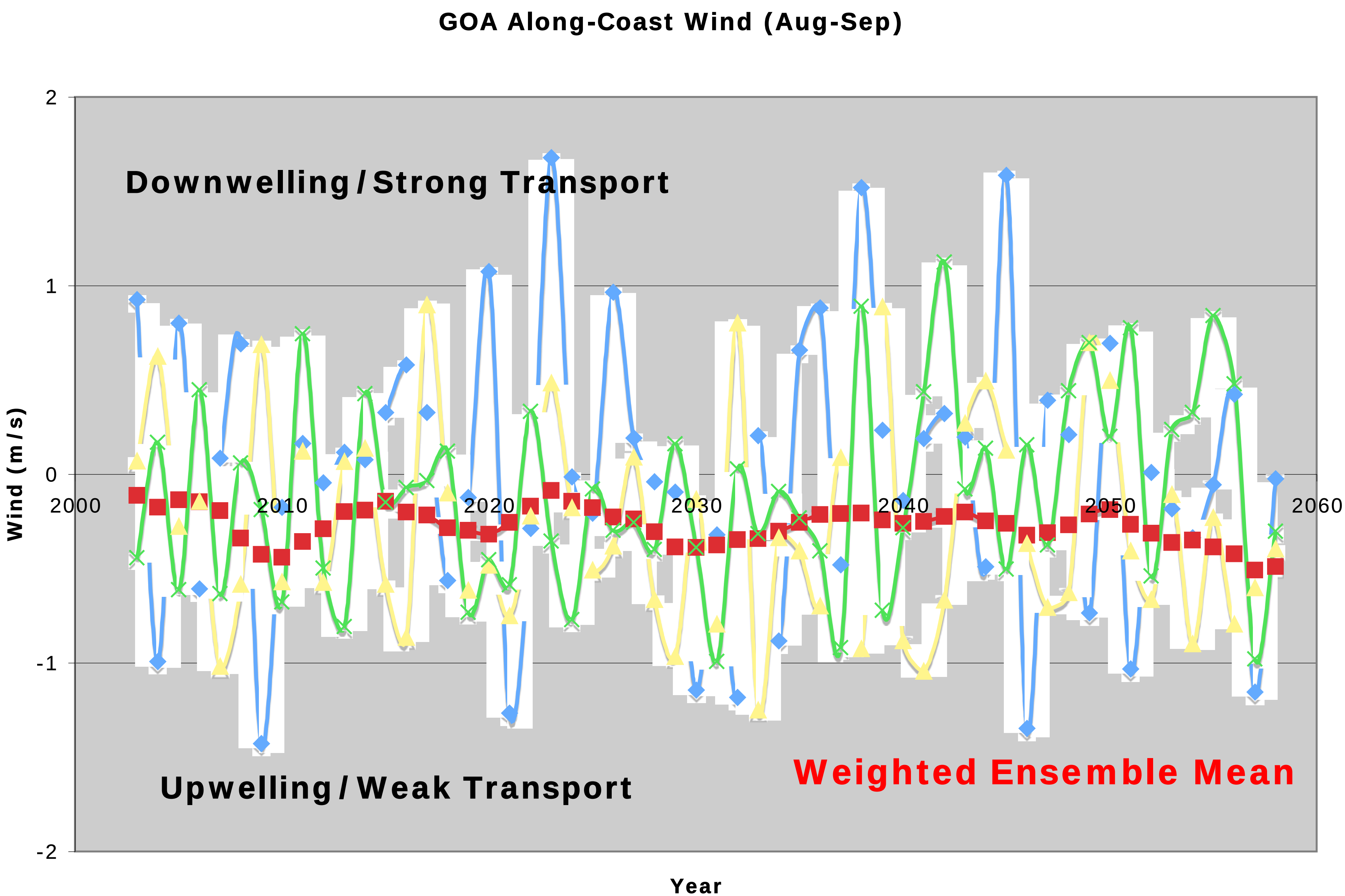


EOF2 of SST for 2001-2099 in A1B

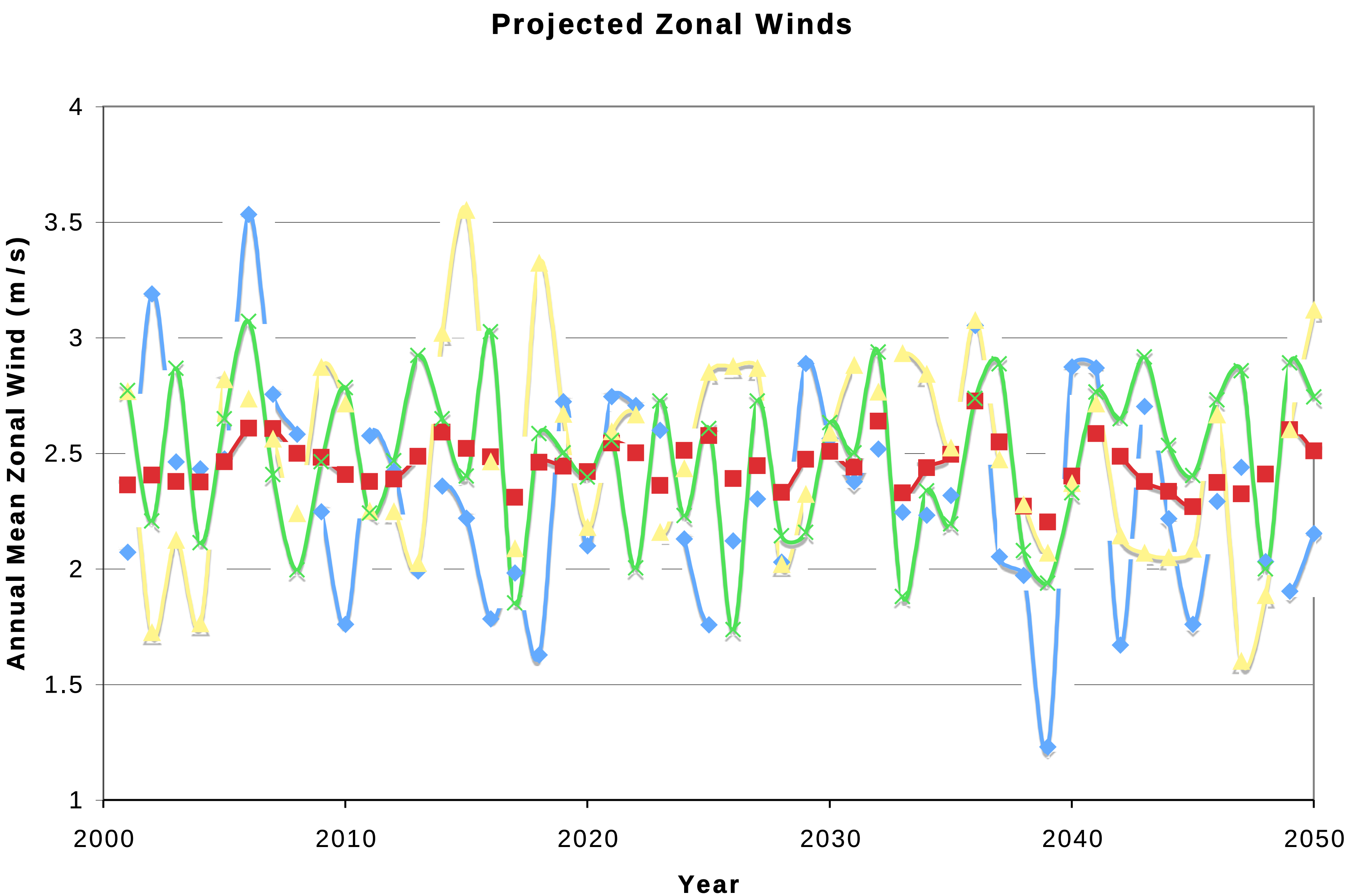




Bering Sea SST (JAS) - A1B Scenario
Mean SST (JAS)
14
13
12
11
10
9
8
7
6
2000
2010
2020
2030
2040
2050

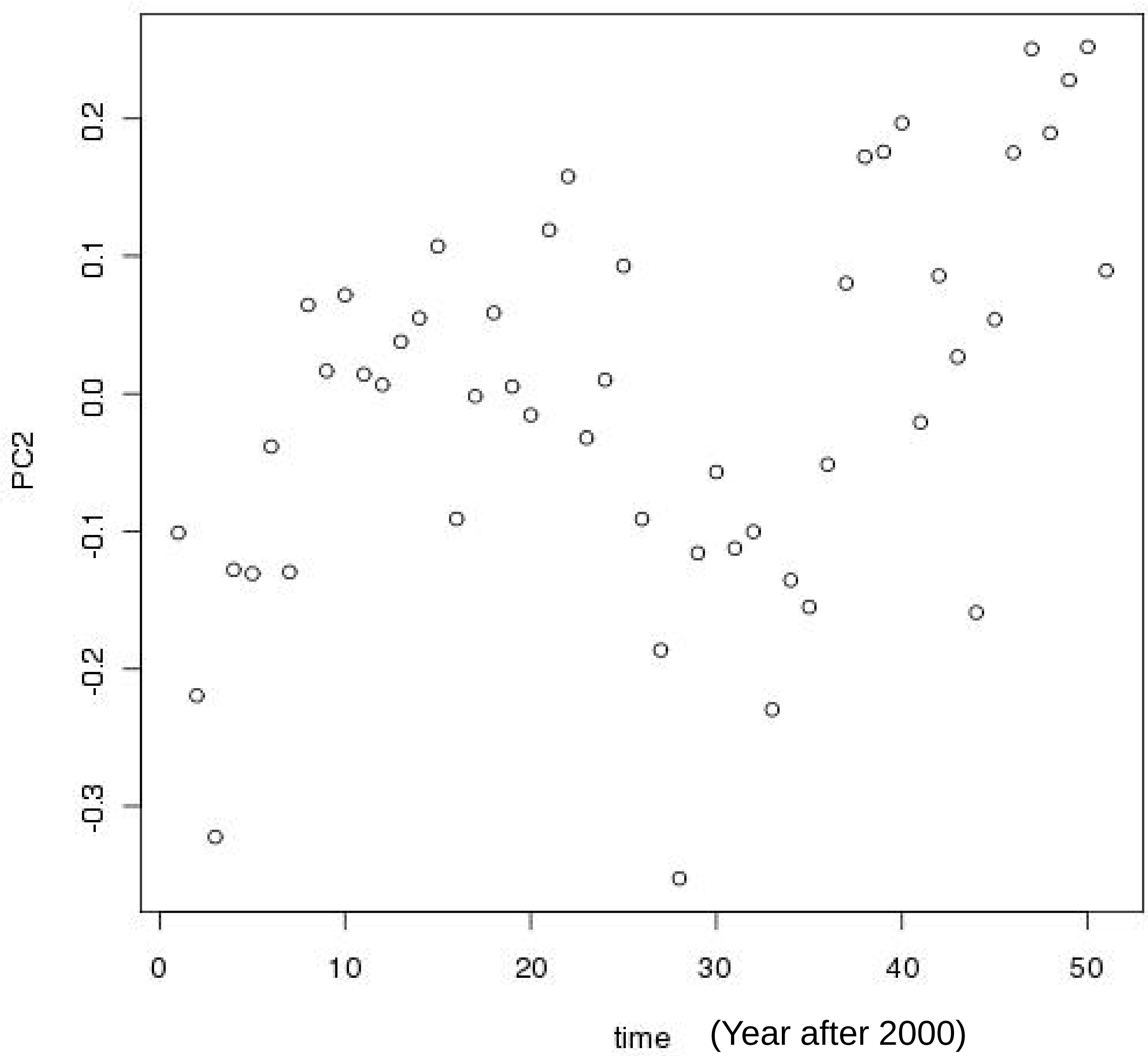


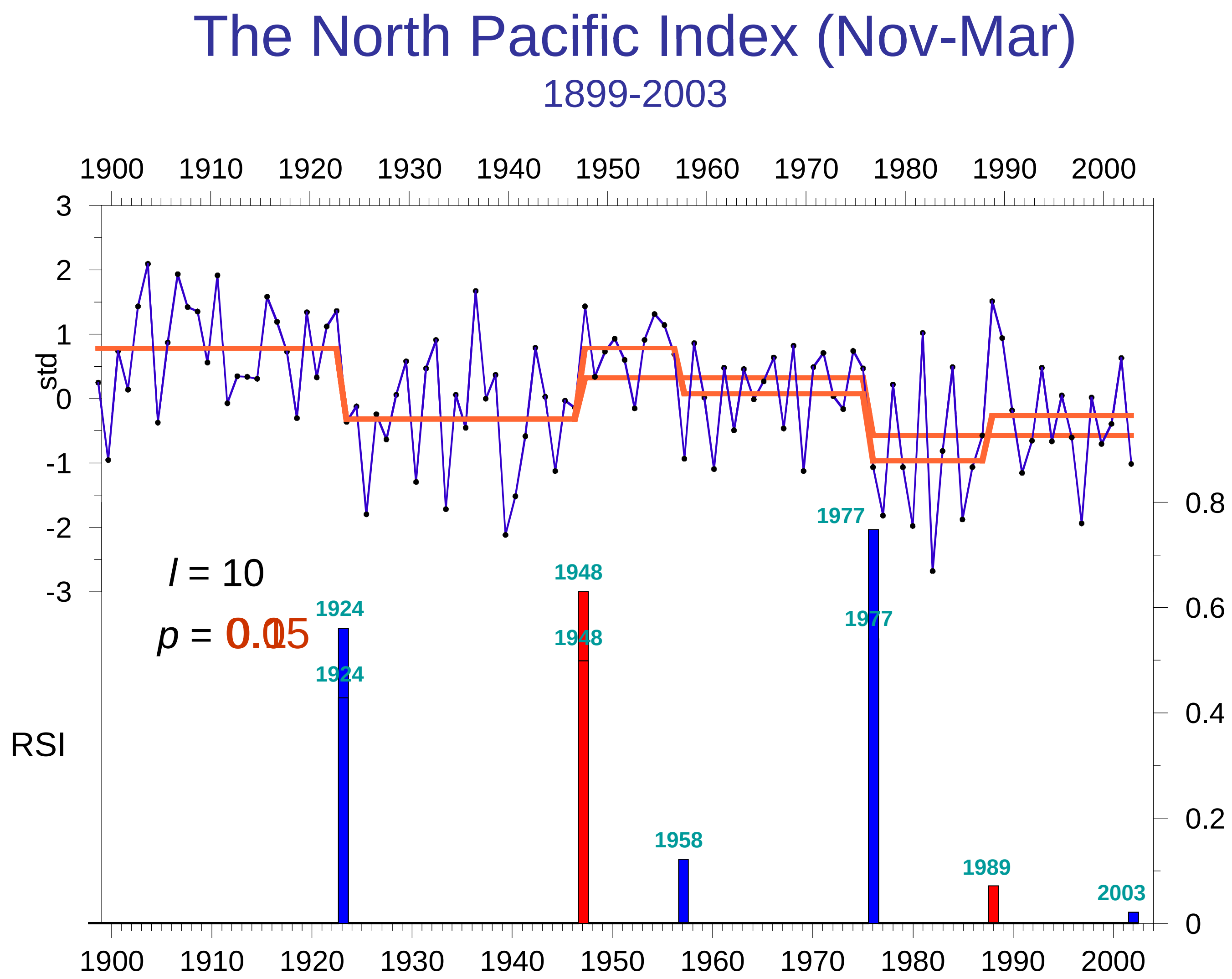
GOA Along-Coast Wind (Aug-Sep)
Downwelling / Strong Transport
Upwelling / Weak Transport
Weighted Ensemble Mean
Wind (m/s)
Year
2
1
0
-1
-2
2000
2010
2020
2030
2040
2050
2060



Projected Zonal Winds
Annual Mean Zonal Wind (m/s)
4
3.5
3
2.5
2
1.5
1
2000
2010
2020
2030
2040
2050
Year

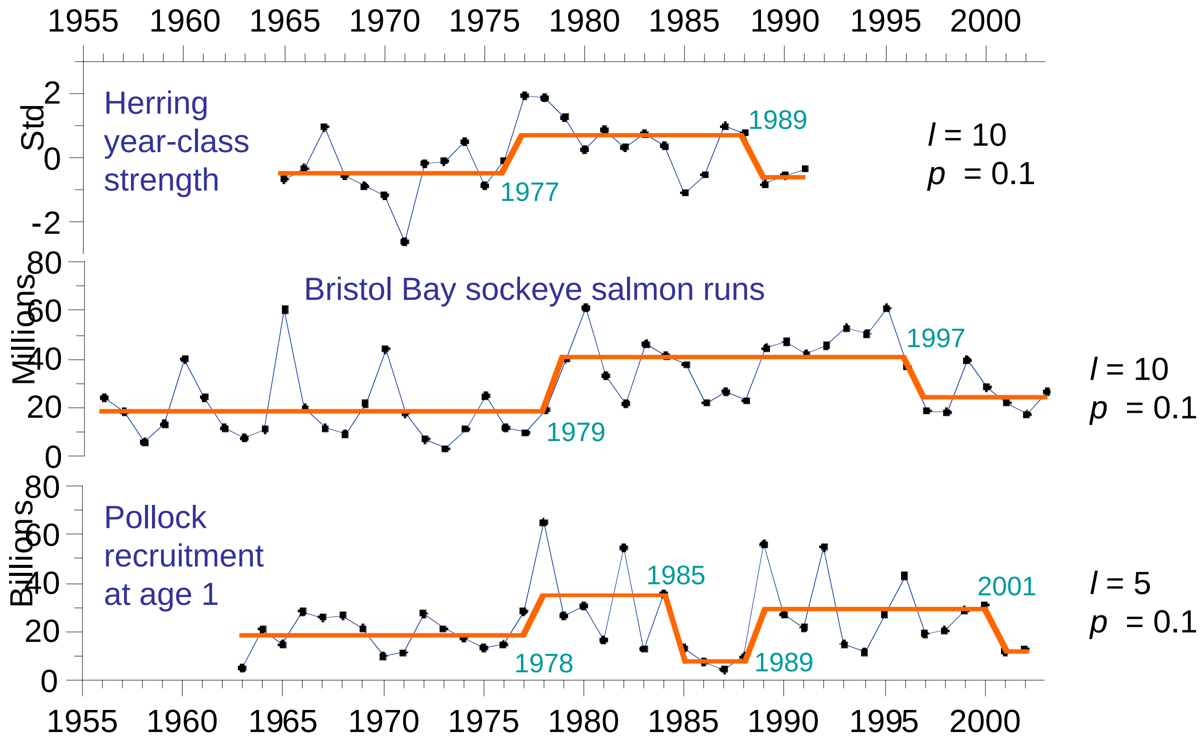
Principal Component Analysis of Time Series of Summer SST from IPCC Models



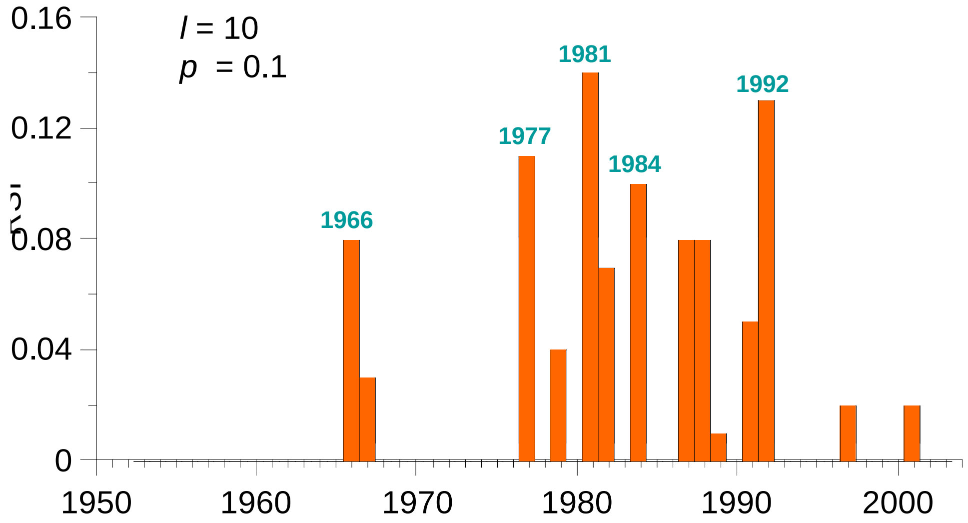


The North Pacific Index (Nov-Mar)
1899-2003
std
RSI
l = 10
p = 0.05
1924
1948
1958
1977
1989
2003
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
3
2
1
0
-1
-2
-3
0.8
0.6
0.4
0.2
0

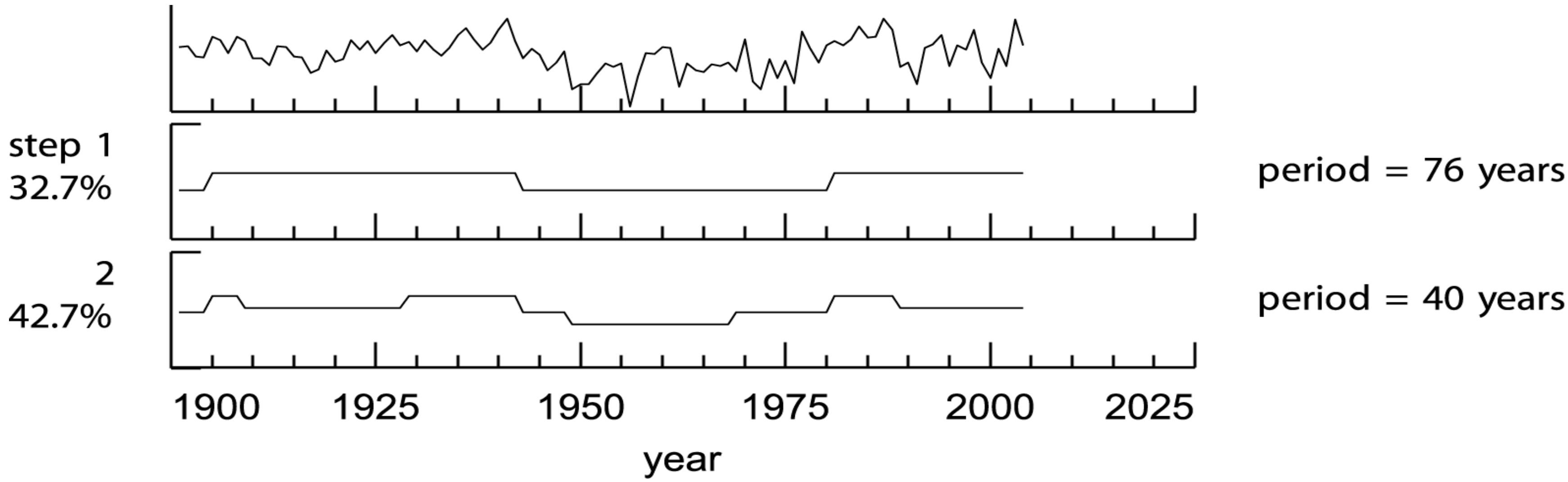
Time Series of Fish Stocks



Regime Shifts in Biological Indices



A square oscillator can be fit to the
Pacific Decadal Oscillation (PDO) timeseries to give "multiple stable states"



BUT: Other simple times series models without multiple stable states (e.g., red noise) fit the PDO data equally well

CONCLUSION: *Cannot determine underlying process model from data alone for records shorter than 200 years.*
Past history provides little information for anticipating future shifts and episodic events

Overland et al. (2006)

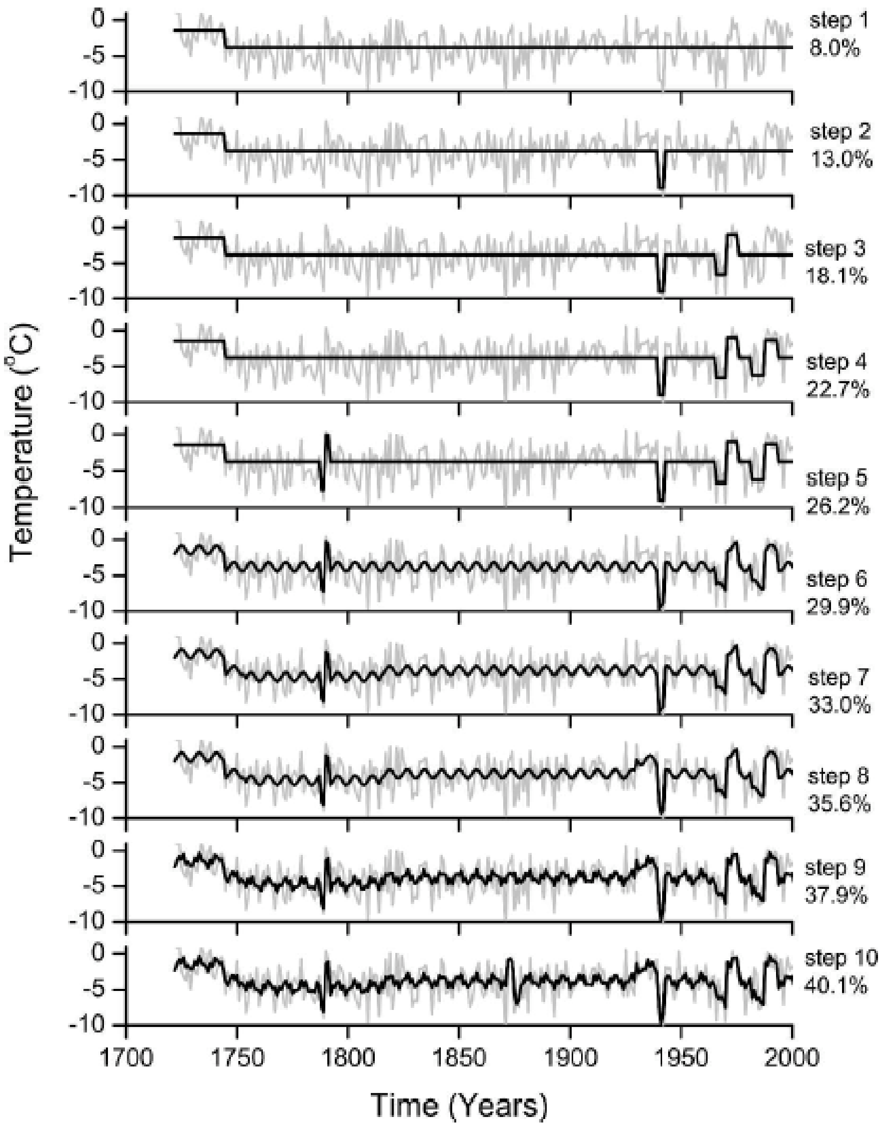


FIG. 4. Matching pursuit analysis of Uppsala winter air temperature. Top panel shows the first event (black line) picked out by the matching pursuit analysis, together with the original time

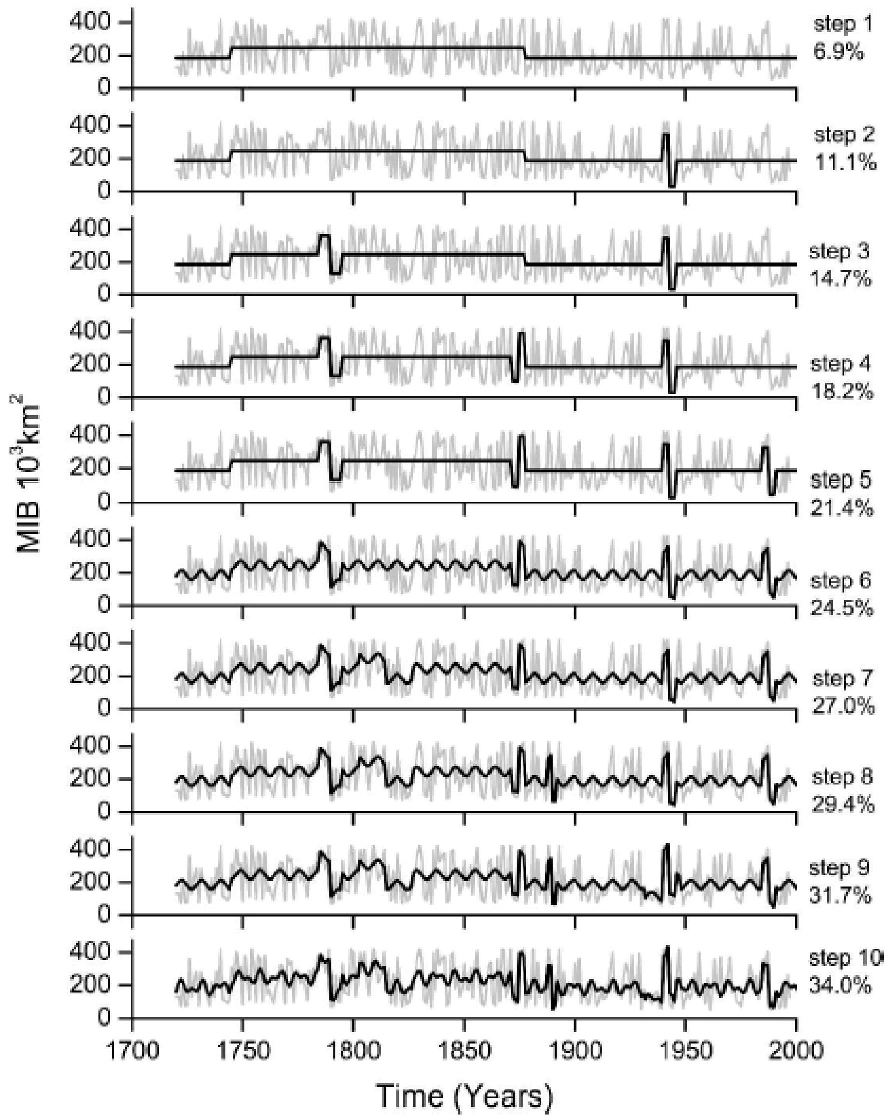


FIG. 5. As in Fig. 4, but for MIB.

Regimes in Ecosystems/Fish Populations

The responses to climate shifts by biological systems are diverse because intervening processes introduce amplifications, time lags, hysteresis, and non-linearities, *leading a variety of climate to ecosystem transfer functions:*

1) red noise of the physical system to redder (lower frequency) noise of the biological response,
2) climatic red noise to discontinuous biological shifts,
3) transient climatic disturbance to a prolonged ecosystem trend,
4) transient disturbance to sustained ecosystem regimes.

All of these ecosystem response characteristics are likely to be active.

Final Remarks

- Climate: Decadal variability more “event-like” than regular oscillations. Large and long deviations from averages. Limited to stochastic projections.

- Ecosystems: *a variety of climate to ecosystem transfer functions* result in a mix of slow fluctuations, lags, prolonged trends, and step-like changes in response to climate variability. Simple, consistent relationships are apt to be rare.

- Current-generation global climate models indicate little change in the temporal and spatial nature of the variability in the climate of the North Pacific through about the middle of the 21st century.