Patterns and Mechanisms of Decadal Climate Variability

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Interannual to Decadal Predictability of Tropical and North Pacific Sea Surface Temperatures

Is PDO really predictable?

- Background
- Linear Inverse Modeling
- Model and Data
- Results
- Discussion
- Summary
Background

• Just a reminder!
  – Predictability comes primarily from the OCEAN

• Other sources of predictability?
  – Proxy data
  – Modeling studies

• Unresolved question
  – How much North Pacific SST predictability affected by Tropics?
Background

Huybers and Curry, Nature 441 (2006)
doi:10.1038/nature04745

1.64 ± 0.04

0.37 ± 0.05

1.29 ± 0.13

0.56 ± 0.08
Focus

• Need for Multivariate Analysis
  – Representation of tropical and North Pacific SST anomalies as individual single patterns not ideal
  – There is interaction

• Propose to apply Linear Inverse Modeling (LIM)
  – Empirically derive linear dynamic system
Some Basics

- Approaches to modeling Physical System (Tarantola, 2004)
  - Parameterization of the System
  - Forward Modeling
  - Inverse Modeling

Source: HWR 521 Systems Approach to Hydrologic Modeling
Linear Inverse Modeling

- Basic Equation

\[
\frac{dx}{dt} = Lx + \xi,
\]

- State evolution in time
- Stable and predictable linear dynamics
- Unpredictable white noise

- Where does the inverse part come in?

\[
\frac{dx}{dt} = \frac{d}{dt}\begin{bmatrix} x_N \\ x_T \end{bmatrix} = \begin{bmatrix} L_{NN} & L_{NT} \\ L_{TN} & L_{TT} \end{bmatrix}\begin{bmatrix} x_N \\ x_T \end{bmatrix} + \begin{bmatrix} \xi_N \\ \xi_T \end{bmatrix}.
\]
Data

- HadISST 1900-2002
- EOF computed 1950-2002

Results – Is the LIM good enough?

Does the LIM reproduce the main features of the observed power spectra for Tropical Pacific?

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Does the LIM reproduce the main features of the observed power spectra for North Pacific?

Newman M.,
J. of Climate, 2007
Why does the forecast skill reduce from 1yr to 2yr forecast?

Newman M.,
J. of Climate, 2007
Results – Tropical North Pacific Coupling

Create scenarios by setting off diagonal terms to zero

Newman M.,
J. of Climate, 2007
Fig. 14. Correlation between ENSO (leading tropical Pacific PC) and PDO (leading North Pacific PC) for observations, LIM, and IPCC coupled GCMs, for July–June annual means (blue bars) and 5-yr running means (green bars). The gray bars indicate the 95% confidence interval for PDO–ENSO correlation based on 100-yr samples from the LIM (see text for further details). The correlations for the GISS AOM model are negative and so are not shown.

Discussion and open Questions

• Pros of LIM
  – Simple (assumes stable linear dynamics)
  – Current observations of state (SST) sufficient
  – Empirically derive modes
  – Allows predictability up to 1yr lead times

• Cons of LIM
  – Assumes stable linear dynamics
  – Are we getting the right answers for the right reasons

• How can a system exhibit decadal variability and yet have skillful predictability for perhaps only 1 year lead times?
Real world application

http://www.cdc.noaa.gov/forecast1/PDO.html
Summary

- LIM can explain observed power spectra of annual mean Tropical and North Pacific SST on interannual and interdecadal timescales.
- Interaction between North Pacific and tropics appears poorly represented in coupled GCMs.
- LIM can be used to constrain GCMs.
- Decadal SST predictability does not equal decadal atmospheric predictability or predictability over land.
References

- Inverse Problem Theory, Albert Tarantola, 2004, SIAM
- http://www.cdc.noaa.gov/forecast1/PDO.html