The Role of Atmosphere Feedbacks During ENSO: AMIP Results

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1. Motivation
- General Circulation Models (GCMs) still have trouble simulating the observed frequency, structure and amplitude of the El Niño-Southern Oscillation (ENSO) phenomenon.
- Recent work (Guilyardi et al., 2004, 2009) suggests that the atmosphere plays a dominant role in determining the properties of ENSO.
- The work described here builds on this by analyzing the two main ENSO-relevant ocean-atmosphere feedbacks in 9 AMIP runs (1980-1998) from the CMIP3 multimodel dataset.
- We use a simple approach based on linear ENSO theory to help understand model biases.

2. ENSO Ocean-Atmosphere Feedbacks
There are two main ocean-atmosphere feedbacks relevant to ENSO:
- Dynamical (Bjerknes) feedback: \( \tau_x = \mu T' \)
  Positive feedback (\( \mu \)) linking zonal surface wind stress (\( \tau_x \)) and SST (\( T' \)) anomalies.
- Thermodynamical feedback: \( Q = \alpha T' \)
  Negative feedback (\( \alpha \)) linking total surface heat flux (\( Q \)) and SST anomalies.

These feedbacks are diagnosed by linearly regressing the relevant variables:

(a) \[ \mu \sim 12 \times 10^{-3} \text{Nm}^{-1} \text{C}^{-1} \]

(b) \[ \alpha \sim -19 \text{Wm}^{-2} \text{C}^{-1} \]

3. The Feedbacks in the AMIP Runs

a) \( \mu \) and \( \alpha \): AMIP vs. coupled
Both feedbacks are improved in the AMIP runs compared to the coupled runs.
- \( \mu \) in the AMIP runs exhibits no clear bias with respect to ERA40 but is generally stronger than in the coupled runs.
- \( \alpha \) is still underestimated in the AMIP runs.

b) Splitting up the net \( \alpha \) feedback
The total heat flux is made up of four components: shortwave (SW), longwave (LW), latent heat (LH) and sensible heat (SH) fluxes. Each individual flux feedback is calculated in Niño 3 for the AMIP runs:
- The LH and SW components dominate, but the shortwave component, \( \alpha_{SW} \), exhibits the most variation between models.
- However, improvements in \( \alpha_{SW} \) are most responsible for the AMIP vs. coupled \( \alpha \) differences.

4. Understanding the SW and LH Feedbacks

a) The SW component, \( \alpha_{SW} \)
In most models, \( \alpha_{SW} \) biases are linked to an overly strong low cloud positive feedback in the eastern Pacific, as shown here for the 1997-98 El Niño:

- The dynamical response (\( \omega_{SW} \)) is generally better represented than the cloud response.
- Analysis of cloud radiative forcing in the East Pacific (not shown) suggests that errors in both the amount and optical thickness of low clouds play a role in the \( \alpha_{SW} \) biases.

b) The LH component, \( \alpha_{LH} \)
The latent heat flux anomaly can be represented by:

\[ F_{LH} = L \cdot C_\rho \left( U \Delta q - \Delta Lh \Delta q_{SC} \right) \]

\( L, C_\rho \) and \( \rho \) are constants. \( U \sim \) near-surface wind speed, \( \Delta q = \) near-surface specific humidity difference, \( SC = \) seasonal cycle.


5. Conclusions
- The two feedbacks, \( \mu \) and \( \alpha \), are generally improved in the AMIP runs compared to the coupled runs.
- The SW component of the heat flux feedback, \( \alpha_{SW} \), is the main source of model diversity in the overall \( \alpha \).
- AMIP runs tend to have an overly strong positive SW feedback in East Pacific, linked to cloud biases.
- The negative LH feedback in the East Pacific is driven by changes in the near-surface specific humidity difference and is thus a thermodynamical feedback. This is well simulated by the models.

6. References