Teleconnection Sensitivity to El Niño Diversity

Martin Hoerling, NOAA

Do Atmospheric Teleconnections Significantly Differ Among Various ENSO Flavors?

Yes.

What Dynamical Processes are Responsible?

Illustrate for summertime Indian monsoon & wintertime North American climate variability.
The Observed Wintertime ENSO Teleconnection Pattern at 500 hPa

*Is This the Only One?*

Linear correlation between OBS DJF 500 hPa height and an ENSO SST index*

*see Horel and Wallace 1981, MWR*

* PC time series of the first EOF of tropical Pacific SST variability
Multiple ENSO Teleconnection Patterns: *El Niño vs La Niña*

Based on Observations; from Hoerling et al. 1997; JCLIM

![Maps of El Niño, La Niña, El Niño-La Niña, El Niño+La Niña](image)

**Fig. 3.** Same as in Fig. 1 except for the observed eddy 500-mb heights. Eddy refers to the departure of the height from its zonal mean value and indicates the stationary wave behavior. Contour interval is 10 m. Polar stereographic projection extends to 70°N.

Model-based confirmation of multiple ENSO patterns (multi-linearity/nonlinearity):

Multiple Teleconnection Patterns: *Flavors of El Niño*

Fig. 13. GCM ensemble winter (DJF) anomalies of (top) 500-hPa height, (middle) tropical rainfall, and (bottom) tropical SST for varying strengths of equatorial Pacific warm events during (left) 1980, (middle) 1958, and (right) 1983. The year refers to the Jan of the season. The height and rainfall anomalies have been scaled by the amplitude of the EOF1 index of ENSO for each case. Contours for height are drawn every 5 m, with positive (negative) values solid (dashed). Shading interval for rainfall is every 1 mm day$^{-1}$, with positive (negative) anomalies in blue (red). Shading interval for SST is every 0.5°C, with positive (negative) anomalies in red (blue).

Based on 4-model, 46-member AMIP ensemble; from *Hoerling and Kumar 2002, JCLIM*
Getting the Signal Right Matters

US Pcpn, based on Hoerling and Kumar 2002, JCLIM
Getting the Signal Right Matters

North American SfcT, based on Yu et al. 2012, GRL

OBS Composite. ~10 cases

CAM4, T42; 10-member
# Large Ensemble AGCM Simulations
## AMIP

<table>
<thead>
<tr>
<th>Institution</th>
<th>Model</th>
<th>Ensemble Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECHAM (IRI)</td>
<td>ECHAM4.5 (T42)</td>
<td>85 (1950-2003)</td>
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<tr>
<td>NCEP (ESRL)*</td>
<td>GFSv2 (T126)</td>
<td>50 (1979-2010)</td>
</tr>
<tr>
<td>NCEP (ESRL)*</td>
<td>GFSv2 (T126): eof1 SST</td>
<td>24 (1979-2010)</td>
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</tbody>
</table>

*Simulations conducted by Tao Zhang*

- Conduct an EOF analysis of each model’s ensemble averaged 500 hPa height
- Perform a DJF analysis for the NH (poleward of 20°N)
- Apply the analysis over the common model simulation period, 1979-2003

from detrended global monthly SSTs, 1978-2011: 18% variance
Leading SST-Forced Teleconnection Bound to Leading SST Pattern: 
*Sensitivity to the Equatorially-Avgd Pacific SST east of the Dateline*

Relationship Between Simulated DJF 500z Factor Scores 
and DJF Sea Surface Temperature: EOF 1

**ECHAM 4.5**

**GFSv2**

**Correlation Coefficient**

\[-0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 0.0 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9\]
Second SST-Forced Teleconnection Link to Second Tropical SST Pattern: 
*Sensitivity to the Gradient in SSTs Across the Tropical Pacific*

Relationship Between Simulated DJF 500z Factor Scores and DJF Sea Surface Temperature: EOF 2

**ECHAM 4.5**

**GFSv2**

**Correlation Coefficient**

\[-0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9\]
DJF EOF 1: 1979–2003

GFSv2 AMIP Run 52.3%

GFSv2 EOF1 Run 74.2%
DJF EOF 2: 1979–2003

GFSv2 AMIP Run 24%

GFSv2 EOF1 Run 10.7%
Naturally Varying ENSO Flavors

*Newman et al. 2011, GRL*

Two Leading Patterns of SST Anomaly Growth Over a 6-Month Period

*Observational analysis, 1959-2000, using LIM*
East Pacific El Niños

Central Pacific El Niños

La Niñas

Asymmetry of ENSO
Do Atmospheric Teleconnections Significantly Differ Among Various ENSO Flavors?

Yes --- There is “Signal Diversity”

Q2: What Dynamical Processes are Responsible?

° There are Two Dominant Flavors of El Niño
° There are Two Distinguishable Teleconnections Associated With The El Niño Flavors
° El Niño/La Niña SST Asymmetry Also Yields Two Distinguishable Teleconnections
° Amplitude Variability of Leading SST EOF Yields Two Distinguishable Teleconnections
The Indian Monsoon Story
A Mystery of Indian Monsoon Failure during El Niño*
Why have warm events of the tropical east Pacific not consistently yielded Indian drought?

*KKumar et al. 2006 Science
A Mystery of Indian Monsoon Failure during El Niño

Why have warm events of the tropical east Pacific not consistently yielded Indian drought?

Disaggregate El Niño Years
According to “Severe Drought” vs “Drought Free” Cases
India Monsoon Failure and the Flavors of El Niño

Contours: SST Anomalies during “drought-free” El Niños
Shading: SST difference between “severe drought”- “drought free” El Niños

SST Composites Indicate Increased Warmth in the Tropical Central Pacific During Severe Drought-Producing El Niños
Leading Patterns of Tropical Pacific SST Variability

Two leading EOFs provide a useful empirical basis for reconstructing inter-El Niño differences in tropical Pacific SSTs.
Strong East Pacific El Niño Warmth

Proxy for “drought free”: (EOF1 - EOF2)

Strong Central Pacific El Niño Warmth

Proxy for “severe drought”: (EOF1 + EOF2)

Difference
Multi-Model Atmospheric GCM
Forced by EOF1 and EOF2 Pacific SST

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<tr>
<td>GFDL</td>
<td>AM2 (2°x2.5°)</td>
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</tr>
<tr>
<td>NCEP</td>
<td>GFS (T62)</td>
<td>30</td>
</tr>
<tr>
<td>NCAR</td>
<td>CCM3 (T42)</td>
<td>20</td>
</tr>
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Rainfall and 200 hPa Velocity Potential Responses
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Rainfall and 200 hPa Velocity Potential Responses
Indian Monsoon Sector, AM2

![Graph showing probability density function for JJAS Precip (mm) with a peak at around 1200 mm and a control line labeled as "Control".](image-url)
Indian Monsoon Sector, AM2

Probability density function

JJAS Precip (mm)

Control
2x(EOF1 - EOF2)
Probability of Indian Monsoon Drought Is Increased By Canonical El Nino Forcing, It is Further, and Equivalently, Increased by Shifting El Nino’s Centroid Toward the Warm Pool.