The Pacific Decadal Oscillation Revisited

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(paper submitted to J Climate)

BAMS article to follow

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**PDO**

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

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

Newman, Alexander et al., 2015; J. Climate, submit.
The PDO a multi-process Phenomena?

Response to ENSO/Tropical SSTs: “Atmospheric Bridge”

JFM ENSO Composite

Model design: SSTS specified in the tropical Pacific + MLM w Ekman Transport Explains ~30-40% of North Pacific anomalies on decadal time scales

Alexander and Scott 2008, J. Climate; Alexander, 2010, AGU Monograph Chapter
Random Forcing Aleutian Low Variability

- Ocean is a simple slab, 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

Alexander, 2010; AGU Monograph Chapter
Midlatitude Ocean Processes: I

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

Newman, Alexander et al., 2015; J. Climate, submitted
- Wind stress curl in the central/eastern Pacific generated Ocean 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 height (m) response

Smirnov, Newman, Alexander et al., 2015; J. Climate
Building the PDO

- Empirical Model (LIM)
- Leading Pacific dynamical modes
  - Not EOFs,
  - not orthogonal
- Time series show projection of each mode onto the PDO

Newman, Alexander et al., 2015; J Climate, submitted
Epoch Differences in SST °C

Newman, Alexander et al., 2015; J. Climate, submitted
Summary of Processes

- Processes:
  - Atmospheric Bridge (ENSO)
  - Random forcing
  - Reemergence
  - Ocean Rossby waves & ocean fronts
  - Atmospheric response to KOE SST anomalies?

Newman, Alexander et al., 2015; J. Climate, submitted
Climate Model Simulations and Paleoclimatic Reconstructions of the PDO

- The observed PDO spectra can be simulated by the LIM
- Most CMIP5 models:
  - Have a recognizable PDO pattern
  - 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
- Paleo reconstructions of the PDO differ widely prior to the recent period that they were trained on

Newman, Alexander et al., 2015; J. Climate, submitted
Climate Division Correlations with the PDO; ENSO and the NPI (Aleutian Low SLP Index)

Not Independent!
Nov-Mar Temperature °C ENSO Composites stratified by High and Low PDO values
PDO/ENSO spectra

Gray shading: 1000 1000-yr LIM (multivariate AR1) realizations

CMIP5 spectra lies within confidence interval (a-c)

Newman, Alexander et al., 2015; J. Climate, submitted
Pacific Ocean currents and variability

Kuroshio-Oyashio Extension (KOE) system is a key component of the North Pacific ocean-atmosphere system.

Shifts in the subarctic SST front are associated with longer time scales (westward propagating Rossby waves).
Removing tropically-forced portion of the PDO yields “internal” North Pacific SST mode

Multivariate AR1 model (LIM):

\[ \frac{dx}{dt} = Bx + F_s \]

Determined from observations, where \(x\) represents seasonal mean anomalies (1958-2008) of:
- **Tropical Pacific** [SST, thermocline depth]
- **North Pacific** [SST, mixed layer temp (30-100m)]
Taylor diagram compares PDO determined from HadISST, 1901-2004, to
- CMIP3: green
- CMIP5: red
- Black dots: 50-yr Monte Carlo subsampling
- Triangles: other data sets

Key result:
- Models reproduce a PDO EOF but none reproduce PDO well
Fitting (simpler) AR1 model to observations and CMIP5 models, 1901-2004

Key results:
- Most models reproduce PDO EOF
- Almost all models underestimate tropical forcing of PDO ($a$)
- Most models (slightly) overestimate $r$

\[ \text{PDO}(n) = r \text{PDO}(n-1) + a \text{PC1}_{\text{Tropics}}(n) + b \text{PC2}_{\text{Tropics}}(n) + e \]
PDO and ENSO “climate signals” are not independent

Nov-Mar precipitation correlated with PDO

Nov-Mar precipitation correlated with ENSO

(NOAA/ESRL PSD and CIRES–CDC)
PDO simulated in NCAR models

- Most climate models overestimate western North Pacific variability and underestimate connection to tropics.

- Recent NCAR models fairly good – much improved over previous CCSM models.