Climate Dynamics: Why Does Climate Vary?

El Nino: Coupling between the Atmosphere and Ocean in the Presence of Nonlinearity

http://www.esrl.noaa.gov/psd/people/dezheng.sun/lectures/ATOC7500.html
The ENSO Phenomenon

La Niña

El Niño

East Pacific (Nino3) SST Anomalies
Ocean-Atmosphere Coupling
The Bjerknes Feedback
Ocean-Atmosphere Coupling
The Oceanic Adjustment To Changing Winds
Ocean-Atmosphere Coupling
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Ocean-Atmosphere Coupling
The Oceanic Adjustment To Changing Winds

Time Evolution for the Idealized Experimental Kelvin and Rossby Waves Across the Pacific

International Research Institute for Climate and Society
Equilibrium State Versus Time-Mean State

The System:\[ \frac{dA}{dt} = f(A, \lambda) \] (1)

Equilibrium State:\[ f(A_0, \lambda) = 0 \] (2)

Time Mean State:\[ f(\bar{A} + A', \lambda) = 0 \] (3)

\[ f(A_0, \lambda) + \frac{\partial f}{\partial A}(\bar{A} + A' - A_0) + \frac{\partial^2 f}{\partial^2 A}(\bar{A} + A' - A_0)^2 + \ldots = 0 \] (4)

When \( f(A, \lambda) \) is nonlinear \( \bar{A} \neq A_0 \) (5)
A Box Model for the ENSO System

\[
\frac{dT_1}{dt} = c(T_e - T_1) + sq(T_2 - T_1)
\]

\[
\frac{dT_2}{dt} = c(T_e - T_2) + q(T_{sub} - T_2)
\]

\[
q = \frac{\alpha}{a} (T_1 - T_2)
\]

\[
T_{sub} = \Phi(-H_1 + h_2')
\]

\[
\Phi(z) = T_e - \frac{T_e - T_b}{2} (1 - \tanh\left(\frac{z + z_0}{H^*}\right))
\]

\[
h_2' - h_1' = -\frac{H_1}{H_2} H \frac{\alpha}{b^2} (T_1 - T_2)
\]

\[
\frac{1}{r} \frac{dh_1'}{dt} = -h_1' + \frac{H_1}{2H_2} H \frac{\alpha}{b^2} (T_1 - T_2)
\]

Sun 1997
Tropical Pacific Climate as a Function of $T_e$.

(a) Equilibrium and Time-Mean SST

(b) Amplitude of ENSO
Oscillations in the Model
Oscillations in the Model
Oscillations in the Model different regimes

Te=28.0 °C

SST (°C)

Time (year)

Te=31.0 °C

SST (°C)

Time (year)
Oscillations in the Model

(a) SST (°C) vs Time (year) 
(b) $h_1$ (m) vs Time (year)

$T_e = 31.0$ °C

time-mean solution

equilibrium solution

(b) $T_2$ (°C) vs $h_1$ (m)
A New Way to Look at El Nino

![Graph showing temperature and height relationship
with labels for equilibrium and time-mean solutions]

- $T_i = 31.0 \, ^\circ C$
- Equilibrium State
- El Niño State
- Time-mean State

![Bars representing equilibrium and time-mean temperatures](a) Equilibrium State (b) El Niño State (c) Time-mean State
Tsub, q, h1, and h2 as a function of $T_e$. 
Tropical Pacific Climate as a function of $T_e$

Equilibrium and Time-Mean SST

$$\Phi(z) = T_{s0} + \gamma(z + H_1)$$

$$T_{sub} = T_{s0} + \gamma h'_2$$

Amplitude of ENSO

![Graph showing SST as a function of $T_e$](image)
Tropical Pacific Climate as a Function of $T_e$

Sensitivity to Parameter S

(a) $s=0$

(b) $s=0$

(c) $s=0.096$

(d) $s=0.096$
Implications of the Box Model Results
Why no trend has shown up in the zonal SST contrast in the observations?