Reassessing the Role of Stochastic Forcing in ENSO Events

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Forecasts of the 1997/98 El Niño
(Landsea & Knaff 2000)
1997/98 El Niño
Equatorial anomalies
1997/98 El Niño
Equatorial totals

precip

τ_x

T300

SST
Hypothesis:

Unpredictable wind stresses ruined the forecasts.

Initial test:

Partition the observed stress: \( Y = XW + E \)

- \( Y_{n \times q} \) = stress anomalies
- \( X_{n \times p} \) = SSTA predictors
- \( W_{p \times q} \) = regression coefficients
- \( E_{n \times q} \) = residual stress

Estimate \( \tilde{W} \) and \( \tilde{E} \) from observations.

Investigate how \( \tilde{E} \) affects coupled forecasts.
Statistical Atmosphere (Mode 1)

SST and wind stress from NCEP2 (1979–2002)

(a) SSTA singular vector #1

(b) $\tau_{x'}$ regression
Statistical Atmosphere (Mode 2)
SST and wind stress from NCEP2 (1979–2002)

(a) SSTA singular vector #2

(b) $\tau_\times$ regression
Wind stress decomposition: monthly NCEP2 obs
Wind stress decomposition: low-pass NCEP2 obs
Hybrid Coupled Model

Statistical atmosphere:

- tuned to NCEP2 obs SST/stress (1979–2002)
- 120°E–70°W by 5°; 20°S–20°N by 2°

Ocean model (GFDL MOM4):

- 2°lon × 25 levels; \( \Delta y = 0.5° \rightarrow 1.5° \rightarrow 4.5° \)
- global domain, sponge to obs poleward of 45°
- free surface, freshwater fluxes
- KPP vertical mixing
- Laplacian horizontal diffusion & viscosity
Hybrid Model Ocean Grid

(a) Meridional grid

(b) Vertical grid

(c) Top 300m
Spinup of the hybrid coupled model

- Initialize ocean from observed climatology (1955-1979).
- Couple spinup in 1978.
- Compute climatological SST bias in 1979.
- Subtract bias from SST nudging target and run again.
- Impose FA + 30-day nudging to clim SST/SSS in 2002.
Mean state from flux-adjusted HCM

Temperature (°C) at Equator
Assim (1980–2000), Hybrid (bias shaded)

Subsurface U (cm/s) at Equator
HCM vs. TAO obs (ADCP & fixed-depth)

165°E  170°W  140°W  110°W
Deterministic forecasts of east Pacific SST anomalies
Random initial conditions
no residual forcing
Random initial conditions
forced by 1997 stress residual
SST change induced by 1997 residual
Are the residual stresses random?

Only one realization of the obs!

Invoke an atmospheric GCM:

1. Force an AGCM ensemble with obs SSTs.

2. Fit a linear stress model to each run.

⇒ Ensemble mean should vanish if residual is noise.

GFDL AM2p12
2.5°lon × 2°lat × 24 levels
10 members
AGCM wind stress decomposition: monthly mean
AGCM wind stress decomposition: low-pass
AGCM residual zonal wind stress
“Cheatcasts” forced by AGCM stress residuals
What drives the WWEs?

non-ENSO composite of WWE SSTAs (Vecchi & Harrison 2000)

- linked to eastward SSTA gradients in west
- connected with large-scale warming
AGCM $\tau_x'$ driven by precursive SSTA

Skewness of AGCM $\tau_x'$ noise

Black line climo.
4x10 member experiments
$\tau_x'$ driven by Pacific precursive SSTA

$\tau_x'$ driven by IndoPacific precursive SSTA
Background SST affects the WWEs

Control AGCM

Cold West Pacific

Warm East Indian
Background SST affects the convection.
CGCM biases

SST (°C)

Precip (mm/day)

NOAA 0.12
1982-2003

CMAP
1979-2003

CM2.0
Summary

1. **Regression onto tropical Pacific SST** captures most interannual variance of equatorial Pacific $\tau_x'$. 

2. But the **residual stress matters**. It induces strong dispersion of ENSO forecasts.

3. Pacific was **preconditioned** for warming in 1997. But unusually intense residual westerlies greatly amplified the warming.

4. The residual is **not completely independent of SST**.

5. **Convective nonlinearity**  
   - role for background SST, Indian Ocean  
   - challenge for CGCMs (climate drift)