THE ROLE OF TROPICAL-EXTRATROPICAL INTERACTIONS ON THE OPTIMAL GROWTH OF MADDEN-JULIAN OSCILLATION EVENTS

Stephanie A. Henderson
Daniel J. Vimont
Matthew Newman
THE ROLE OF TROPICAL-EXTRATROPICAL INTERACTIONS ON THE OPTIMAL GROWTH OF THE PACIFIC-NORTH AMERICAN PATTERN

Stephanie A. Henderson
Daniel J. Vimont
Matthew Newman
Data

• ERA-Interim reanalysis:
  • 200-hPa and 850-hPa streamfunction (15°N – 90°N)
  • Vertically integrated apparent heat source (Q1; Yanai et al. 1973)
    20°S – 15°N

• NOAA Optimum Interpolation Sea Surface Temperature (OISST) dataset (20°S – 15°N)

• Pentad (5-day) anomalies

• December – February (DJF)

• Range: December 1982 – February 2015

• Daily NOAA/NCEP Climate Prediction Center (CPC) PNA index
Linear Inverse Modeling (LIM)

\[
\frac{dx}{dt} = Lx + \zeta
\]

LIM approximates the evolution of a dynamical system by a multivariate linear model.
Linear Inverse Modeling (LIM)

\[ \frac{dx}{dt} = Lx + \zeta \]

- The forecast, \( x(\tau) \), is the solution to the homogeneous part:

\[ x(\tau) = e^{L\tau}x(0) \]

\[ x(t) = \begin{bmatrix} \text{SST} \\ \text{Q1} \\ \Psi_{200} \\ \Psi_{850} \end{bmatrix} \]
Linear Inverse Modeling (LIM)

\[
\frac{dx}{dt} = Lx + \zeta
\]

- The forecast, \( x(\tau) \), is the solution to the homogeneous part:

\[
x(\tau) = e^{Lt}x(0) = G_\tau x(0)
\]

\[
G_\tau = C_\tau / C_0
\]
The forecast, \( x(\tau) \), is the solution to the homogeneous part:

\[
\frac{dx}{dt} = Lx + \zeta
\]

State of system \quad \text{Dynamics} \quad \text{Noise}

\[
x(t) = \begin{bmatrix} \text{SST} \\ \Psi_{Q1} \\ \Psi_{200} \\ \Psi_{850} \end{bmatrix}
\]

- The forecast, \( x(\tau) \), is the solution to the homogeneous part:

\[
x(\tau) = e^{L\tau}x(0) = G_{\tau}x(0)
\]

\[
L = \ln(G_{\tau})/\tau \quad G_{\tau} = C_{\tau}/C_0
\]

\[x(0) \quad G_{\tau} \quad x(\tau)\]
- We can estimate an optimal initial condition ($p$) by maximizing growth in the direction of a chosen norm ($N$) by solving the eigenvalue problem:

$$G_T^T N G_T p - \mu(\tau) p = 0$$

- Growth towards the MJO
200-hPa streamfunction

Initial condition

200mb PSI initial conditions

Final PNA pattern

200mb PSI final conditions at lag 15

Q1

Q1 initial conditions

Initial condition

Final condition

Q1 final conditions at lag 15

[K/day]
200-hPa streamfunction

Initial condition

Final PNA pattern

SST

Initial condition

Final condition
Two eigenspaces of $L$

Recall: $L = \ln(G_\tau) / \tau$ $G_\tau = C_\tau / C_0$
Two eigenspaces of L

Recall: \[ L = \frac{\ln(G_\tau)}{\tau} \quad G_\tau = \frac{C_\tau}{C_0} \]

- **coupled modes**
  - Low frequency
  - Longer eft

- **internal atmospheric modes**
  - Inc. high frequency
  - Short eft
Uncoupled LIM

200-hPa streamfunction

Initial Condition

200mb PSI initial conditions

Final PNA pattern

200mb PSI final conditions at lag 15

[\times 10^6 \text{ m/s}^2]
Uncoupled LIM

200-hPa streamfunction

Initial condition

Final PNA pattern

200mb PSI initial conditions

200mb PSI final conditions at lag 15

Q1 initial conditions

Q1 final conditions at lag 15

Initial condition

Final condition

[10^6 m/s^2]

[K/day]
Tropical initial conditions removed

200-hPa streamfunction

Unmodified $p$ final PNA

200mb PSI final conditions at lag 15

Modified $p$ final PNA

200mb PSI final conditions at lag 15

Q1

Initial condition

Final condition
Extratropical initial conditions removed

Unmodified $p$ final PNA

200mb PSI final conditions at lag 15

Initial condition

Final condition

Modified $p$ final PNA

200mb PSI final conditions at lag 15

Q1 initial conditions

Q1 final conditions at lag 15

200-hPa streamfunction

$Q_1$
Summary

• Linear inverse modeling (LIM) is used to examine the optimal conditions that lead to PNA pattern growth.

• Unfiltered LIM: suppressed tropical heating in the SPCZ, ENSO-related heating, and MJO-like heating in the east Indian Ocean optimally lead to PNA pattern growth.

• An uncoupled LIM is developed to examine PNA growth outside of ENSO. Optimal PNA growth is from MJO anomalous heating over the east Indian Ocean and suppressed heating over the Maritime continent and SPCZ.

• In the extratropics, the optimal initial condition agree with previous studies, including an anticyclonic anomaly over the East Pacific that retrogrades, becoming part of the PNA pattern.

• Modifying the initial conditions suggest both tropical heating and the extratropical circulation are important for PNA pattern growth in the uncoupled LIM.