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

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Introduction

- 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

Statistical Techniques

- <u>Canonical Correlation Analysis</u>
  - Multivariate regression algorithm designed to maximize the correlation between the time-series from different datasets, **P(x,t)** and **T(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:

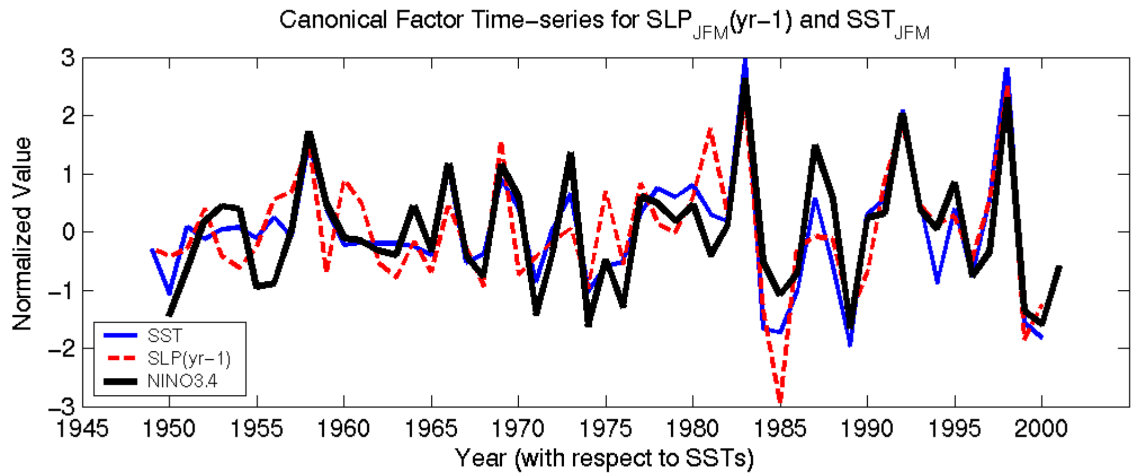
$$\left(\langle \overleftrightarrow{\mathbf{U}}\overleftrightarrow{\mathbf{U}} \rangle^{-1} \langle \overleftrightarrow{\mathbf{T}}\overleftrightarrow{\mathbf{U}} \rangle' \langle \overleftrightarrow{\mathbf{T}}\overleftrightarrow{\mathbf{T}} \rangle^{-1} \langle \overleftrightarrow{\mathbf{T}}\overleftrightarrow{\mathbf{U}}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

λ - Eigenvalues: Represents correlation between canonical factor time-series

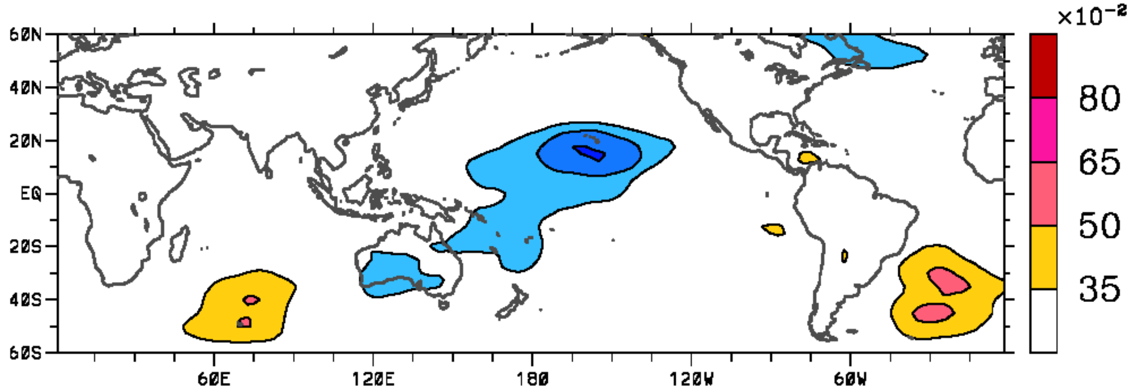
$\overleftrightarrow{\mathrm{A}}$ - Eigenvectors: Represents "spatial maps" for canonical factors of $\overleftrightarrow{\mathrm{T}}$

Jan.-Mar. SLP and SSTs the Following Year

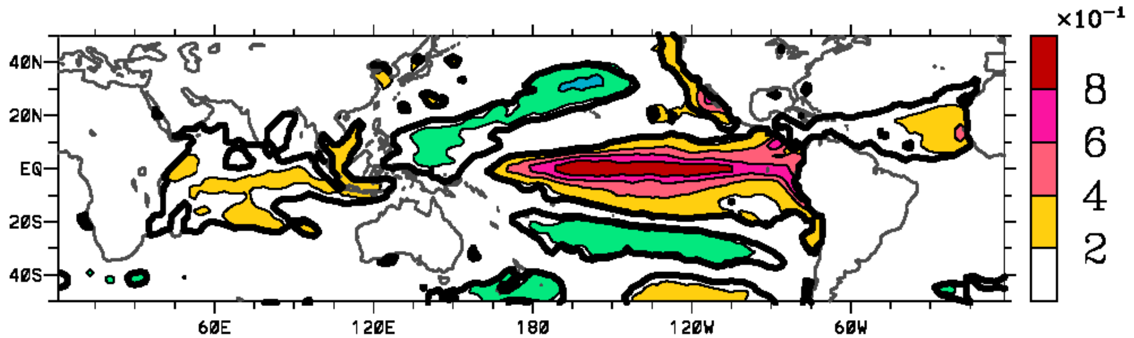
Time-Series



Sea-Level Pressure

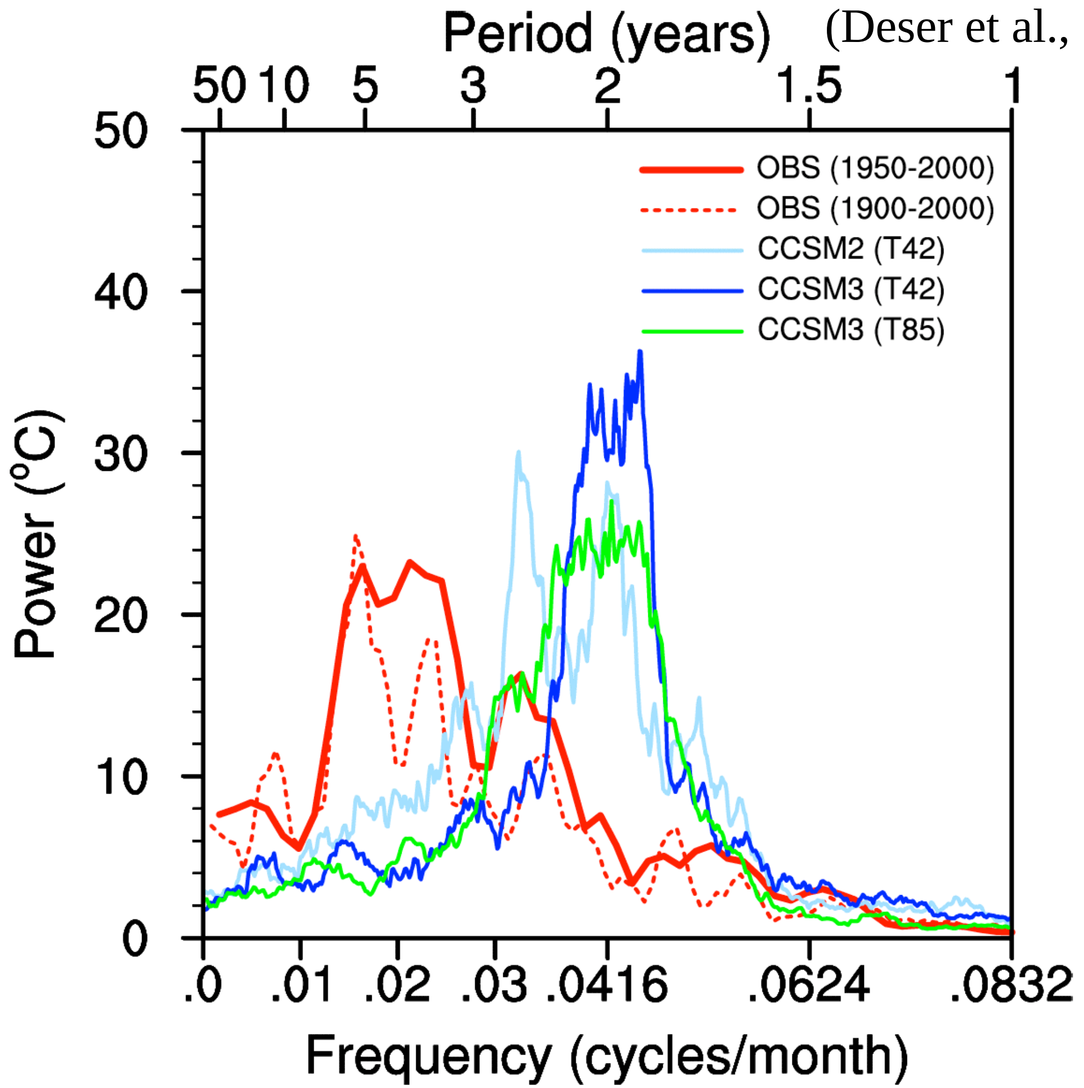


Sea-Surface Temp.



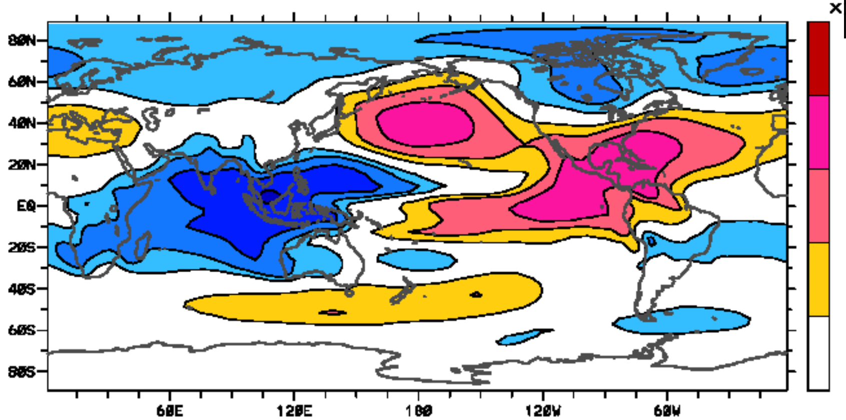
ENSO in Observations and Climate Simulations

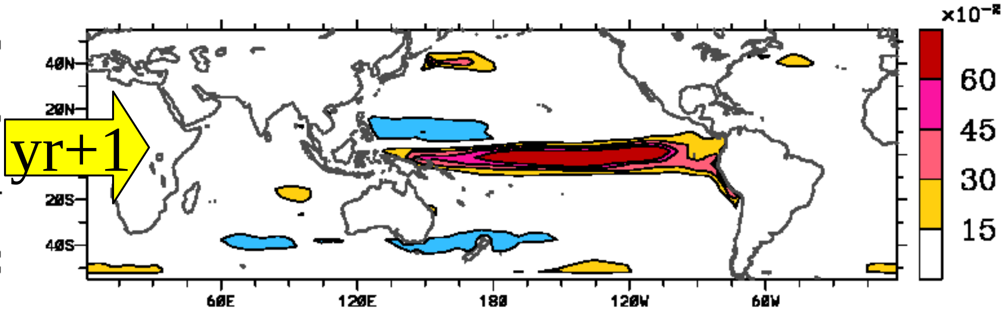
(Deser et al., 2005 - Draft)



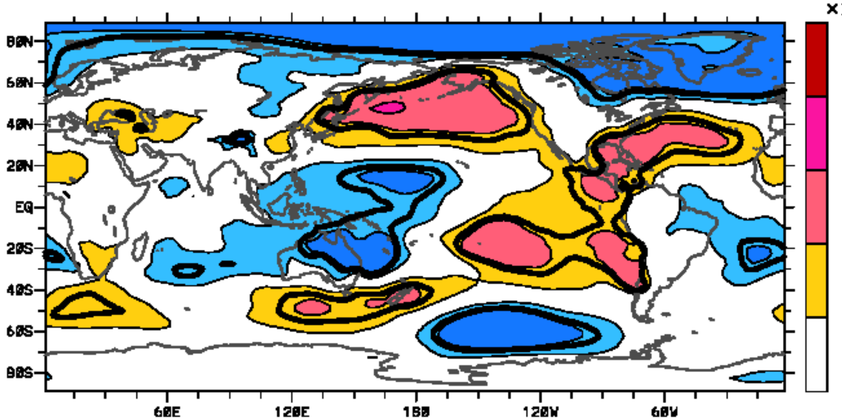
Comparison of Simulated and Observed Patterns

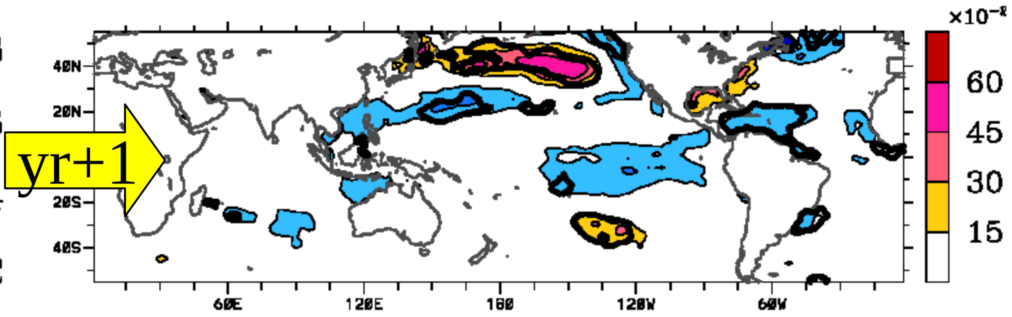
Simulated: CF1



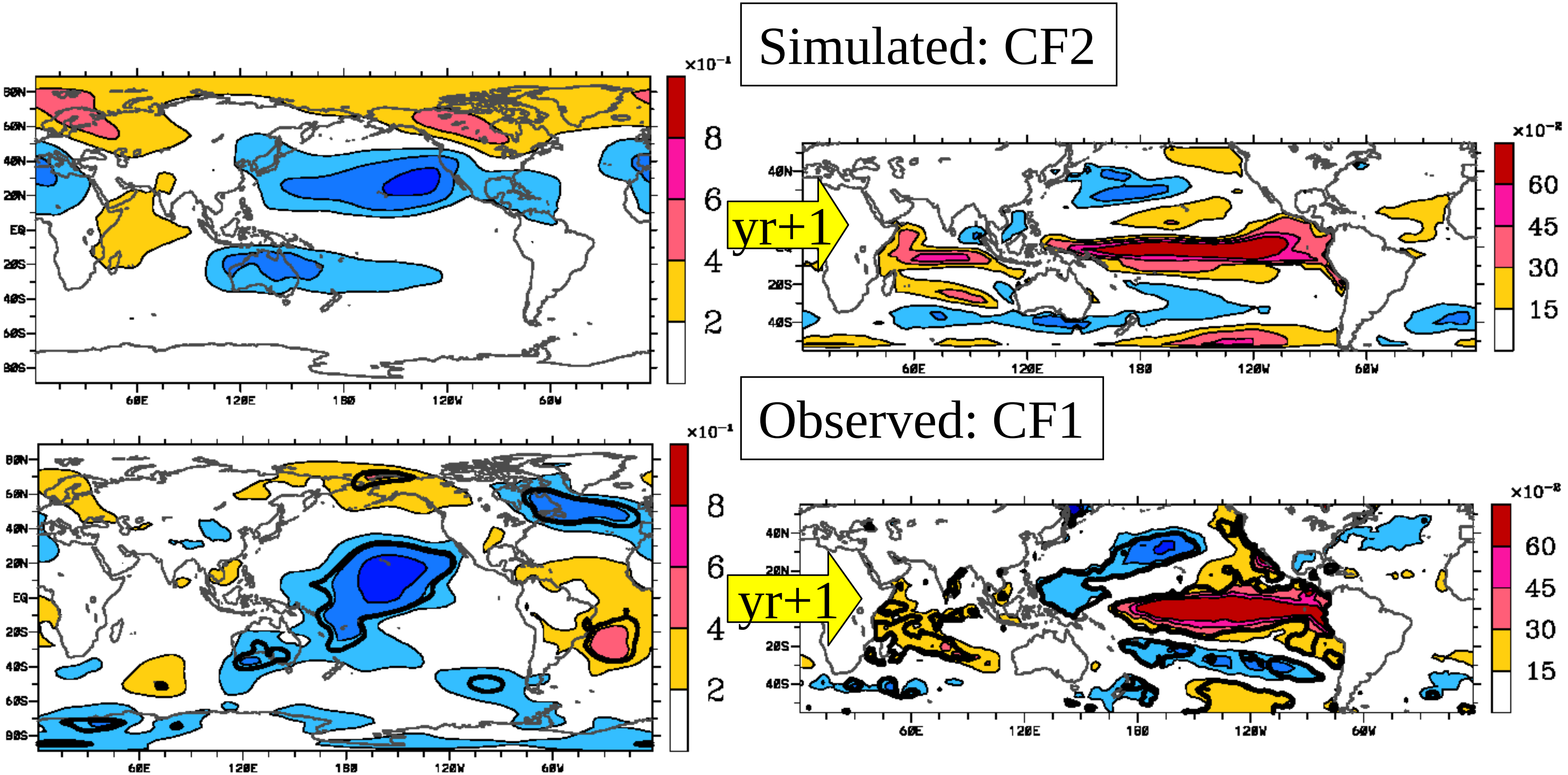


Observed: CF3

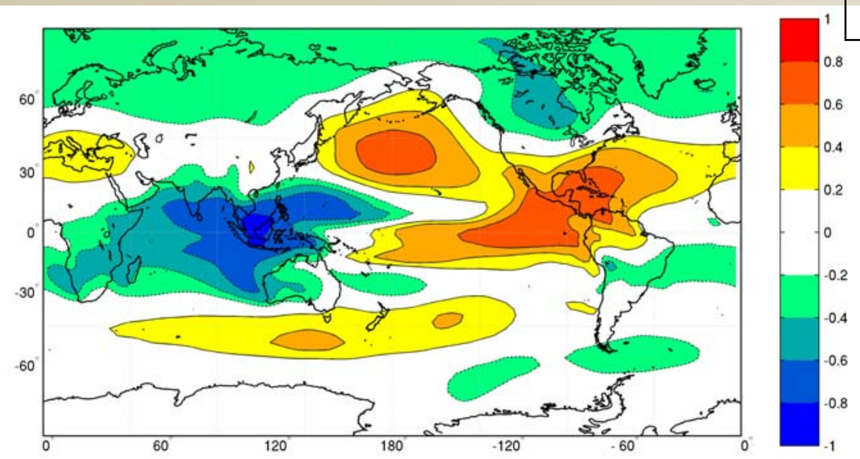




Comparison of Simulated and Observed Patterns

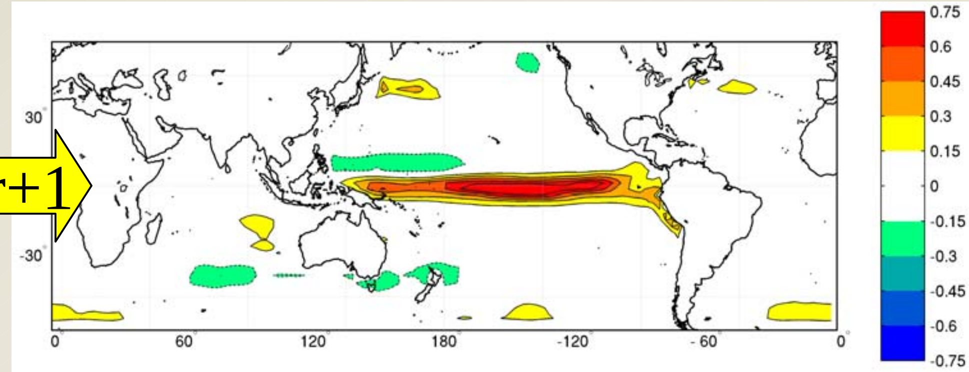


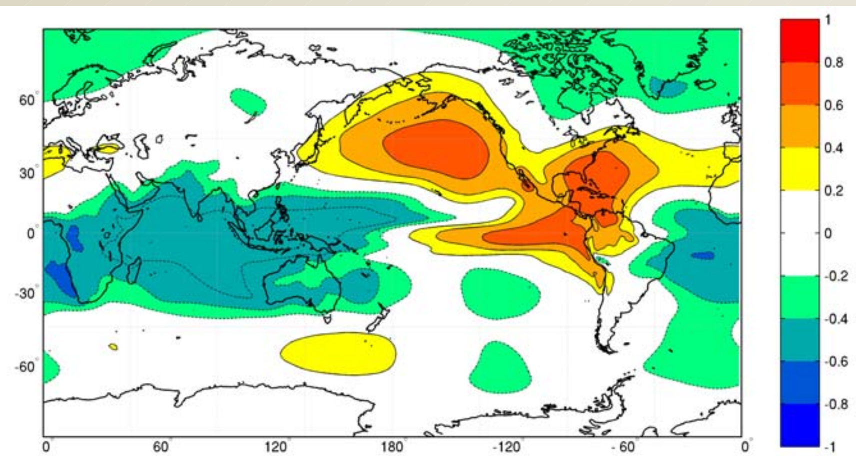
Comparison of CCSM2 and CCSM3 Patterns



CCSM2: CF1

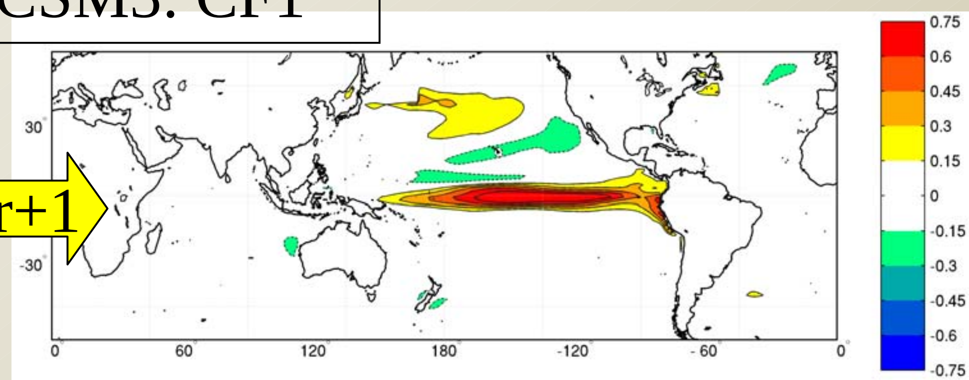
yr+1





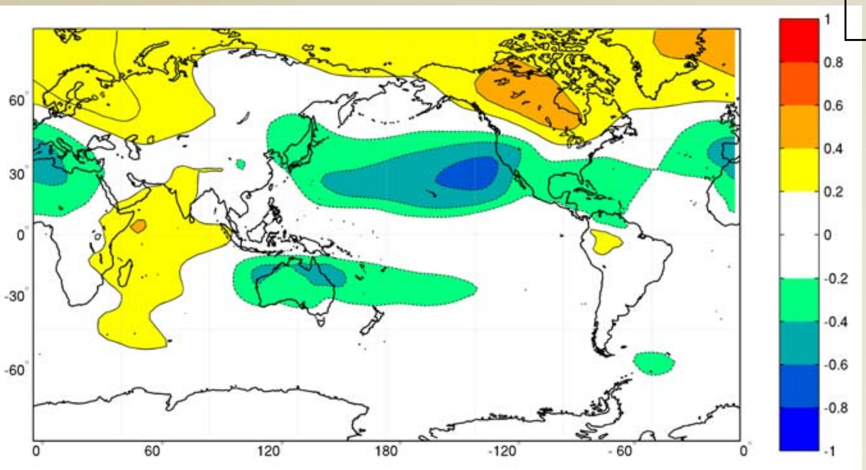
CCSM3: CF1

yr+1

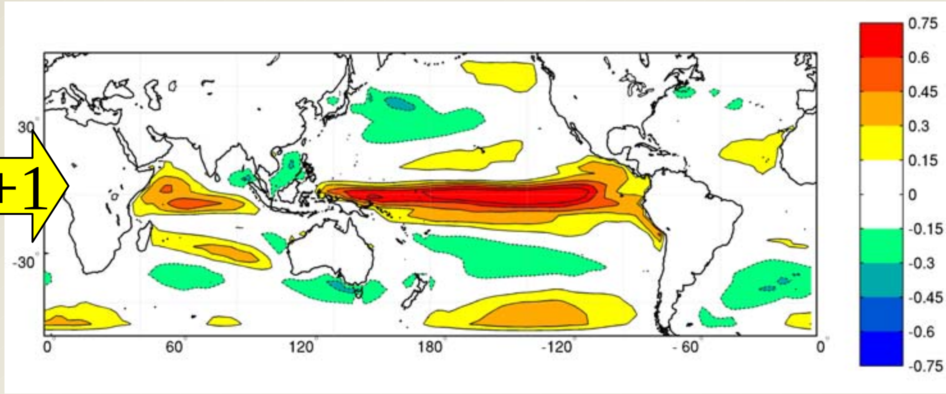


Comparison of CCSM2 and CCSM3 Patterns

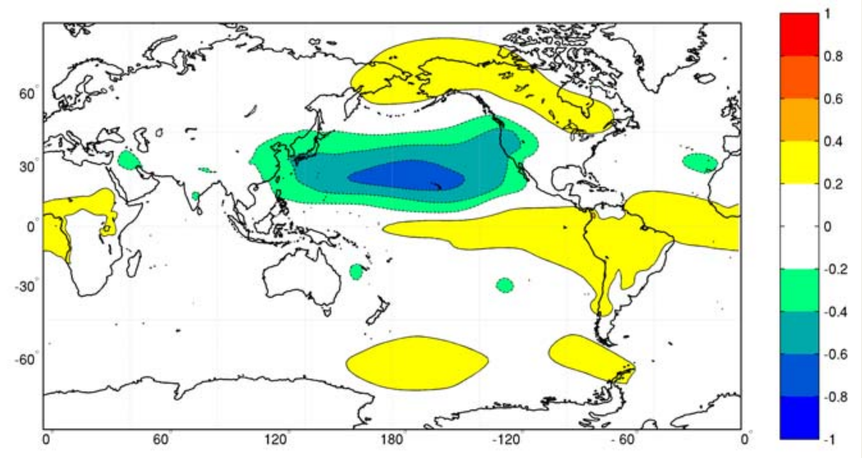
CCSM2: CF2



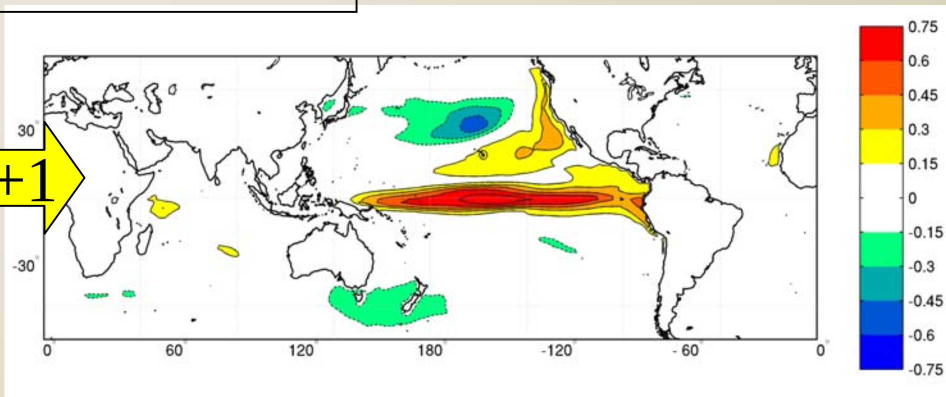
yr+1



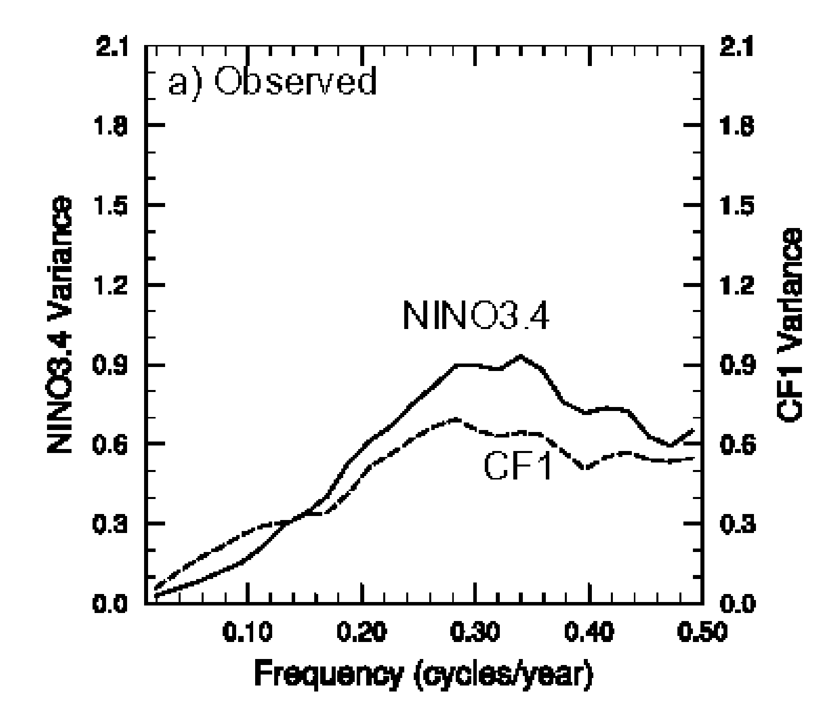
CCSM3: CF2

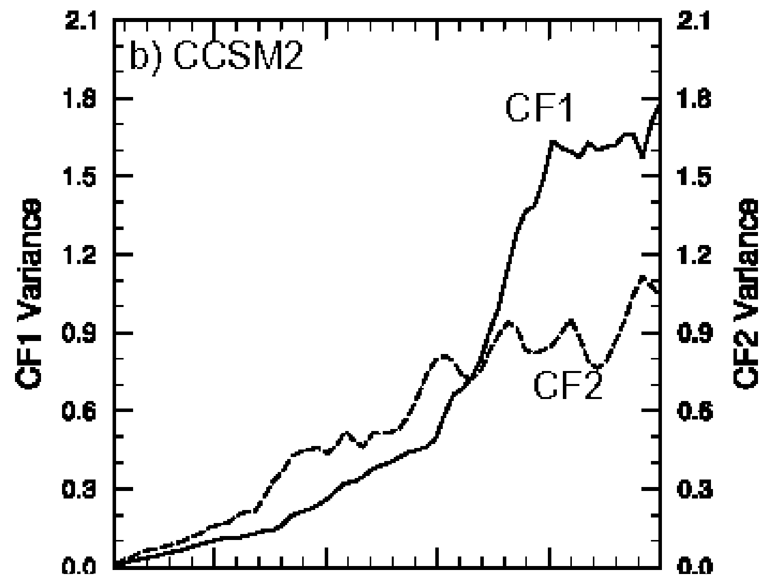


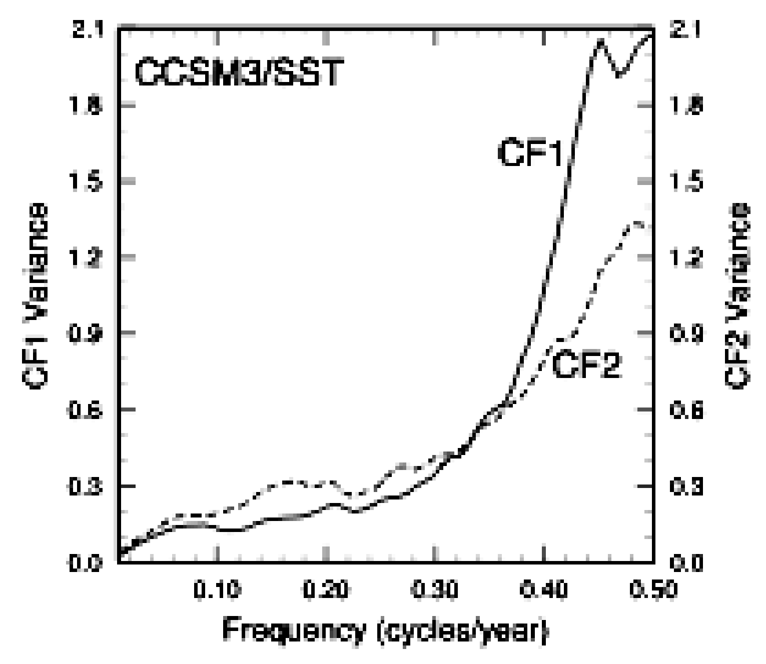
yr+1



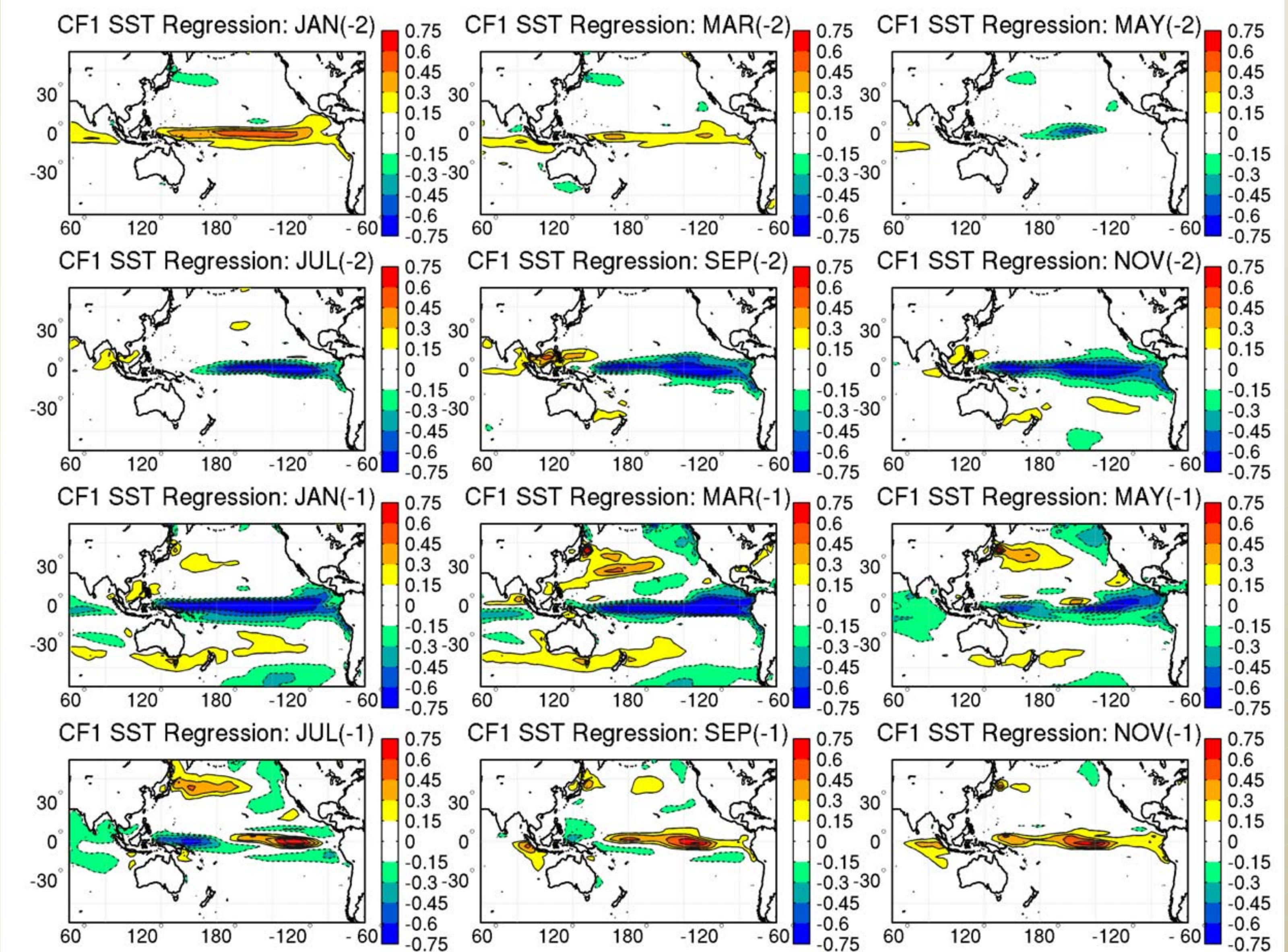
Simulated and Observed Temporal Patterns



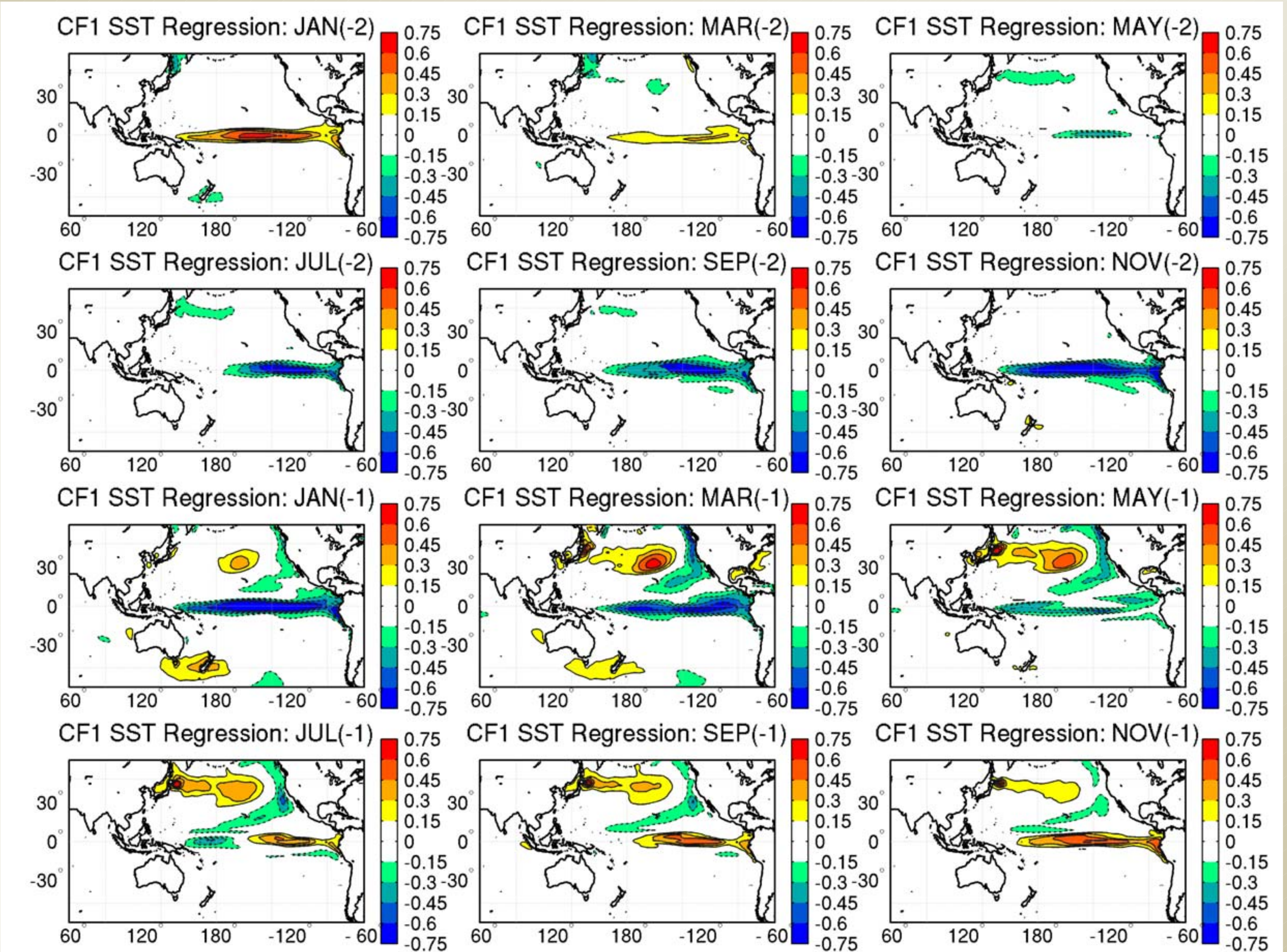




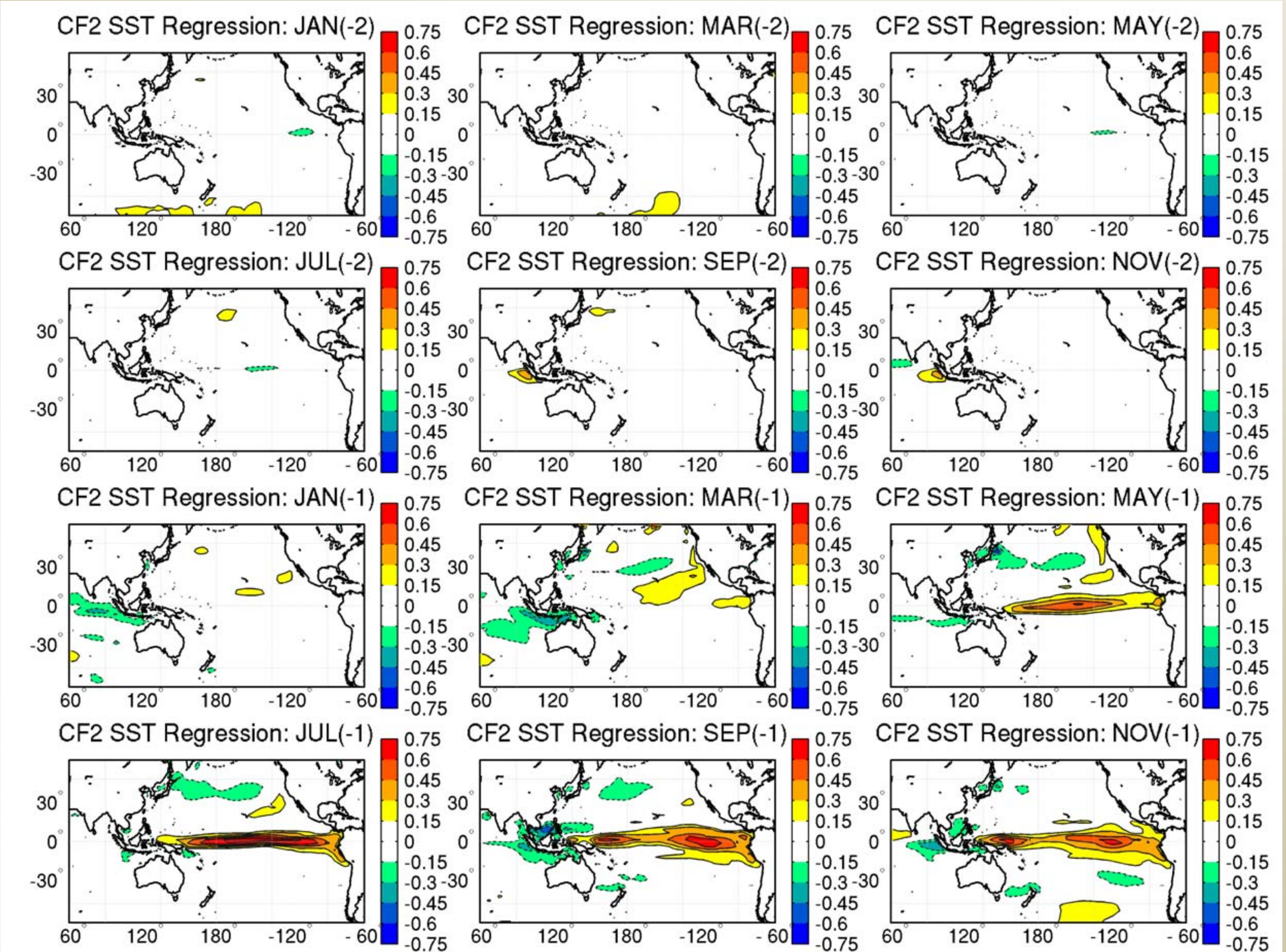
Evolution of Simulated SSTs for CF1



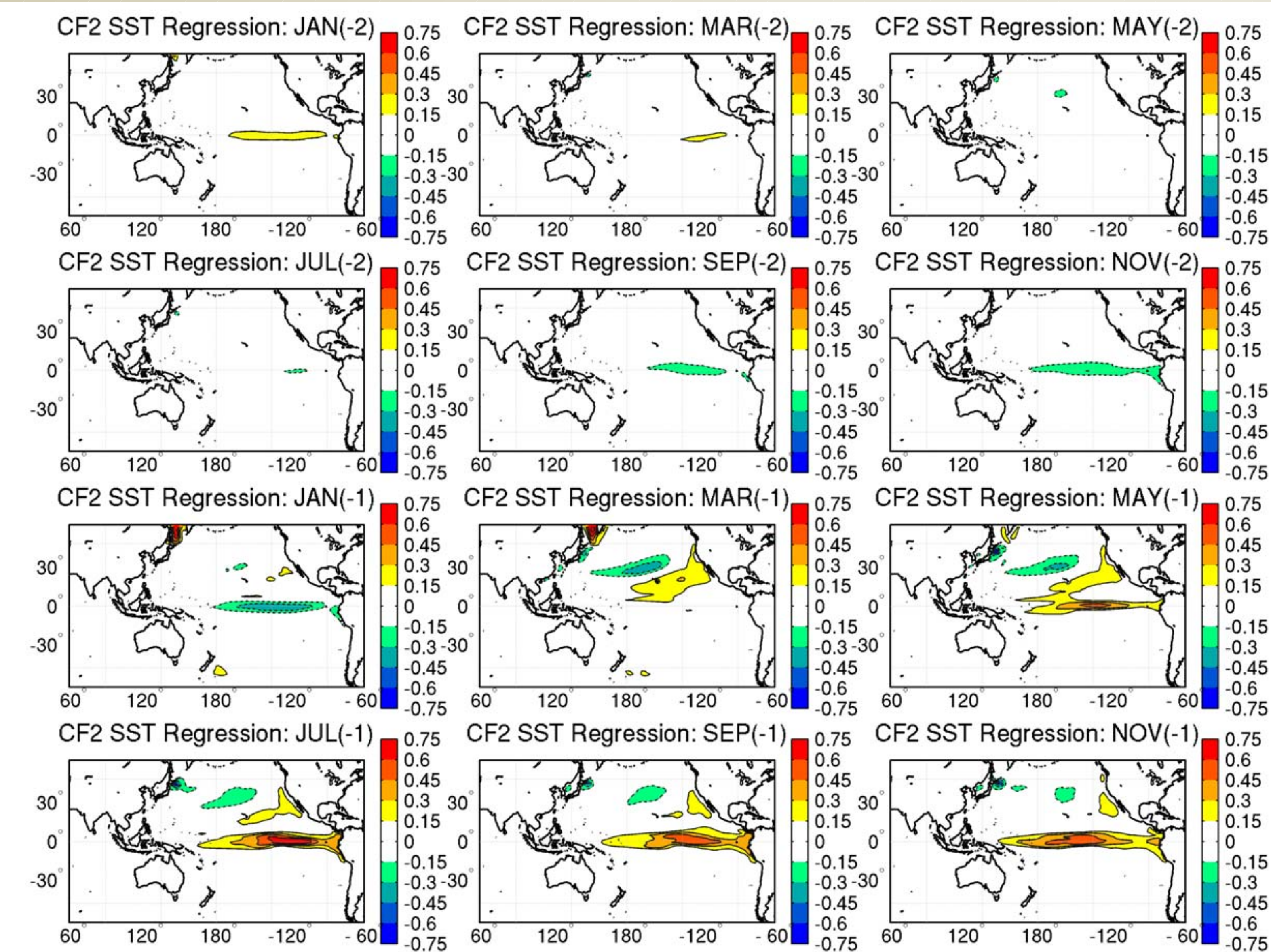
Evolution of Simulated SSTs for CF1



Evolution of Simulated SSTs for CF2

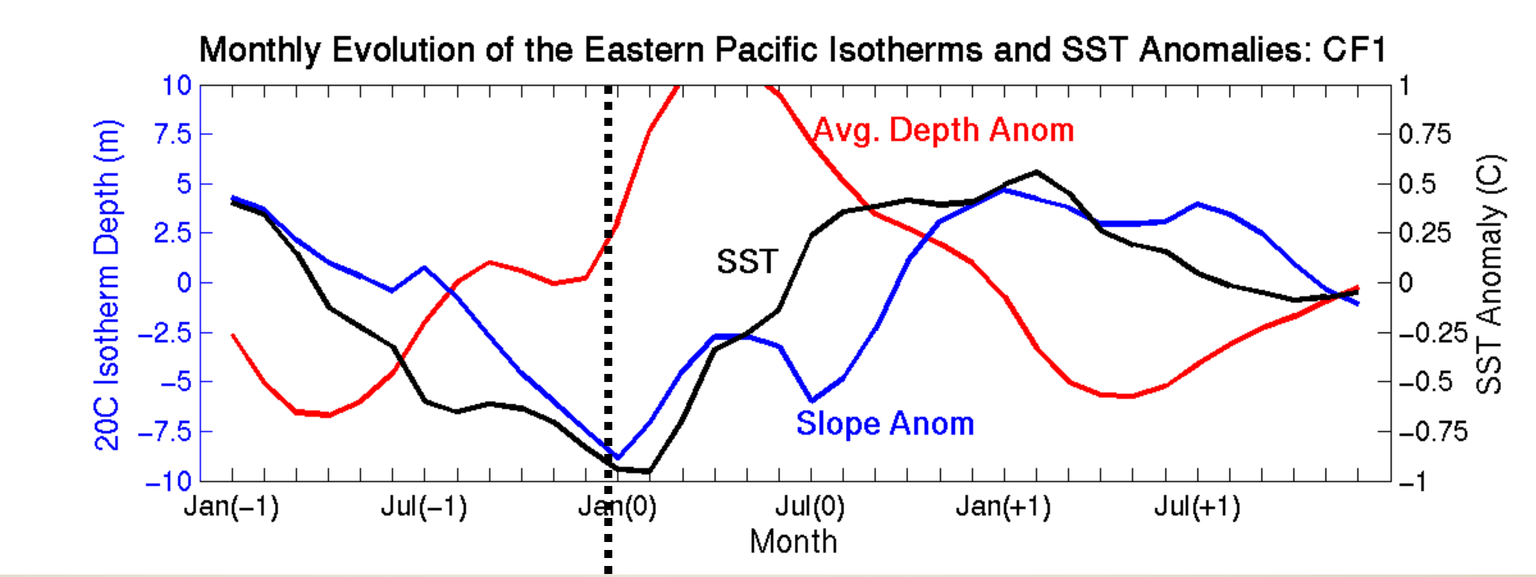


Evolution of Simulated SSTs for CF2

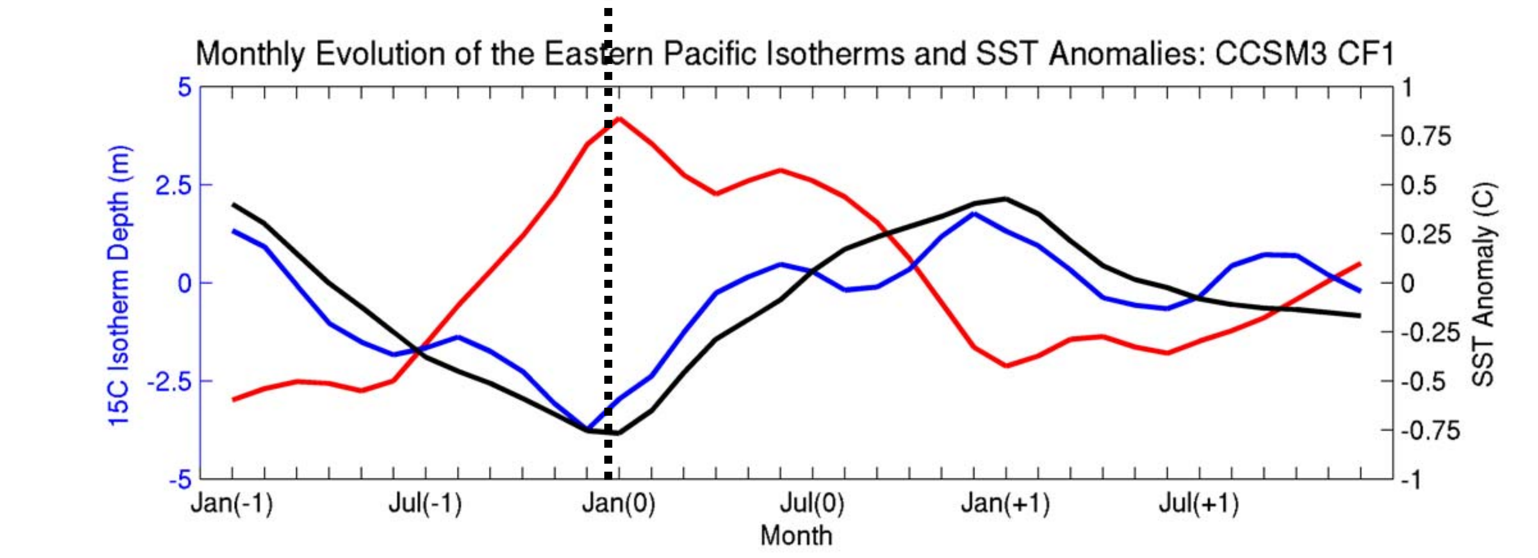


Evolution of Mixed Layer Depth and SSTs

CCSM2



CCSM3

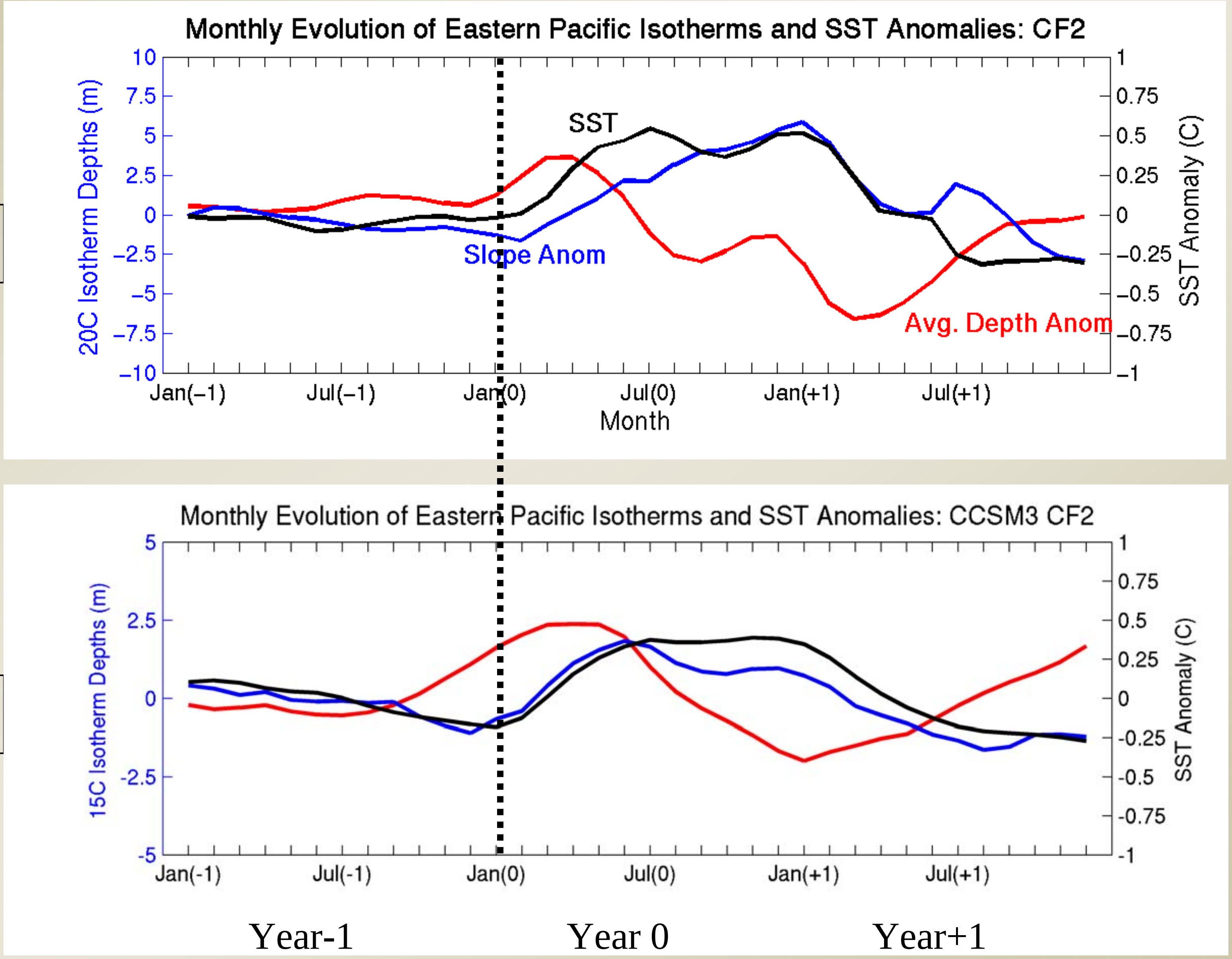


Year-1 Year 0 Year+1

Evolution of Mixed Layer Depth and SSTs Con't

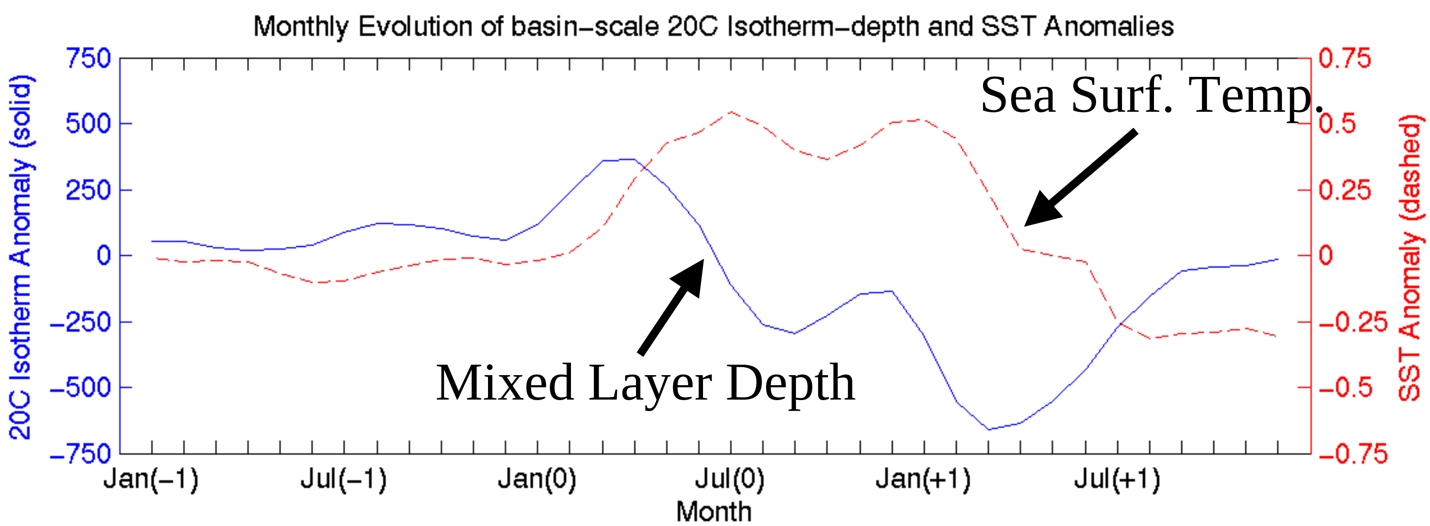
CCSM2

CCSM3

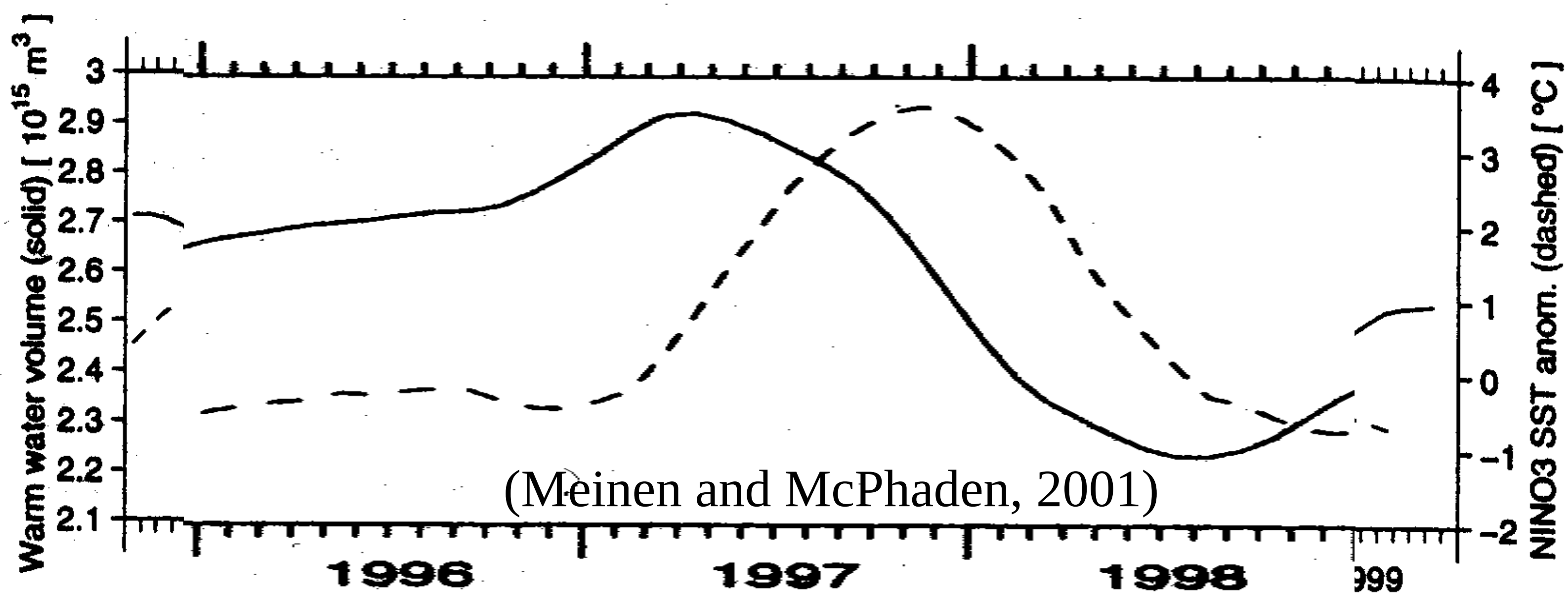


Evolution of Mixed Layer Depth and SSTs con't.

Model



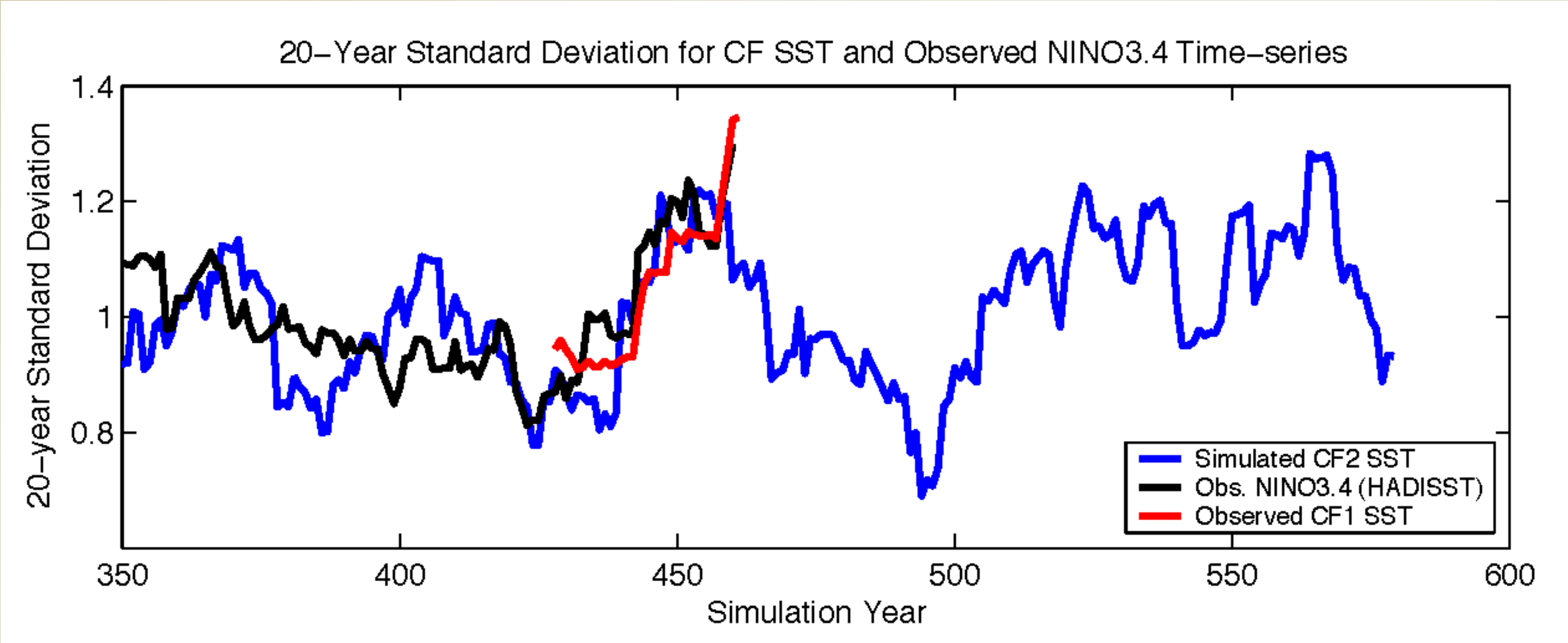
Obs.
1993-99



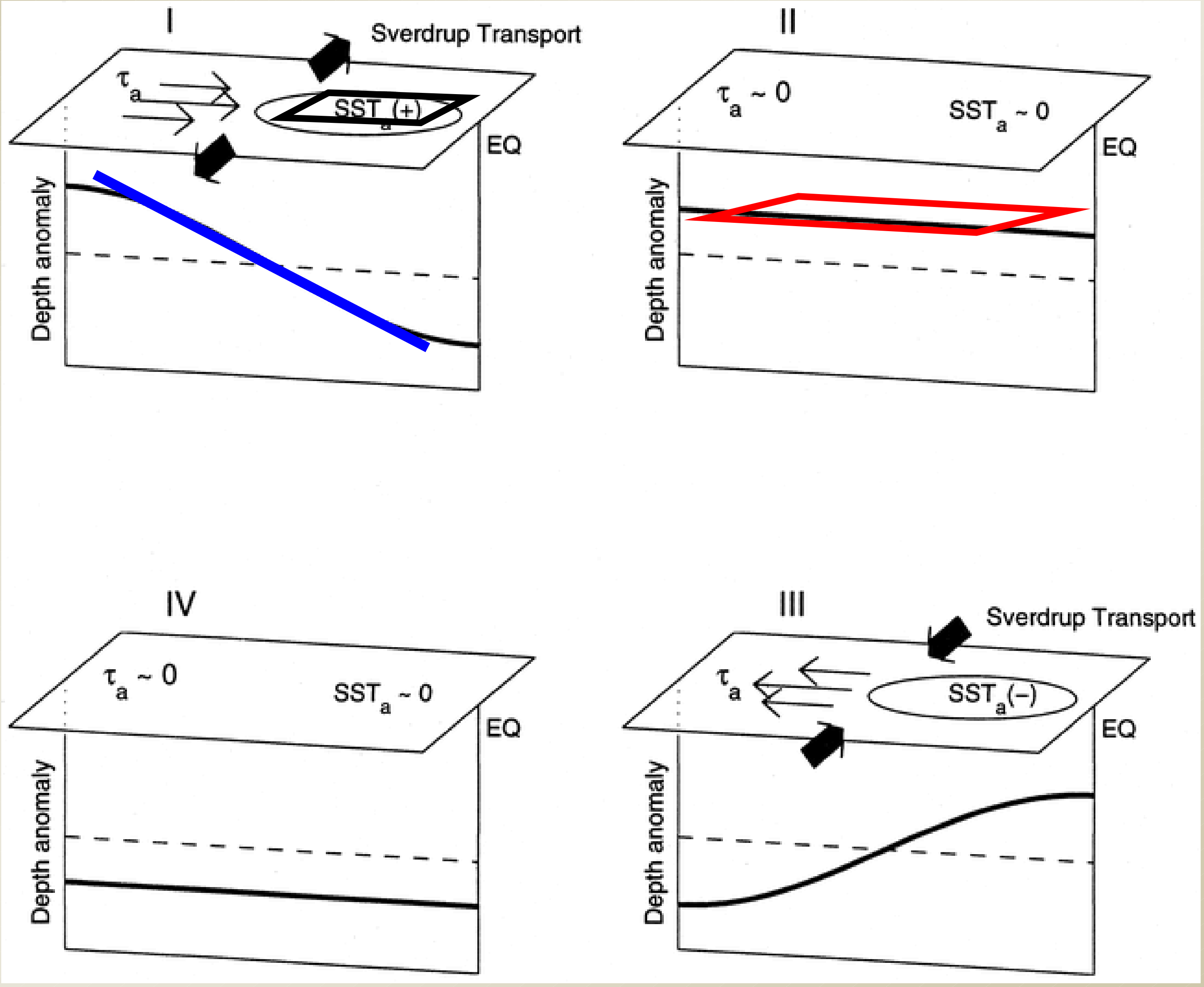
Conclusions

- 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

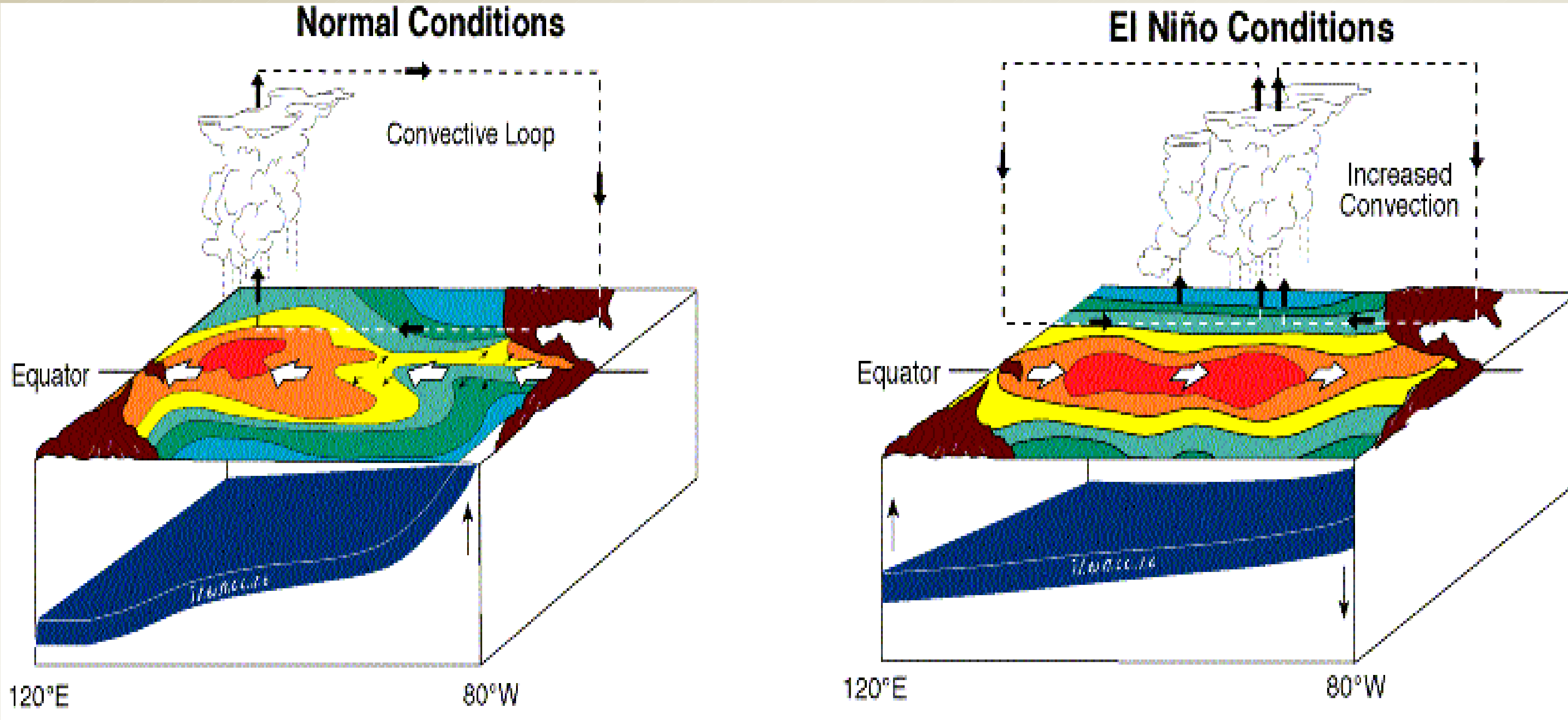


Recharge/Discharge Paradigm for ENSO

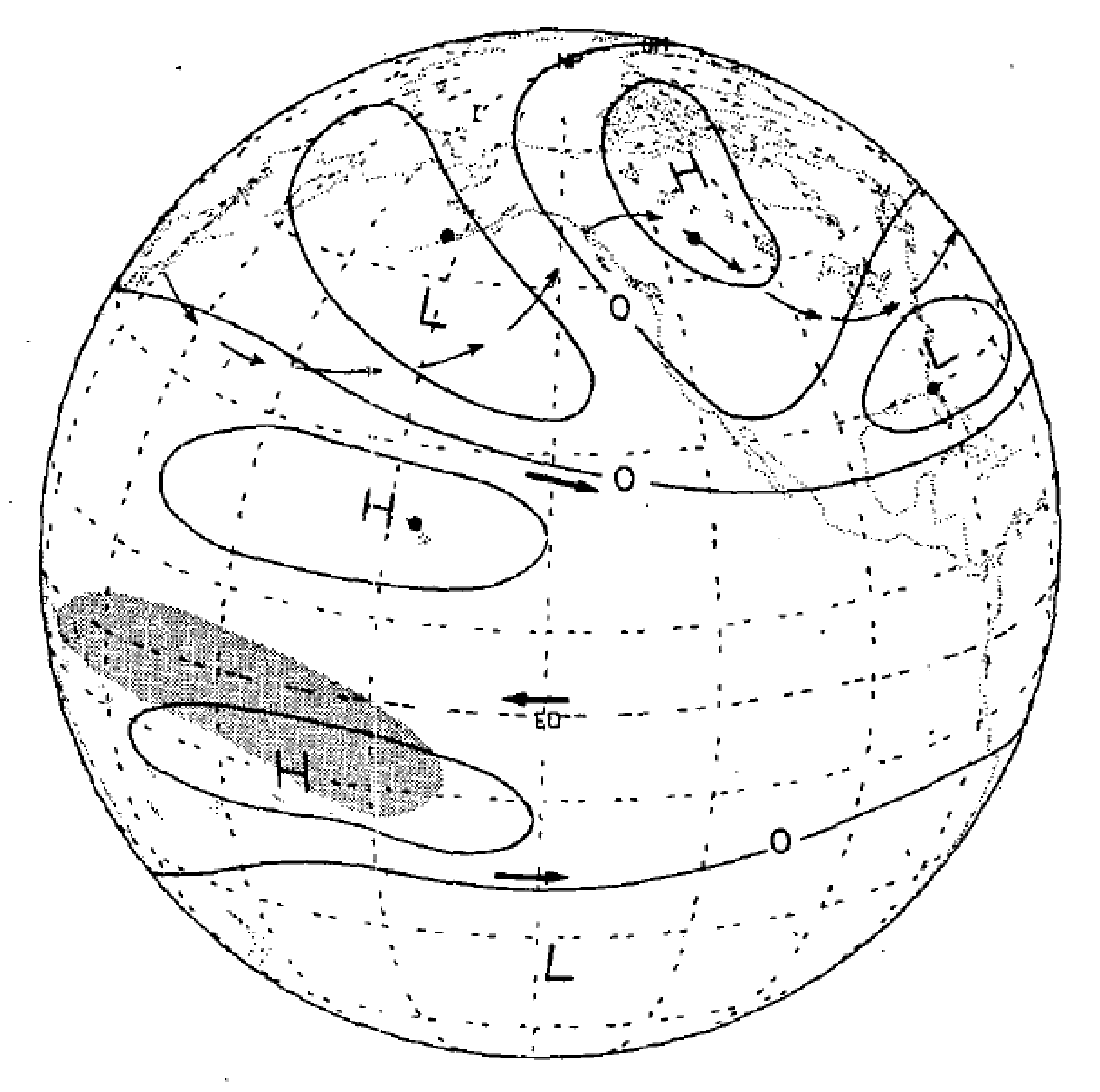


(Meinen and McPhaden, 2000)

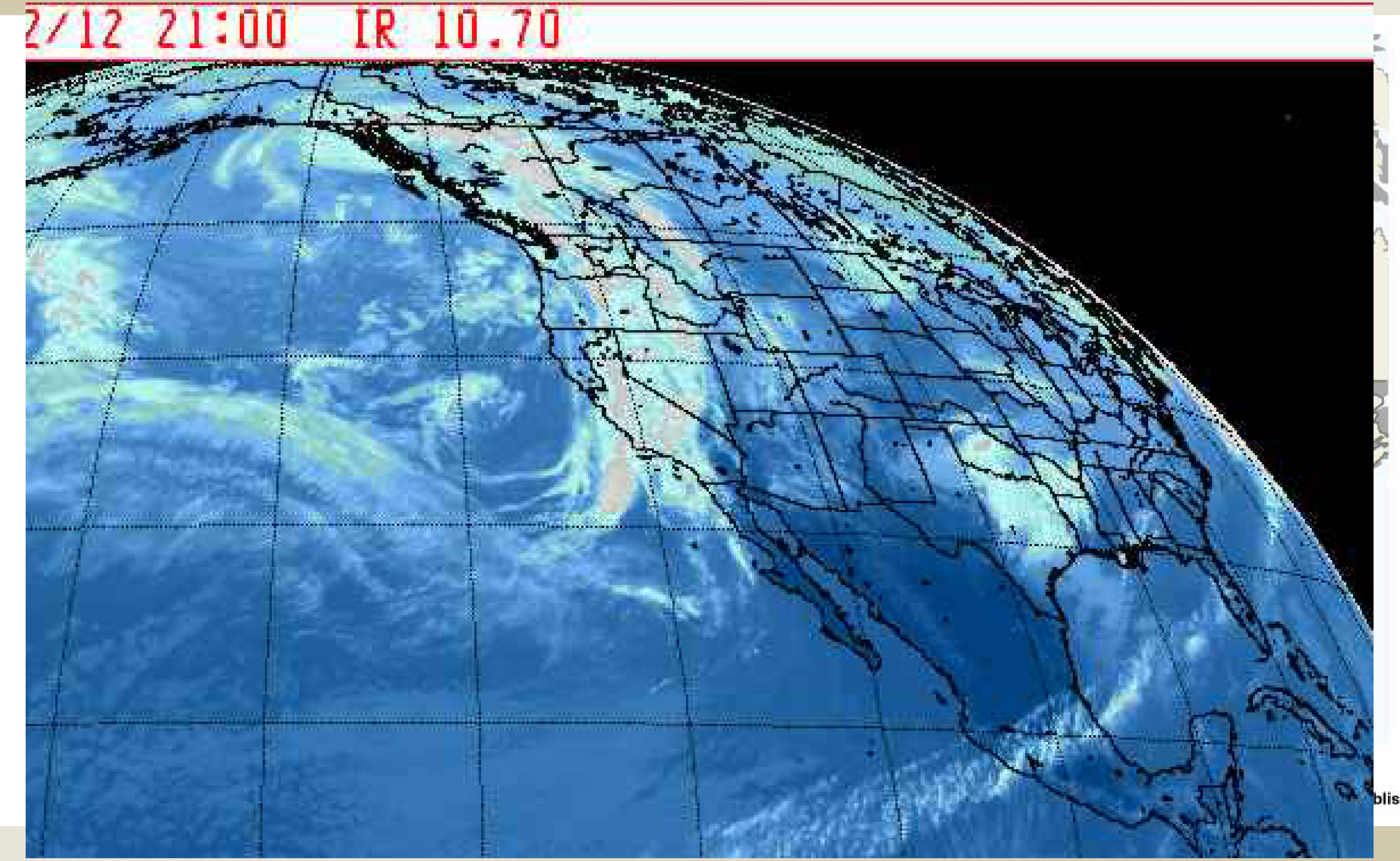
El Nino/Southern Oscillation



El Nino/Southern Oscillation Impacts



El Nino/Southern Oscillation Impacts



CCSM2 and CCSM3 Temporal Patterns