The Pacific Decadal Oscillation, Revisited

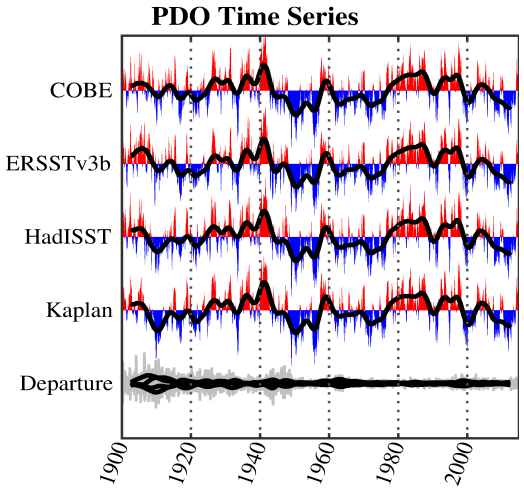
Matt Newman
University of Colorado/CIRES
and NOAA/ESRL/PSD

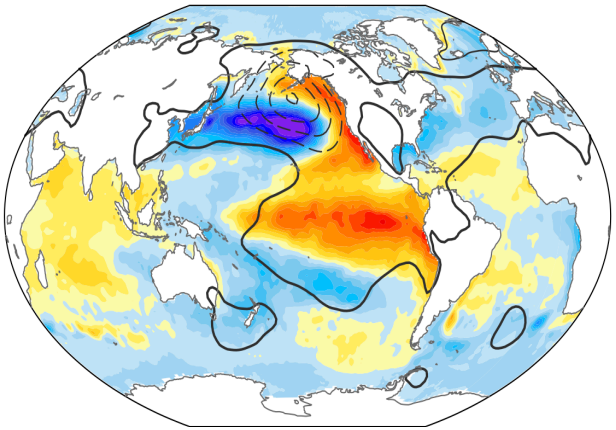
Matthew Newman, Michael Alexander, Toby Ault, Kim Cobb, Clara Deser, Emanuele DiLorenzo, Nathan Mantua, Arthur Miller, Shoshiro Minobe, Hisashi Nakamura, Niklas Schneider, Daniel Vimont, Adam Phillips, James Scott, and Catherine Smith, 2015: **The Pacific decadal oscillation, revisited.** *J. Climate*, submitted

http://www.esrl.noaa.gov/psd/people/matt.newman/PDO_Revisited_submitted.pdf

Summary Slide

- The PDO is **not a physical mode** but rather is the **sum of several physical processes**
  - North Pacific SST *integrates* effects of extratropical weather noise and particularly of ENSO (“reddened ENSO”)
  - Re-emergence brings back anomalies in succeeding winters (no summer/fall PDO)
  - KOE variations provide more persistent SST anomalies and perhaps much of the predictable atmospheric response
- Need to differentiate **PDO-forced** signal from **PDO-correlated** signal (for impacts and reconstructions)
- CGCMS capture some aspects of PDO but with balance of processes more independent of Tropics than observed
- We need to be careful when we reduce North Pacific decadal variability to any single index





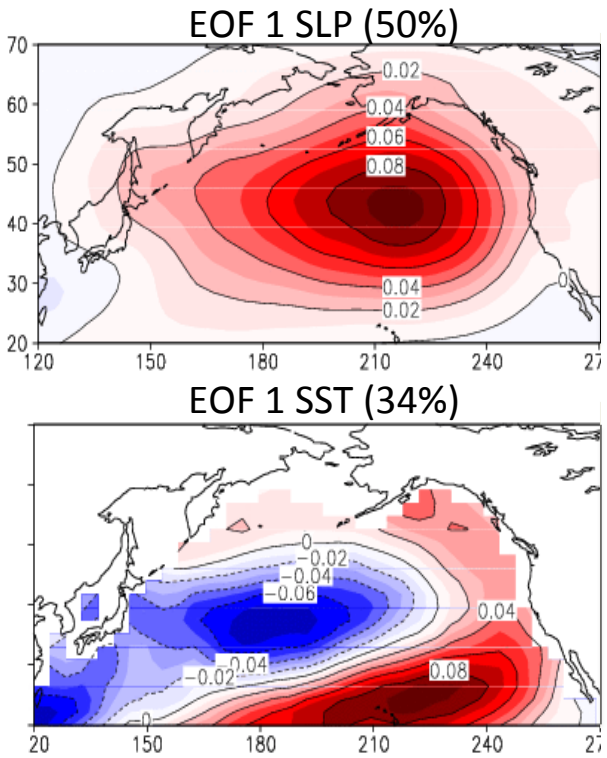
PDO

- Associated with climate, ecosystem and hydrologic fluctuations
- Develop a process understanding - key to prediction and applications

- Leading pattern of monthly SST variability in the North Pacific (> 20°N), *monthly global mean SST removed*
- Defined from North Pacific SSTs but global in Nature

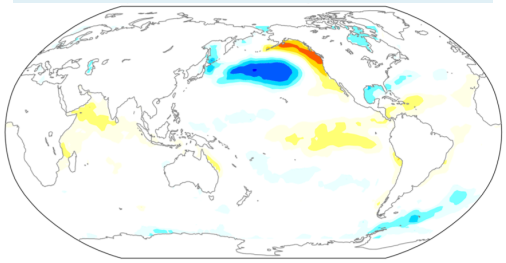
PDO resulting from stochastic forcing (Aleutian Low Variability)

- AGCM + simple slab ocean model: no currents thus no ENSO or ocean gyres
- Leading pattern => changes in strength of the Aleutian Low
- Changes in surface fluxes forces ocean
- Ocean integrates flux forcing: creates SST anomalies that resemble the PDO

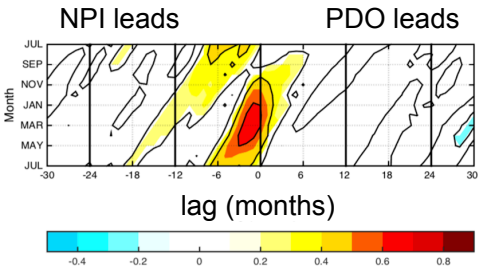


The atmosphere forces the PDO both locally,

NDJ NPI correlated with FMA SST

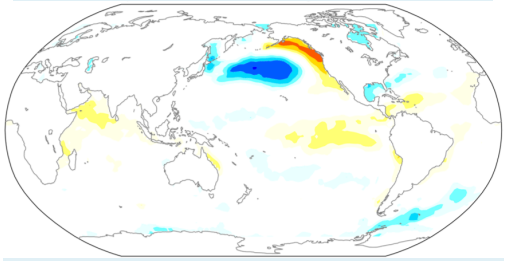


NPI vs. PDO cross correlation

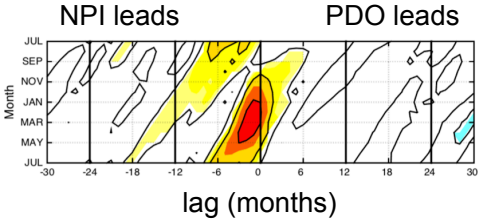


The atmosphere forces the PDO both locally, and remotely through ENSO teleconnections ("atmospheric bridge")

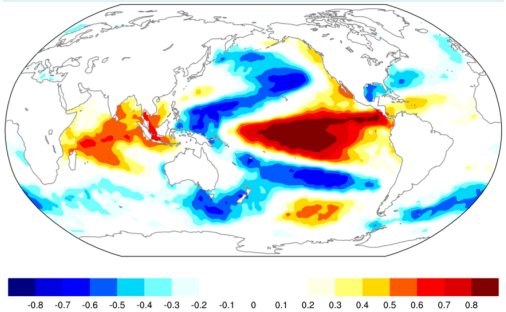
NDJ NPI correlated with FMA SST



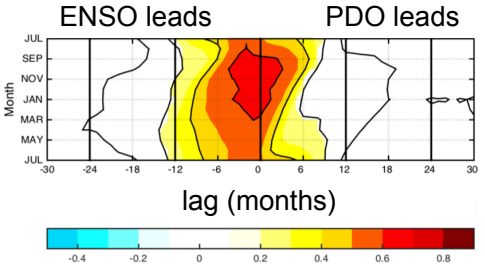
NPI vs. PDO cross correlation



NDJ ENSO correlated with FMA SST

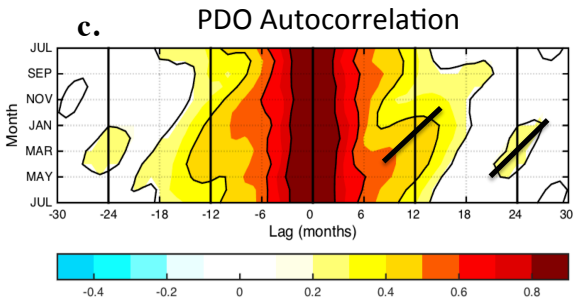


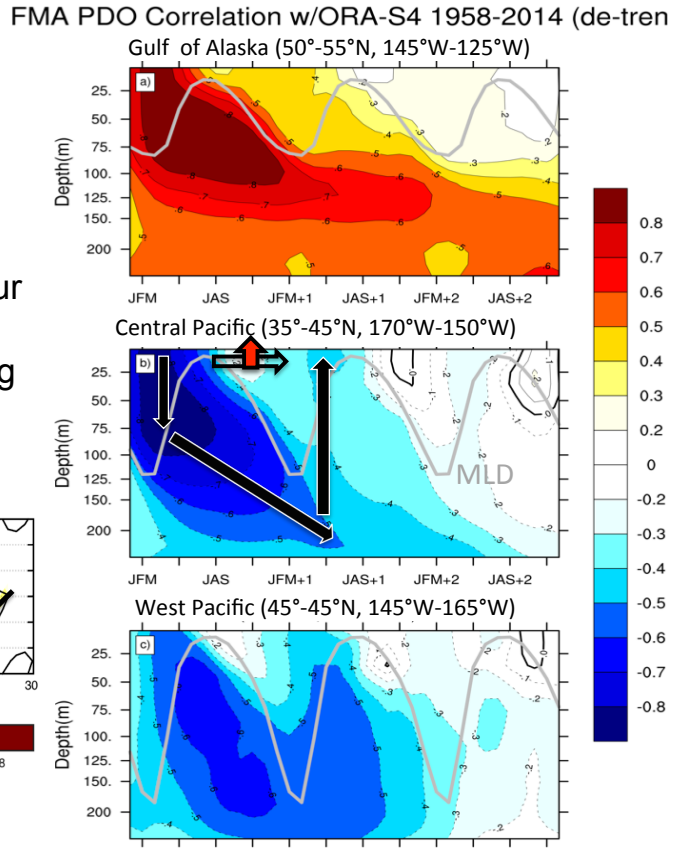
ENSO vs. PDO cross correlation



Midlatitude Ocean Processes: I

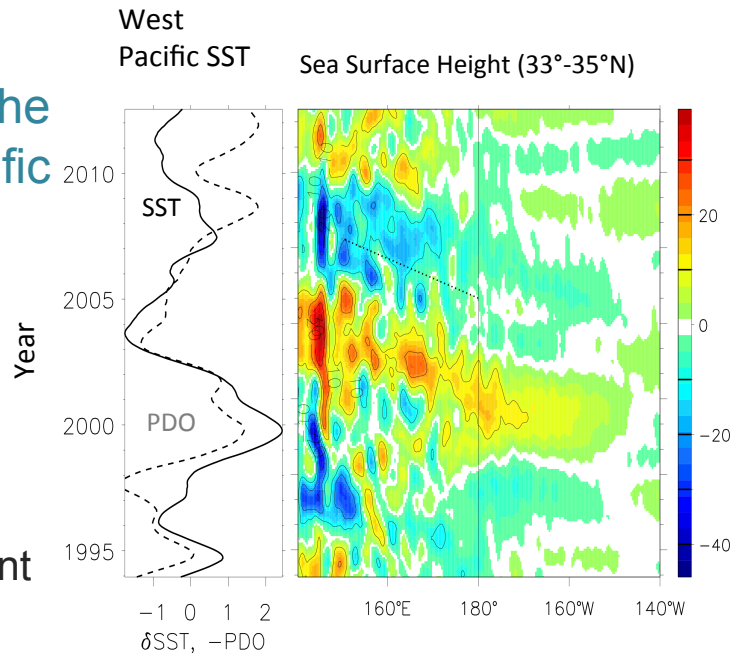
- SST Reemergence
  - Winter SST Anomalies recur
    Acts to “redden” ENSO &
    random atmospheric forcing





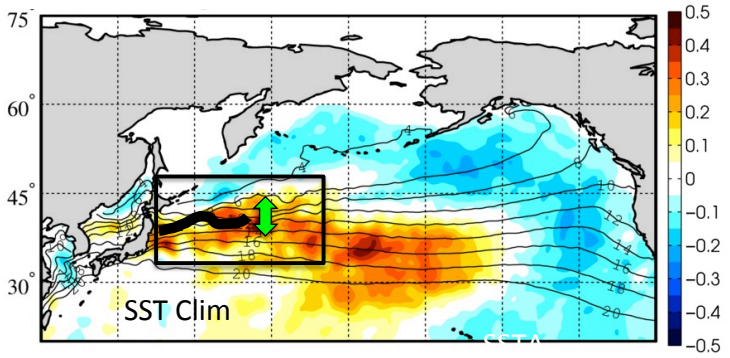
Midlatitude Ocean Processes II

- Wind stress curl in the central/eastern Pacific generates oceanic Rossby waves
  - Impacts SST near Japan, along the Kuroshio-Oyashio Extension (KOE) front

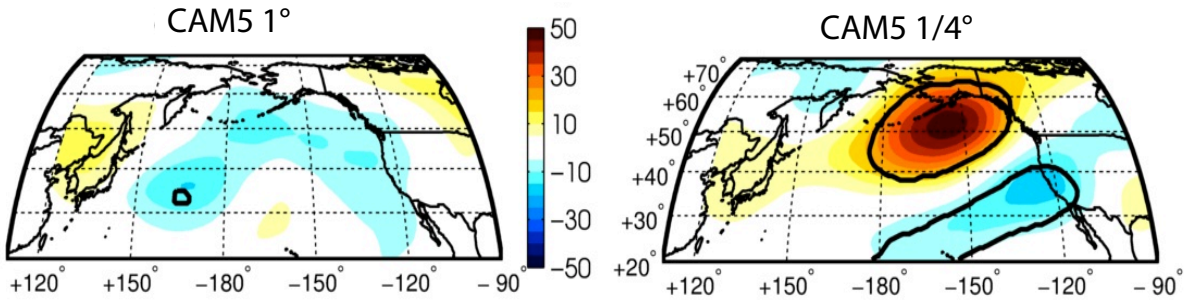


Kuroshio-Oyashio frontal variability

- SST anomalies and the atmospheric response to the frontal anomalies in an atmospheric model



300 hPa DJFM height (m) response



Smirnov, Newman, Alexander, Kwon, and Frankignoul, 2015, *J. Climate*

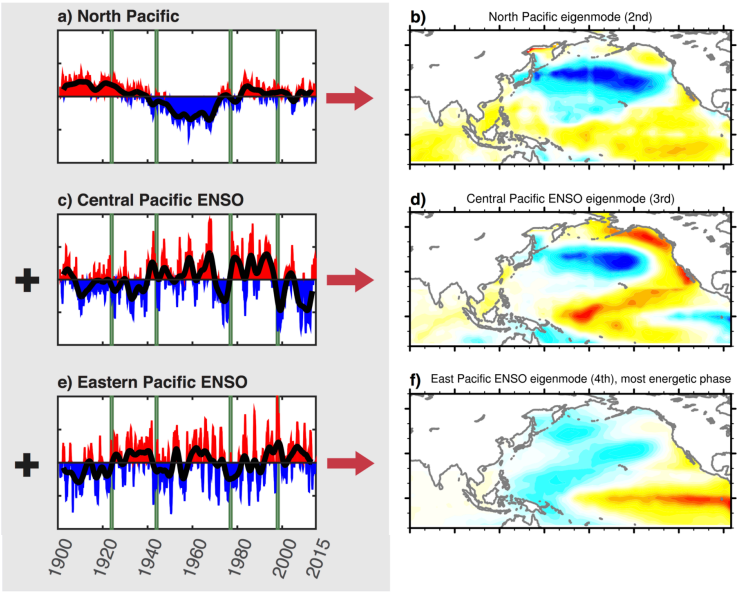
Building the PDO

- Multivariate AR1 model (Linear Inverse Model, LIM):

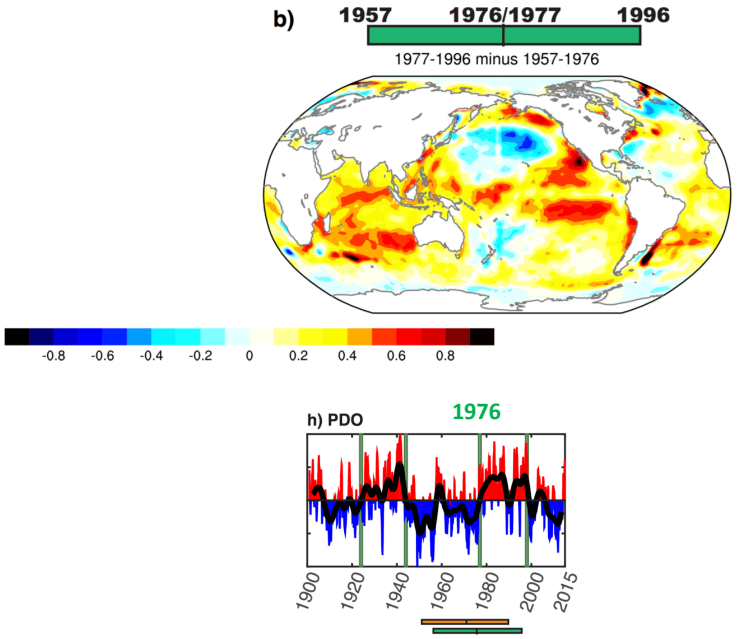
  $\mathbf{x}(t+1) = \mathbf{G}\,\mathbf{x}(t) + \eta$

- Leading Pacific dynamical modes: eigenvectors of **G**
  - Not EOFs, not orthogonal

Dynamical Modes

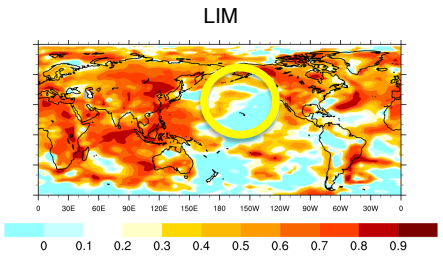


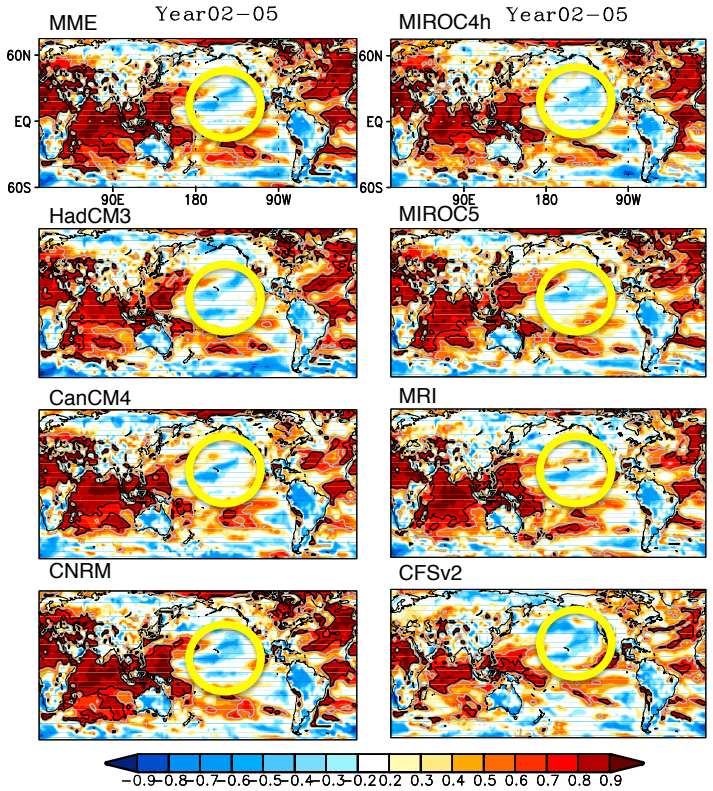
Example: was 1976/77 a coherent North Pacific regime shift?



Decadal hindcast skill is *low* (blue) in PDO region: **ENSO is noise for decadal forecasts**

Skill of LIM and CMIP5 CGCM decadal hindcasts, 1960-2000 (Newman 2013)





Kim et al., GRL (2012)
ERA40/ERAI verification

Climate Model Simulations and Paleoclimate Reconstructions of the PDO

- Most CMIP5 models:
  - Have a recognizable PDO pattern but not within sampling uncertainty
  - Overestimate variability in the KOE region
  - Underestimate the connection to the leading EOF (ENSO) in the tropical Pacific
  - Overestimate the connection to the second EOF (ENSO) in the tropical Pacific
- The observed PDO spectra can be simulated by the LIM
- Paleo reconstructions of the PDO differ widely prior to the recent period on which they were trained

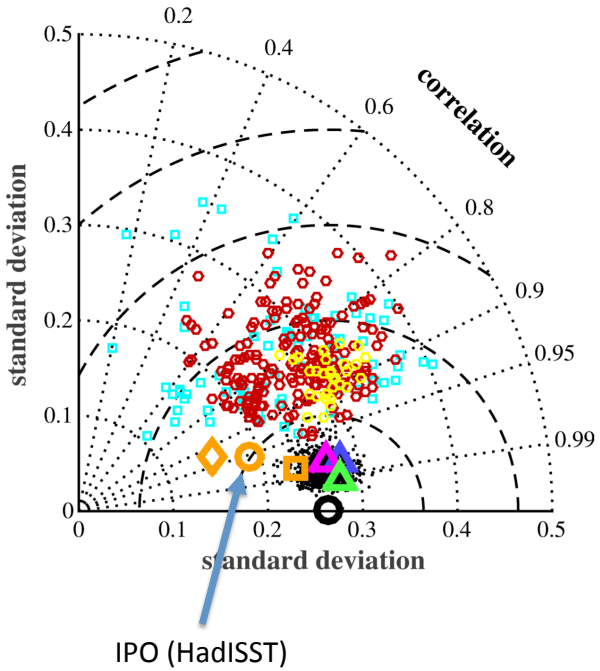
PDO representation in CGCMs

Taylor diagram compares PDO determined from HadISST, 1901-2014, to

- CMIP3 : cyan
- CMIP5: red
- CESM-LE: yellow
- Black dots: 50-yr Monte Carlo subsampling
- Triangles: other data sets

Key results:

- Models reproduce a PDO EOF but none do it well
- Little change from CMIP3 to CMIP5



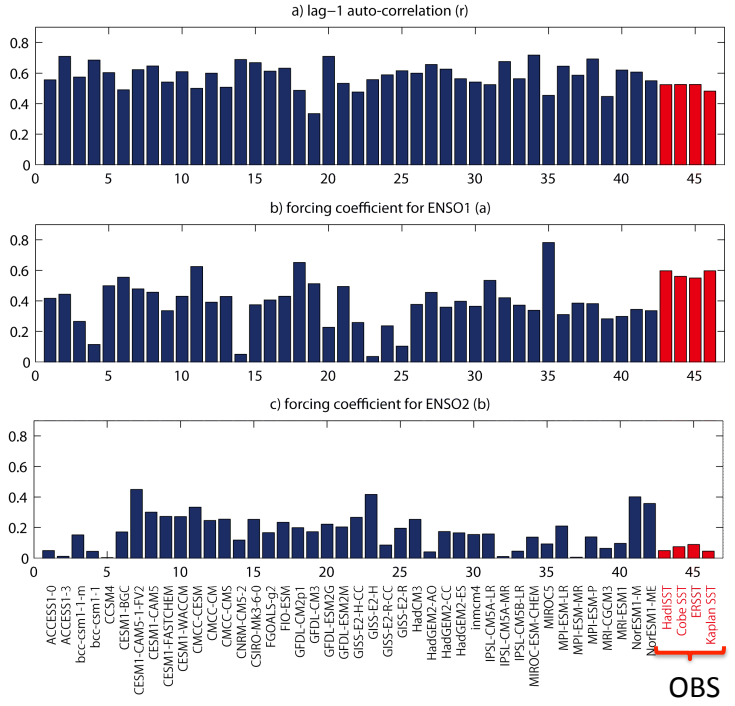
ENSO-PDO relationship in CMIP5

$$PDO(n) = r\,PDO(n-1) + a\,PC1_{Tropics}(n) + b\,PC2_{Tropics}(n) + e$$

Fitting (simpler) AR1 model to observations and CMIP5 models, 1901-2004

Key results:

- **Almost all models significantly underestimate tropical forcing of PDO**
- **Many models overestimate "internal" PDO variability**

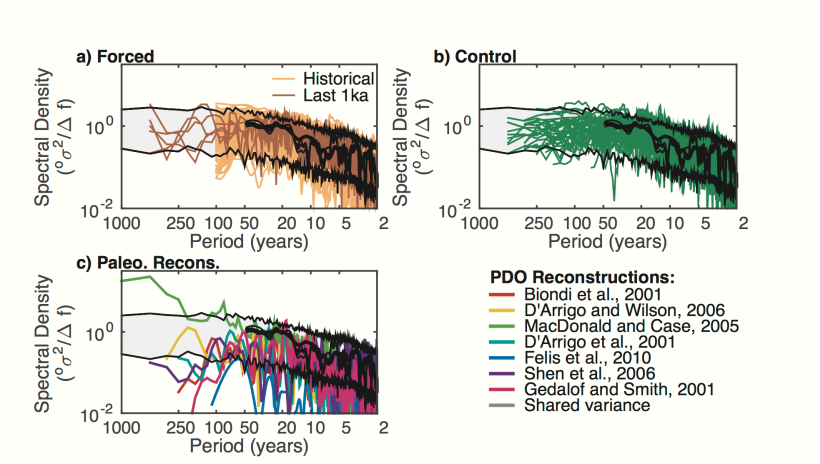


PDO spectra

Black lines: obs
Gray shading: LIM 95%
confidence interval

PDO spectra: no obvious peak but has ***spectral slope***, for both observations and LIM

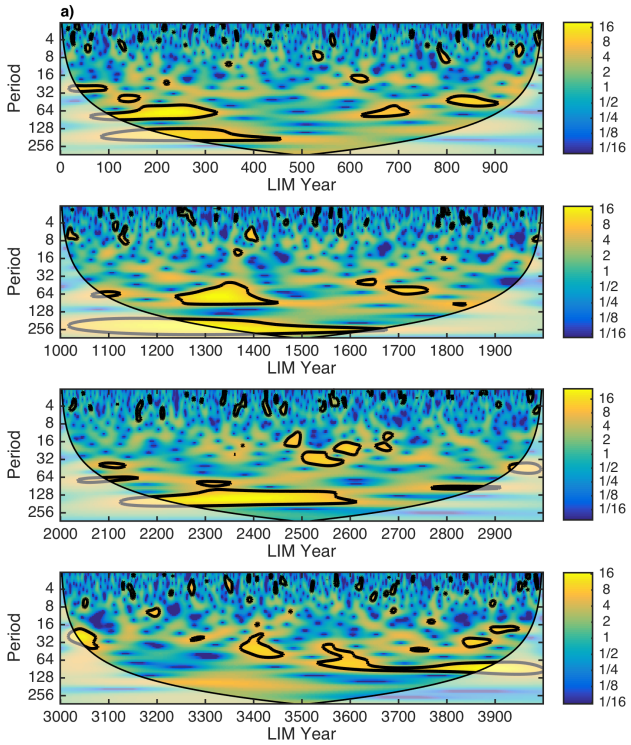
PDO paleo reconstructions seemingly too weak, poor agreement



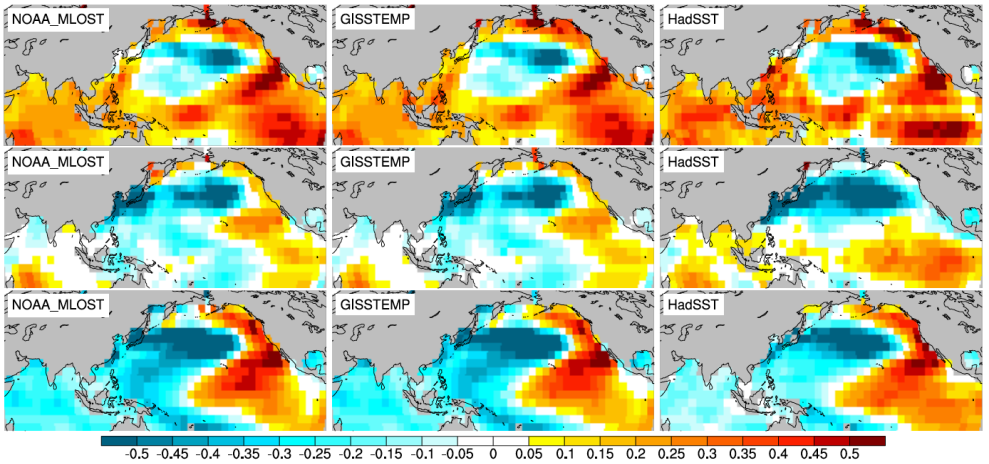
PDO wavelet spectra from 4000 years of LIM (multivariate AR1)

Key result:

- **Variations in low-frequency power only appear significant relative to *univariate* AR1 process (red noise)**



How does 1976/77 PDO transition compare to other transitions 1943/44 and 1998/1999?

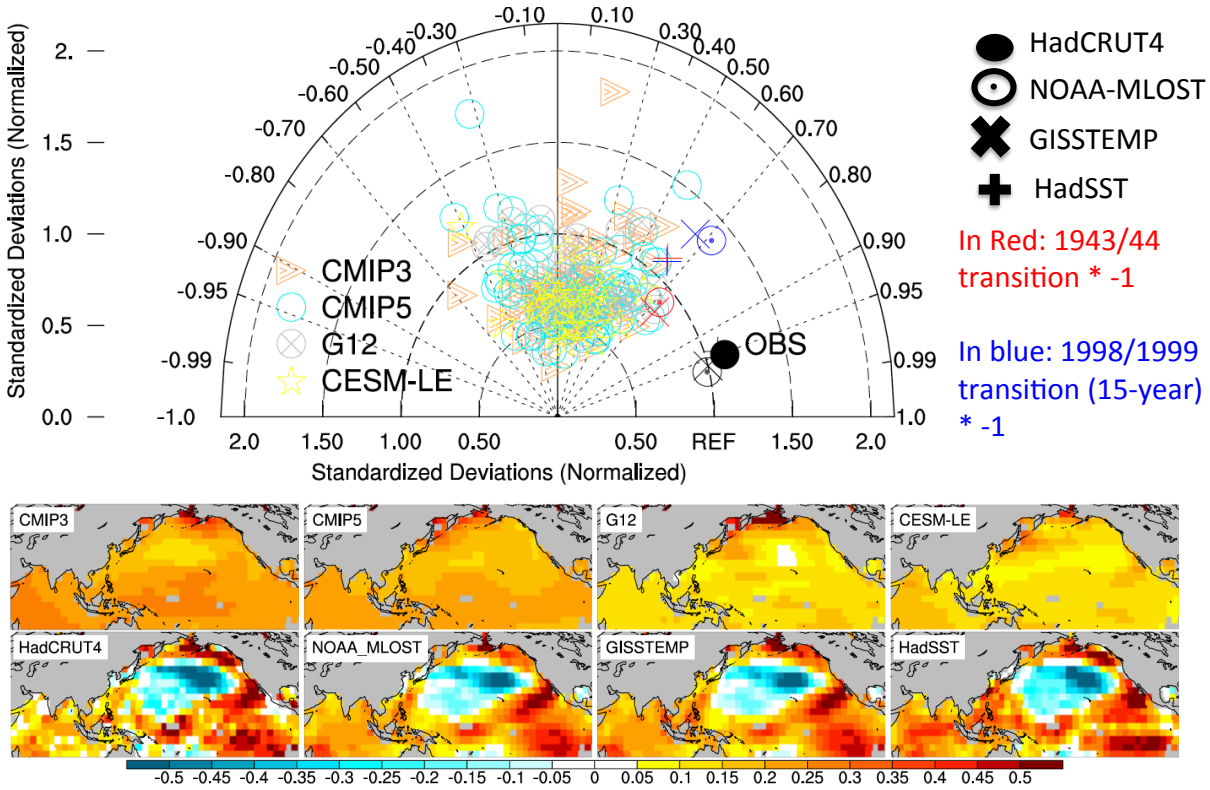


[1977/1996 – 1957/1976]

[1944/1963 – 1924/1943] * (-1)

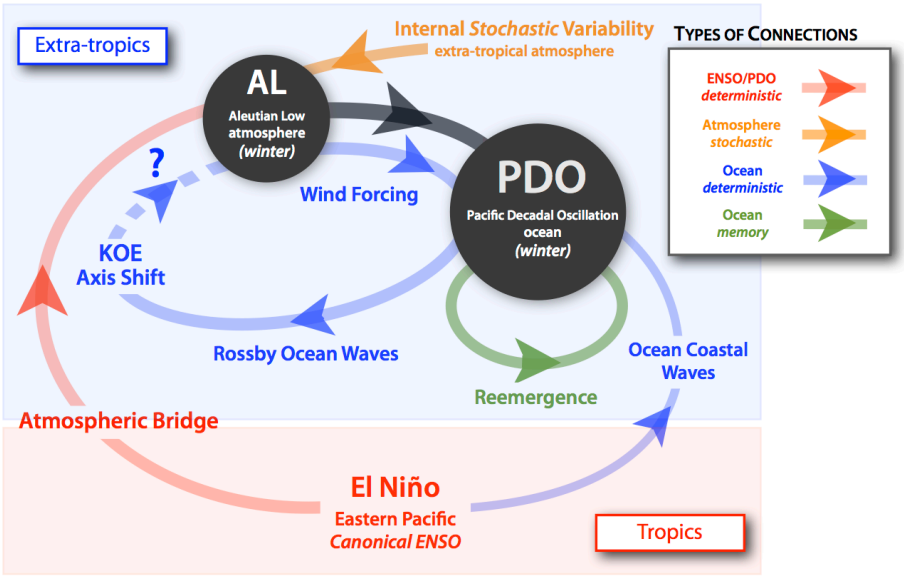
[1999/2013 – 1984/1998]* (-1)

(1977 to 1996) - (1957 to 1976)



Summary View

MECHANICS OF THE PACIFIC DECADAL OSCILLATION



Implications of this view for PDO "best practices"

- **Differentiate PDO-predicted signal from PDO-correlated signal**
- Take care when representing multivariate climate system with a single index (paleoreconstruction issues? are regime shifts an artifact?)

Summary Slide

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  - North Pacific SST *integrates* effects of extratropical weather noise and particularly of ENSO (“reddened ENSO”)
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