ENSO Radiative Feedbacks and their Possibility as an Emergent Constraint

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The Pattern Effect

\[ ECS = -\frac{F_{2x}}{\lambda} \]

\[ (\lambda_{eq}) \]

\textbf{abrupt-4xCO2}

\[ \text{Surface T} \]

\[ \text{Equilibrium} \]

\[ \text{Historical (1870)} \]

\[ \text{Difference} \]
Emergent constraint:

physically-explainable relationship between intermodel variations in some current *observable* climate quantity and future projections of it can be combined with an observational estimate to constrain the future projections.
ENSO – A Pattern Effect Analog?

CMIP6

* Pattern Effect: \( \Delta \lambda \) \([W/m^2/K]\)
* ENSO Feedback: \( \lambda_{ENSO} \) \([W/m^2/K]\)

**All Sky** \( r = 0.82 \)
**Net CRE** \( r = 0.93 \)
ENSO – A Pattern Effect Analog?

- **Introduction**
- **Results**
- **Summary**
- **Future Work**

**Pattern Effect (Δλ) \[\text{W/m}^2/\text{K}\]**

**ENSO Feedback (λ_{ENSO}) \[\text{W/m}^2/\text{K}\]**

- CMIP6
- Obs. ENSO
- Obs. Pattern Effect

![Graph showing the relationship between Pattern Effect and ENSO Feedback](image)

All Sky (r = 0.82)
Net CRE (r = 0.93)
ENSO – A Pattern Effect Analog?

\[ \Delta \lambda = \text{Strong EP} \quad \Delta \lambda = \text{Strong CP} \quad \Delta \lambda = \text{Weak} \]

\[ \lambda_{\text{ENSO}} = \text{Strong EP} \quad \lambda_{\text{ENSO}} = \text{Strong CP} \quad \lambda_{\text{ENSO}} = \text{Weak} \]

\[ \lambda_{\text{CERES}} = \text{Strong EP} \quad \lambda_{\text{CERES}} = \text{Strong CP} \quad \lambda_{\text{CERES}} = \text{Weak} \]

Introduction · Results · Summary · Future Work
Observational Radiation Patterns

EP and CP ENSO SSTs

Introduction · Results · Summary · Future Work
Observational Radiation Patterns

- All-Sky ENSO pattern dominated by net cloud.
- Low cloud CRE contributes most in tropical and midlatitude EP.
- High cloud CRE contributes most near warm pool and equatorial CP.
- Clear-Sky largely only modulates cloud response.

EP and CP ENSO SSTs

Cloud Controlling Factors (CCFs)

Introduction • Results • Summary • Future Work
Observational Radiation Patterns

EP and CP
ENSO SSTs

Cloud Controlling Factors (CCFs)

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Observational Radiation Patterns

Introduction

Results

Summary

Future Work

Ceppi & Fueglistaler (2021)
Observational Radiation Patterns

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Lapse Rate

W/m²/°

Lag (month)

EP ENSO

CP ENSO

WV (LW)
Summary

• ENSO is a potential emergent constraint on the pattern effect
  • ENSO feedbacks have strong linear relationships with pattern effects in 8 CMIP6 models
  • Model pattern effects appear to have similar spatial diversity as their ENSO feedbacks (CP vs EP)

• Low cloud radiative feedbacks drive the spatial pattern and evolution of ENSO TOA variability
  • Low cloud feedbacks evolve in-phase with EP ENSO SST patterns but out-of-phase with CP ENSO SST patterns
  • Driven by atmospheric destabilization for EP patterns, but changes in atmospheric stability, SSTs, and warm air advection contribute to CP patterns

• Clear-sky radiation helps modulate low cloud feedbacks following peak CP ENSO SST anomalies
  • The clear-sky feedback evolution in both modes is driven by a balance between water vapor and lapse-rate feedbacks, with lapse-rate “winning out” for CP patterns
Future Work

• Fully understand the physics and dynamics linking ENSO feedbacks to the pattern effect
  • Will need more models running amip-piForcing simulations
  • CERES-MIP to partition model cloud radiative fluxes into low/high clouds, include larger period of record
  • Maybe use ERBE to extend CERES backward to include more ENSO events in observational study?

• Evaluate the impacts for ECS
Thank You!
Questions?