The Role of Atmosphere Feedbacks During El Niño

James Lloyd*1, Eric Guilyardi1, Julia Slingo2, Hilary Weller1, Adam Scaife2

1 NCAS Climate, Department of Meteorology, University of Reading, UK
2 Met Office, Exeter, UK

*Email: j.b.b.lloyd@reading.ac.uk

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, 2008) 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 the WCRP CMIP3 multimodel dataset. Can differences in the modelled feedbacks help explain the diverse ENSO simulation in models?

2. ENSO Ocean-Atmosphere Feedbacks

There are two main ocean-atmosphere feedbacks relevant to ENSO:

• Dynamical (Bjerknes) feedback: \( rA = \mu SSTA \)
  Positive feedback (\( \mu \)) linking zonal wind stress (\( rA \)) and SST anomalies (SSTA).

• Thermodynamical feedback: \( QA = \alpha SSTA \)
  Negative feedback (\( \alpha \)) linking total surface heat flux (QA) and SST anomalies.

These feedbacks are diagnosed in GCMs by linearly regressing the relevant variables:

(a) Annual averages of \( \mu \) and \( \alpha \) in Niño3 region:

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

(b) Relationship to ENSO strength:

The relationship of \( \alpha \) to the ENSO strength (measured by the SST Niño 3 standard deviation) shows that the models with strongest damping have the weakest ENSO, whereas those with the weakest damping generally exhibit a stronger ENSO.

4. Understanding the \( \alpha \) Feedback

(a) Splitting up the net feedback

The total heat flux can be separated into four components: shortwave radiation (SW), longwave radiation (LW), latent heat flux (LH) and sensible heat flux (SH). The individual feedbacks are calculated for each of these in the Niño3 region:

\[ \alpha = -19 \text{ Wm}^{-2} \text{C}^{-1} \]

(b) The SW component, \( \alpha_{SW} \)

In the East Pacific the sign of \( \alpha_{SW} \) depends on the large-scale circulation, with a negative feedback in areas of ascent and a positive feedback in subsident regimes. (R & C, 1991; Philander et al., 1996) By binning the vertical velocity at 500hPa (\( w_{500} \)) according to SST we have calculated the Niño3 'ascent threshold' for each model, the average SST above the mean state at which ascent occurs.

5. Conclusions

• The heat flux feedback, \( \alpha \), can be related to the ENSO amplitude in the models.
• The SW component could help explain the model diversity in both overall \( \alpha \) and ENSO amplitude.

Next steps:

• Look for links between the feedbacks and the mean state biases in the models.
• Understand the dynamical \( \mu \) feedback, especially the relationship with ENSO amplitude.

6. References

• Philander, G., Gu, D., Halpern, D., et al., 1996. J. Climate, 9, 2958-2972