Subtropical Clouds Key to Southern Ocean Teleconnection to the Tropical Pacific

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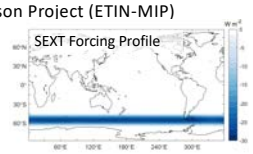
Introduction

- ✓ Southern Ocean warm bias has been suggested to cause the double ITCZ bias through teleconnection based on inter-hemispheric energetics.
- ✓ Models disagree on the quantitative importance of the remote Southern Ocean contribution to the double ITCZ bias.
- ✓ We investigate the Southern Ocean-driven teleconnection mechanism and the cause for the inter-model differences in the teleconnection efficiency.

Data and Methods

Extratropical-Tropical Interaction Model Inter-comparison Project (ETIN-MIP)

- ✓ 8 fully coupled models
- ✓ Control simulation: Pre-industrial run
- ✓ Perturbed simulation: Solar insolation reduction between 45°S-65°S by 0.8 PW
- ✓ Averaged response over year 101-150



Teleconnection from Southern Ocean to Tropical Pacific

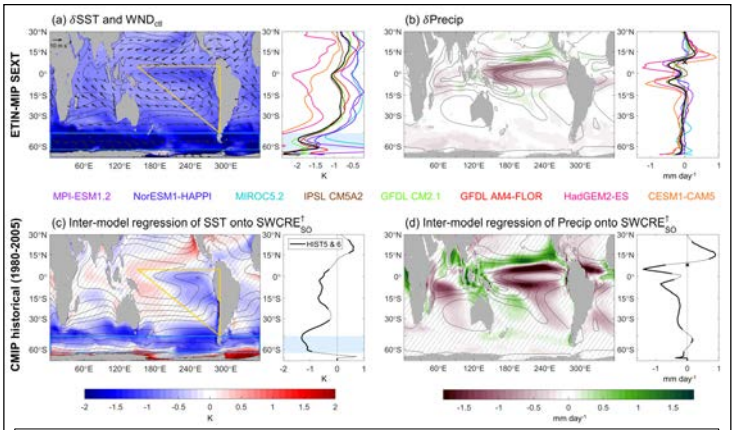


Fig.1. MMM responses in (a) SST and (b) precipitation for the ETIN-MIP SEXT simulations. Inter-model regression of the annual mean (c) SST and (d) precipitation onto the upward SWCRE over 65°S-45°S using historical simulations of 39 CMIP5 and 52 CMIP6 models (1980-2005). Right panels show the eastern Pacific average, with MMM in black for ETIN-MIP results.

- ✓ Southern Ocean cooling induces a triangular cold patch over the South Pacific and displaces the eastern Pacific ITCZ northward, alleviating double ITCZ problem (Fig. 1).
- ✓ Large inter-model diversity in the teleconnection efficiency (right panels of Fig. 1a,b).

Teleconnection Mechanism

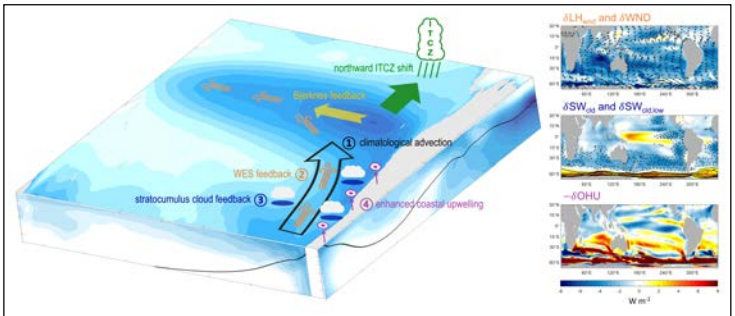


Fig.2. Schematic of Southern Ocean-to-tropics teleconnection mechanism. The Southern Ocean cooling propagated into the subtropics by the atmospheric eddies and oceanic Ekman transport is ① further advected equatorward by the climatological southeasterlies (black arrow) west of South America. The southeastern Pacific cooling is amplified by the interactions between ② wind-evaporation-SST (WES) feedback, ③ subtropical stratocumulus cloud feedback, and ④ coastal upwelling. The eastern equatorial Pacific cooling is further intensified via the Bjerknes feedback. As a consequence, the triangular cooling patch extending from the southeastern Pacific to the zonal band across the equatorial Pacific is manifested by the Southern Ocean-driven teleconnection, inducing the northward shift of the eastern Pacific ITCZ.

Inter-model Diversity and Subtropical Cloud Feedback

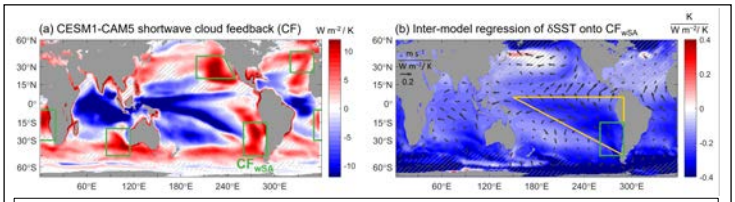


Fig. 3. (a) The shortwave cloud feedback strength (CF) for CESM1-CAM5. The green box indicates the region used to define the subtropical cloud feedback west of South America, CF_{wSA}. (b) Inter-model regression of the SST responses (shading) and surface wind responses (arrows) onto CF_{wSA} in ETIN-MIP SEXT simulation.

- ✓ SW cloud feedback is estimated by regressing de-seasonalized and de-trended SWCRE onto the underlying SSTs at each grid point using 100-yr monthly data of the pre-industrial control simulation (Fig. 3a).
- ✓ Models with stronger subtropical cloud feedback tend to show a larger triangular cooling and more northward eastern Pacific ITCZ shift (Figs. 3b,4a,4b).

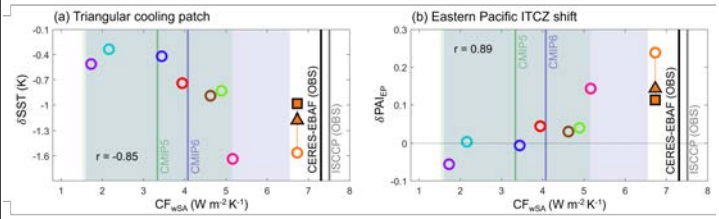


Fig. 4. Relationship between CF_{wSA} versus (a) strength of triangular cooling patch and (b) δPAI_{EP}, the precipitation asymmetry index in the eastern Pacific for ETIN-MIP SEXT simulations. The filled triangle (rectangle) orange symbols indicate the CESM experiment in which clouds are locked west of South America (all major Southern Hemisphere continents). Green (blue) shadings indicate CF_{wSA} for 39 CMIP5 (52 CMIP6) and achromatic vertical lines represent observed estimate of CF_{wSA}.

- ✓ Regional cloud locking experiments clearly demonstrate that the subtropical stratocumulus cloud feedback regulates the teleconnection efficiency (Figs. 4,5).
- ✓ Most climate models underestimate the strength of subtropical cloud feedback, suggesting that teleconnections from Southern Ocean to tropical Pacific are stronger than widely thought.

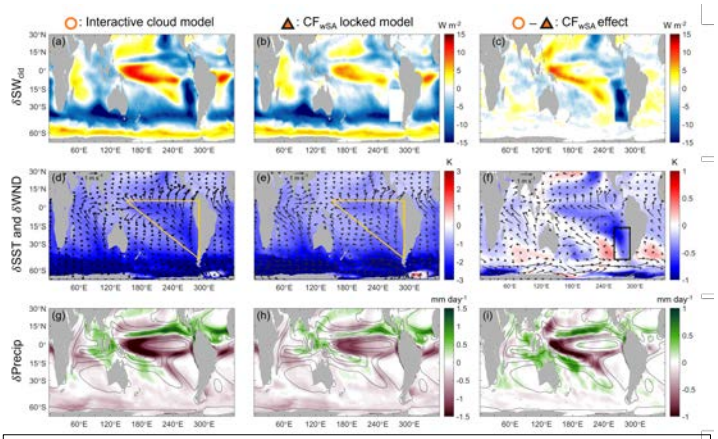


Fig. 5. The response to ETIN-MIP SEXT forcing of (a) shortwave cloud radiative anomalies at the surface, (d) SST (shadings) and surface wind (arrows), and (g) precipitation (shadings) for interactive cloud simulations. (b,e,h) Similar to (a,d,g) but for the simulations with locked clouds west of South America. (c,f,i) The difference between (a,d,g) and (b,e,h), respectively, to quantify the contribution of the amplifying effect of CF_{wSA}.

Summary and Discussion

- ✓ Here, we reveal a teleconnection from Southern Ocean to the tropical Pacific that is mediated by subtropical stratocumulus cloud feedback.
- ✓ The delayed Southern Ocean warming in global warming scenarios would induce a similar teleconnection pattern with a reversed sign.