Ocean-Atmosphere Climate Variations

1. **P**acific Decadal Variability

Mantua, N. J. and S. R. Hare, 2002: The Pacific Decadal Oscillation. J. Oceanogr., 58, 35-44.

2. **N**orth **A**tlantic **O**scillation

Atlantic **M**ultidecadal **O**scillation

North **P**acific **G**yre **O**scillation

North **P**acific **O**scillation

Indian **O**cean **D**ipole

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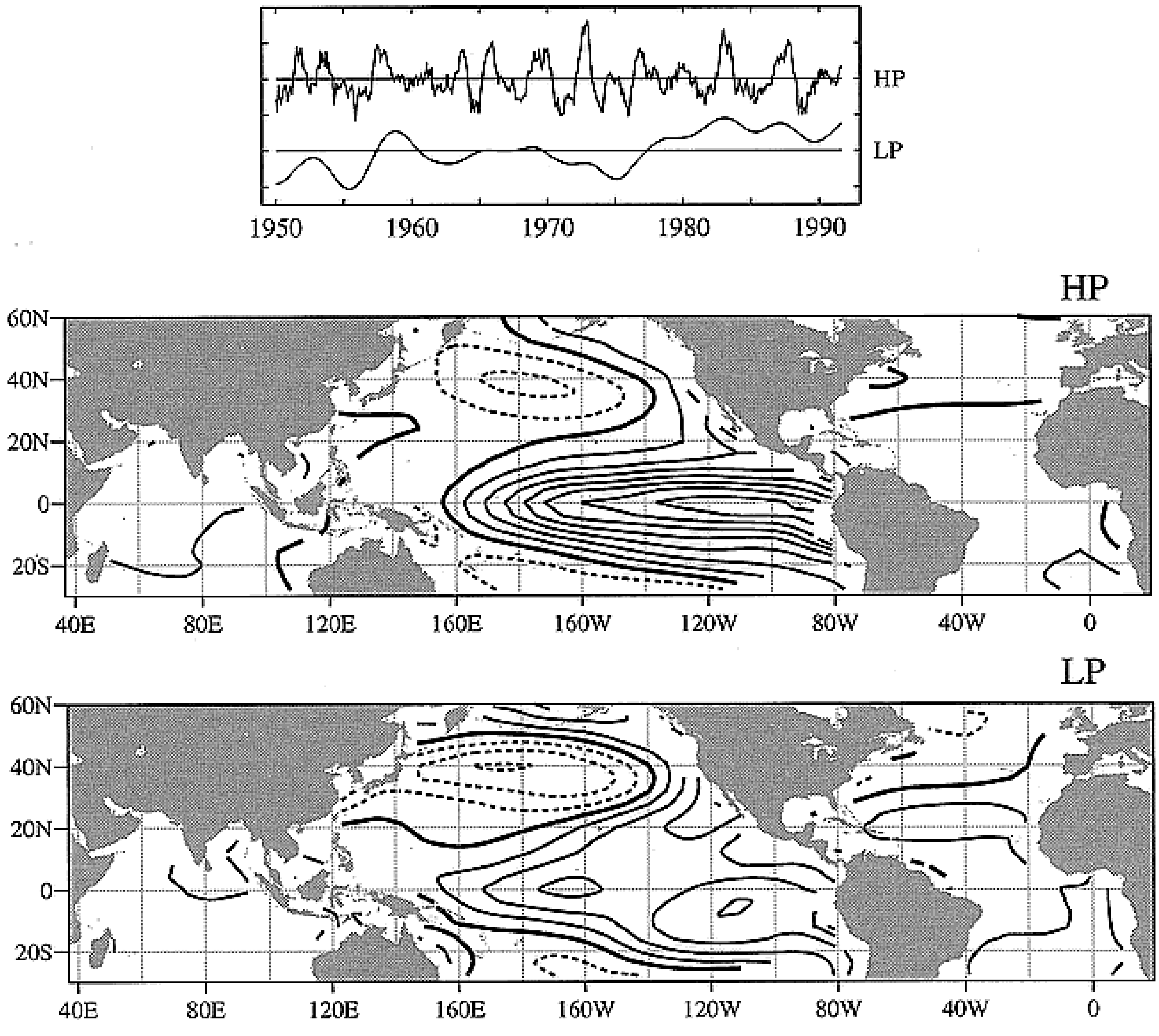
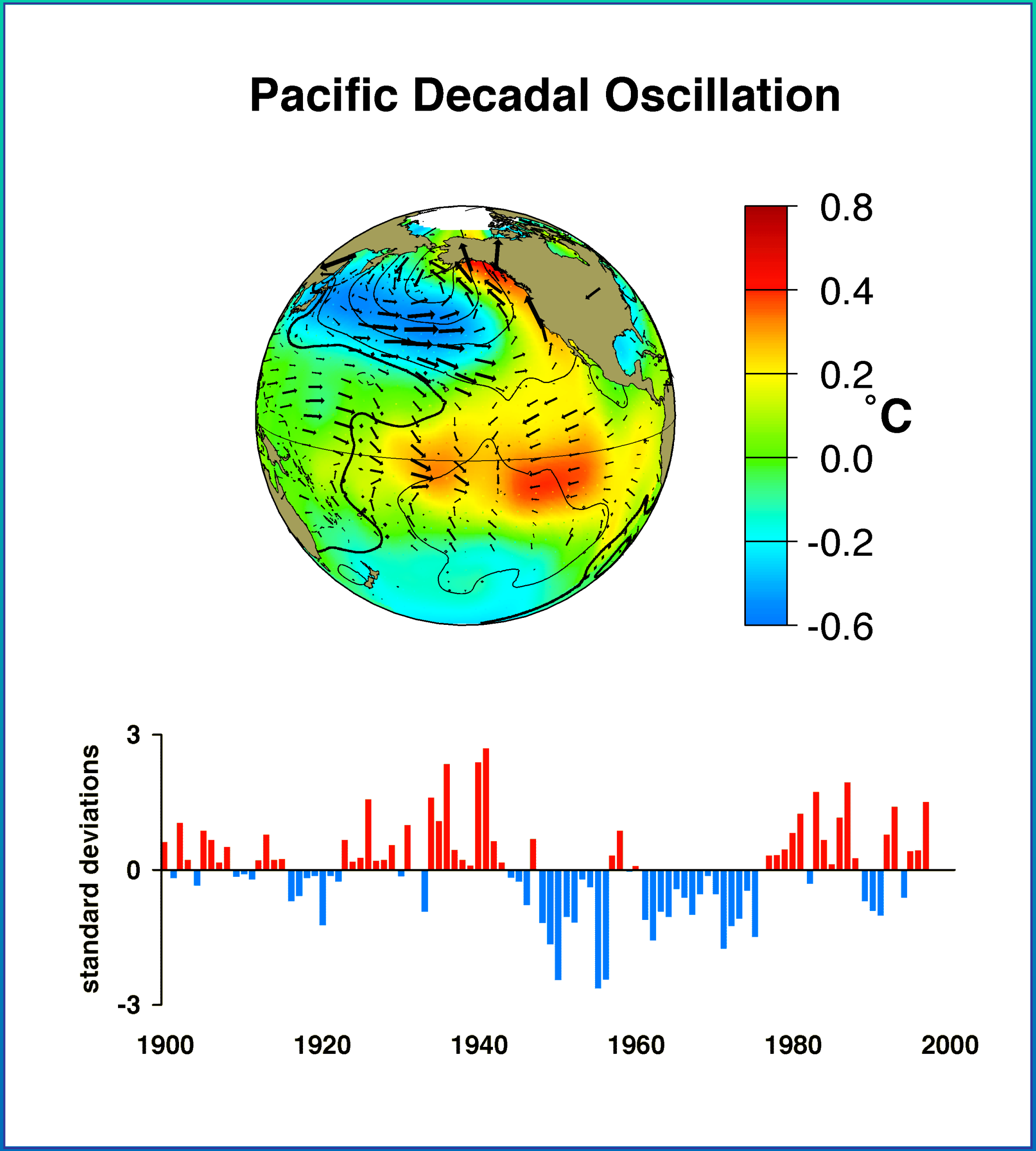


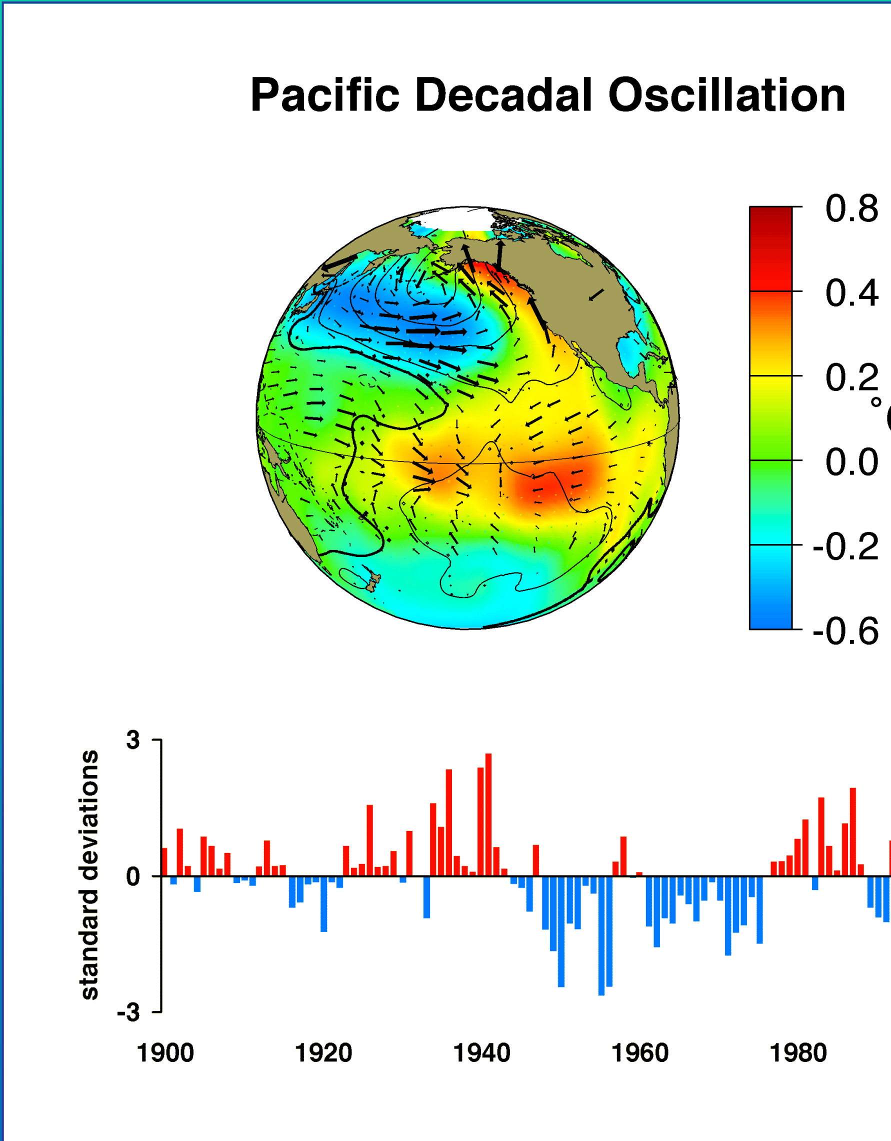
Zhang, Wallace, Battisti 1997

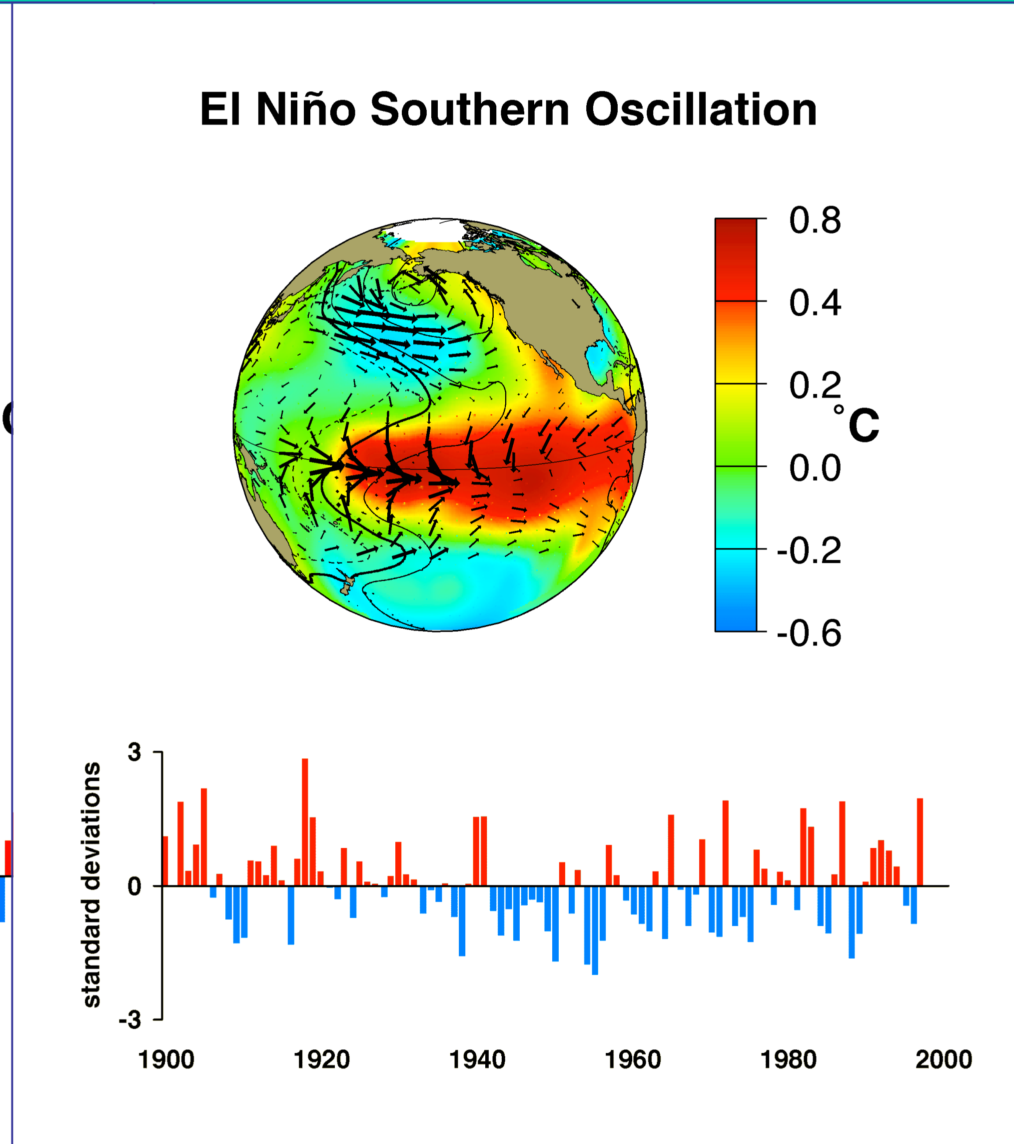


The Pacific Decadal Oscillation (PDO) is a coherent basin scale fluctuation of the ocean-atmosphere system. Its temporal evolution has been characterized as either an oscillation with periods of 10-70 years, or as a sequence of regime shifts every 20-30 years. Theories are numerous and controversial. PDO is sometimes referred to as "ENSO-like Decadal Variability."

PDO

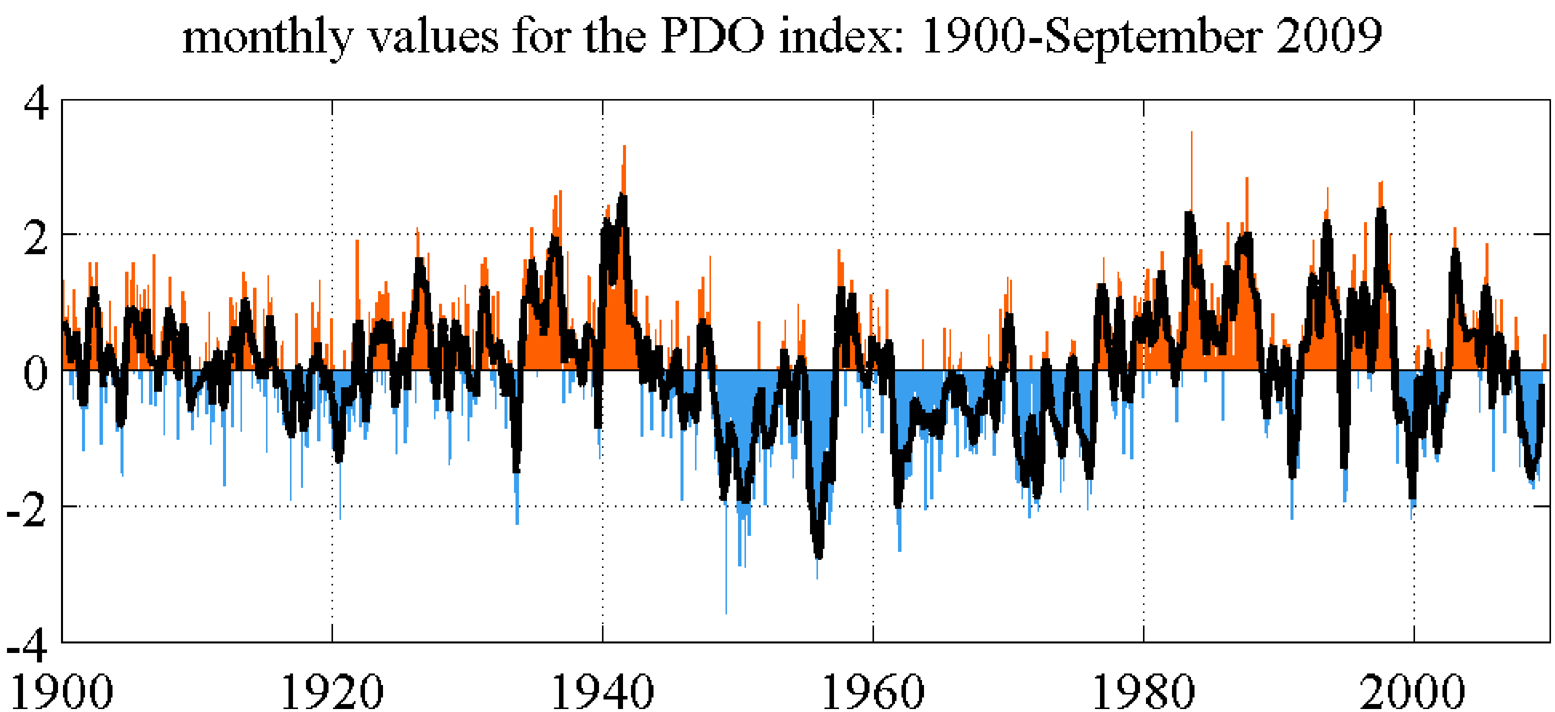
S. Hare, personal comm.





PDO

S. Hare, personal comm.


monthly values for the PDO index: 1900-September 2009
4
2
0
-2
-4
1900
1920
1940
1960
1980
2000

'Impact' of Pacific Decadal Variability

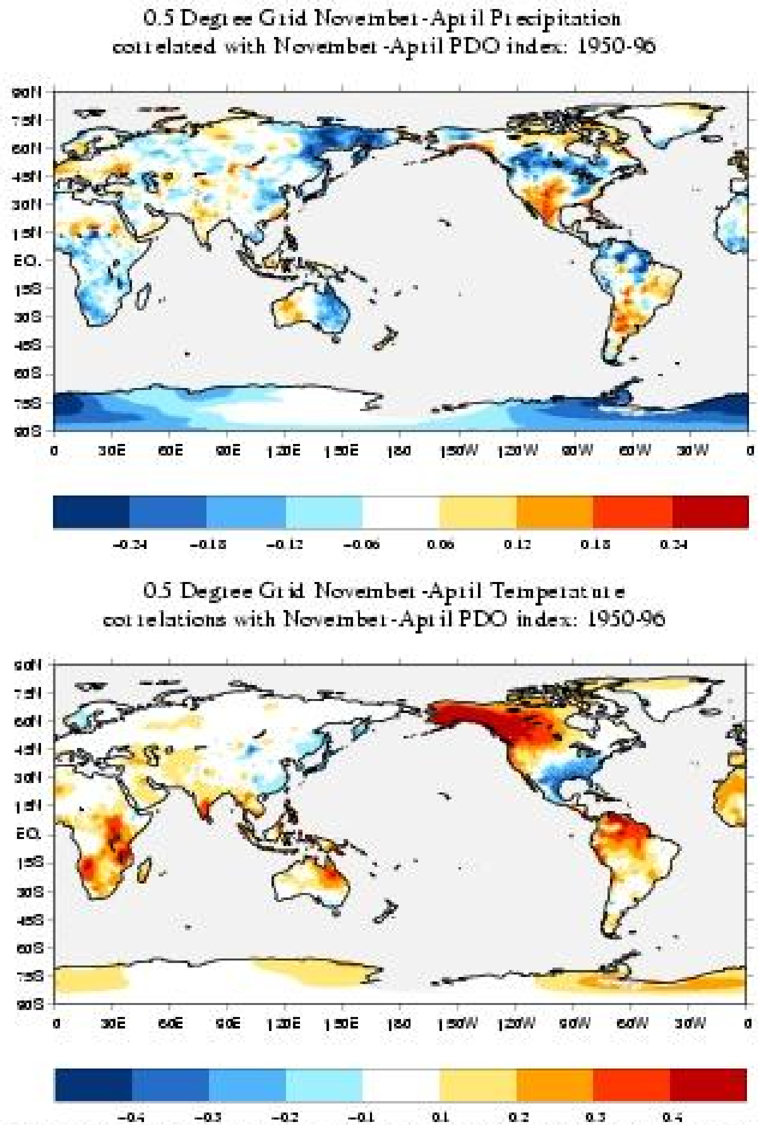


Figure 3: Correlations between November-April mean precipitation (top) and temperature (bottom) and the November-April mean PDO index. Precipitation and temperature data are the 0.5 Degree grid climatologically aided interpolation (CAI) fields produced at the University of Delaware by Cort Willmott and collaborators (available via the internet at http:// (also see Willmott and Robeson 1995). Negative correlation coefficients are shaded in blues, positive correlation coefficients are shaded in reds and yellows.

Mantua and Hare, JO, 2002

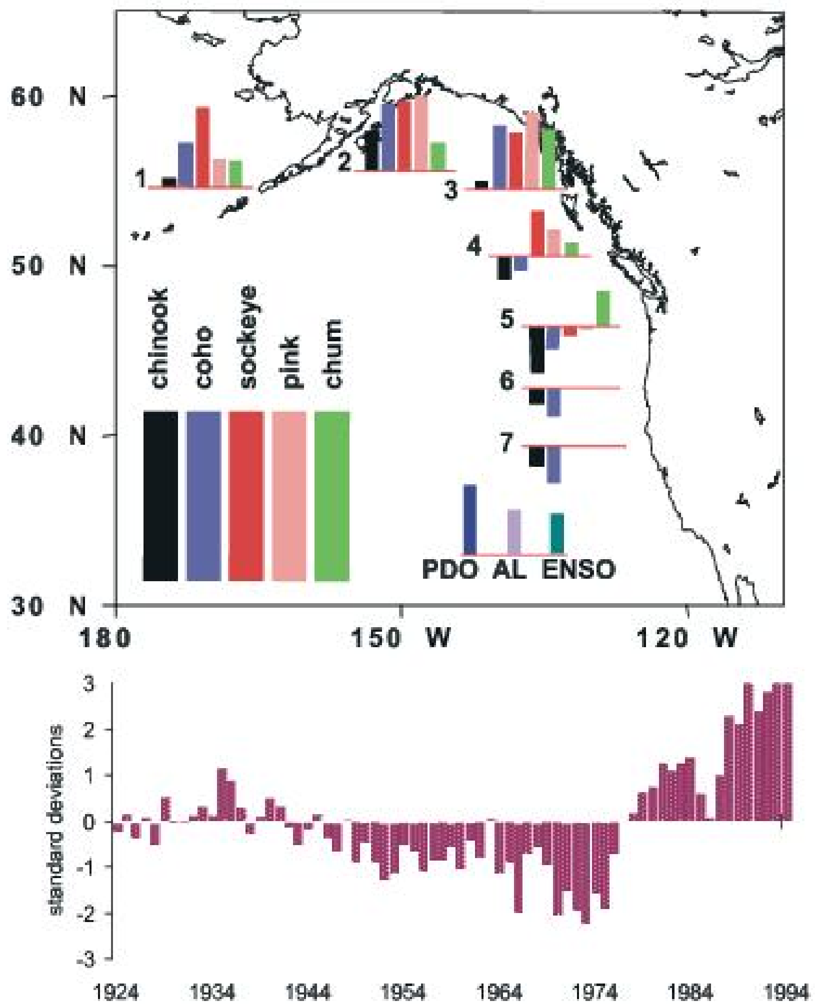


Figure 4. A graphical depiction of the "Inverse Production Regimes" of Hare et al. (1999). The bars represent loadings from a principal component analysis (PCA) of 30 salmon time series for the period 1925-1997. Regional definitions are as follows: 1 – Western Alaska, 2 – Central Alaska, 3 – Southeast Alaska, 4 – British Columbia, 5 – Washington, 6 – Oregon, 7 – California. Three climate indices were included in the PCA: Pacific Decadal Oscillation (PDO), Aleutian Low Pressure Index (AL) and the El Niño-Southern Oscillation (ENSO). The longest bar, Central Alaska pink salmon, represents a correlation coefficient with a value of 0.855, and represents the correlation between that time series and the illustrated temporal component (score) from the PCA.

Mantua and Hare, JO, 2002

Further reading:

Mantua, N. J. and S. R. Hare, 2002: The Pacific Decadal Oscillation, *J. Oceanogr.*, 58, 35-44.

Miller, A. J. and N. Schneider, 2000: Interdecadal climate regime dynamics in the North Pacific: theories, observations and ecosystem impacts. *Prog. Oceanogr.*, 47, 355-379.

Schneider, N. and B. Cornuelle, 2005: The forcing of the Pacific Decadal Oscillation. *J. Climate*, 18, 4355-4373.

The North Atlantic Oscillation

A nice set of pages is found at
http://www.ldeo.columbia.edu/res/pi/NAO/

Marshall, J., Y. Kushnir, D. Battisti, P. Chang, A. Czaja, R. Dickson, J. Hurrell, M. McCartney, R. Saravana and M. Visbeck, 2001: North Atlantic climate variability: Phenomena, impacts and mechanisms. International J. Climatology, 21, 1863-1898.

North Atlantic Oscillation NAO

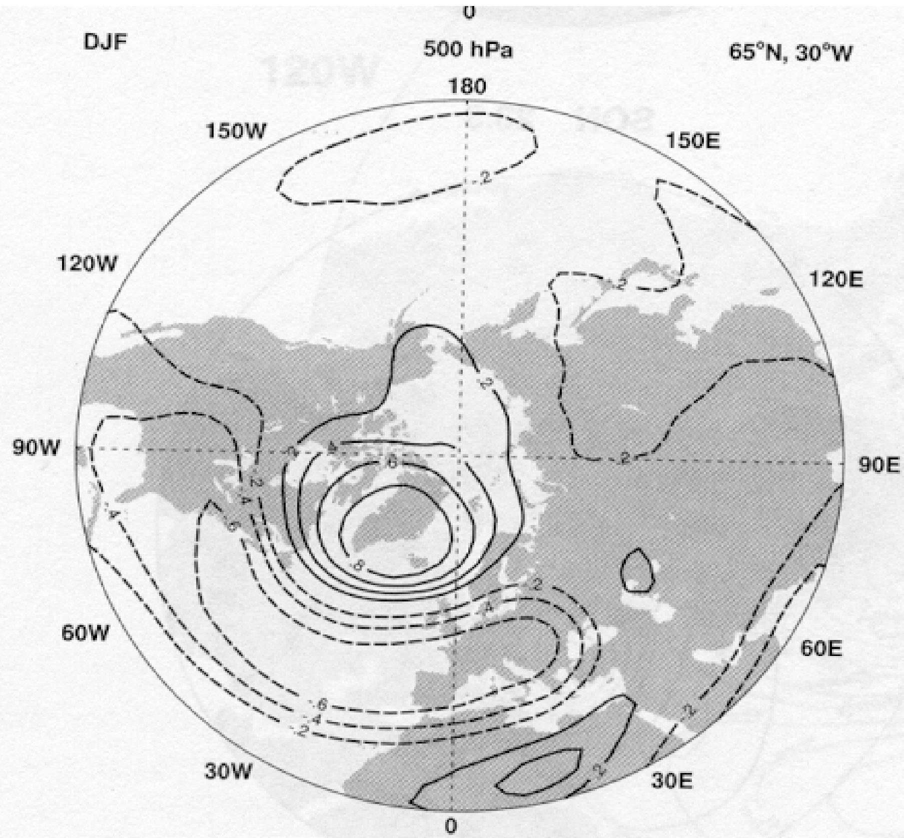


Figure 5. One-point correlation maps of 500 hPa geopotential heights for boreal winter (December-February) over 1958-2001. In the top panel, the reference point is 45°N, 165°W, corresponding to the primary center of action of the PNA pattern. In the lower panel, the NAO pattern is illustrated based on a reference point of 65°N, 30°W. Negative correlation coefficients are dashed, the contour increment is 0.2, and the zero contour has been excluded.

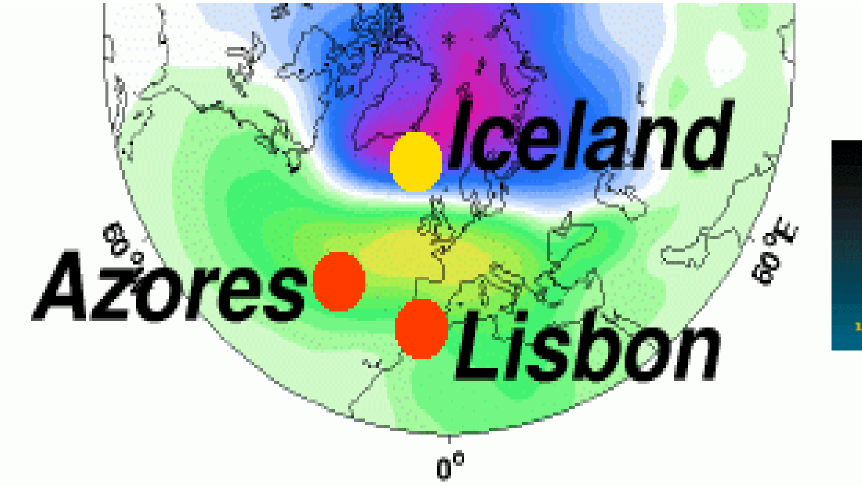
✔A sea saw of atmospheric mass which alternates between the polar and subtropical regions.

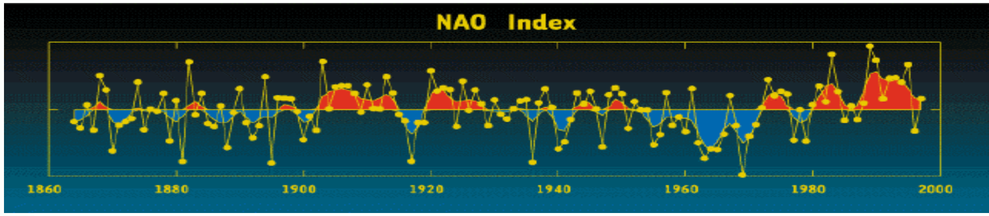
✔Changes in the mass and pressure fields lead to variability in the strength and pathway of storm systems crossing the Atlantic from the US East coast to Europe.

✔The NAO is most noticeable during the winter season (November - April) with maximum amplitude and persistence in the Atlantic sector.

Visbeck; Hurrell et al. 2003

The North Atlantic Oscillation Index

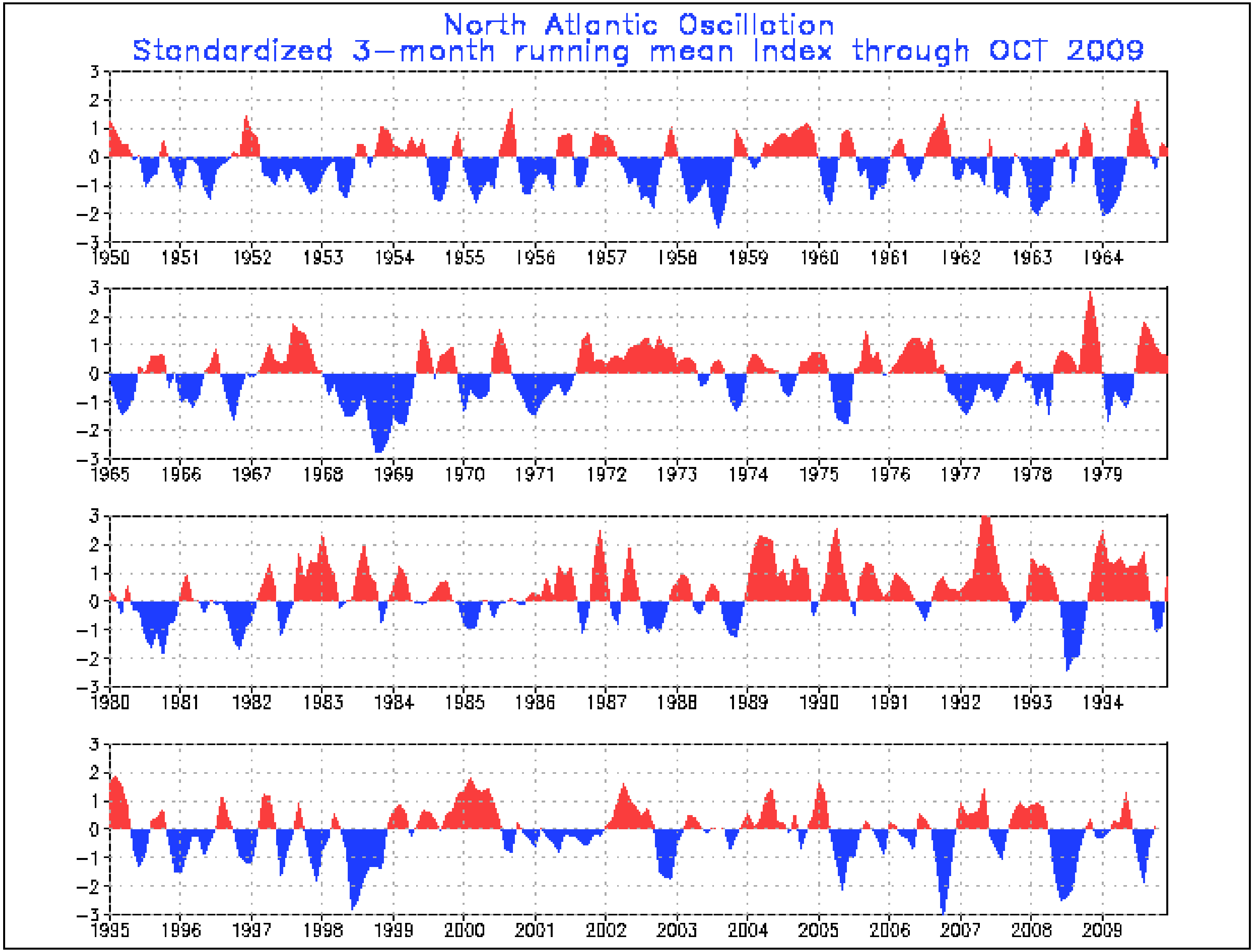




✔ The NAO index is based on the surface pressure difference between the Subtropical (Azores) high and the Subpolar (Island) low.

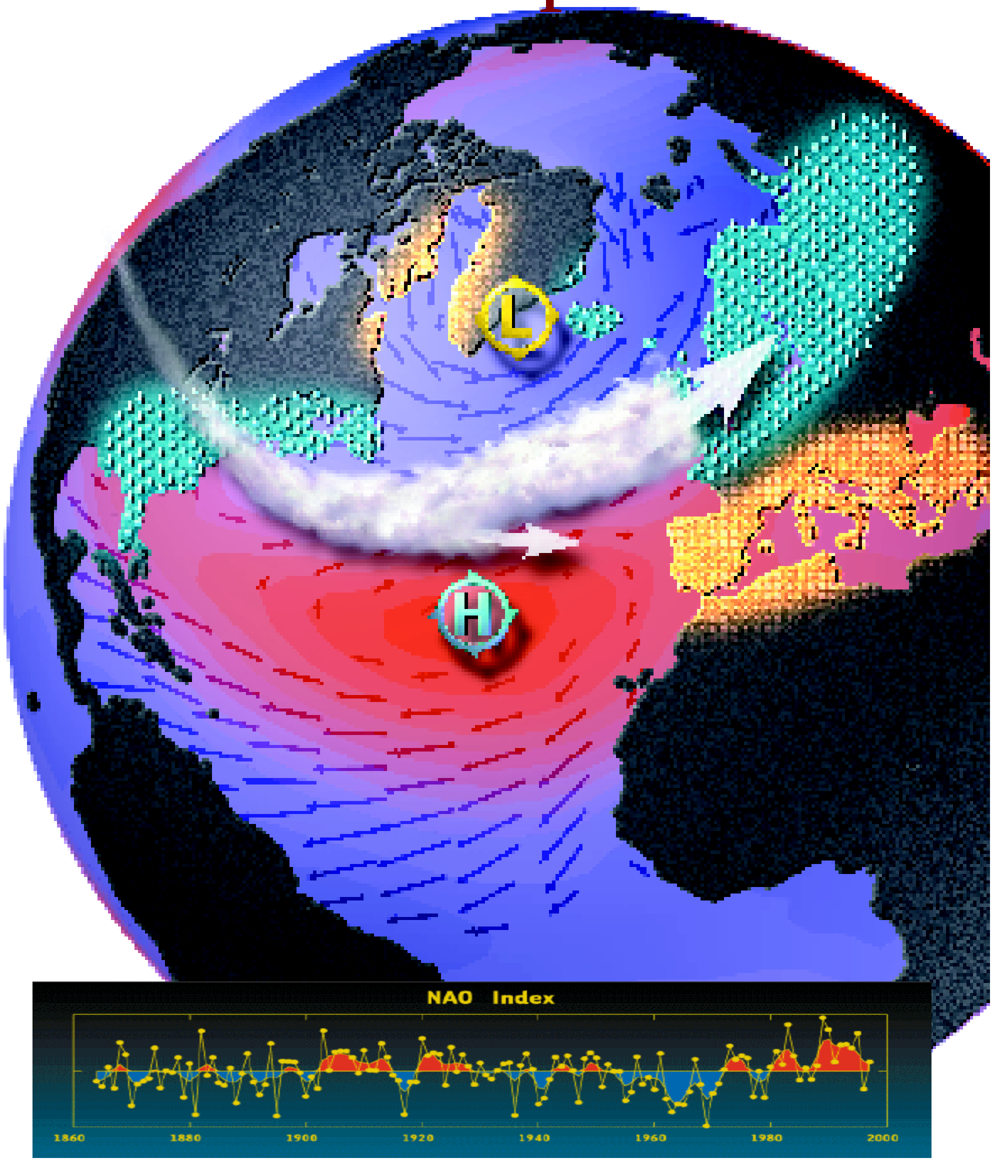
✔To obtain the longest record, the pressure readings from stations on Iceland and from either the Azores, Lisbon or Gibraltar are used. The twice daily reading are averaged from November through March and the difference in then the winter NAO index.

Martin Visbeck



http://www.cpc.noaa.gov/data/teledoc/nao.timeseries.gif

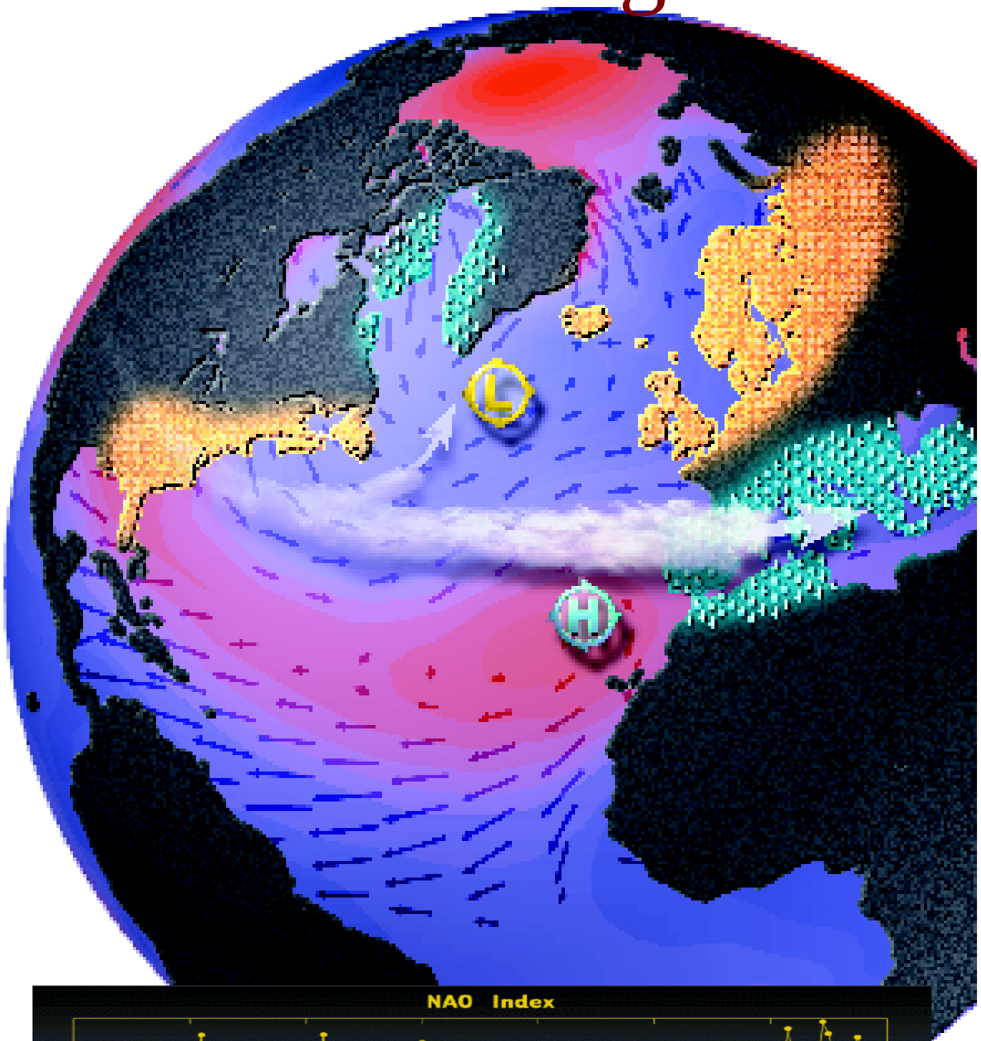
The positive NAO index phase

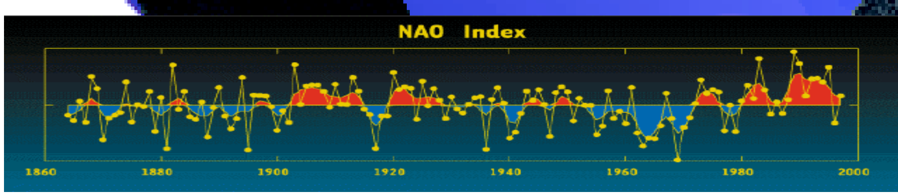


- The positive NAO index phase shows a stronger than usual subtropical high pressure center and a deep than normal Icelandic low.
- The increased pressure difference results in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track.
- This results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland.
- The eastern US experiences mild and wet winter conditions.

Martin Visbeck

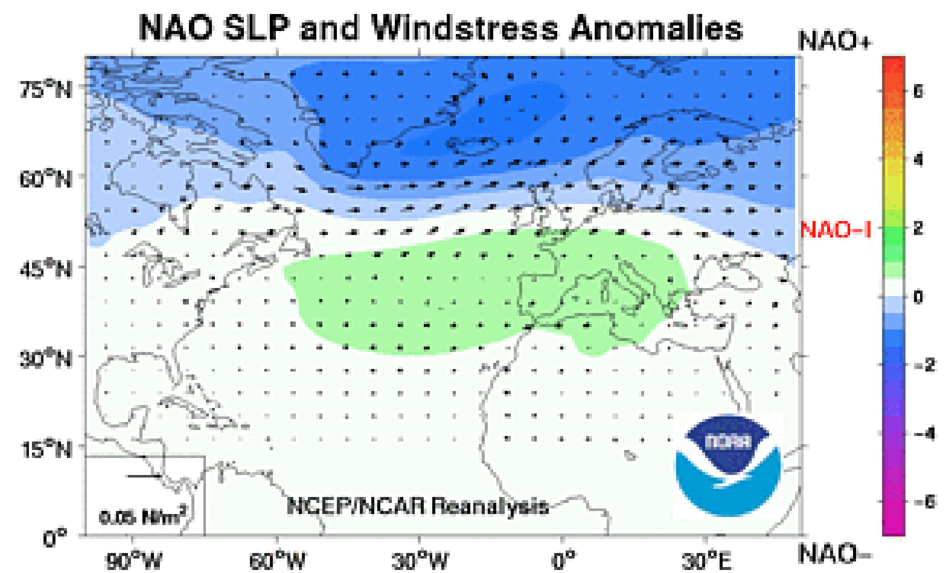
The negative NAO index phase

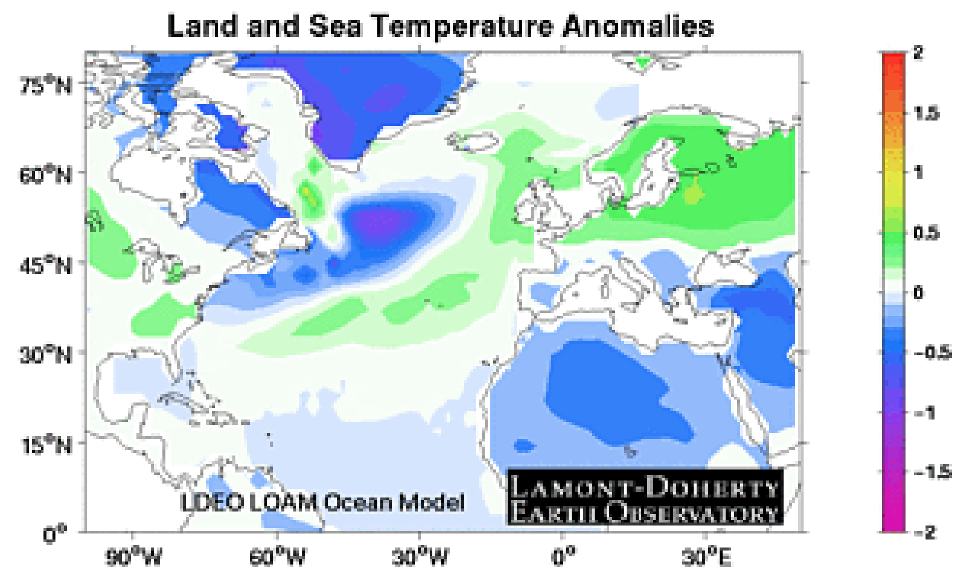


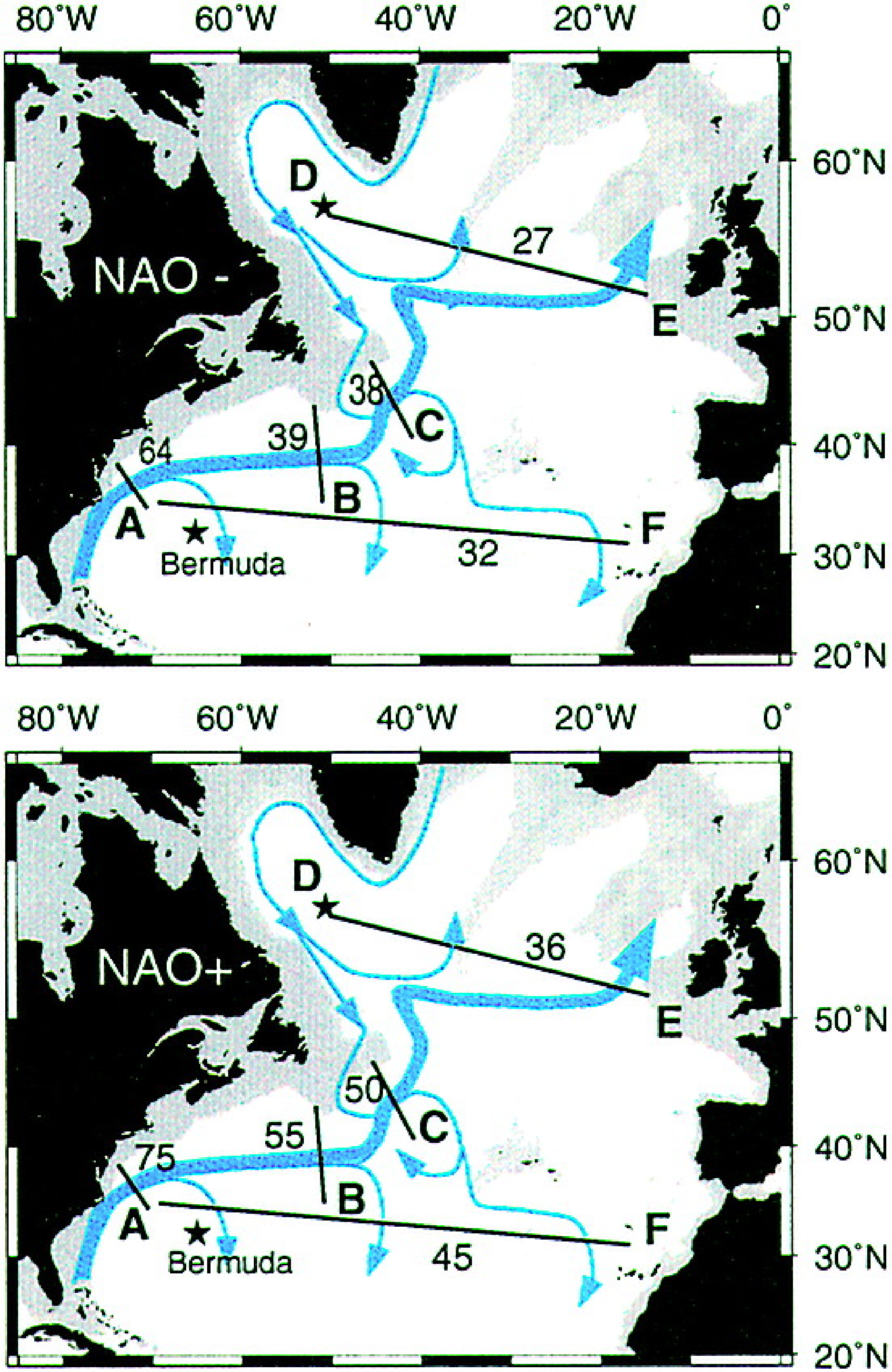


- The negative NAO index phase shows a weak subtropical high and weak Icelandic low.
- The reduced pressure gradient results in fewer and weaker winter storms crossing on a more west-east pathway.
- They bring moist air into the Mediterranean and cold weather to northern Europe.
- The US east cost experiences more cold air outbreaks and hence snowy winter conditions.
- Greenland, however, will have milder winter temperatures.

Martin Visbeck


NAO SLP and Windstress Anomalies
NAO+
NAO-I
NAO-
75°N
60°N
45°N
30°N
15°N
0°
90°W
60°W
30°W
0°
30°E
0.05 N/m²
NCEP/NCAR Reanalysis
6
4
2
0
-2
-4
-6


Land and Sea Temperature Anomalies
75°N
60°N
45°N
30°N
15°N
0°
90°W
60°W
30°W
0°
30°E
LDEO LOAM Ocean Model
Lamont-Doherty
Earth Observatory
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2



Schematic representation of the North Atlantic gyre circulation pathways and 0–2000-db baroclinic mass transports in the low NAO (top panel) and high NAO (bottom panel) phases. From the composite maps of PEA distribution in Figs. 4a and 4b, mass transports have been estimated from the PEA difference between locations at the ends of each of five black line segment labeled with the letters –. The transport estimates are the numbers given in units of megatons per second.

Curry and McCartney, JPO, 2001

Changes in water mass characteristics

LSW: Labrador Sea Water, about 3C, salinity minimum
NEADW: North East Atlantic Deep Water, salinity maximum
DSOW: Denmark Strait Overflow Water, < 2C

Widespread freshening of the deep waters (and cooling of the LSW) thought to reflect the North Atlantic Oscillation (NAO) from its most extreme negative state in the instrumental record during winters of the 1960s to its most extreme and prolonged positive state in the early 1990s

Dickson et al., Nature, **416,** 832, 2002

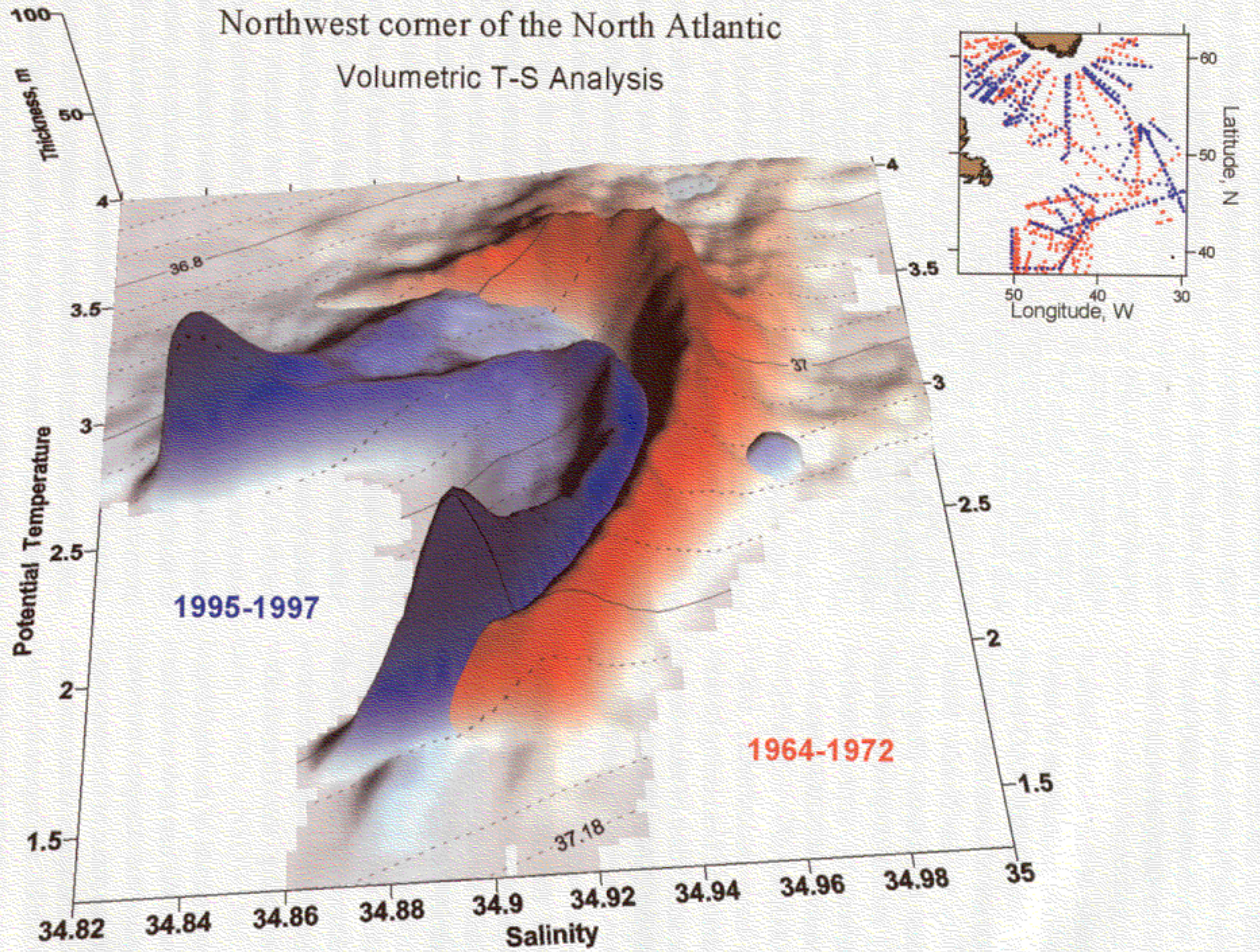
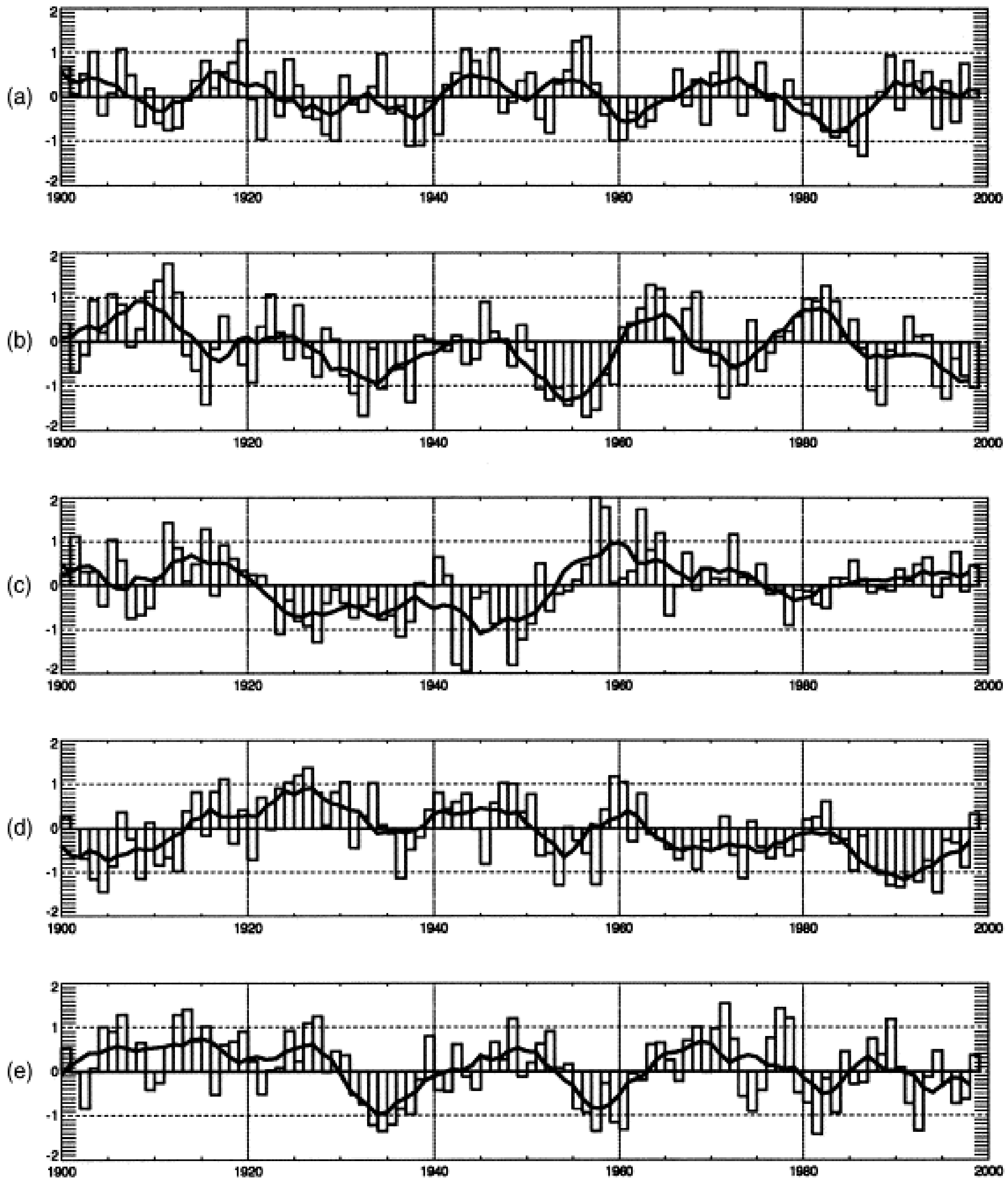
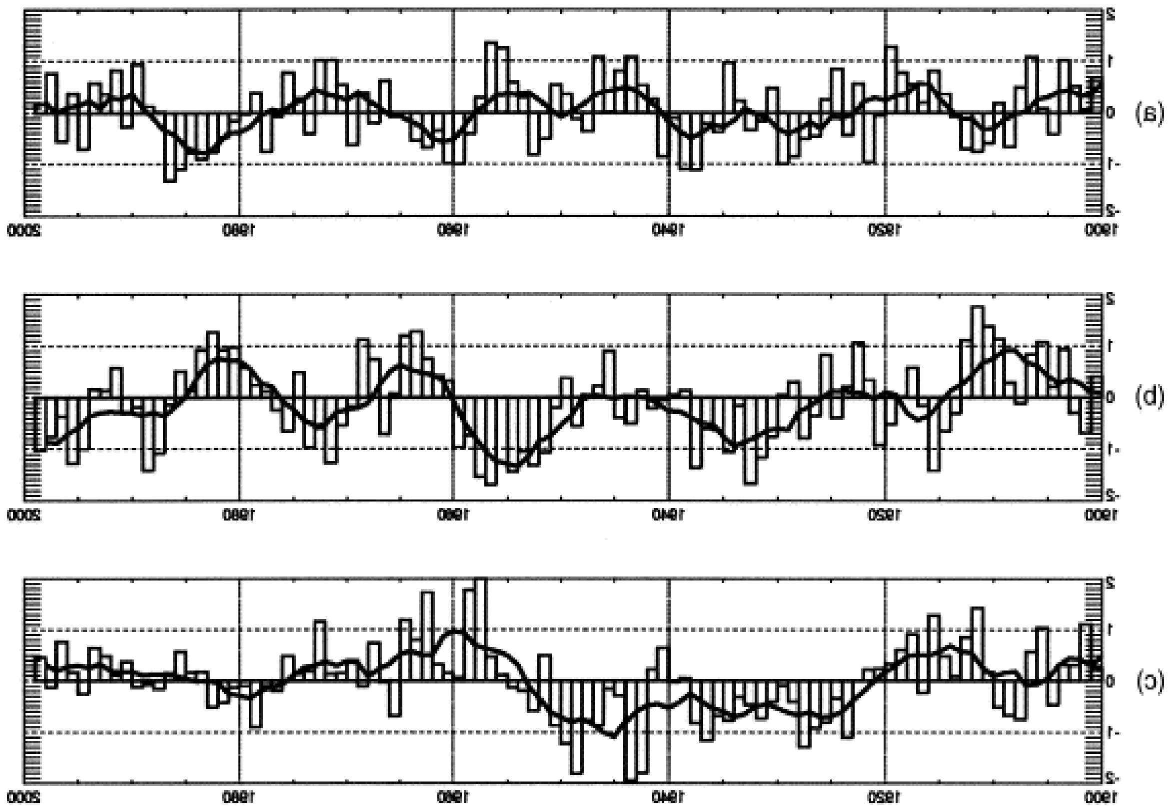


Plate 3. Change in the T-S relation between 1964–1972 and 1995–1997 for deep waters of the NW Atlantic (38°-64°N, 12°-52°W) denser than σ_{t2} =36.84 (LSW + NEADW + DSOW). Figure shows a volumetric T-S analysis kindly provided by Igor Yashayaev, Bedford Institute of Oceanography, Dartmouth, N.S., Canada. This remarkable change reflects the multi-decadal freshening of the entire system of overflow and entrainment that ventilates the deep Atlantic [*Dickson et al.*, 2002].

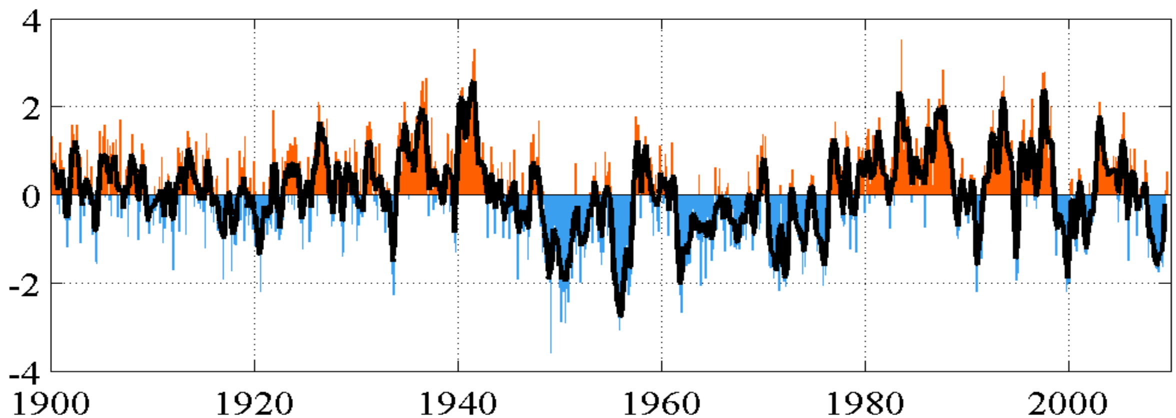
Null hypothesis: Stochastic Forcing



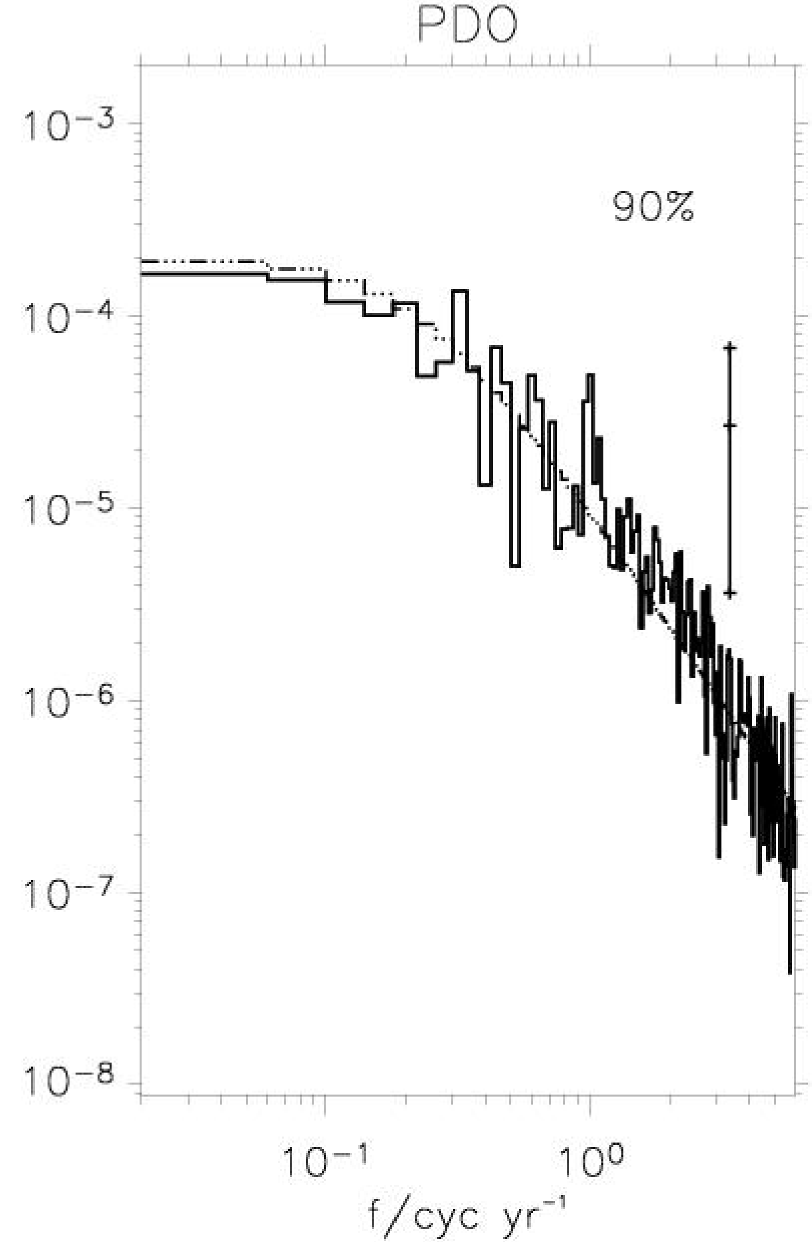
Pierce 2001



monthly values for the PDO index: 1900-September 2009



ʼierce 2001


PDO
90%
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻¹
10⁰
f/cyc yr⁻¹