Ocean/atmosphere variability related to the development of tropical Pacific sea-surface temperature anomalies in the CCSM2.0 and CCSM3.0

Bruce T. Anderson, Boston University
(brucea@bu.edu)

Eric Maloney, Oregon State University
Researchers have spent considerable time investigating forcing mechanisms for the El Niño/Southern Oscillation (ENSO) as well as the evolution of the atmospheric and oceanic components of the ENSO system.

One intriguing set of results involves fields in the extra-tropics that may be related to the initiation of ENSO events.

In this talk, we will attempt to build upon this research by:

- Identifying extra-tropical ocean/atmosphere anomaly patterns that represent statistically significant precursors to the onset of ENSO events.
- Comparing those patterns found in the simulated system with previously-identified patterns in the observed system.
- Investigating the simulated and observed evolution of the ENSO system as it relates to these patterns.
Data Sets

- **NCEP Reanalysis**
  - Atmospheric data at 2.5-degree resolution
  - Sea-surface temperature data at T62 resolution (approximately 2 degrees in latitude and longitude)
  - ~53 years of data (1948-2000)

- **Community Climate System Model (CCSM2.0)**
  - Monthly data at T42 resolution (approximately 2.8 degrees in latitude and longitude)
  - 250 years of data

- **Community Climate System Model (CCSM3.0)**
  - Monthly data at T85 resolution (approximately 1.4 degrees in latitude and longitude)
  - 500 years of data
Canonical Correlation Analysis

- Multivariate regression algorithm designed to maximize the correlation between the time-series from different datasets, $\mathbf{P}(\mathbf{x},t)$ and $\mathbf{T}(\mathbf{y},t)$
- Produces a set of canonical factor (CF) time-series that isolate the highest correlated modes of variability within the two datasets
- Based upon solving the eigenvalue equation:

$$\left(\mathbf{UU}^{-1}\mathbf{T}\mathbf{U}'\mathbf{T}\mathbf{T}^{-1}\mathbf{T}\mathbf{U}\right) - \lambda \mathbf{A} = 0$$

- $\lambda$ - Eigenvalues: Represents correlation between canonical factor time-series
- $\mathbf{A}$ - Eigenvectors: Represents "spatial maps" for canonical factors of $\mathbf{T}$
Jan.-Mar. SLP and SSTs the Following Year

Time-Series

Sea-Level Pressure

Sea-Surface Temp.
ENSO in Observations and Climate Simulations

(Deser et al., 2005 - Draft)
Comparison of Simulated and Observed Patterns

Simulated: CF1

yr+1

Observed: CF3

yr+1
Comparison of Simulated and Observed Patterns

Observed: CF1

Simulated: CF2

yr+1
Comparison of CCSM2 and CCSM3 Patterns

CCSM2: CF1

CCSM3: CF1
Comparison of CCSM2 and CCSM3 Patterns

CCSM2: CF2  yr+1

CCSM3: CF2  yr+1
Simulated and Observed Temporal Patterns
Evolution of Simulated SSTs for CF1
Evolution of Simulated SSTs for CF1
Evolution of Simulated SSTs for CF2
Evolution of Simulated SSTs for CF2
Evolution of Mixed Layer Depth and SSTs

Monthly Evolution of the Eastern Pacific Isotherms and SST Anomalies: CCSM2 CF1

Monthly Evolution of the Eastern Pacific Isotherms and SST Anomalies: CCSM3 CF1

Year-1 Year 0 Year+1
Evolution of Mixed Layer Depth and SSTs Con’t

CCSM2

Monthly Evolution of Eastern Pacific Isotherms and SST Anomalies: CF2

CCSM3

Monthly Evolution of Eastern Pacific Isotherms and SST Anomalies: CCSM3 CF2
Evolution of Mixed Layer Depth and SSTs con’t.

(Model)

Sea Surf. Temp.

Mixed Layer Depth

(Obs. 1993-99)

(Meinen and McPhaden, 2001)

Monthly Evolution of basin-scale 20°C Isotherm-depth and SST Anomalies
Equatorial Pacific SST anomalies appear to be partly related to large-scale atmospheric modes of variability 12-15 months prior to the maturation of the JFM ENSO.

- One mode is related to the strong biennial oscillation in which La Niña-related SLPs precede El Niño-like SSTs the following winter.
- The second mode of variability indicates that boreal-winter tropical Pacific SSTs are also initiated by SLP anomalies over the subtropical central and eastern north Pacific.

The evolution of both modes is characterized by recharge/discharge within the equatorial subsurface temperature field.

- For the first mode, the basin-average equatorial Pacific isotherm depth anomalies, isotherm-slopes, and SSTs show significant oscillatory behavior up to two years prior to ENSO events.
- For the second canonical factor, the recharge/discharge mechanism is induced concurrent with the JFM SLP pattern itself.

- Role of “pre-conditioning” of basin-scale heat content and thermocline slope.
- Low-frequency modulation of subtropical influence.
Non-Stationarity in the Simulated and Obs. Modes

20-Year Standard Deviation for CF SST and Observed NINO3.4 Time-series

- Blue line: Simulated CF2 SST
- Black line: Obs. NINO3.4 (HADISST)
- Red line: Observed CF1 SST

Simulation Year:
- 350 to 600

Y-axis: 20-year Standard Deviation
- Range: 0.8 to 1.4
Recharge/Discharge Paradigm for ENSO

(Meinen and McPhaden, 2000)
El Niño/Southern Oscillation
El Niño/Southern Oscillation Impacts
El Nino/Southern Oscillation Impacts
CCSM2 and CCSM3 Temporal Patterns

CF1 from CCSM3: T85

Normalized Coeff.

Year

100 150 200 250 300 350

SST

SLP: r=0.68

CF2 from CCSM3: T85

Normalized Coeff.

Year

100 150 200 250 300 350

SST

SLP: r=0.58