The Role of Clouds in Shaping Tropical Pacific Sea Surface Temperature Pattern in Response to Extratropical Forcing

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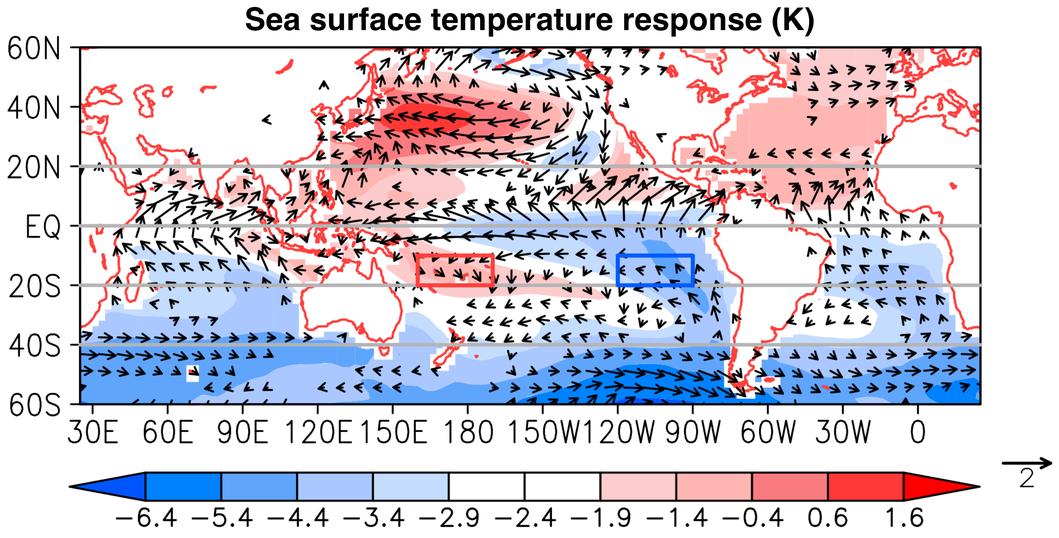
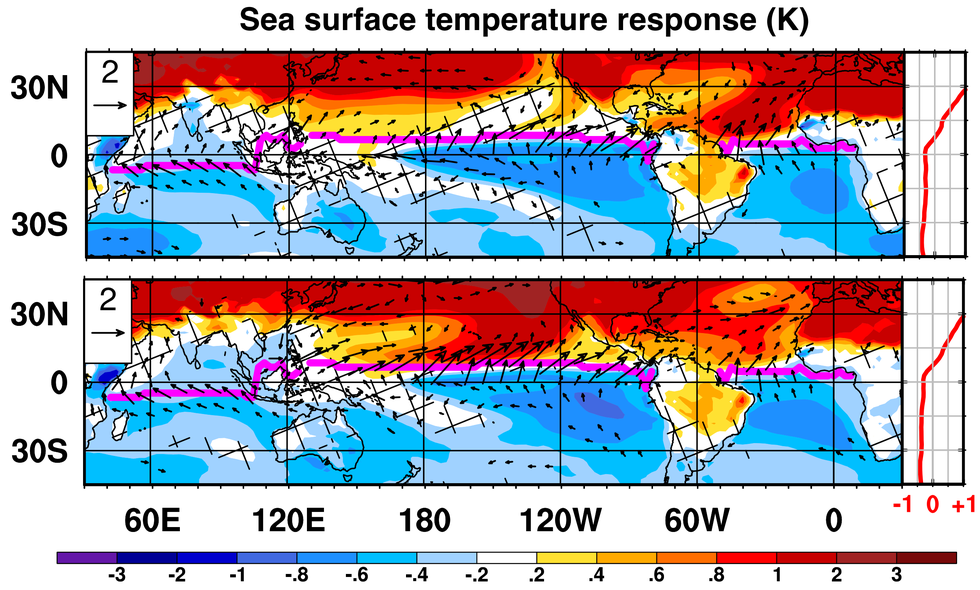
Northern Hemispheric differential heating leads to La Niña-like responses on decadal timescales

Effects of delayed warming in the Southern Ocean (Hwang et al., 2017)



Averaged over years 10-19 from CESM 1 simulations with a slab ocean, forced by 4xCO_2.
The figure shows the difference in SST response: *deepened Southern Ocean* versus *control*.

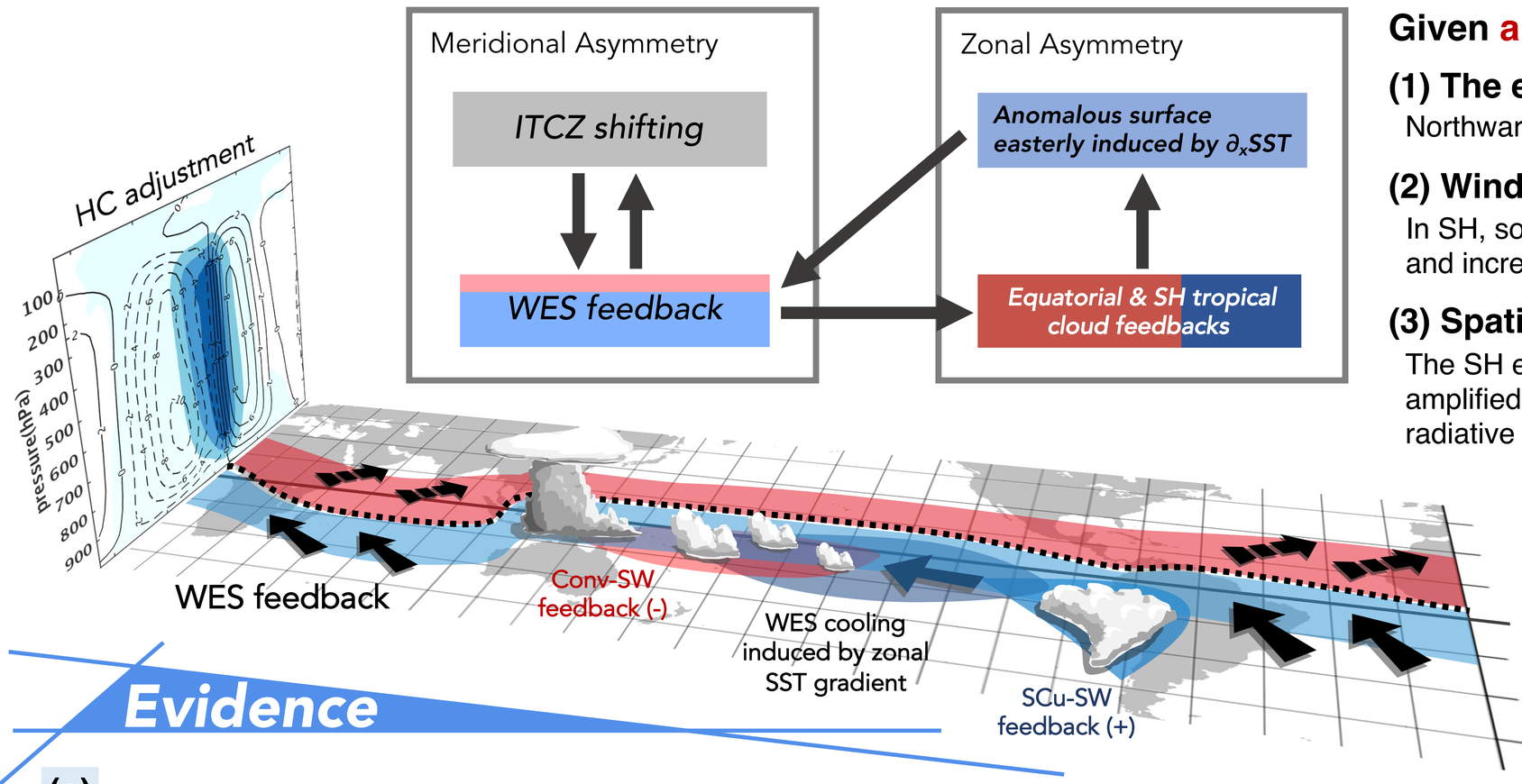
Idealized Warming in the Northern Atlantic and Pacific (Hsiao et al., under revision)



CESM 1 with a slab ocean, forced by *q*-flux.

A feedback loop established by cloud feedbacks, surface wind adjustments & evaporation, and Hadley Cell adjustments:

Climatology control on connecting meridional and zonal sea surface temperature gradients



Given a relatively warm Northern Hemisphere:

(1) The energetic framework of ITCZ position
Northward shifted ITCZ transports excessive heat southward.

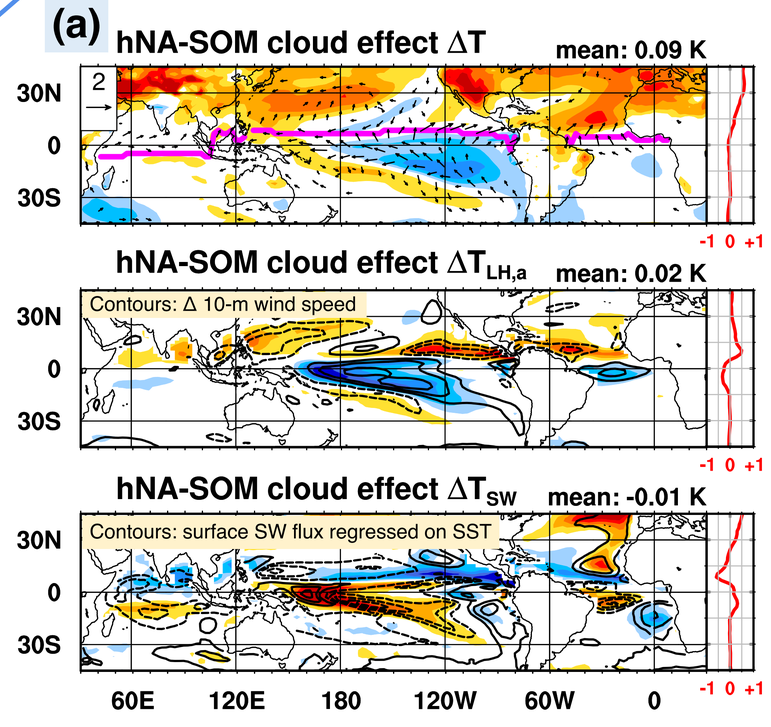
(2) Wind-evaporation-SST feedback
In SH, southeasterly trade winds are strengthened, and increased surface evaporation cools the sea surface.

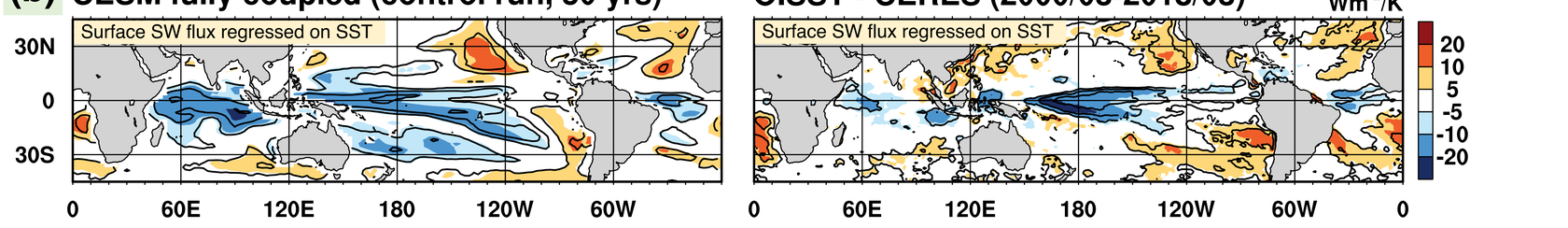
(3) Spatial distribution of cloud types (directly radiative)
The SH evaporative cooling is damped in the west and is amplified in the east in the tropical Pacific by different cloud radiative feedbacks. The zonal SST gradient is strengthened.

(4) Zonal circulation adjustment coupled with cloud feedbacks (indirect cloud feedbacks)
The increased zonal SST gradient by cloud radiative effects further induces stronger surface easterlies, which further cools the sea surface.

(5) Strengthens meridional SST gradient
(4) further strengthens the meridional SST gradient, and this feeds back to (2) and maybe (1).

Evidence

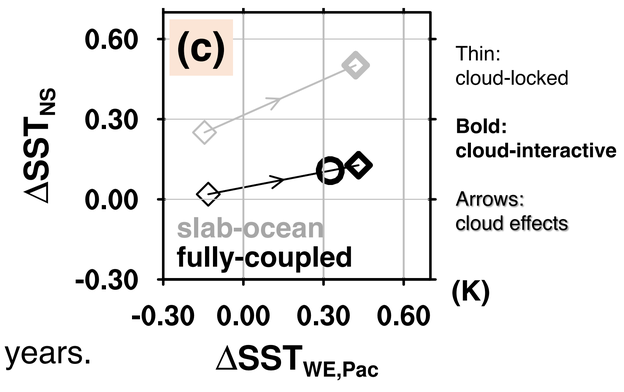




(a) Cloud-locking simulations verify the cloud effects
Radiative effect: strengthens the zonal SST gradient.
Cloud-induced evaporation: strengthens the meridional SST gradient.

(b) Observational evidence
The spatial distribution of **SST - cloud radiative feedbacks** is similar as in CESM1 in observational data (OISST and CERES EBAF).

(c) Similar results with a fully coupled ocean
The conclusion holds in CESM1 coupled with POP2 on timescales < 30 years.



Key points

- Spatial variations of tropical SST change are insensitive to the heating structures in the extratropics on decadal timescales.
- Clouds are essential in forming tropical SST response pattern through their coupling with circulation and surface energy fluxes.
- The climatological rainband position in the tropics determines how clouds shape the tropical responses to extratropical forcing.

Reference

- Hwang, Y.-T., Xie, S.-P., Deser, C., & Kang, S. M. (2017). Connecting tropical climate change with Southern Ocean heat uptake. *Geophysical Research Letters*, 44(18), 9449–9457.
- Hsiao, W.-T., Hwang, Y.-T., Chen, Y.-J., & Kang, S. M. The Role of Clouds in Shaping Tropical Pacific Response Pattern to Extratropical Thermal Forcing. *Under revision*.