Modulation of ENSO by Changes in Tropical Climate

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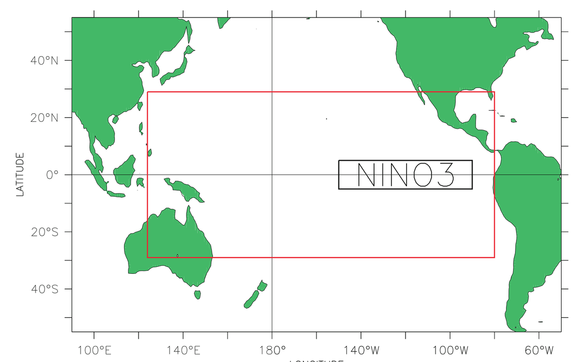
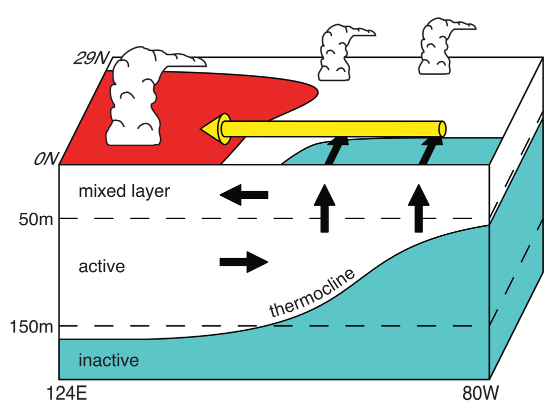
1. INTRODUCTION

The El Niño / Southern Oscillation (ENSO) is now recognized as the world's premier ocean-atmosphere interaction on interannual time scales. Although much progress has been made toward understanding this phenomenon, it remains unclear why ENSO behavior varies from decade to decade. One hypothesis is that ENSO responds to long-term changes in tropical Pacific climate, which might be driven by extratropical influences, by atmospheric noise, or by ENSO self-interactions. The goal of this study is to understand the linkages between the tropical climatology and ENSO physics, using a simple model of the tropical Pacific.



Model Domain and NINO3 Region



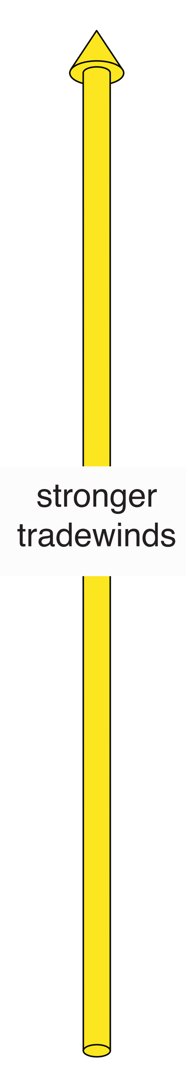
Model Schematic

2. MODEL OVERVIEW

The model is similar to those of Zebiak and Cane (1987) and Battisti (1988), except that no seasonal cycle is imposed.

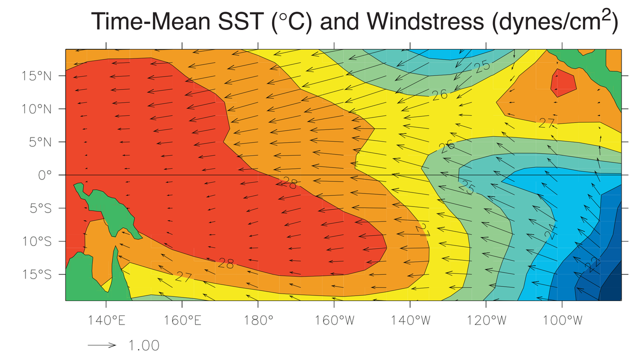
- beta plane, shallow-water dynamics
- 1.5-layer reduced gravity ocean with embedded surface mixed layer
- steady-state atmosphere driven by heating (Gill, 1980)
- iterative wind convergence feedback (Zebiak, 1986)

3. EXPERIMENTS

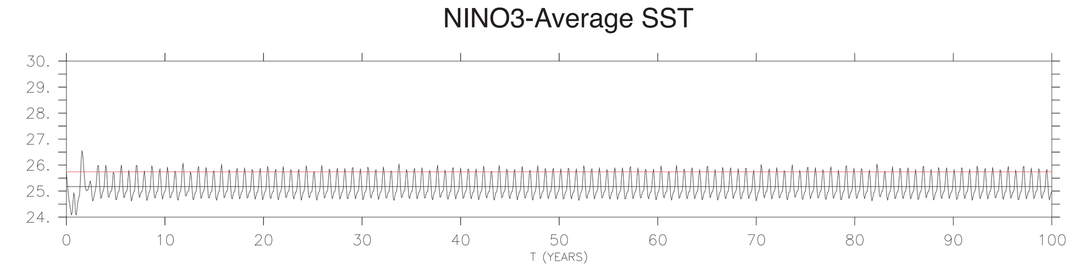


A. Easterly anomalous tradewind forcing

Time-Mean SST (°C) and Windstress (dynes/cm^2)

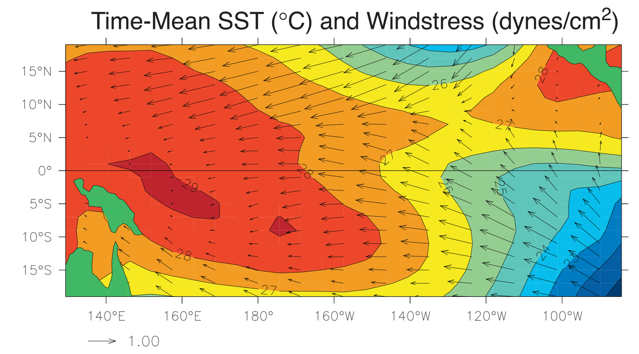


NINO3-Average SST

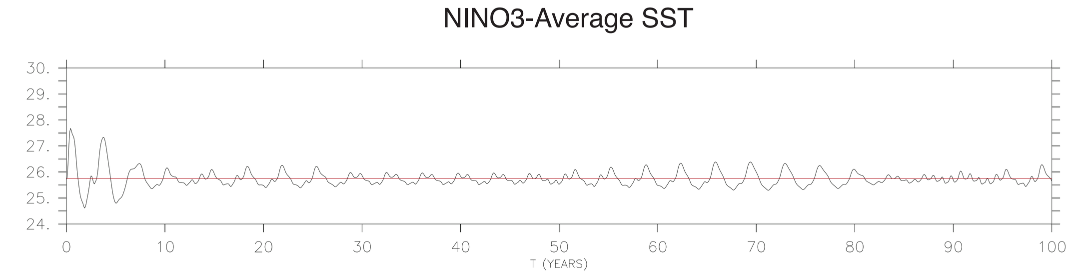


B. No anomalous forcing

Time-Mean SST (°C) and Windstress (dynes/cm^2)

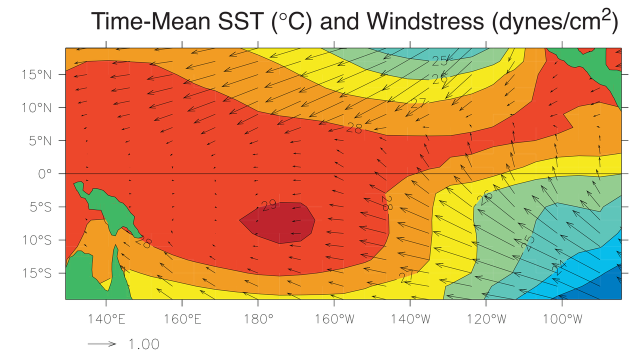


NINO3-Average SST

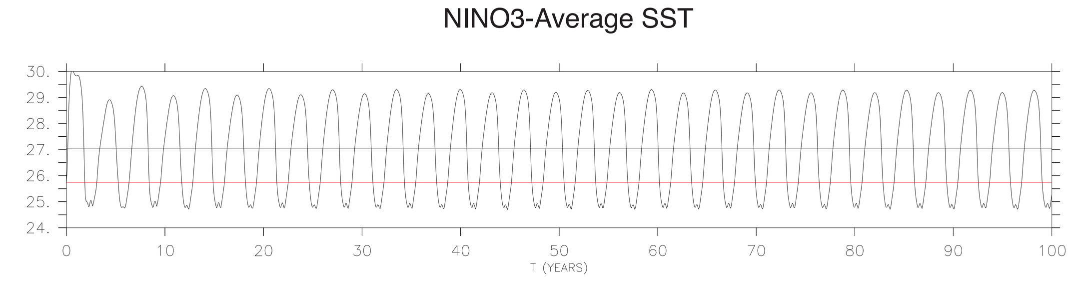


C. Westerly anomalous tradewind forcing

Time-Mean SST (°C) and Windstress (dynes/cm^2)



NINO3-Average SST

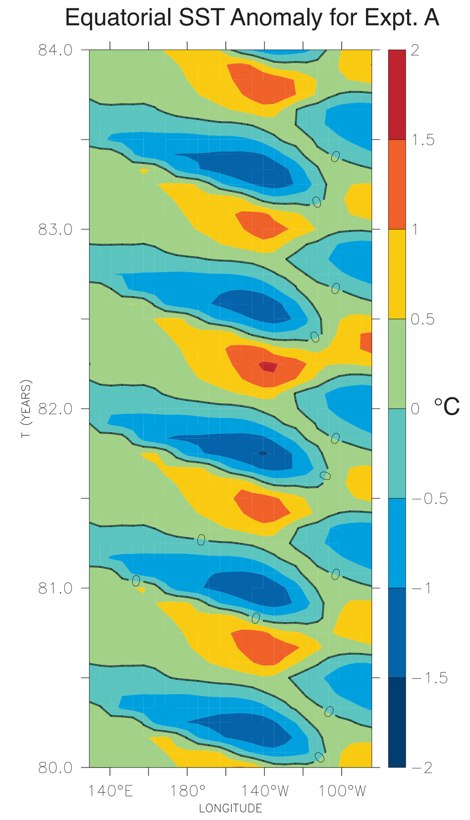


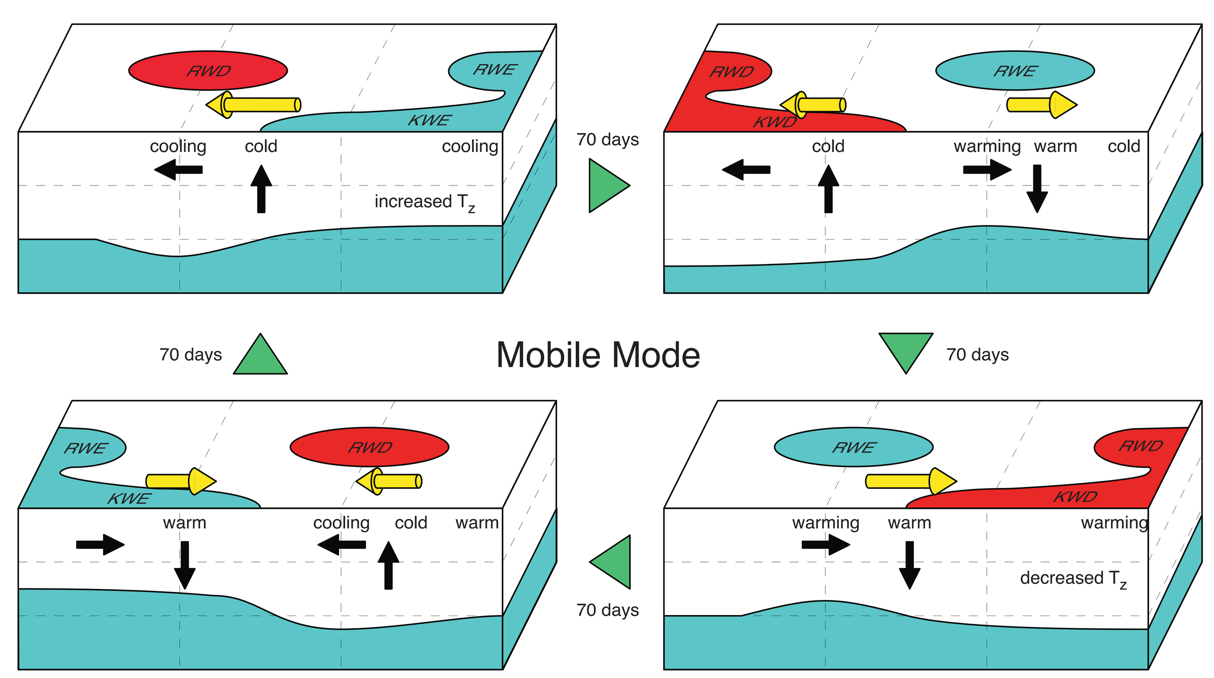
4. MODE PHYSICS

A. Mobile Mode (Mantua and Battisti, 1995)

- favored by strong tradewinds
- 9-month period
- westward SST propagation
- driven by local air-sea feedbacks
- resembles observed seasonal mode

Equatorial SST Anomaly for Expt. A

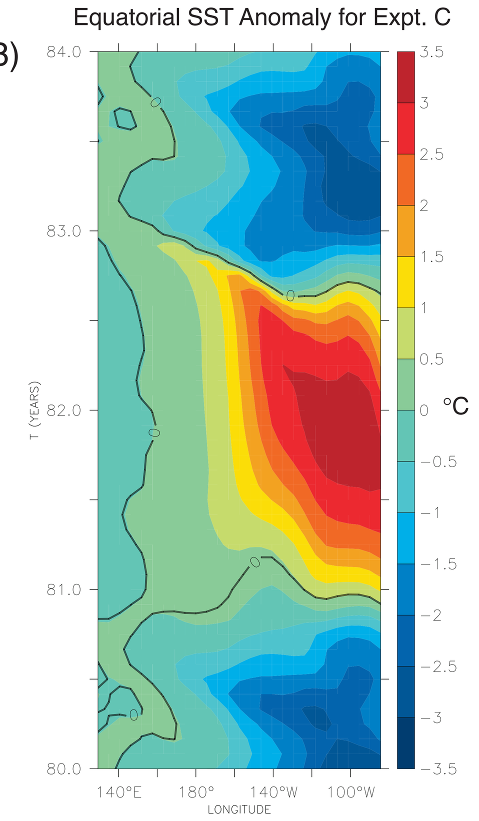


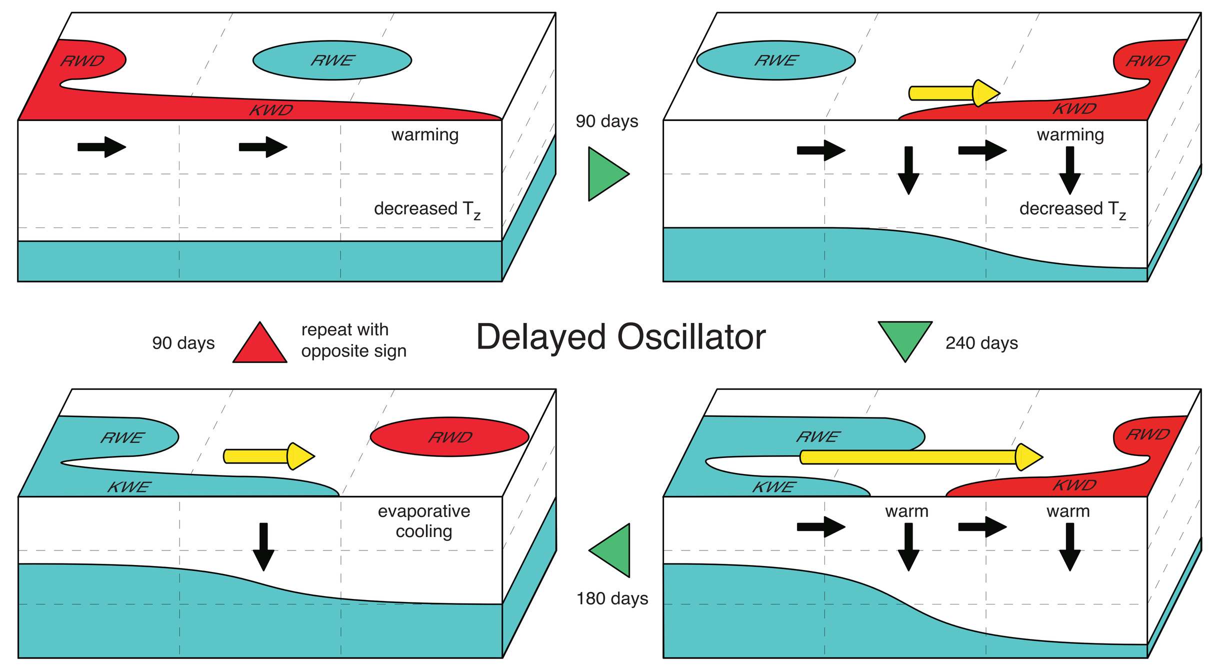


C. Delayed Oscillator (Suarez and Schopf, 1988)

- favored by weak tradewinds
- 40-month period
- nearly stationary SST
- driven by nonlocal air-sea feedbacks
- resembles observed ENSO
- interacts with mobile mode

Equatorial SST Anomaly for Expt. C





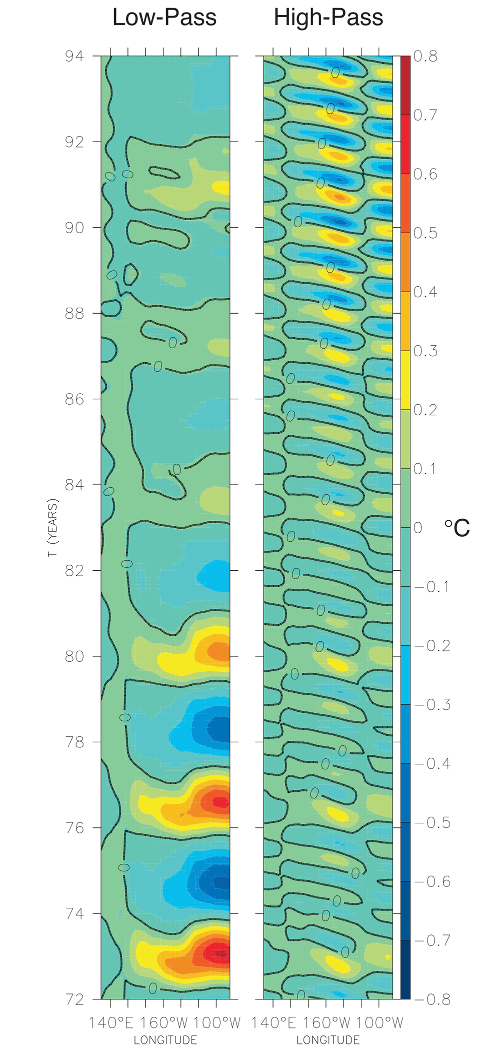
B. Mode Interactions

- occur at intermediate (realistic) tradewind strengths
- produce multi-decadal variability
- sensitive to mean state and model parameters

The figure at right shows the evolution of SST anomalies along the equator for Experiment B. The timeseries in the left panel has been filtered to retain only variability with periods longer than 16 months; the right panel contains the remaining high-frequency variability. The energy in each frequency band waxes and wanes as the delayed oscillator and mobile mode interact. The mobile mode becomes more regular and intense during periods when the delayed oscillator is weak; the delayed oscillator, in turn, is affected by slight shifts in the period of the mobile mode. The relative dominance of one mode over the other, and the ultimate growth or decay of the oscillations, is highly sensitive to the tradewind forcing in this intermediate regime.

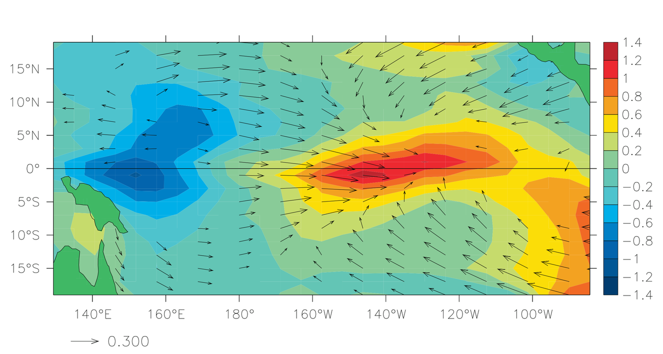
Equatorial SST Anomaly for Expt. B

Low-Pass High-Pass



5. NONLINEARITY

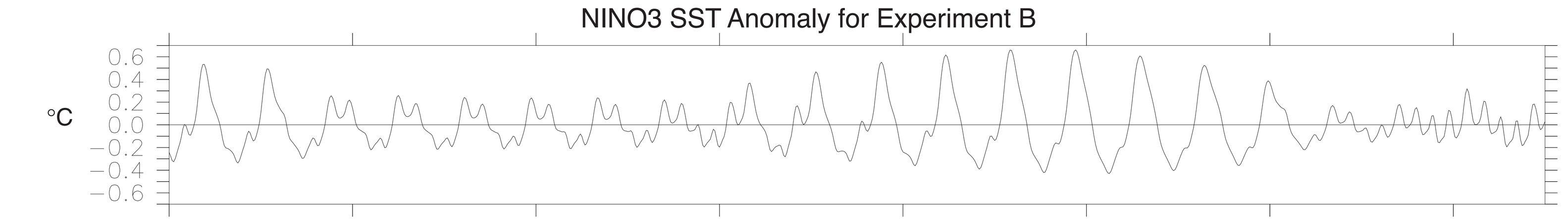
- Entrainment: T_z more sensitive to thermocline deepening than to shoaling.
- Winds: atmospheric heating more sensitive to SST when ITCZ is near equator.
- These favor stronger responses to El Niño-like forcing than to La Niña-like forcing (see figure at right).



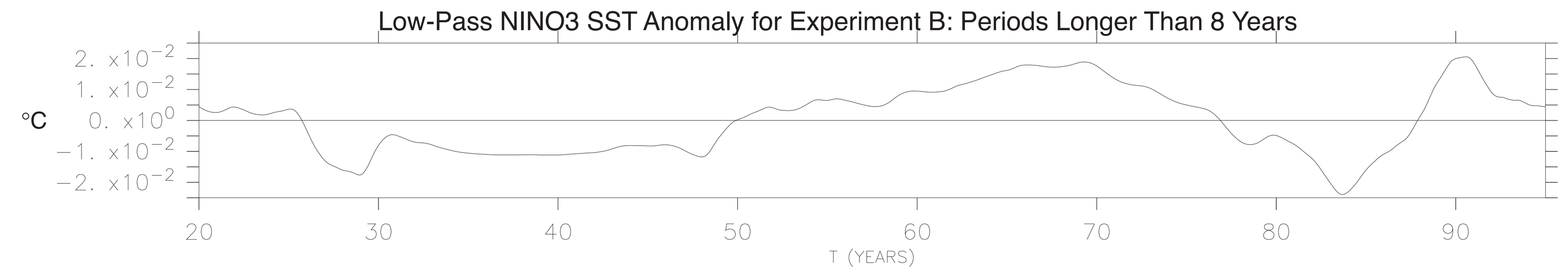
Sum of the time-mean responses to the opposite zonal windstress anomalies of Experiments A and C. Shading represents the net SST anomaly (°C), vectors represent the net windstress anomaly (dynes/cm^2). Nonzero values indicate nonlinearity of the model response.

- As a result, interannual oscillations cause small changes in the time-mean state through rectification:

NINO3 SST Anomaly for Experiment B



Low-Pass NINO3 SST Anomaly for Experiment B: Periods Longer Than 8 Years



6. CONCLUSIONS

- Strong mean trades favor the mobile mode in the model, while weak mean trades favor the delayed oscillator.
- The two modes interact at intermediate tradewind strengths, producing multi-decadal variability.
- Nonlinear oscillations produce rectified warming effects on the time-mean SST, which then feed back and amplify the model oscillations.

Ongoing Research

- Connecting the nonlinear variability with the linear normal modes
- Mapping model behavior as a function of climate parameters
- Understanding the effects of meridional asymmetry and the seasonal cycle on tropical Pacific climate variability

References

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