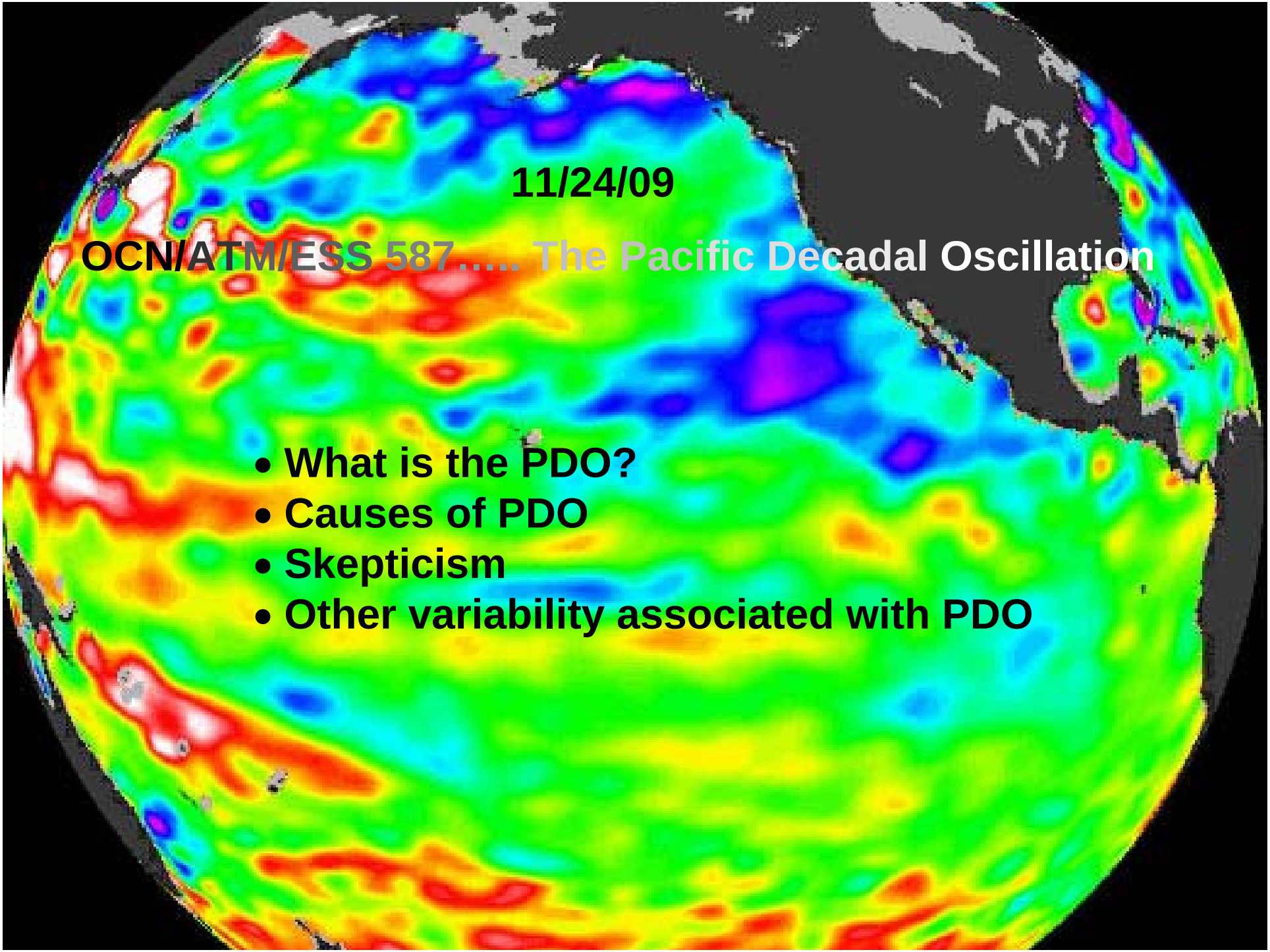
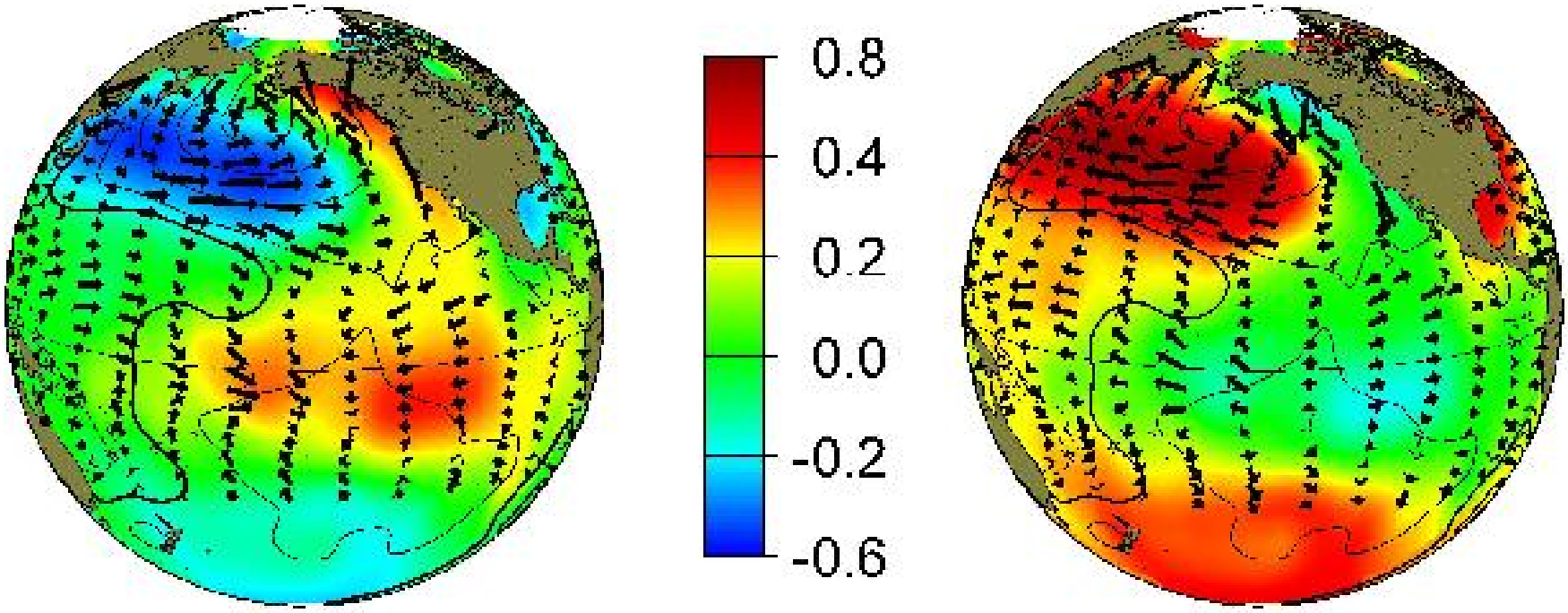


11/24/09

OCN/ATM/ESS 587 ….. The Pacific Decadal Oscillation

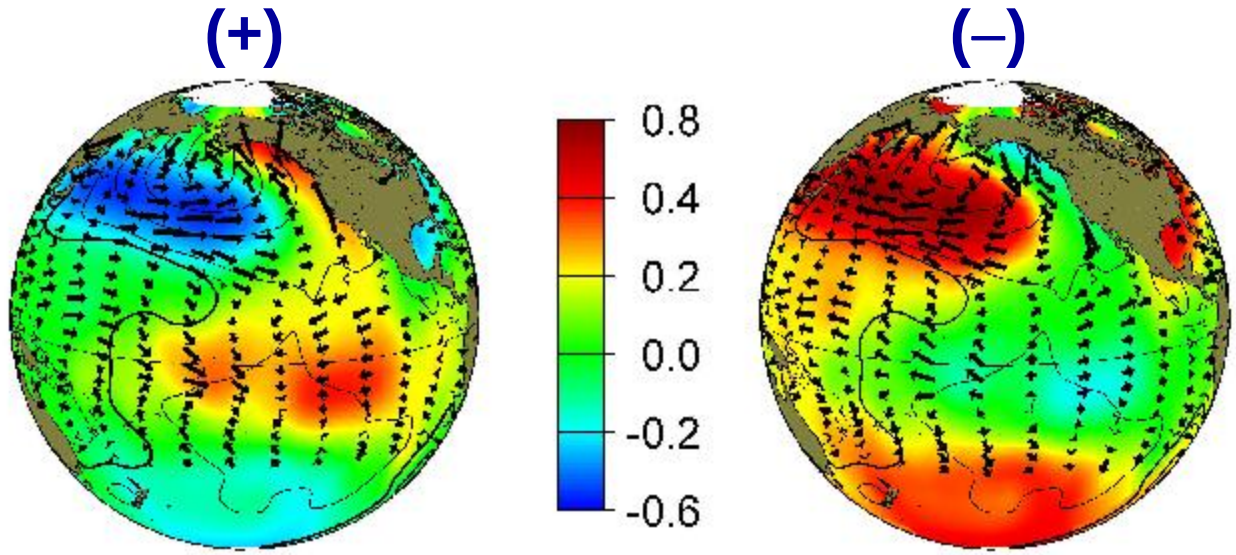
- What is the PDO?
- Causes of PDO
- Skepticism
- Other variability associated with PDO

The Pacific Decadal Oscillation (PDO)….

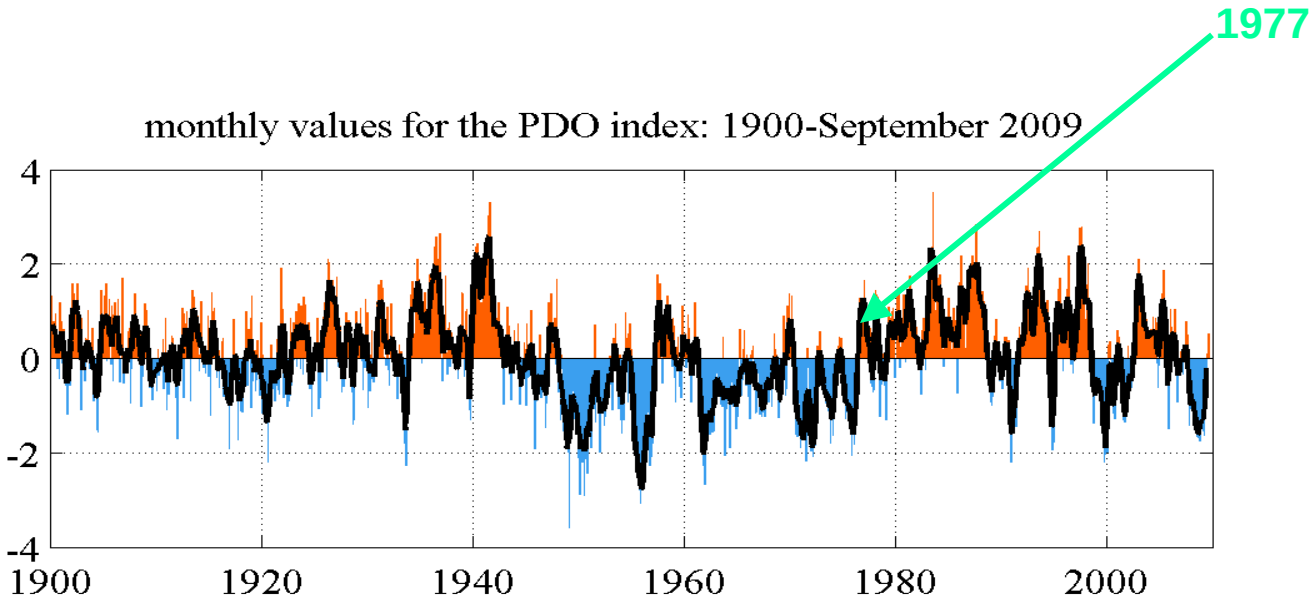


(+) (–)

EOF 1 of SST

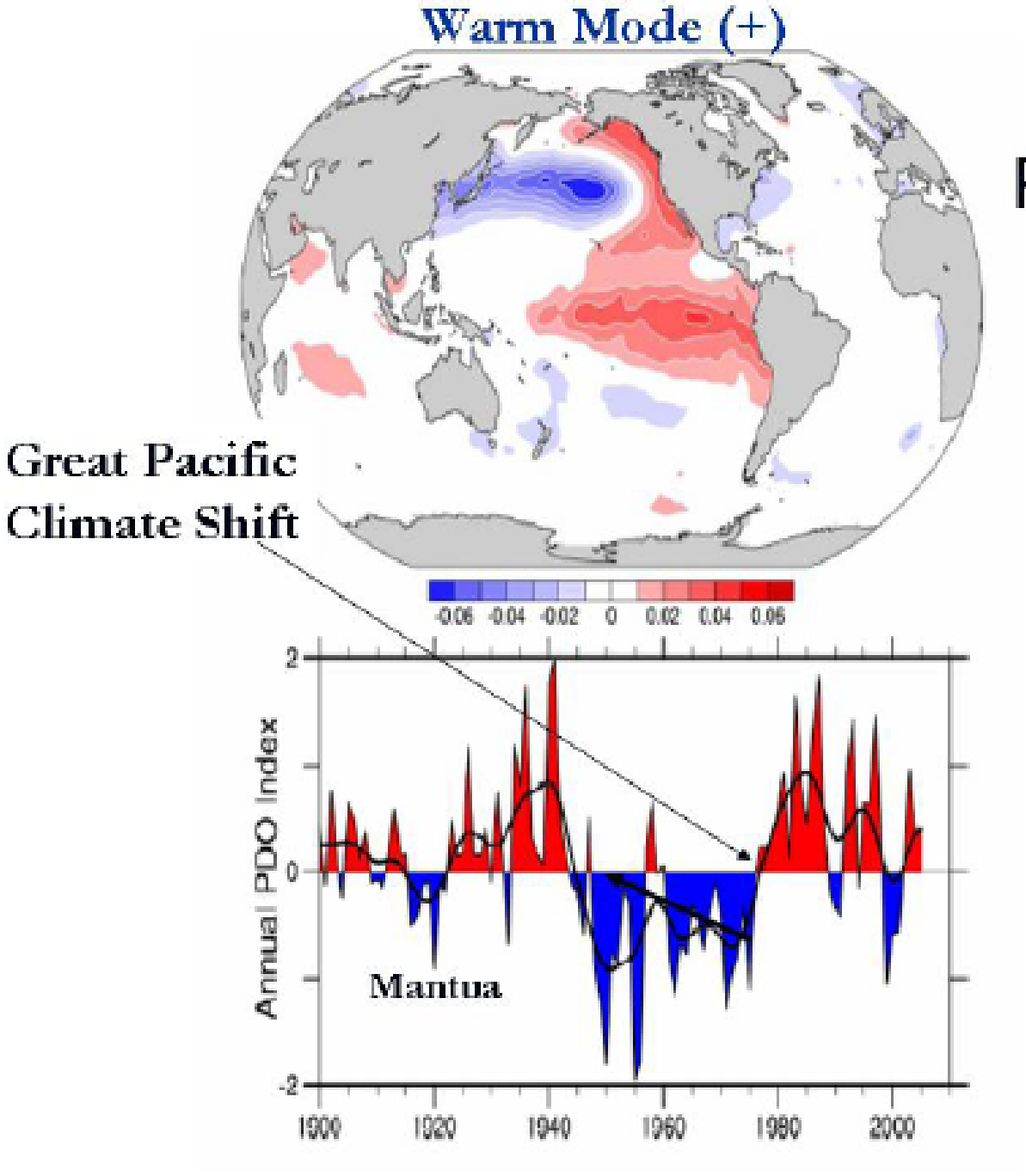


N. Pacific SST anomaly: EOF 1



[maximum amplitude 3-4 °C]

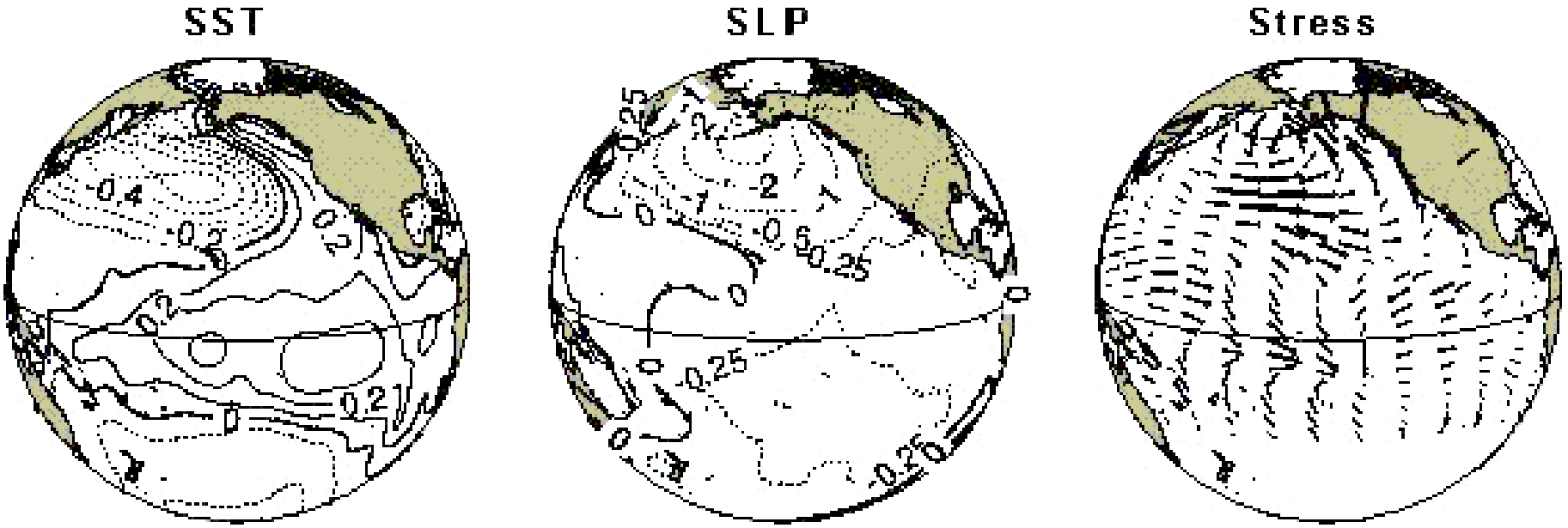
Pacific Decadal Oscillation



Warm PDO (since 1978) favors more El Ninos

[+ phase]

Pacific Decadal Oscillation

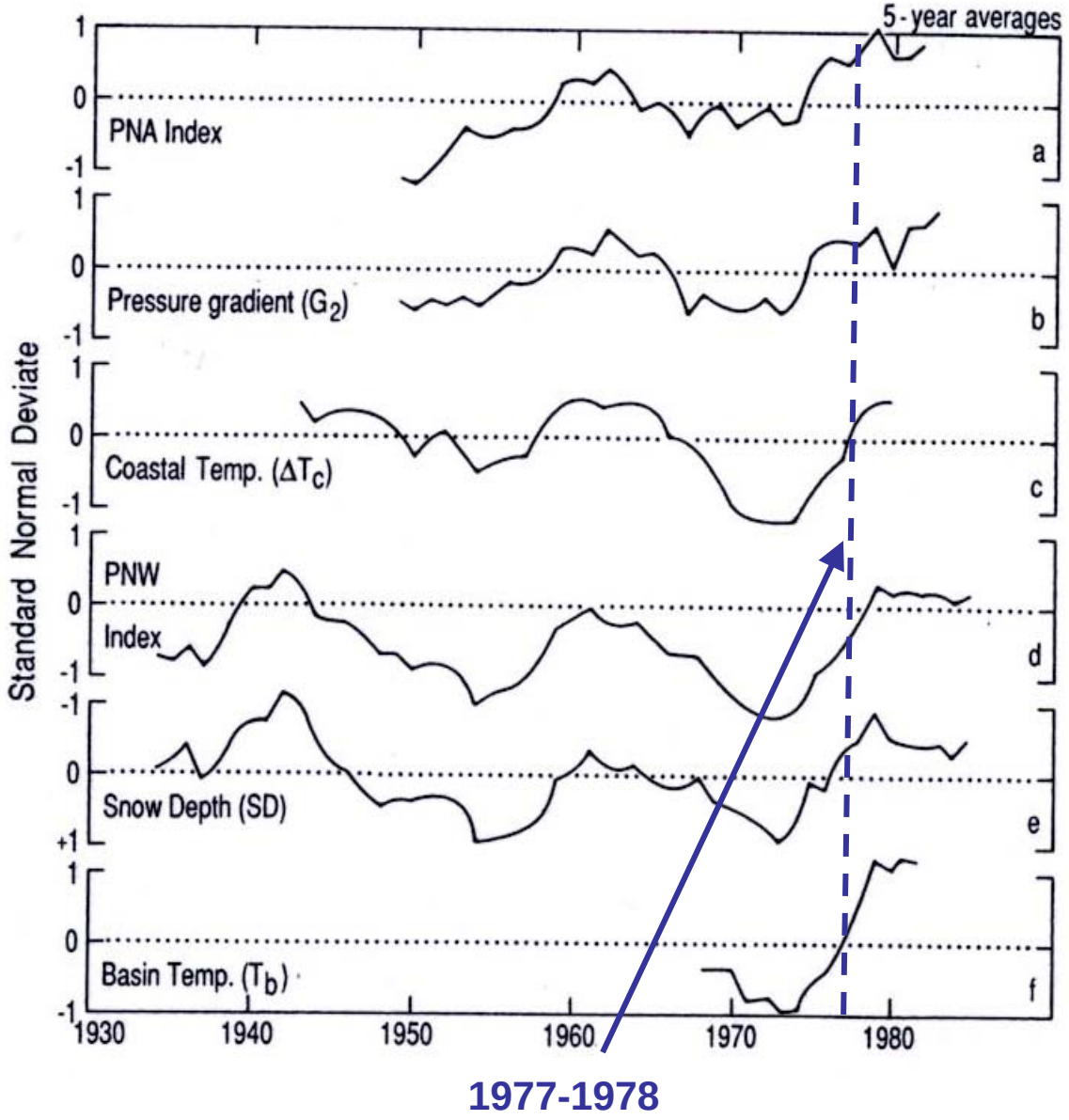


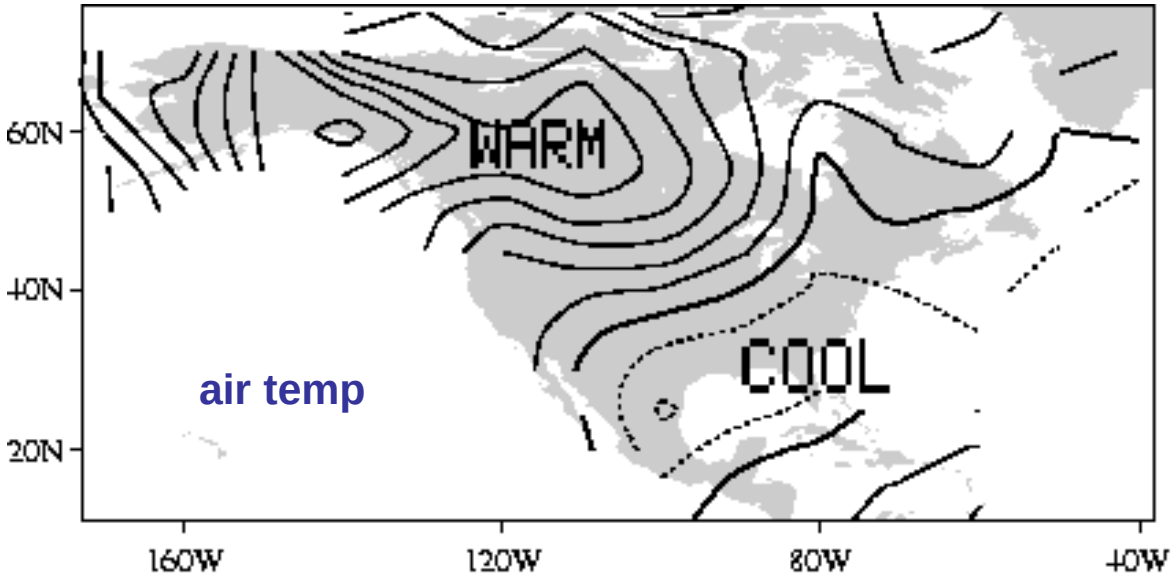
Climate Anomalies	*Warm Phase PDO*	*Cool Phase PDO*
SST, NE and tropical Pacific	Above average	Below average
Oct-March NW N. American air temp.	Above average	Below average
Oct-March SE N. American air temp.	Below average	Above average
Oct-March S N. American air temp.	Above average	Below average
Oct-March NW N. American precip.	Below average	Above average
NW N. American spring snowpack	Below average	Above average
Spring flood risk in Pacific NW	Below average	Above average

Summary of Pacific and N. American climate anomalies associated with extreme phases of the PDO

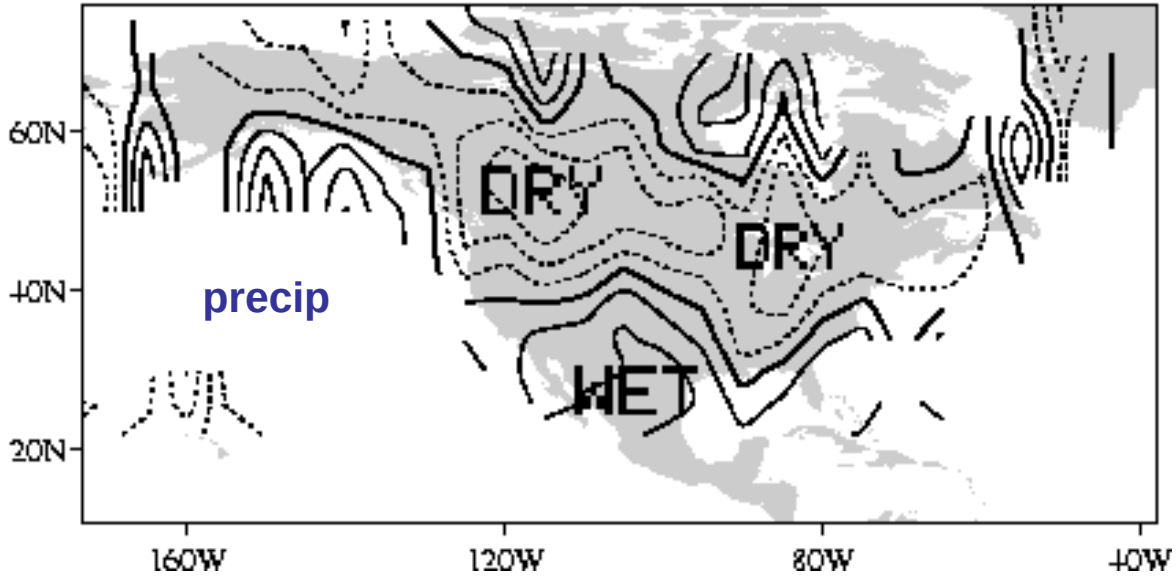
“Regime shifts” associated with PDO….

Long-term behavior of some coastal parameters in the Pacific NW

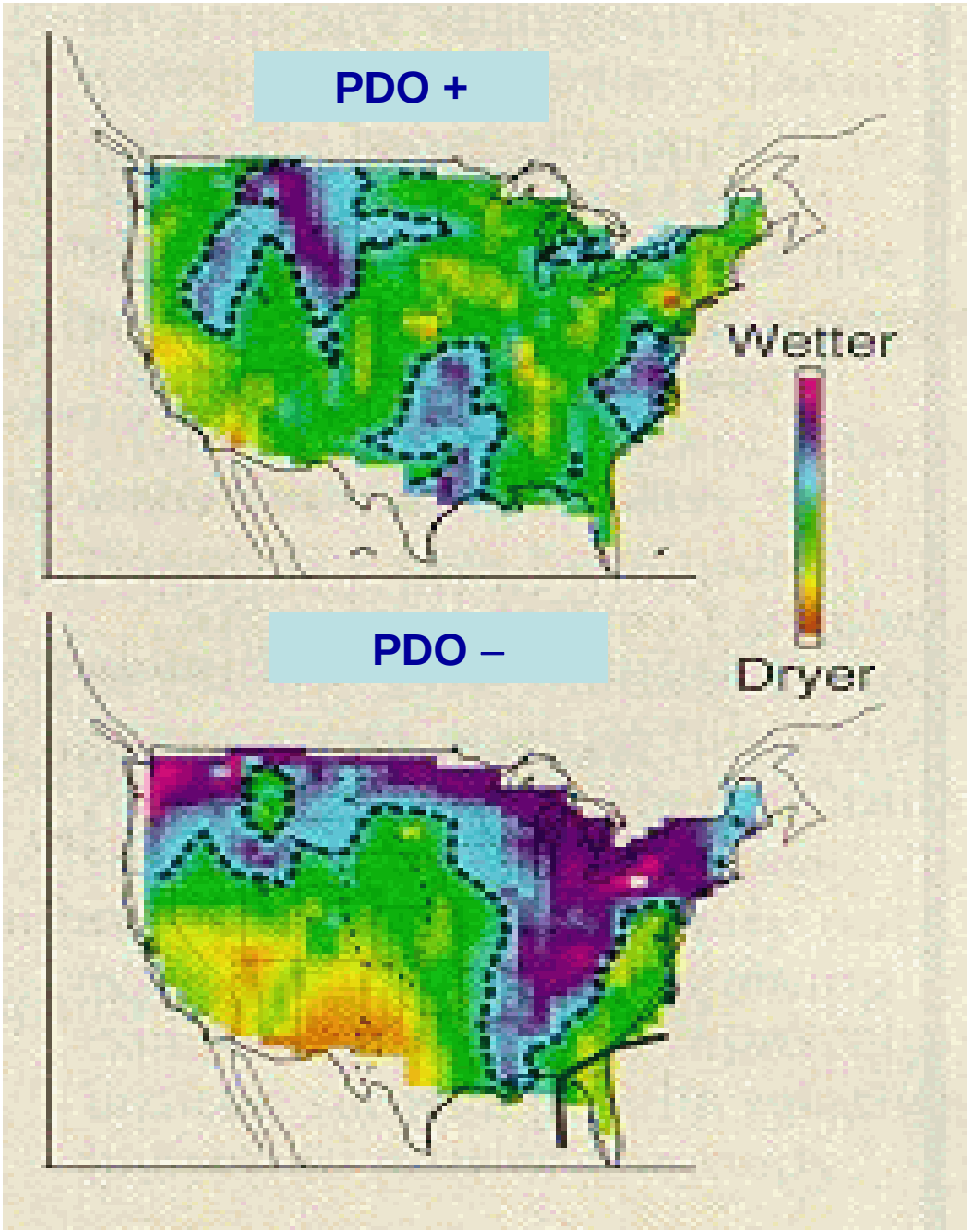




Air temperature and precipitation anomalies associated with PDO+



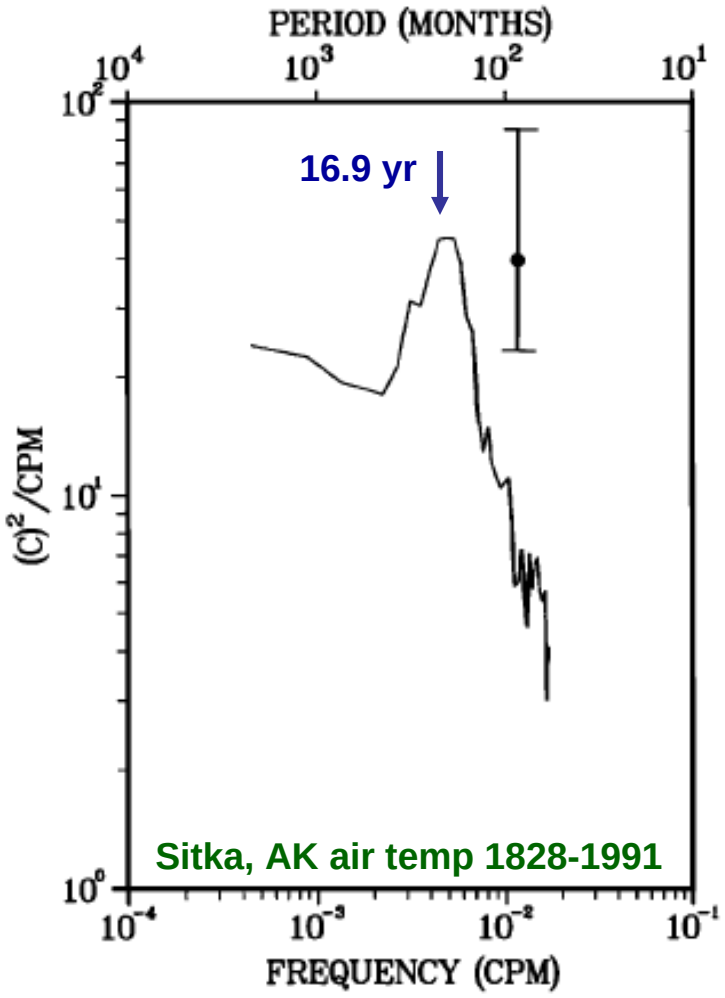
Precipitation over the continental US is correlated to PDO



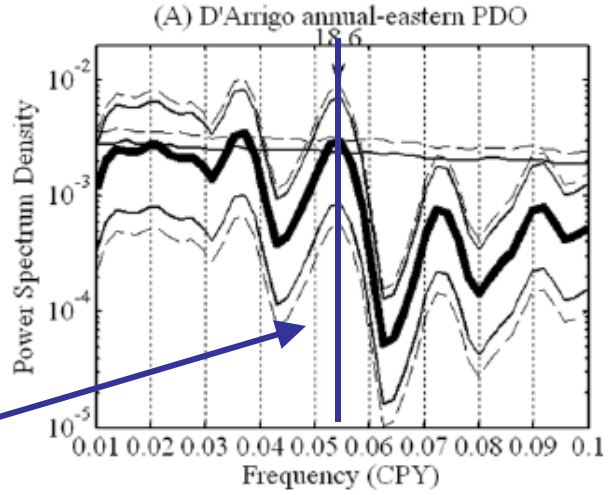
Causes of the PDO….

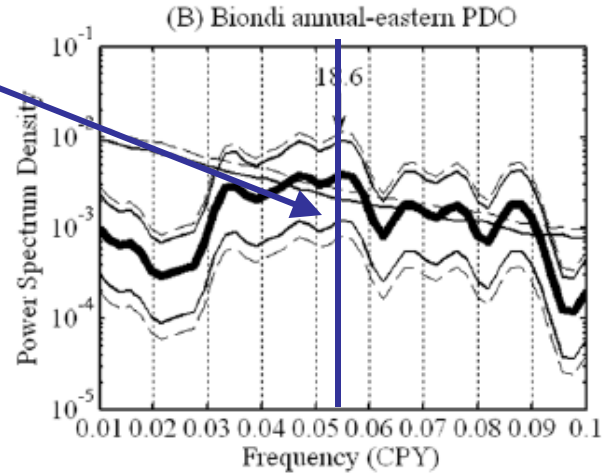
***Problem*: 18.6 yr *tide is associated with sea level changes of* ≤ 1cm !**

(1) Narrow band forcing/response [unlikely; what would it be?] [but see Royer (1993) and Yasuda (2005)]



18.6 yr





PDO index from tree rings, ~ 300 yr

Causes of PDO…

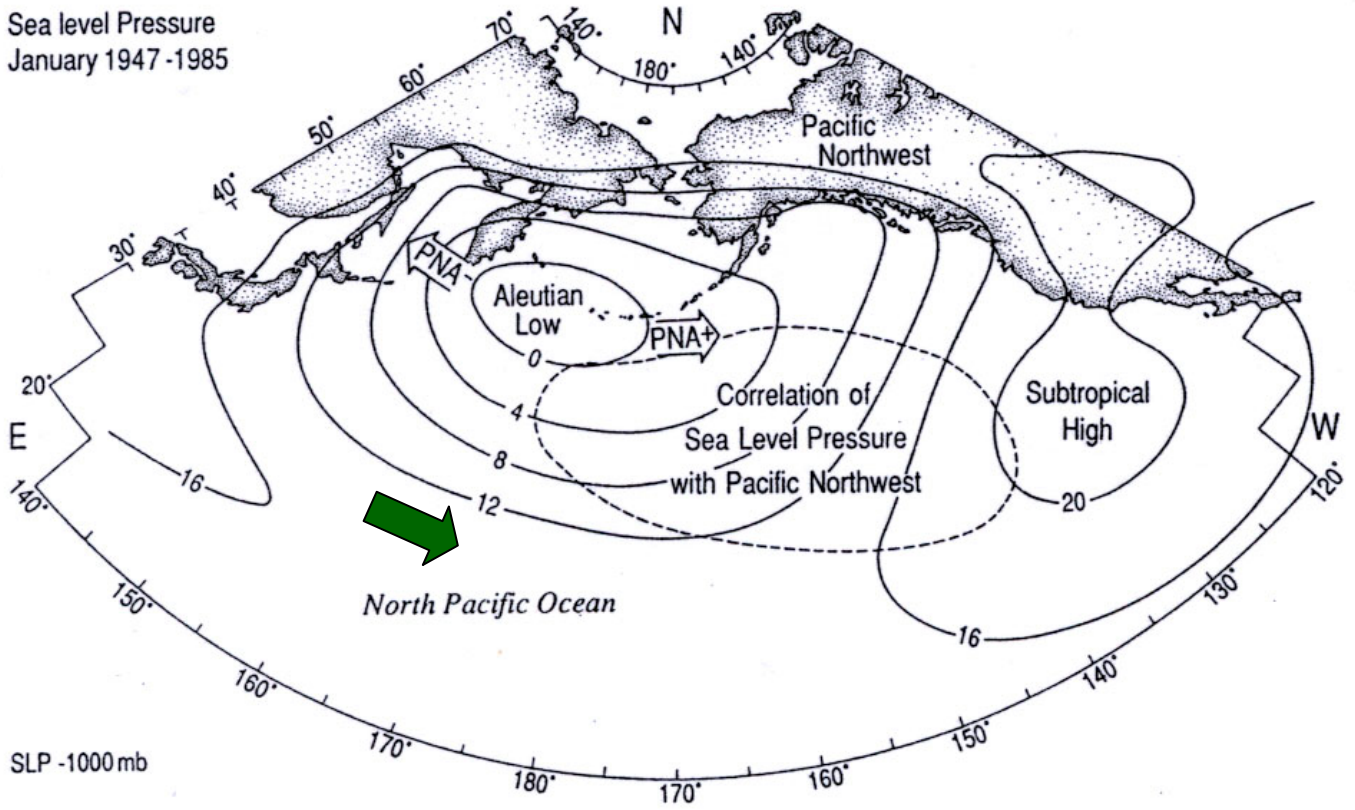
(2) An ENSO-type *coupled mode* of behavior: atmospheric (or oceanic) variability sets up a coupled response in the ocean (or atmosphere).

Latif and Barnett (1996)….the delayed oscillator

2 parts to this oscillation:
(*i*) Atmospheric Aleutian low pressure
(*ii*) Oceanic subtropical gyre

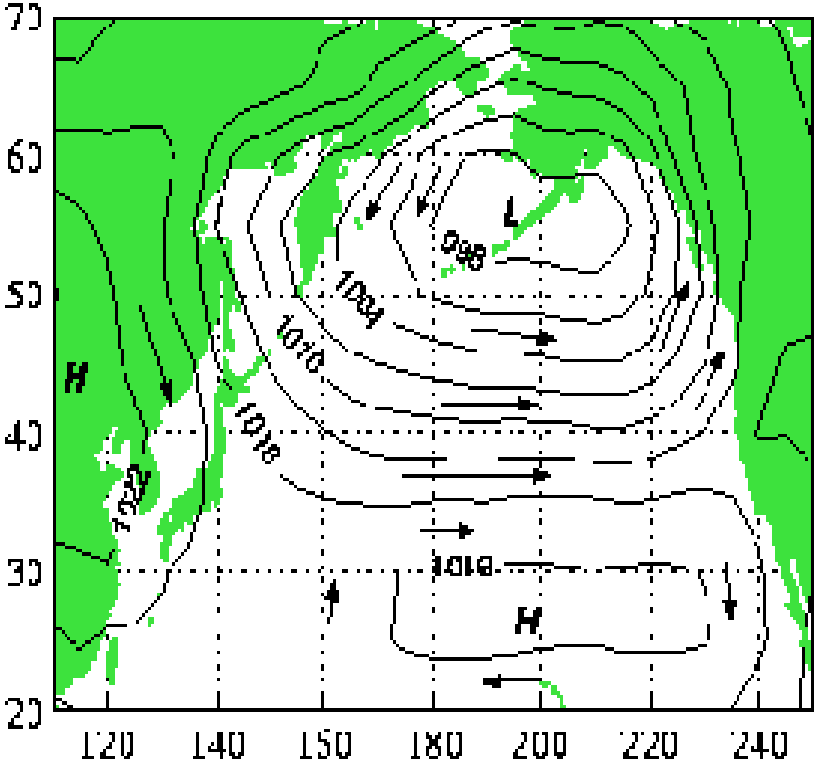
Basic idea: the Aleutian low pressure center in the atmosphere varies in position and strength on time scales of decades (or less: there is an ENSO signature).

This variation in the Aleutian low causes SST changes in the mid-latitude N. Pacific, which feedback to the atmosphere.



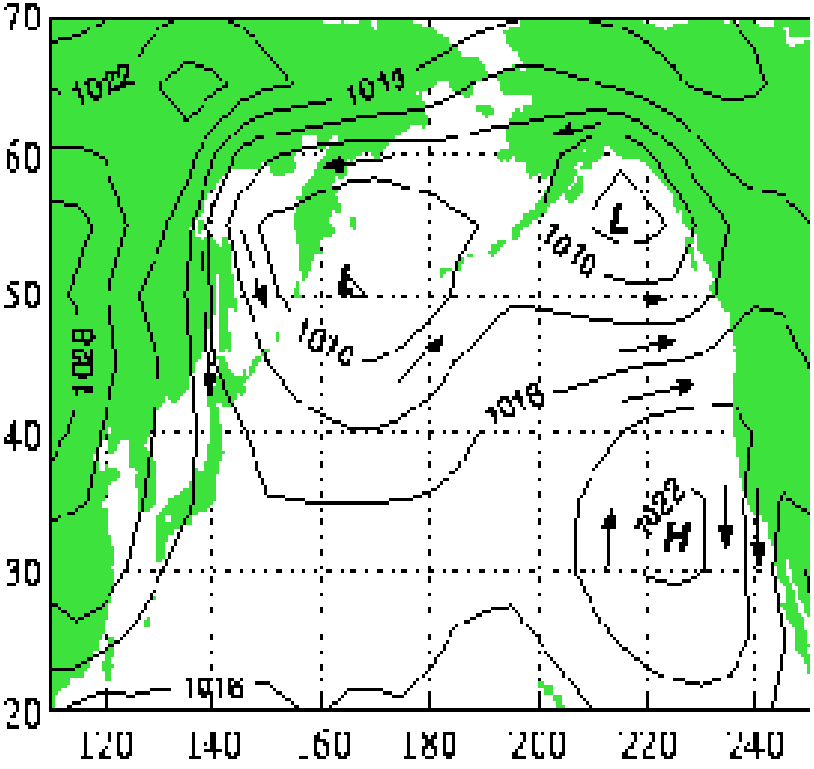
Changes in the SLP field due to PDO influence ocean/land/atmosphere interaction in the central N. Pacific and along the west coast of N. America.

PDO +



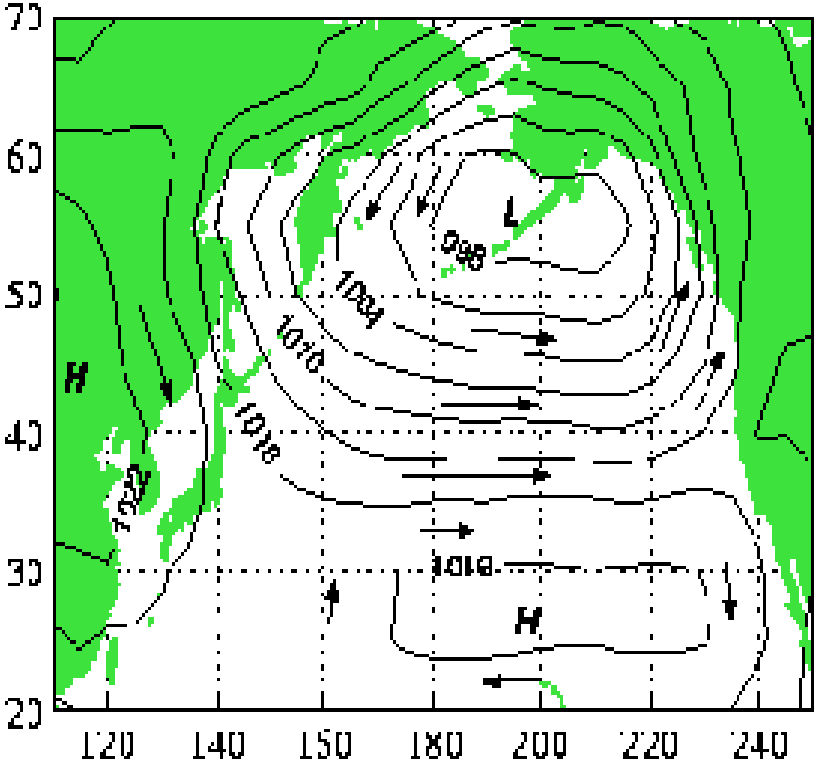
Cold W. Pacific SST
Warm E. Pacific SST
Strong Kuroshio
Large ocean/atm heat flux
Strong E/W SLP gradient

PDO –



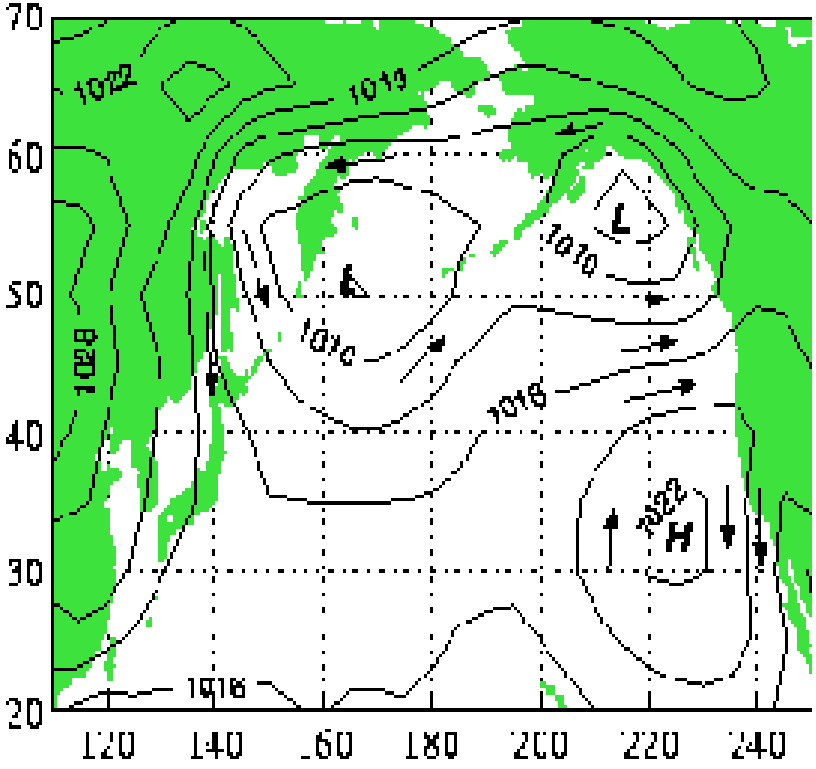
Warm central Pacific SST
Cold E. Pacific SST
Weak Kuroshio
Small ocean/atm heat flux

PDO +



Low precipitation, N American coast

PDO –



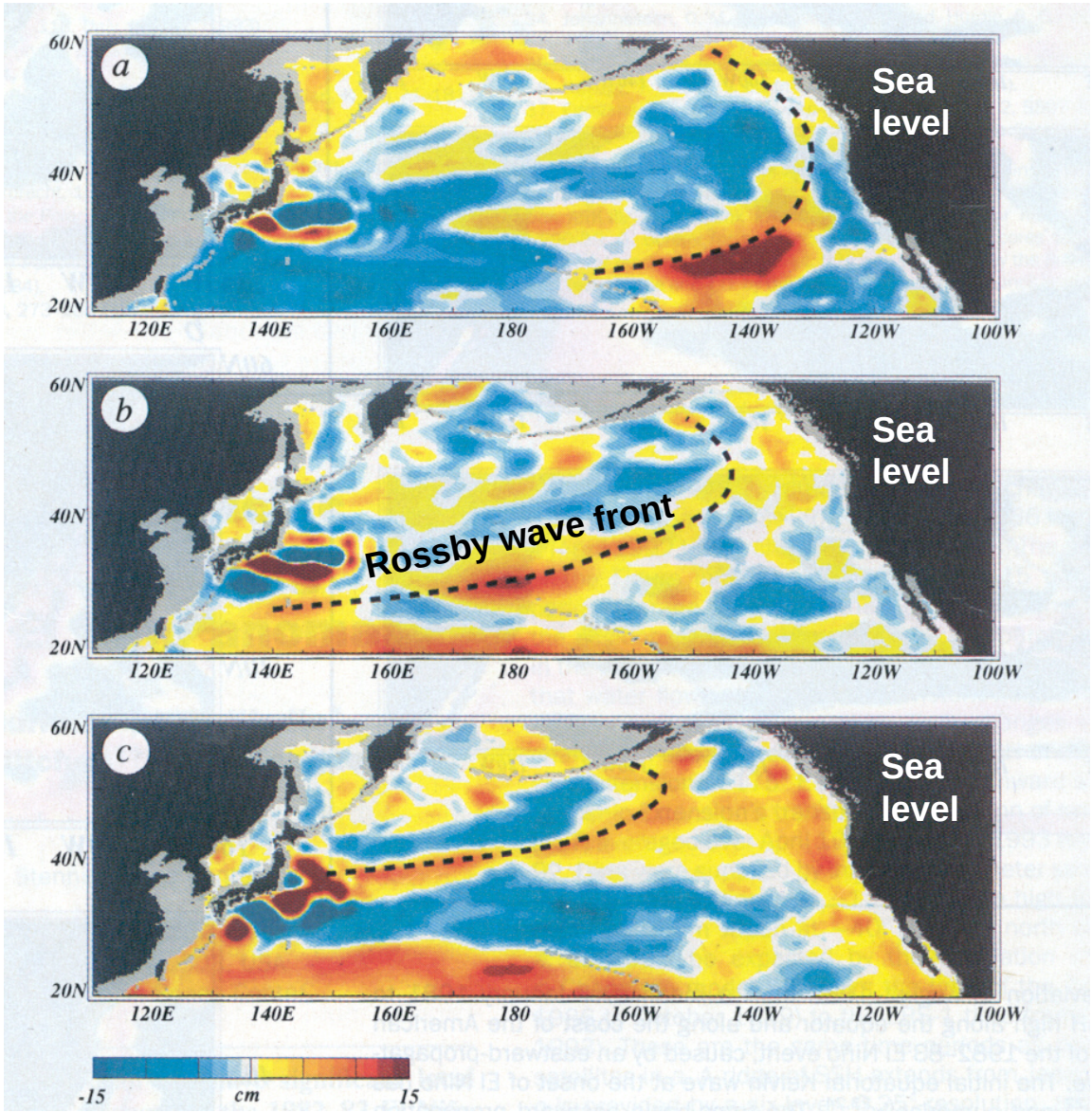
High precipitation, N American coast

No rock

Rock

If a rock is dropped into a pond, gravity waves will communicate this information to the boundaries at a speed $S \sim (g\lambda)^{1/2}$, where λ is the characteristic wavelength of the waves. The information will reach the boundary in a time $T \sim L / S$.

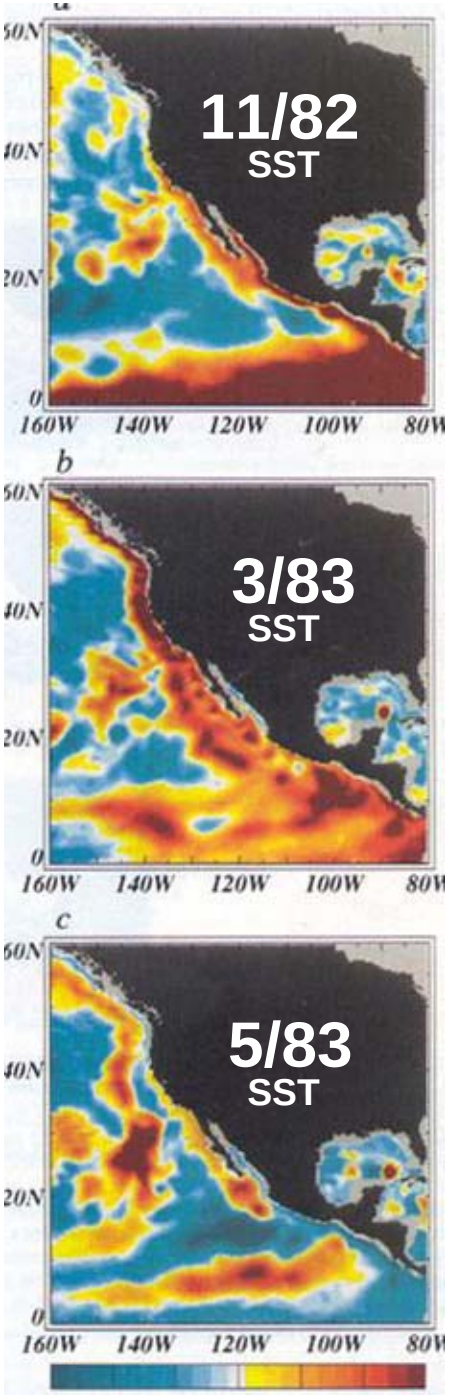
Rossby waves in the ocean and atmosphere play the same role, but they are quite different from ordinary gravity waves due to rotation of the Earth and spherical geometry.



1983 ←

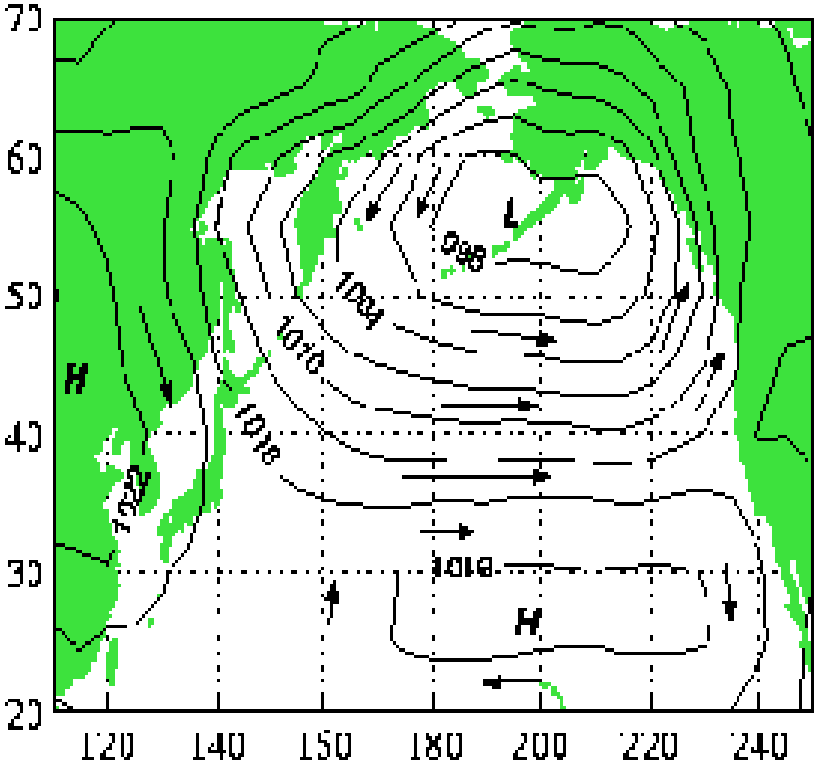
1988 ←

1993 ←



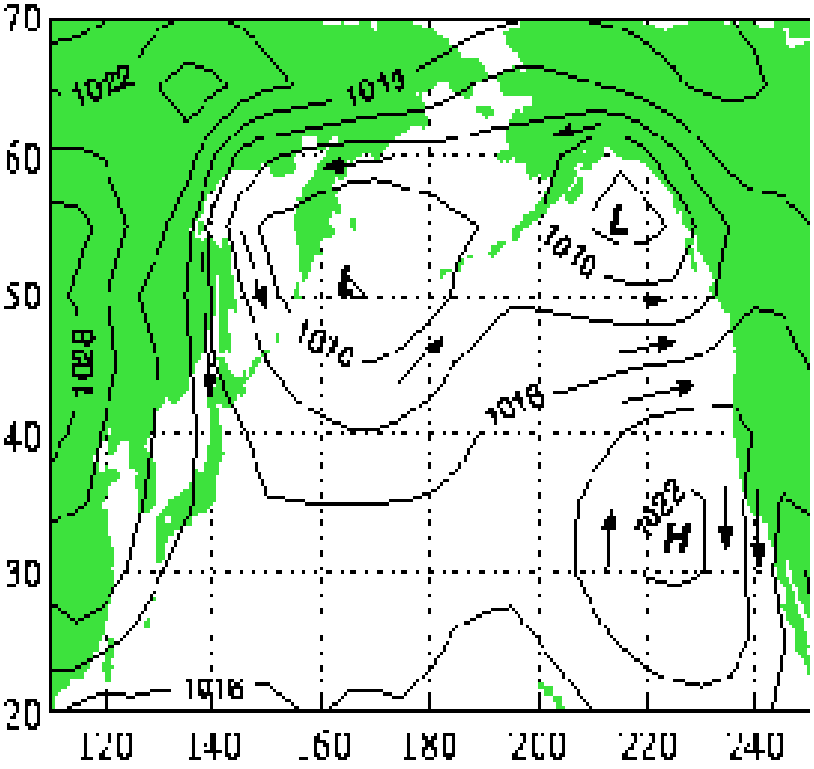
Jacobs et al. (1994) showed how a single ENSO event could affect the N. Pacific sea level, SST, and circulation over a long period.

PDO +



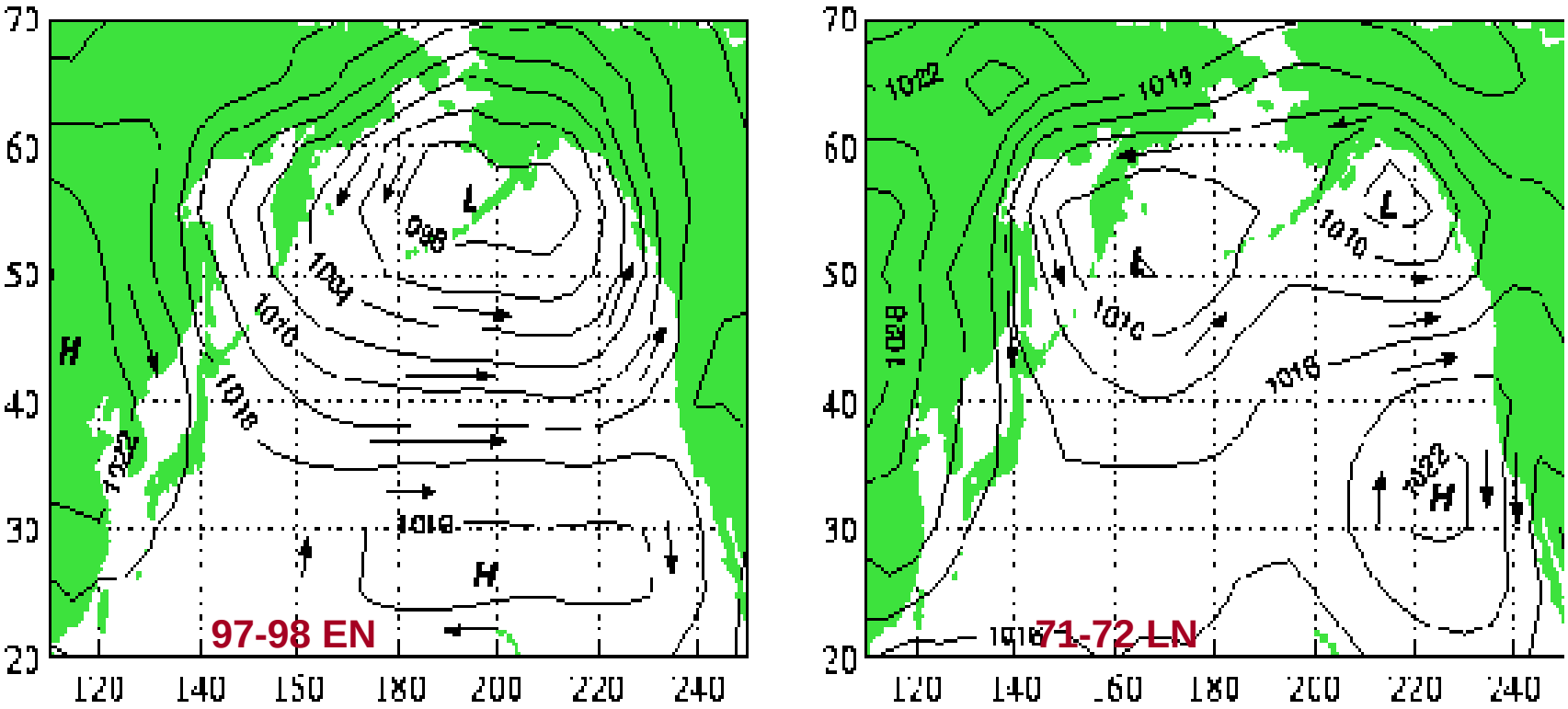
Relaxation: lower SST, E Pacific
Warmer SST, central Pacific
Higher oc/atm heat flux, central Pac.
(~ 10–20 watts/m^2)
Weakening of low P, central Pac.
(positive feedback)
Adjustment mechanism: oceanic
Rossby waves (strong)
Time scale: 10-20 years

PDO –



Relaxation: higher SST, E Pacific
Colder SST, central Pacific
Lower oc/atm heat flux, central Pac.
Strengthening of low P, central Pac.
(positive feedback)
Adjustment mechanism: oceanic
Rossby waves (weak)
Time scale: 10-20 years

What controls the position of the Aleutian low?
Answer: tropical conditions (??) (ie, ENSO)



Position and strength of the Aleutian low pressure during 97-98 El Nino and 71-72 La Nina events

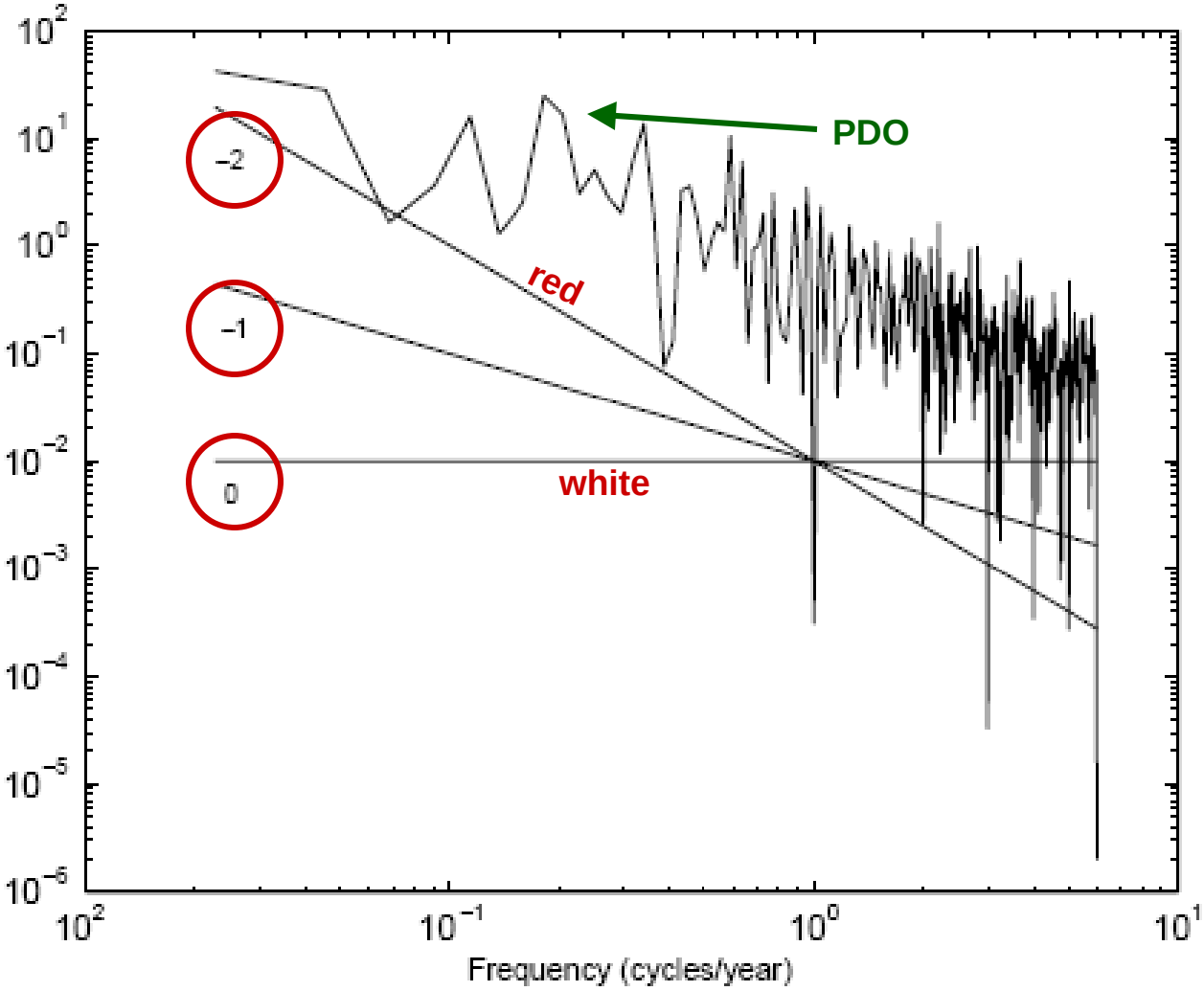
Local sequence of events: wind (atm) → SST (ocn) → OLR (ocn/atm) → P (atm)
Remote events: P (atm) → SST (ocn) ; P (atm) → precipitation

Causes of PDO…

(3) Broad-band stochastic forcing….“red noise”

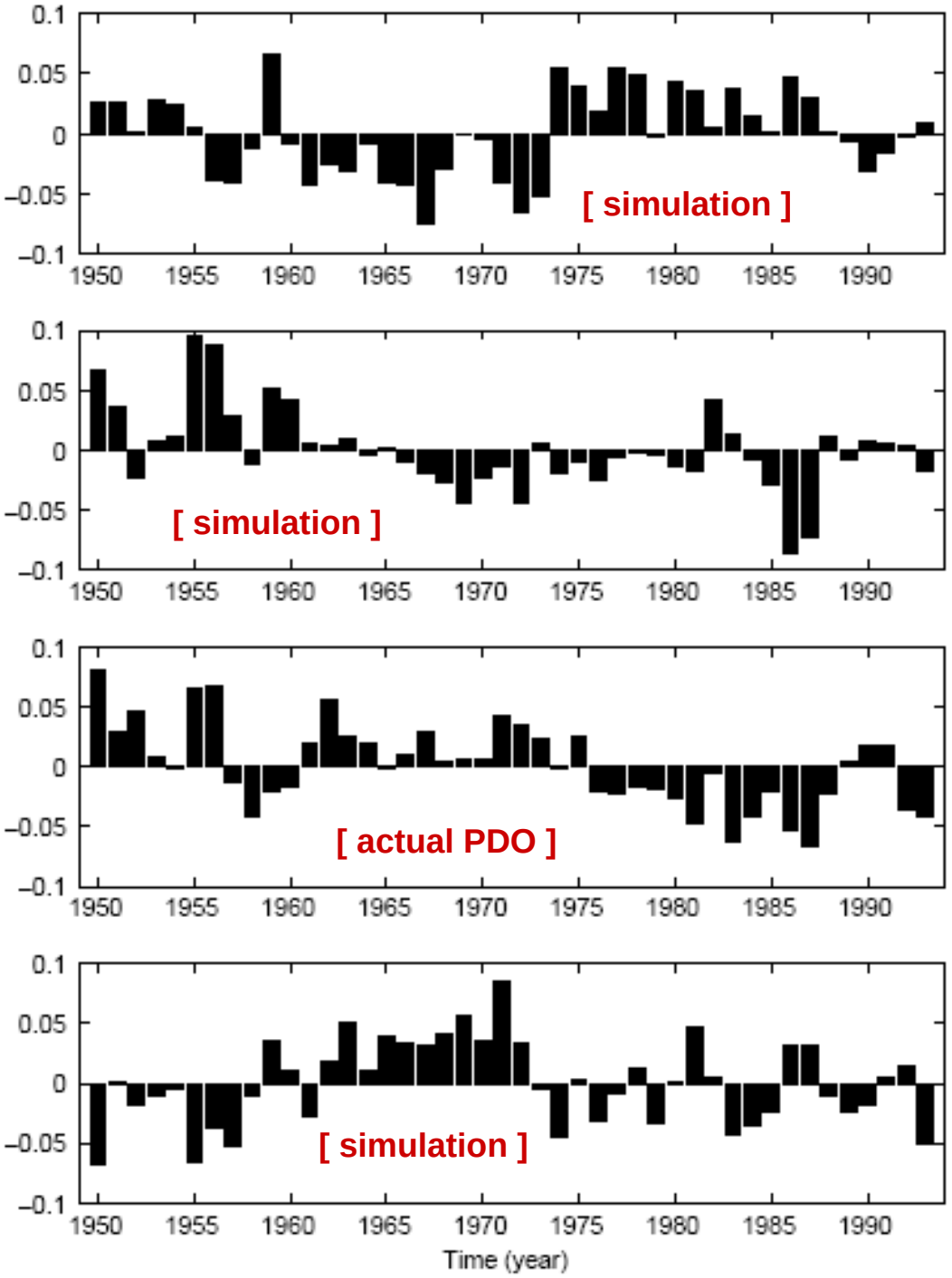
Rudnick and Davis (2003):

“We …believe that our results show that the existence of changes deemed significant by the composite analysis is not evidence for anything more than Gaussian red noise with stationary statistics.”



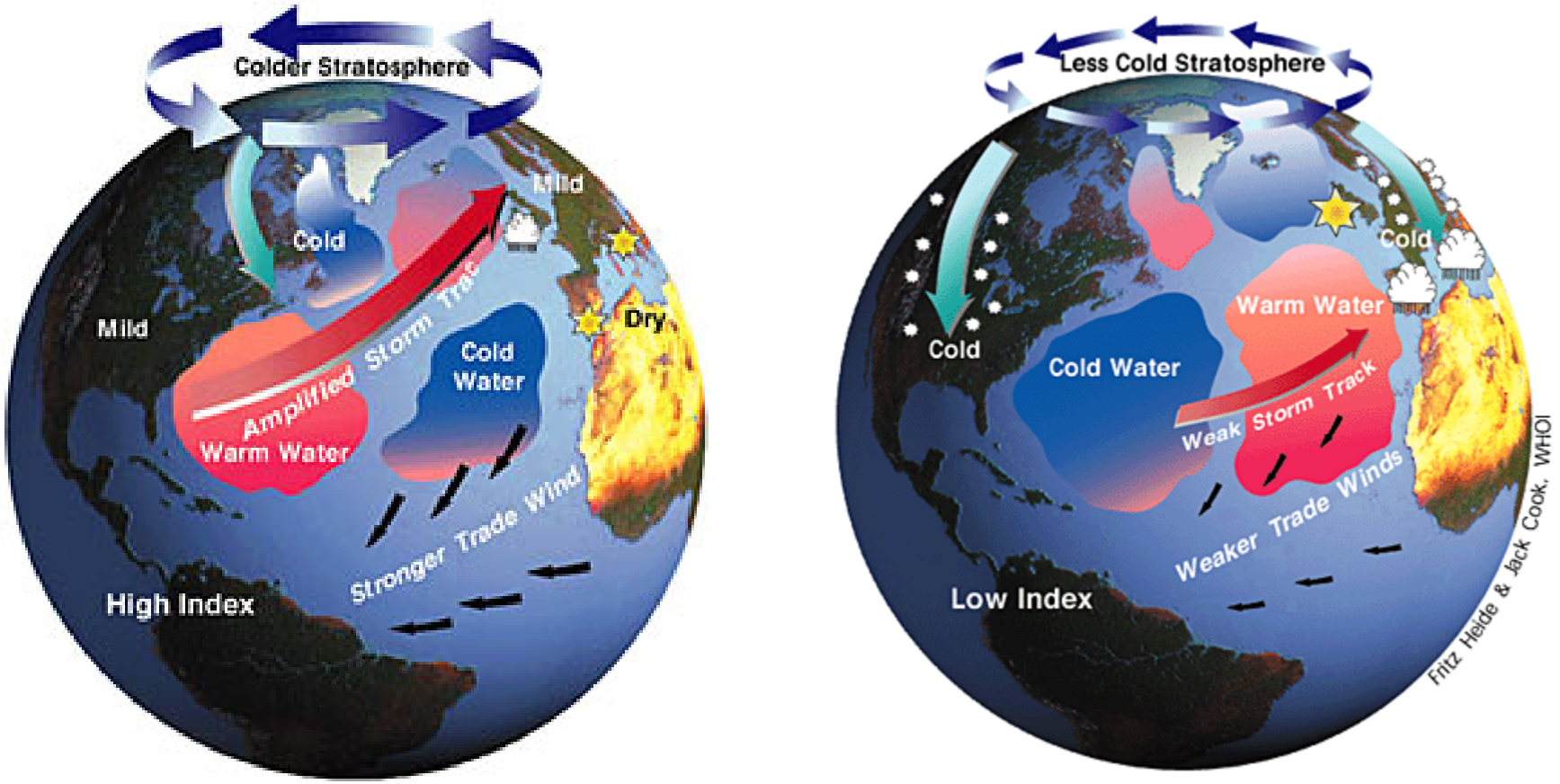
Spectrum of the first EOF of N. Pacific SST; spectral slopes are shown.

The PDO and noise generated to have the same frequency content but random phase. All time series are shown as annual averages. The PDO is third from the top. The noise time series are used as input for the composite analysis.



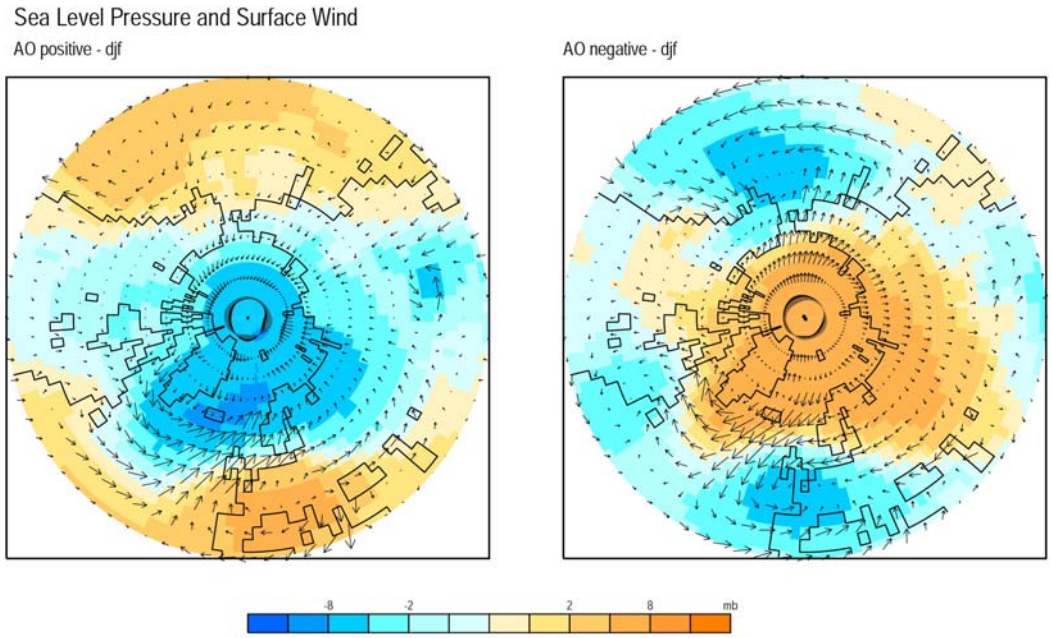
Rudnick and Davis, 2003

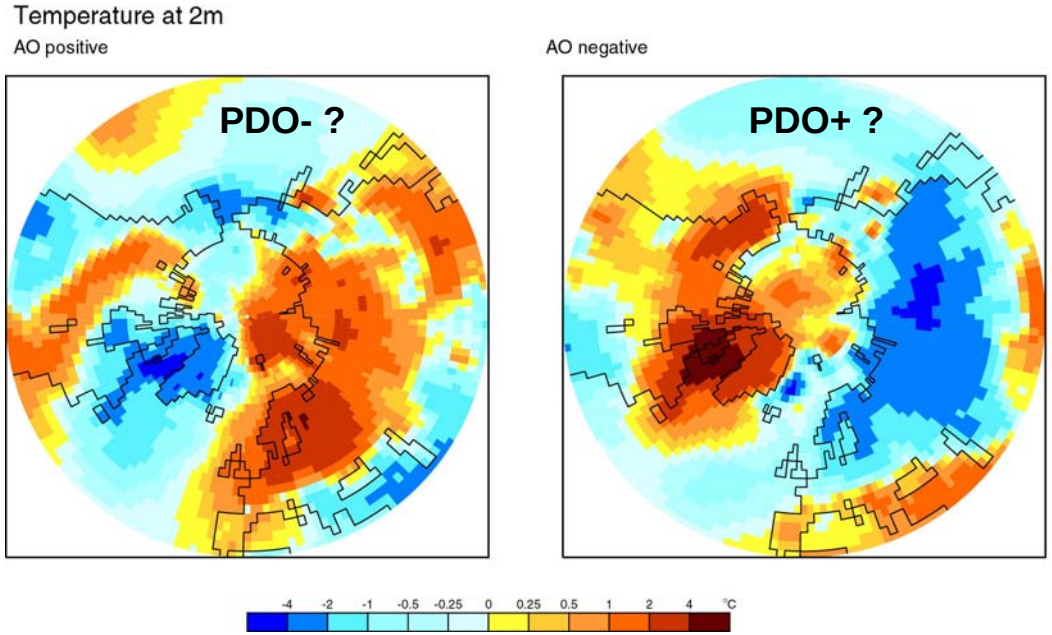
Other modes of variability…..

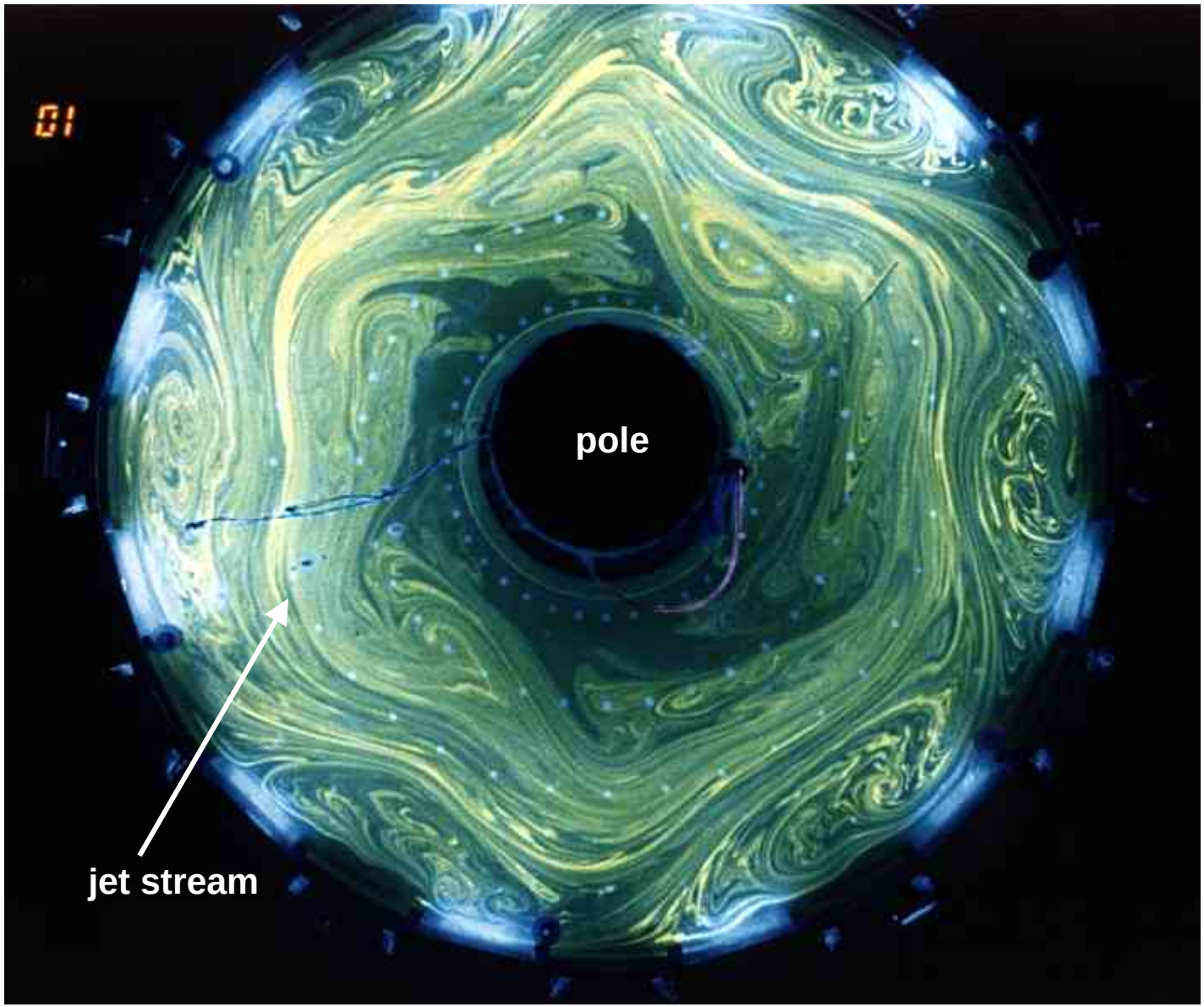


The North Atlantic Oscillation

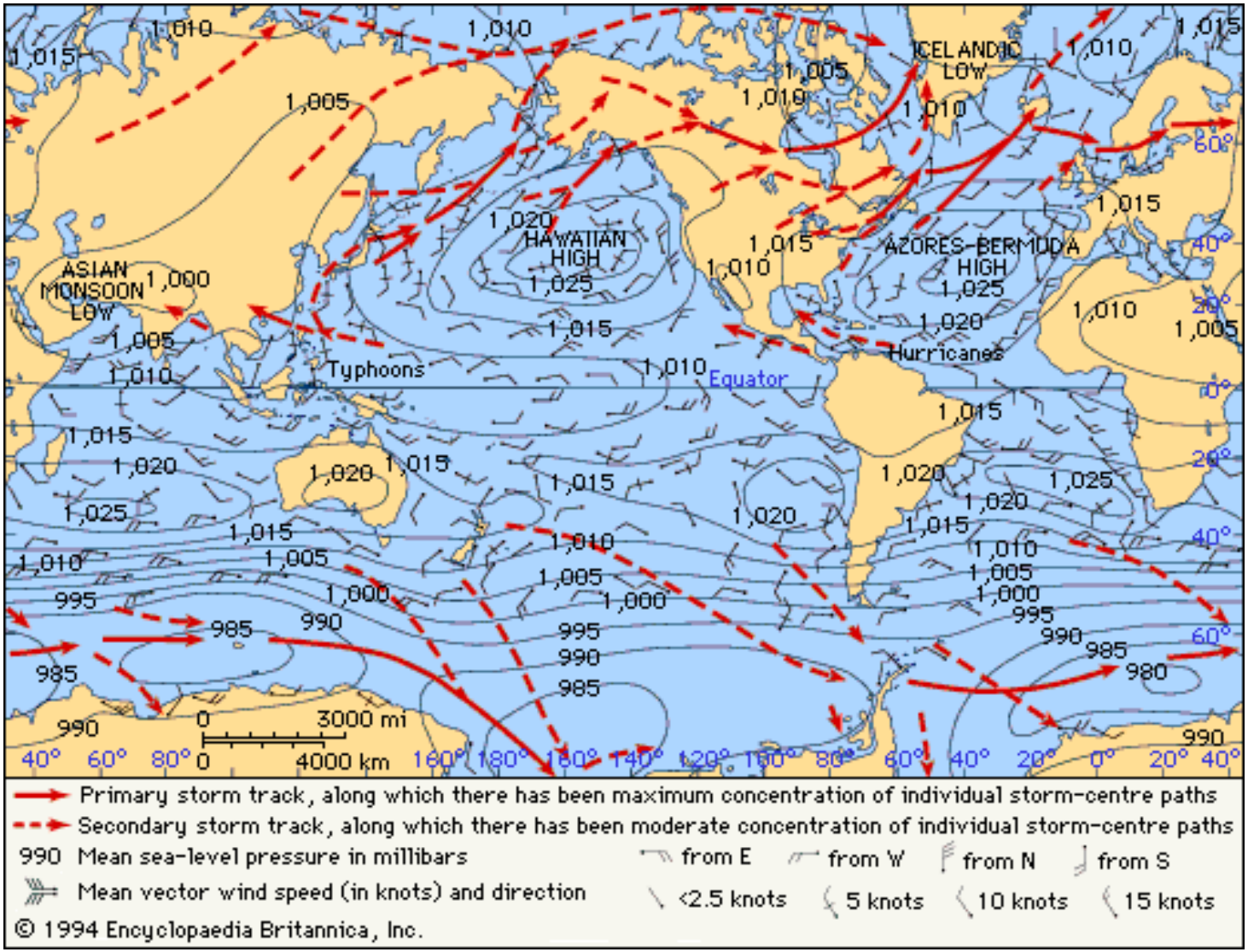
The Arctic Oscillation







Atmospheric oscillations in a laboratory experiment


ICELANDIC LOW
HAWAIIAN HIGH
AZORES-BERMUDA HIGH
ASIAN MONSOON LOW
Typhoons
Hurricanes
Equator
0 3000 mi
0 4000 km
Primary storm track, along which there has been maximum concentration of individual storm-centre paths
Secondary storm track, along which there has been moderate concentration of individual storm-centre paths
990 Mean sea-level pressure in millibars
Mean vector wind speed (in knots) and direction
from E
from W
from N
from S
<2.5 knots
5 knots
10 knots
15 knots
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