Climates Shifts vs. Decadal to Centennial Variability

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Decadal Climate Variability and Predictability
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Acknowledgments

Zaiyu Wang, GMU PhD student

We did “research” online to survey the literature for this talk.

- Google scholar search “climate shift”
- Google scholar search “regime shift”
- Etc.

Concepts

- Climate is the statistics of instantaneous “weather” variables

- Climate variability
  - Change in mean
  - Change in other statistics (variance, frequency correlation, structure, ..).
  - Climate shift (provisional): ***a change in the statistics that persists for much longer than the transition time***, so it is a type of climate variability.
    - Some people use climate shift for a change in sign of some index (AMV, PDV, net TOA heat flux, …), no constraint on time scale for transition.

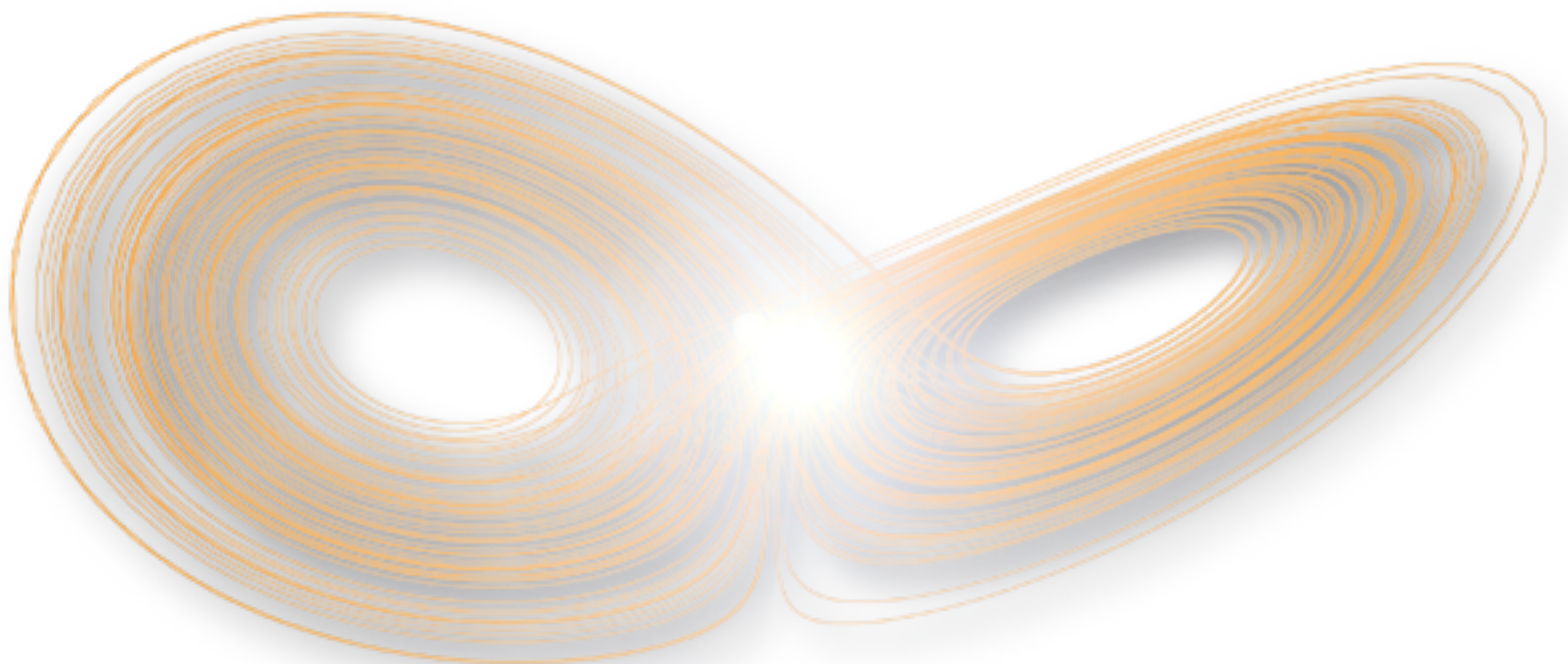
Climate vs. Weather

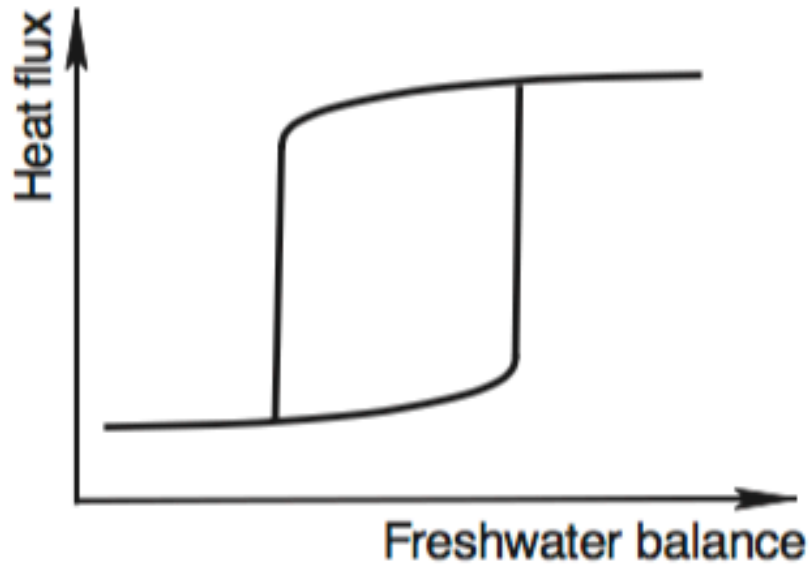
- Weather is instantaneous values of weather variables
- Climate is a lagging indicator – you don't know what the current climate is until it's the past climate.
- Climate prediction vs. weather prediction
  - Have to wait 10 years to verify a decadal climate prediction
  - A weather prediction verifies against instantaneous data.
  - Examples
    - An seasonal ENSO prediction is a weather prediction for SST.
    - A seasonal hurricane forecast is a climate prediction.

Climate Regimes

- **Climate shifts** are related to the concept **climate regimes** and the terms **climate shifts** and **regime shifts** are used interchangeably.

  – Regimes are distinct “climates,” and are motivated by the 3-variable nonlinear Lorenz attractor model
    - The regimes are regions surrounding the (unstable) fixed points (steady solutions).
    - The transitions between different regimes can be thought of as climate shifts.
    - A climate shift by my definition would then be a regime change that lasts much longer than than the transition time.
- **Climate shift** is a cousin to **abrupt climate change**. Abrupt climate change longer than decadal/centennial





Stocker 1999

Fig. 3 The ocean–atmosphere system is a non-linear physical system that can exhibit hysteresis behaviour of the deep circulation in the ocean (Stocker and Wright 1991). Depending on the surface freshwater balance of the Atlantic Ocean, the meridional heat flux in the Atlantic is not unique and multiple equilibria exist. Changes are linear as long as they remain on the same branch of the hysteresis loop. If certain threshold values in the atmosphere–ocean system are passed, the climate state can change abruptly by switching from one branch to the other. This is a robust feature of the climate system as demonstrated by the entire hierarchy of climate models (Stocker and Wright 1991)

Stocker 1999

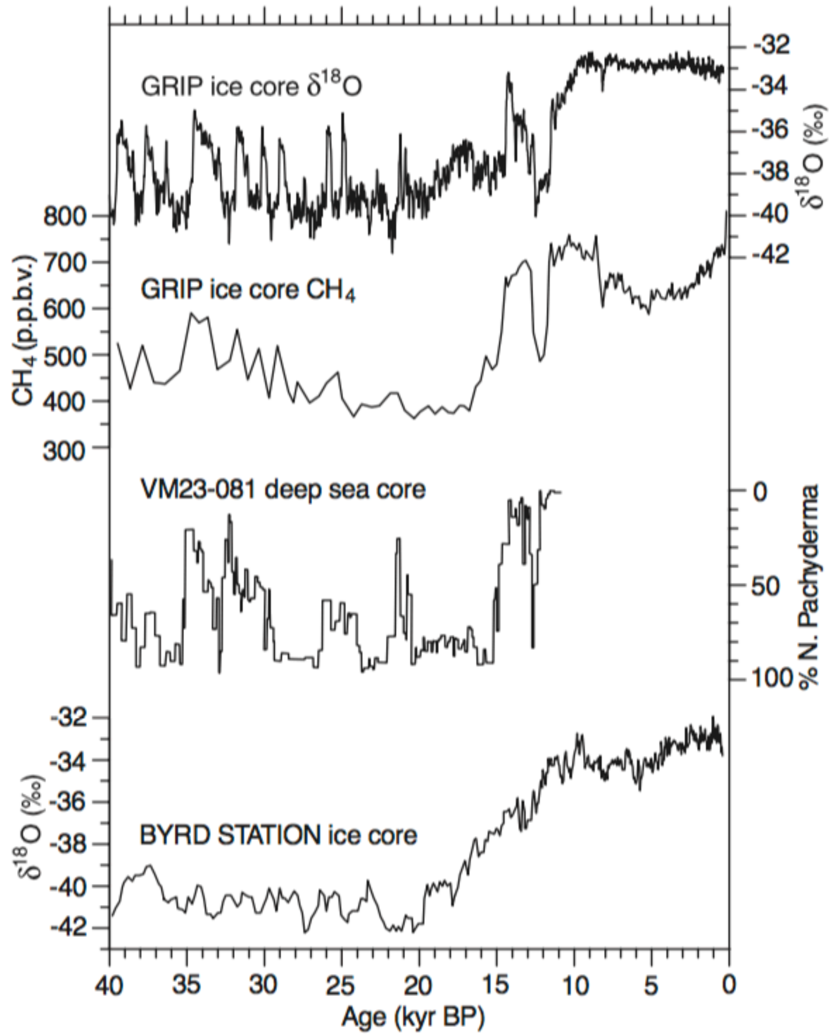
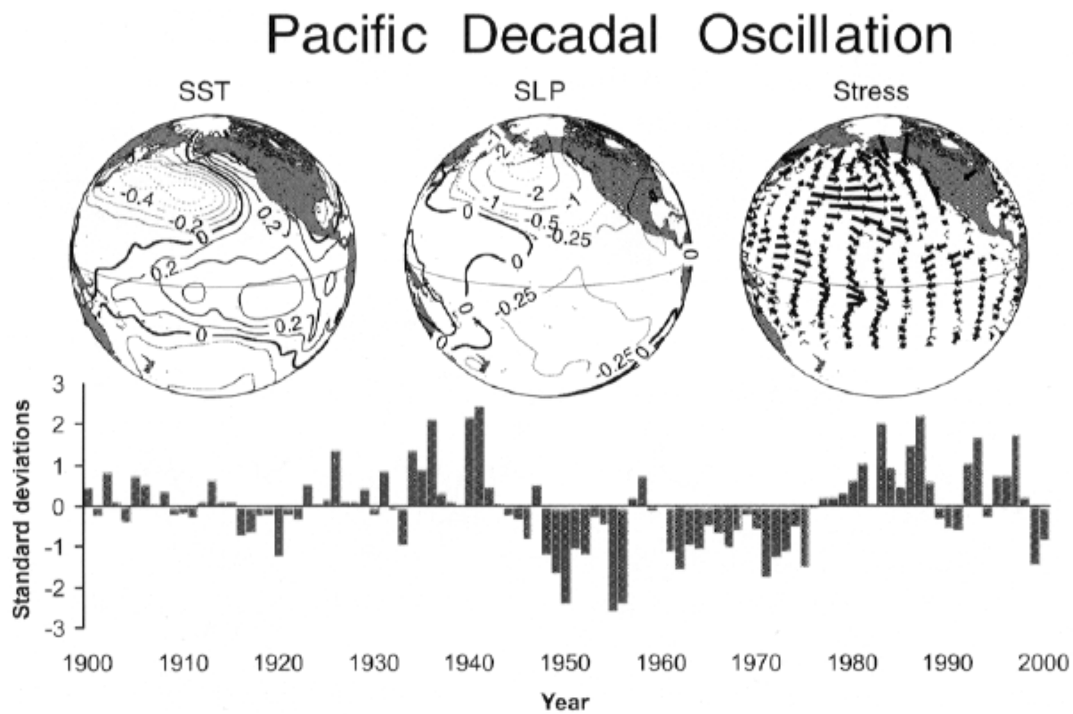


Fig. 1 Climatic change over the past 40,000 years as obtained from the measurement of d^{18}O on ice (from Johnsen et al. 1992, Dansgaard et al. 1993 and Hammer et al. 1994) and CH_4 on air of bubbles trapped in the ice core (from Chappellaz et al. 1993 and Blunier et al. 1995). Four different features of climate variability are evident in the different time series: (a) slow, astronomically forced transition from the glacial to the interglacial ($\delta^{18}O$ records and CH_4); (b) natural variability during the Holocene ($\delta^{18}O$ records); and (c) abrupt reorganisations before 25 kyr BP and during the Bolling/Allerod/Younger Dryas Period (all but Byrd Station core). (Courtesy of T. Blunier)

The Pacific Decadal Oscillation

NATHAN J. MANTUA[1]* and STEVEN R. HARE[2]

Review *Journal of Oceanography*, Vol. 58, pp. 35 to 44, 2002



Interdecadal climate variability and regime-scale shifts in Pacific North America

Ze'ev Gedalof and Dan J. Smith

GEOPHYSICAL RESEARCH LETTERS, VOL. 28, NO. 8, PAGES 1515-1518, APRIL 15, 2001

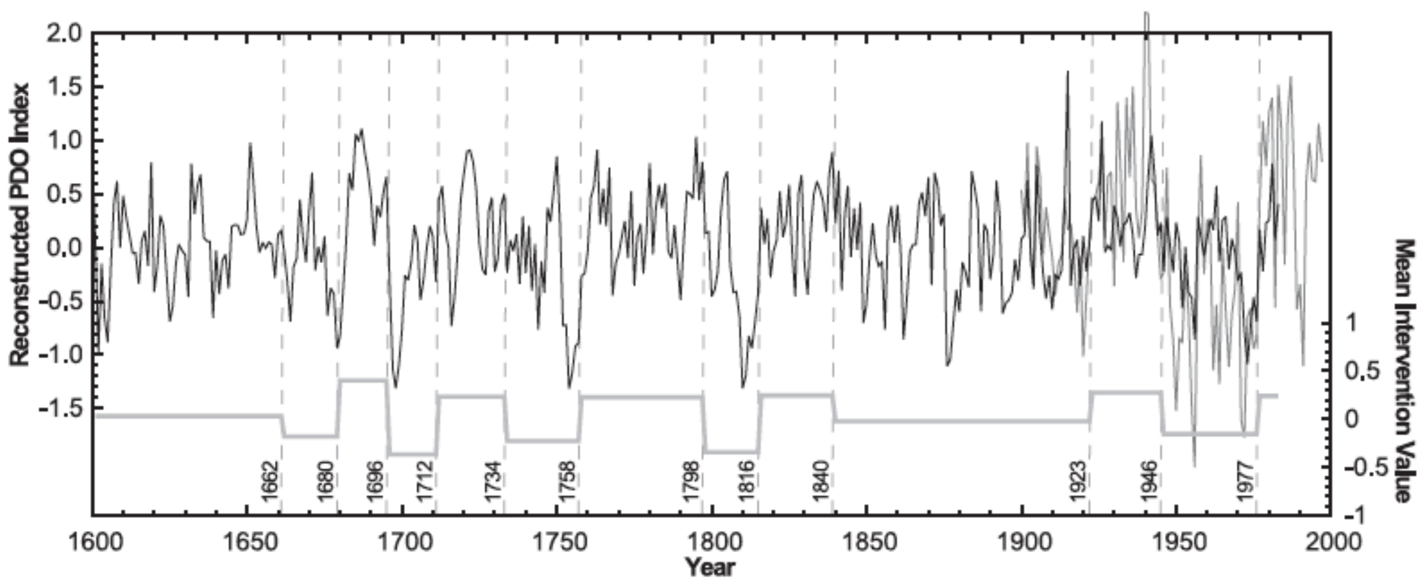


Figure 2. The observed (grey) and reconstructed (black) mean spring (March - May) PDO index. The low frequency component has been emphasized using a spline fit with a 50 percent frequency cutoff of 25 years. Shown at the bottom is the intervention model fit to the reconstructed series.

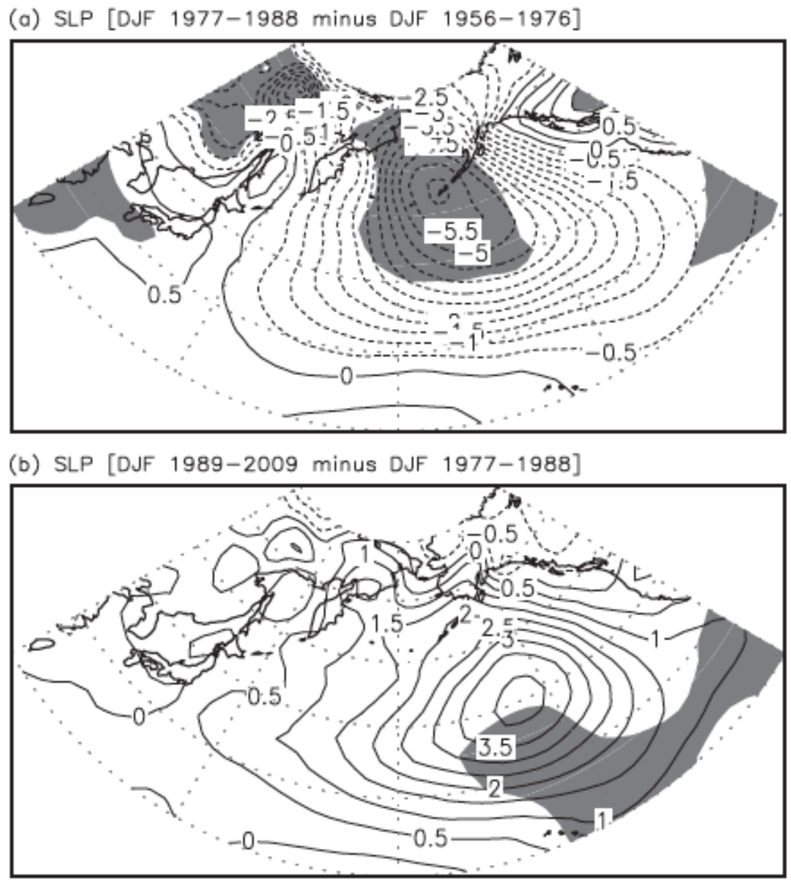


FIG. 7. Changes in winter mean SLP (a) between 1977–88 and 1956–76 and (b) between 1988–2009 and 1977–88. Contour interval is 0.5 hPa, and shading denotes the region where the statistical significance exceeds the 95% confidence level.

Changes in the Statistics: Mean and Variance

ENSO Amplitude Modulation Associated with the Mean SST Changes in the Tropical Central Pacific Induced by Atlantic Multidecadal Oscillation

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FRED KUCHARSKI

Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

JOURNAL OF CLIMATE

Differences in mean state

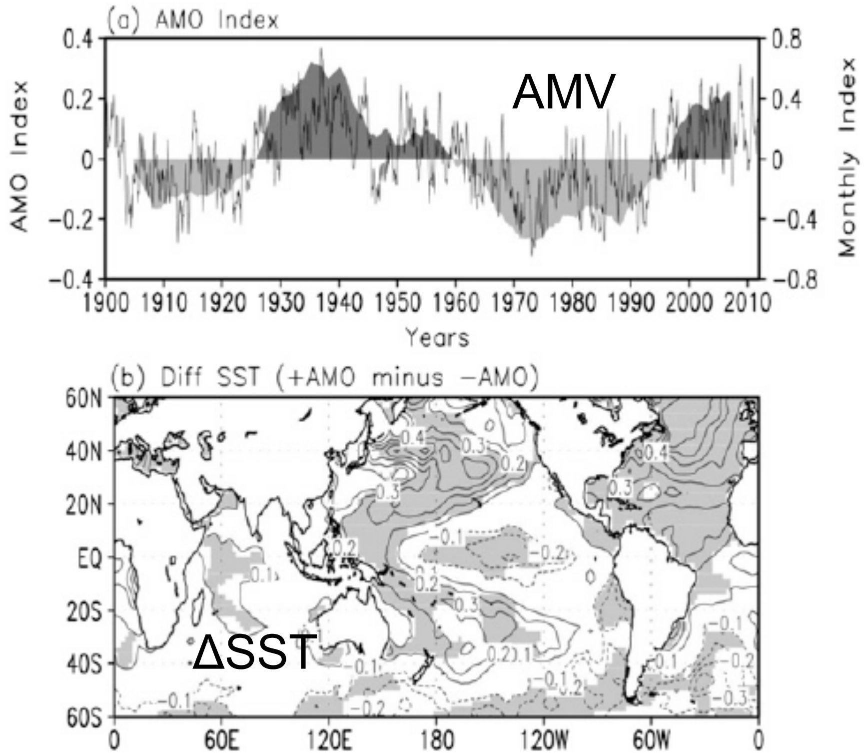
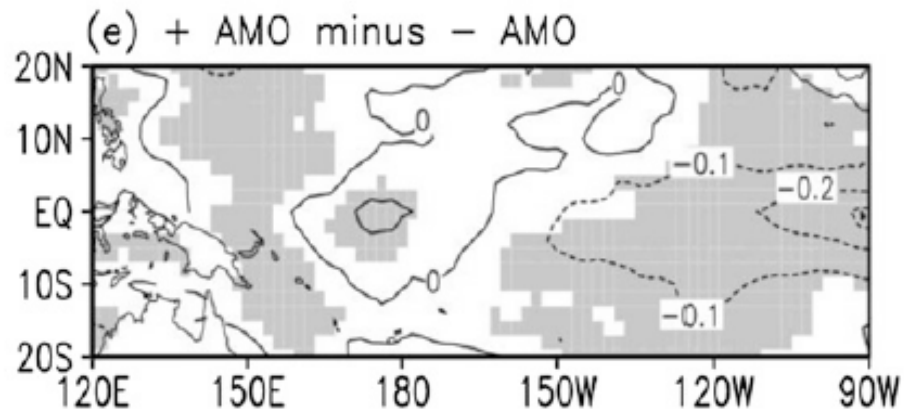


FIG. 1. (a) Time series of the AMO index smoothed with a 121-month running mean (°C, shading) and its monthly index (°C, black solid line). The AMO index is obtained by averaging SST anomalies over the NH Atlantic Ocean. (b) Difference map between the mean SSTs during positive phases of the AMO and those of the negative phases of the AMO. Shading indicates differences above the 95% statistically significant level.

Differences in variability



Difference in SSTA standard deviation

Recent Climate Shifts

- 1976/7 (shift in mean)
- 1988/9 (shift in mean)
- 1998-2015 (shift in the trend)
- NAO/AMV 1995/6

1976 Climate Shift
(Also the year satellite observations began)

- Trenberth, 1990: *Recent* Observed Interdecadal Climate Changes in the Northern Hemisphere.

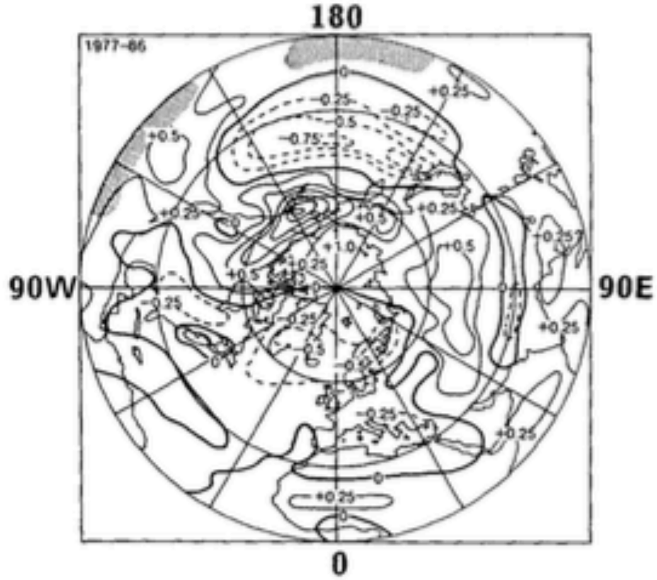


FIG. 1. Decadal average surface-temperature or sea-surface-temperature anomalies as departures from the 1951–80 mean, for 1977–86. Contours every 0.25°C (from Folland and Parker 1989).

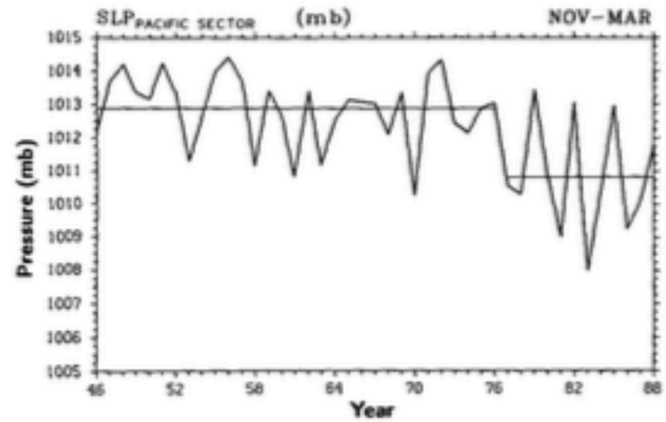


FIG. 2. Time series of mean North Pacific sea-level pressures averaged over 27.5° to 72.5°N, 147.5°E to 122.5°W for the months November–March. Means for 1946–76 and 1977–87 are indicated.

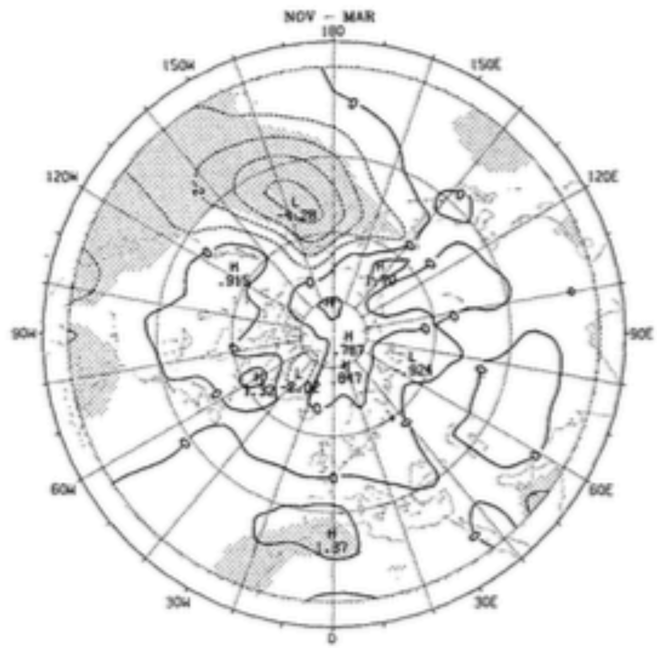


FIG. 3. The difference in mean sea-level pressures from 1977–88 for November–March versus 1924–76 (mb). Stippling indicates statistical significance at 5%.

variations, beginning in 1899, are available. An evaluation (Trenberth and Paolino 1980) shows them to be most reliable after 1924, and we therefore use monthly mean sea-level pressures to examine the changes in circulation.

Time series of Pacific mean sea-level pressure for the winter period November–March (figure 2), averaged from 27.5°N to 72.5°N, 147.5°E to 122.5°W, or virtually the entire North Pacific, reveals the different regime after 1976. This time series depicts changes in the intensity of the Aleutian low, and is also an index of the Pacific–North American (PNA) teleconnection pattern. The PNA appears to be a preferred mode of the atmosphere in the NH in winter and consists of four centers of action in the midtropospheric height field, of one sign near Hawaii and along the West Coast of North America, and of opposite signs over the North Pacific and southeast United States (Wallace and Gutzler 1981). The latter show

Zhang, Wallace, and Battisti 1997

SST

ENSO

Multidecadal

ENSO

Multidecadal

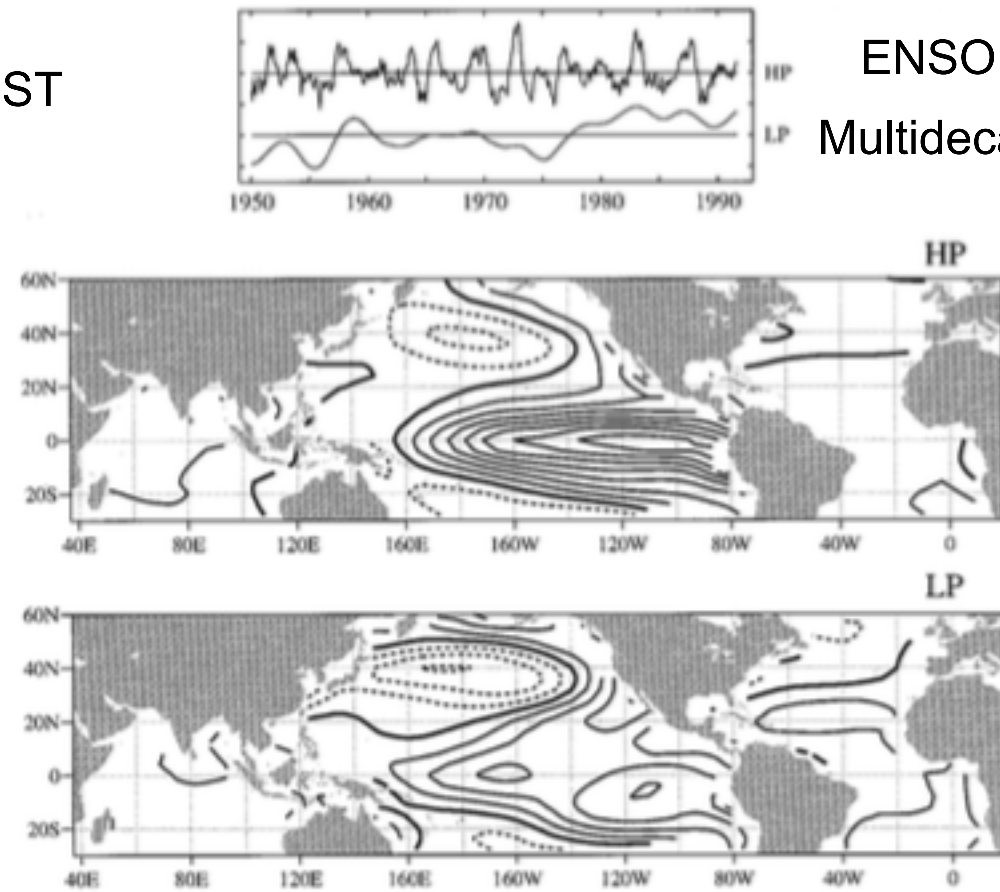


FIG. 3. The leading (normalized) PCs of 6-yr highpass- (HP) and lowpass- (LP) filtered SST over the Pacific domain shown together with the associated regression patterns for global SST. The interval between tick-marks on the vertical axis of the top panel corresponds to 1.0 standard deviation, and the spacing between the curves is arbitrary. Contour interval 0.1 K per standard deviation of the expansion coefficient time series. Negative contours are dashed; the zero contour is thickened.

Mantua et al. 1997 PDO

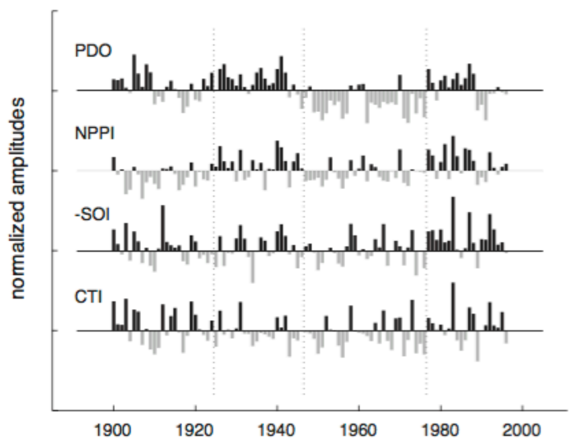


FIG. 1. Normalized winter mean (November–March) time histories of Pacific climate indices. Dotted vertical lines are drawn to mark the PDO polarity reversal times in 1925, 1947, and 1977. Positive (negative) values of the NPPI correspond to years with a deepened (weakened) Aleutian low. The negative SOI is plotted so that it is in phase with the tropical SST variability captured by the CTI. Positive value bars are black, negative are gray.

ZWB. The Tahiti pole is defined as the average SLP anomaly from 20°N to 20°S latitude from the international date line to the coast of South and Central America, while the Darwin pole is defined as the average SLP anomaly over the remainder of the global tropical oceans within the same range of latitudes. Missing SOI values for the period of record 1913–20 and 1993–May 1996, were estimated from a linear regression with the traditional Tahiti–Darwin SOI based on the common period of record 1933–90, obtained from the National Oceanic and Atmospheric Administration/National

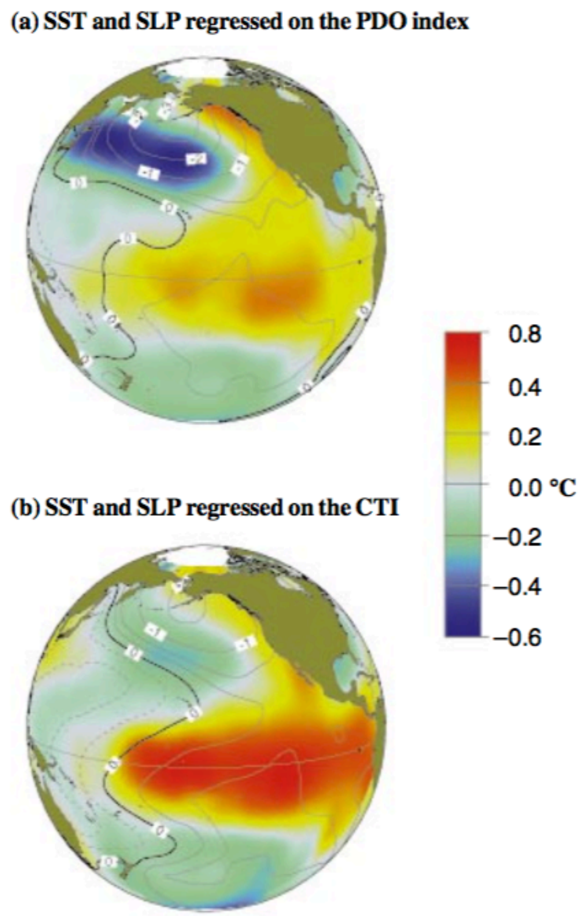


FIG. 2. COADS SST (color shaded) and SLP (contoured) regressed upon (a) the PDO index and (b) the CTI for the period of record 1900–92. Contour interval is 1 mb, with additional contours drawn for +/−0.25 and 0.50 mb. Positive (negative) contours are dashed (solid).

Minobe 1997

Coherent changes in a number of indices = regime shift

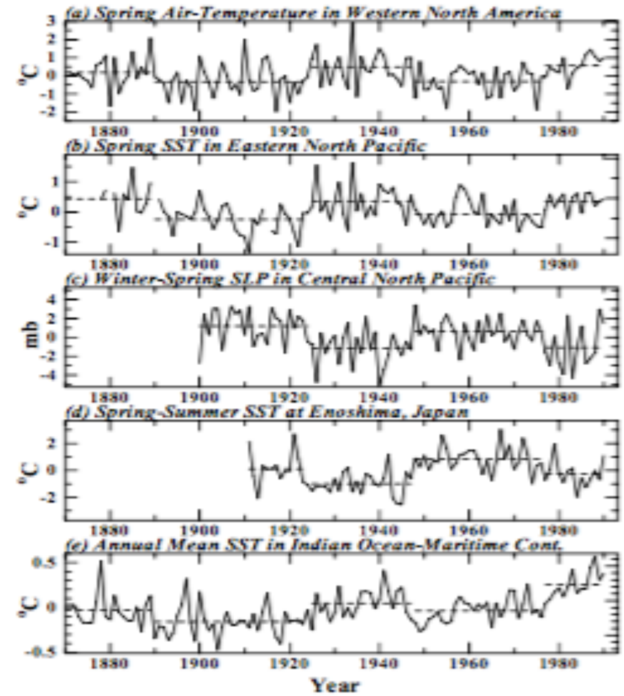


Figure 1. Time series of anomalies exhibiting coherent interdecadal climate changes (thin solid curve), with temporal averages of the anomalies for the periods 1870–1889, 1890–1924, 1925–1947, 1948–1976 and 1977–1990 (thick dashed lines). (a) Spring (Mar.–May) air-temperature anomalies in western North America averaged over 130°W–105°W, 30°N–55°N. The air-temperature anomaly is calculated relative to 1930–50 at each station, and then the anomalies are averaged spatially. (b) Spring SST anomalies in the eastern North Pacific averaged over 140°W–110°W, 30°N–55°N. The average is calculated when available grid points are more than 20% of total grid points in the spring of respective years. (c) Winter-spring (Dec.–May) SLP anomalies in the central North Pacific averaged over 160°E–140°W, 30°N–65°N. (d) Spring-

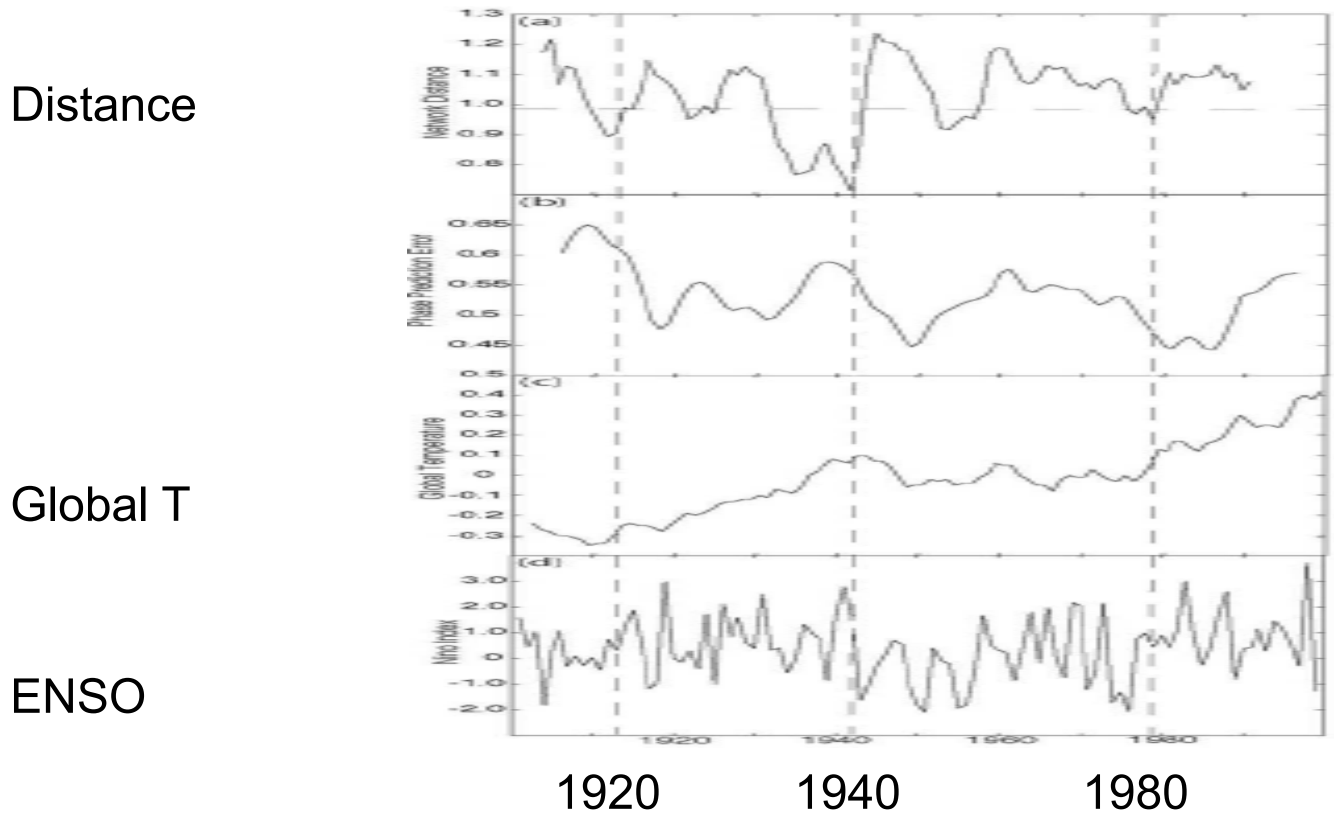
Climate Networks

- Network is a vector of indices: normalized PDO, NAO, ENSO, AMO + distance metric

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L13705, doi:10.1029/2007GL030288, 2007

A new dynamical mechanism for major climate shifts

Anastasios A. Tsonis,[1] Kyle Swanson,[1] and Sergey Kravtsov[1]

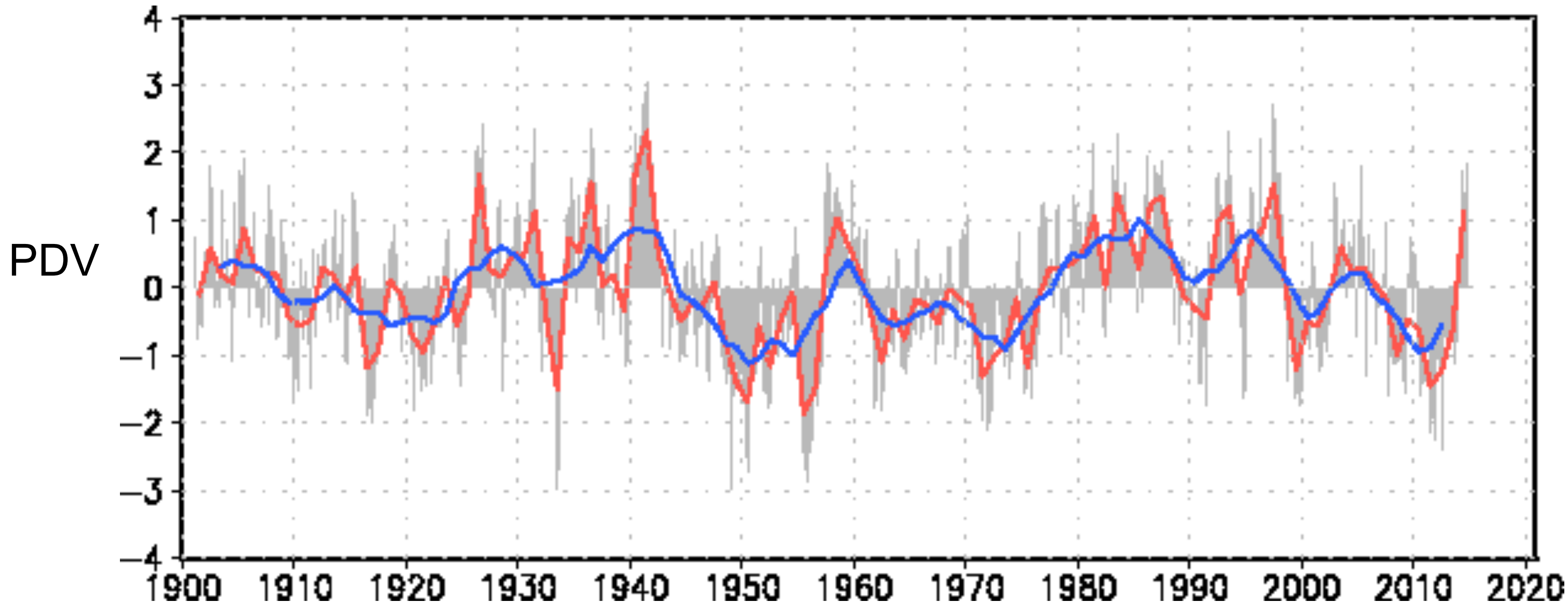


Climate Shift -> Decadal Oscillation -> Multidecadal Variability

- Trenberth 1990 identified a 1976 change in the North Pacific SST and SLP
- Graham 1994 pointed out a1976 transition in the tropics
- Zhang, Wallace and Battisti 1997 showed what is now called the PDV pattern after linearly removing ENSO.
- Mantua et al. 1997 pushed the PDO back to 1900
- 2015: 1976/7 is change of sign in PDV index

1988/9 Regime Shift?

- Change of sign of PDV, mentioned in ~2000 (Hare and Mantua)
- Also changes in fish abundances in North and Baltic Seas noted in late 1990s



Change in Global Mean Temperature Trend

- Reduced trend 1998 to present
- Lots of press, erudite explanations
- Data reevaluated, new correction applied:
  - Conclusion: never mind

Possible artifacts of data biases in the recent global surface warming hiatus

Thomas R. Karl,[1*] Anthony Arguez,[1] Boyin Huang,[1] Jay H. Lawrimore,[1] James R. McMahon,[2] Matthew J. Menne,[1] Thomas C. Peterson,[1] Russell S. Vose,[1] Huai-Min Zhang[1]

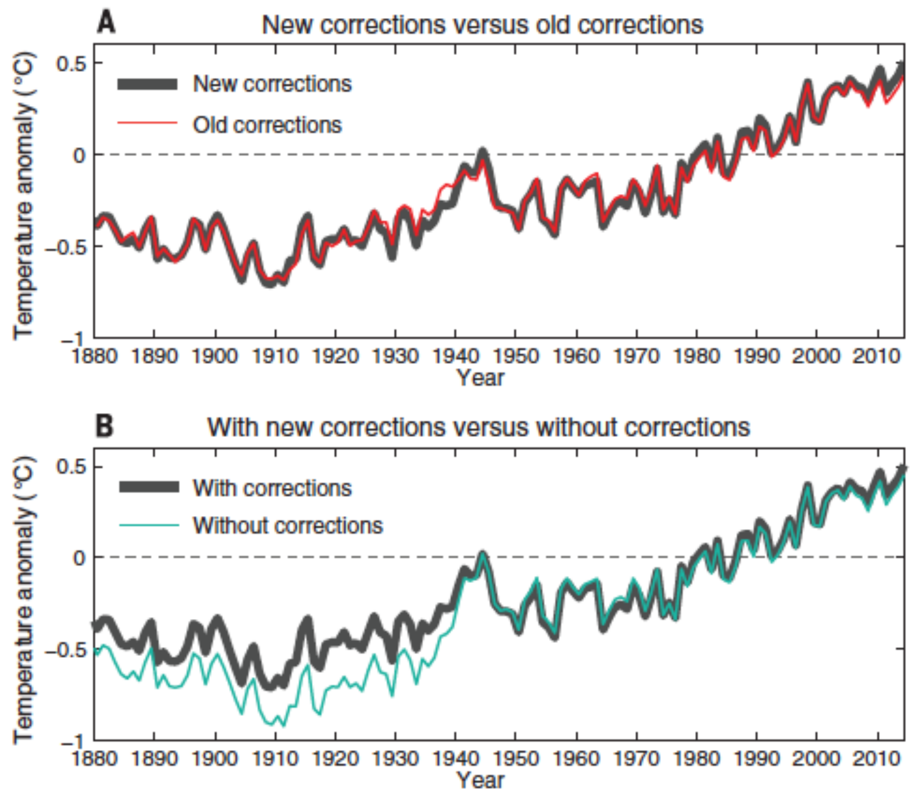
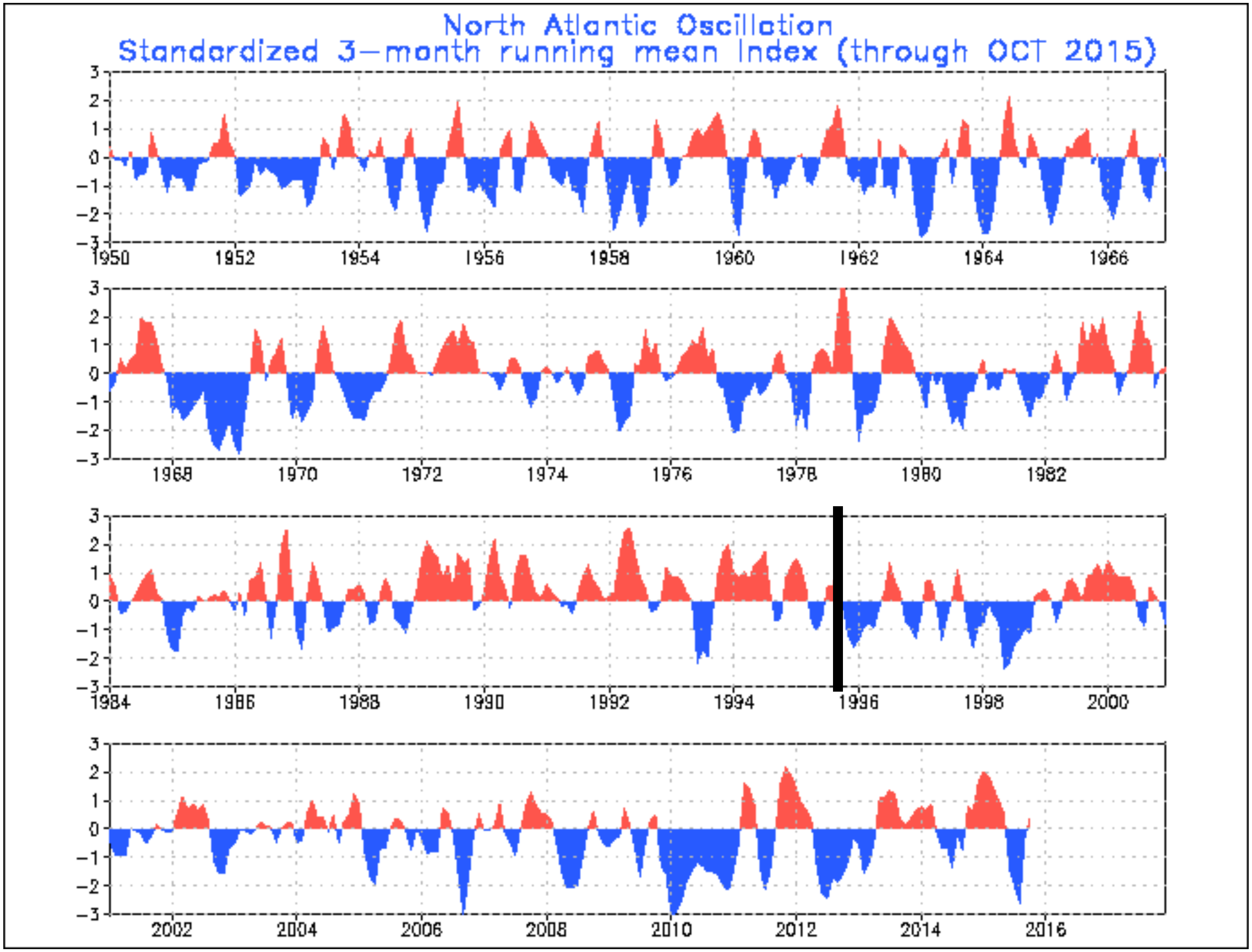


Fig. 2. Global (land and ocean) surface temperature anomaly time series with new analysis, old analysis, and with and without time-dependent bias corrections. (**A**) The new analysis (solid black) compared with the old analysis (red). (**B**) The new analysis (solid black) versus no corrections for time-dependent biases (blue).

NAO/AMV 1995/6 Shift

NAO



NAO Shift

- Schneider, E. K., L. Bengtsson, and Z.-Z. Hu, 2003: Forcing of Northern Hemisphere climate trends. *J. Atmos. Sci.*, **60**, 1504-1521.
- NAO trend 1950-1999 consistent with atmospheric noise (AMIP ensemble statistics, all members with same observed SST)

Conclusions

- Climate shifts can be defined as a rapid change between distinct climate regimes to distinguish them from quasi-oscillatory climate variability on decadal to centennial time scales.
- It is difficult to find evidence of obvious climate shifts defined in this way in the recent record, but plenty of examples of "regime changes."