On the remote impact of observed Southern Ocean cooling

A pacemaker study

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NCAR

NCAR

CFMIP Oct 2, 2019

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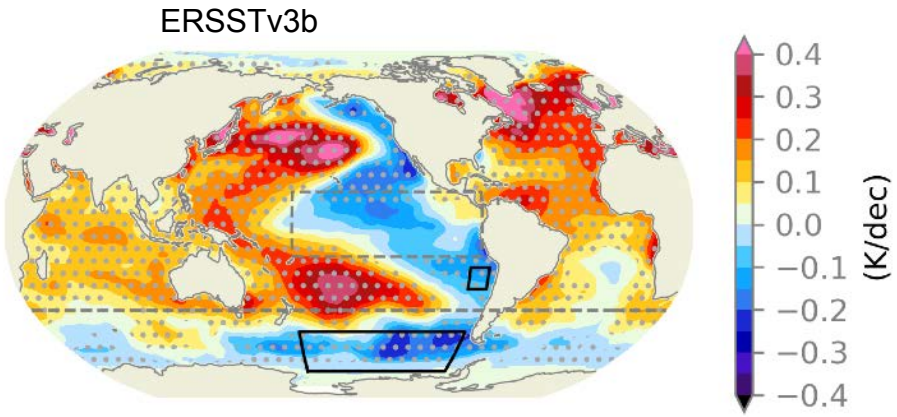
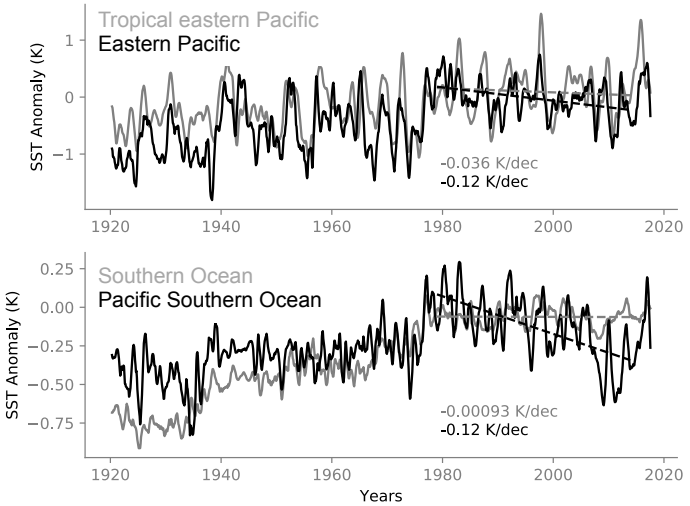
Observed SST trend during satellite era (1979-2013)





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Stippling indicates trends significant above 95% level

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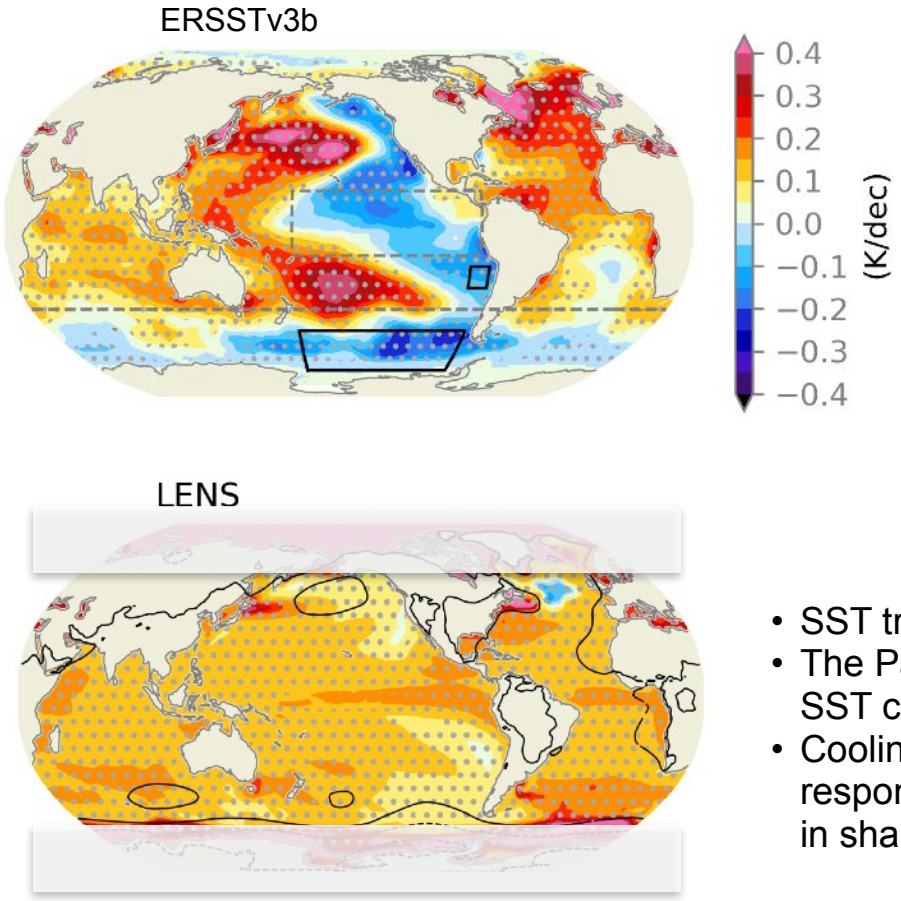

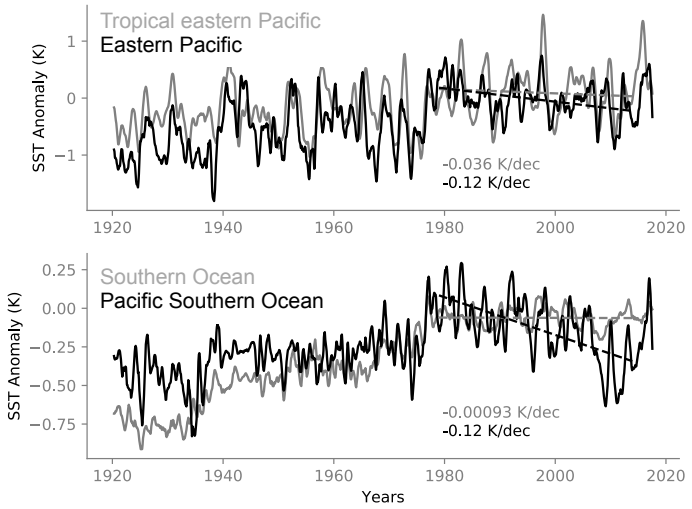

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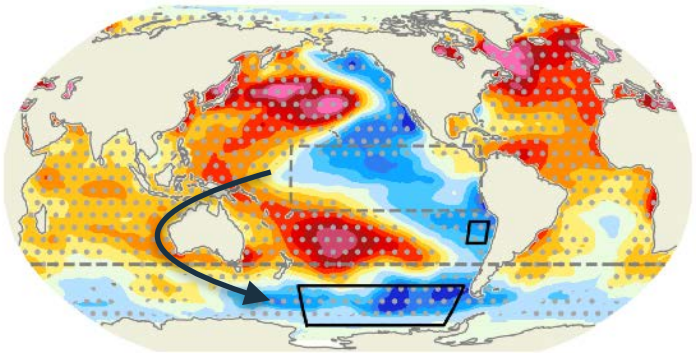

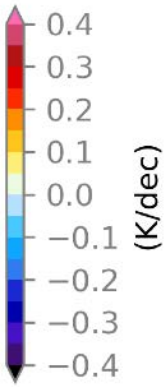

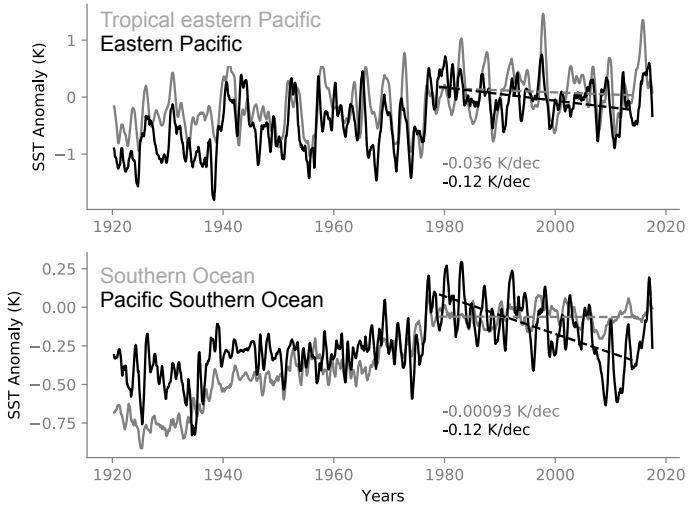

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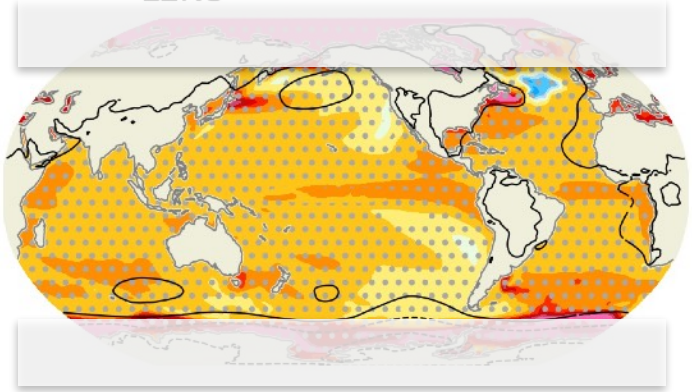

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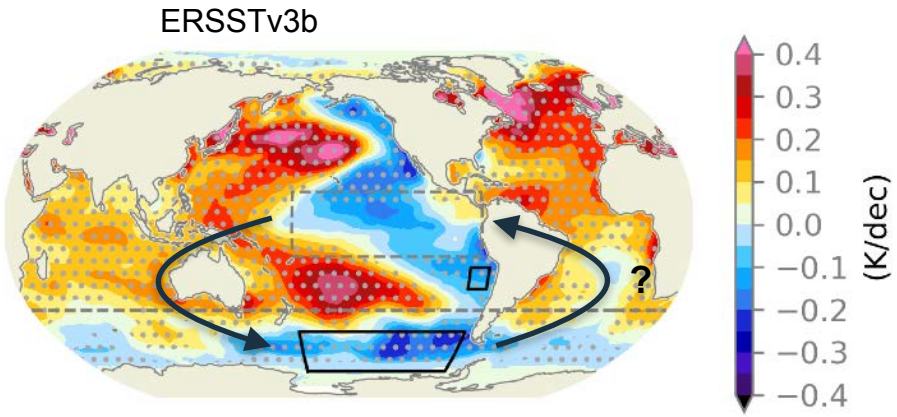

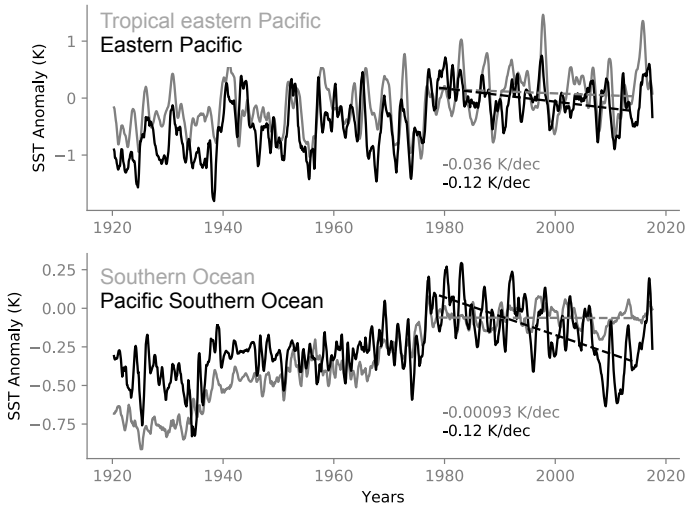

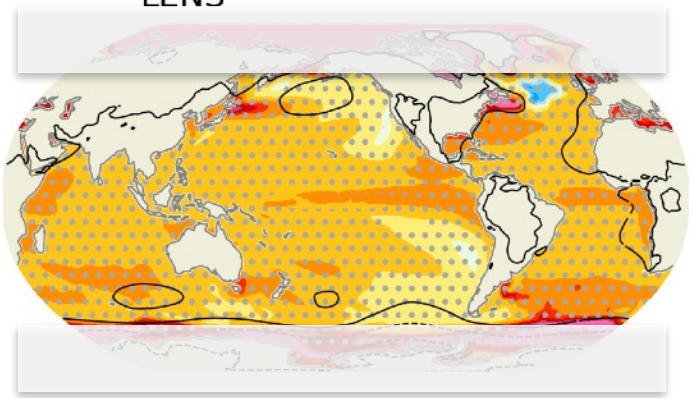

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Teleconnection processes

(Not a comprehensive list…)

Tropics —> Extratropics

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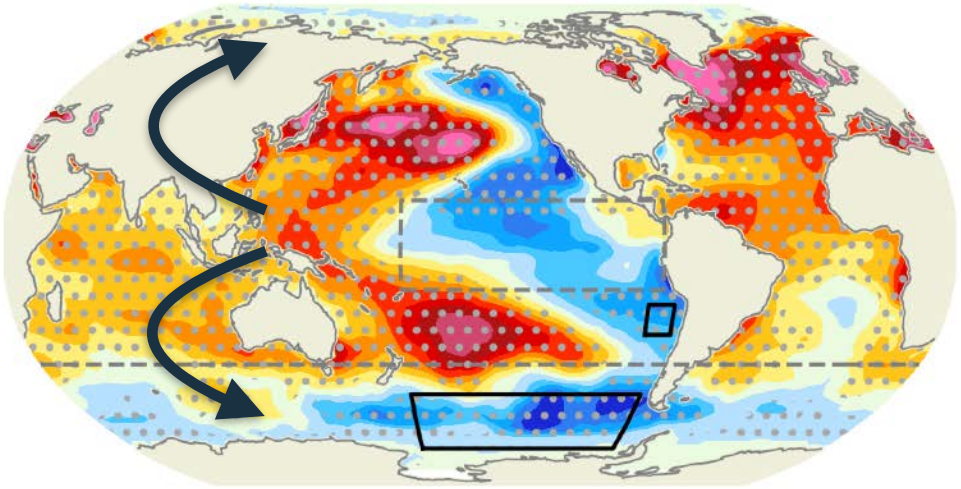

Hadley Cell

Atmospheric Rossby Waves
(e.g. Tropical Pacemaker,
Schneider and Deser, 2018)

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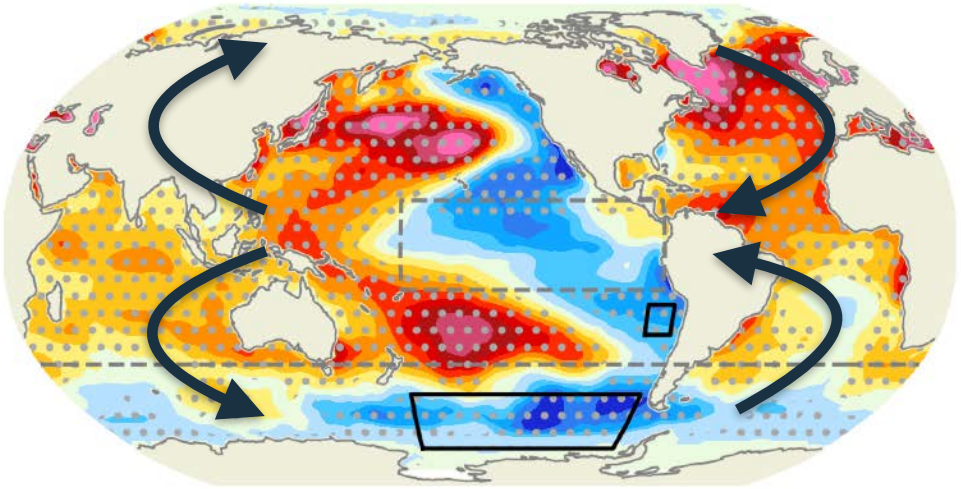

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(e.g. seasonal footprinting mechanism)

Thermohaline circulation

Teleconnection processes

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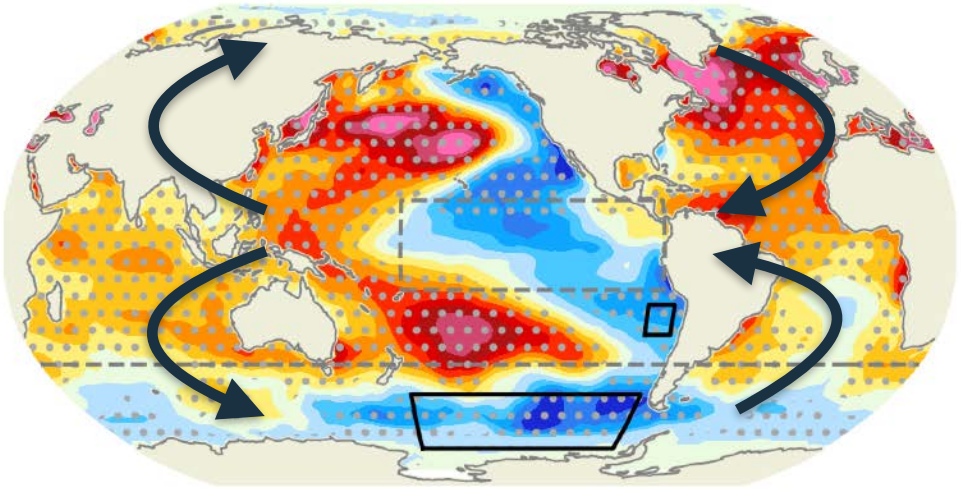

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Ocean Gyre/Subtropical Cell

Wind-SST-Evaporation feedback

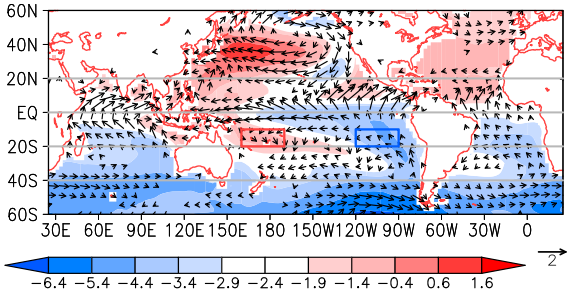
Clouds

Stochastic atmospheric forcing
(e.g. seasonal footprinting mechanism)

Thermohaline circulation

Southern Ocean's effects on global SST pattern

(Idealized and/or strong forcing experiments)



Hwang et al. (2017)

Effect of Southern Ocean heat uptake in slab ocean GCM: Anomalous SST response to CO2 quadrupling shows zonal asymmetry, due to wind-evaporation-SST and cloud feedbacks

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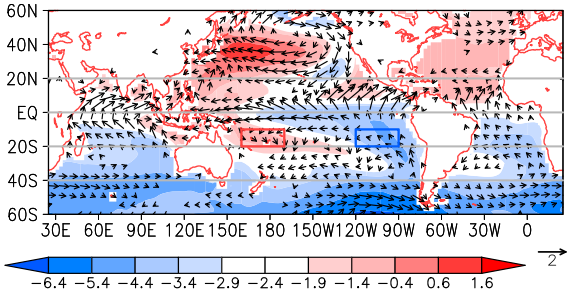

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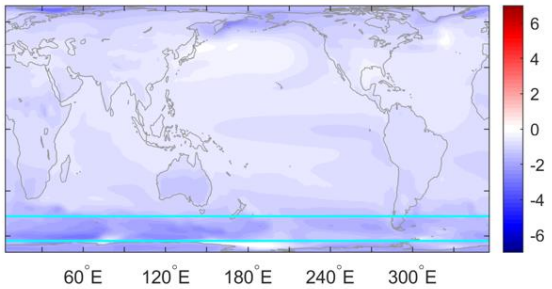
Equilibrium response of SST pattern shows zonal asymmetry; tropical response is damped by sub polar ocean heat uptake



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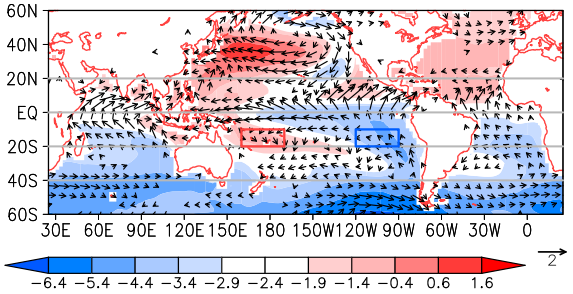

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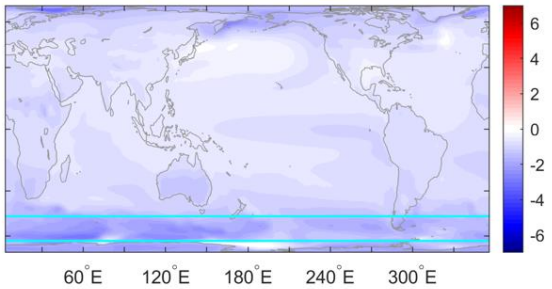

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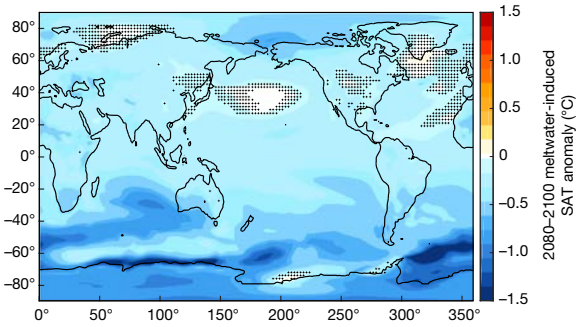

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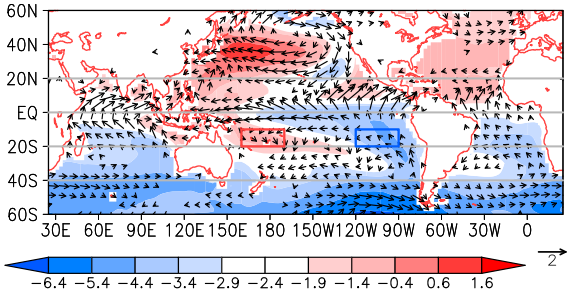

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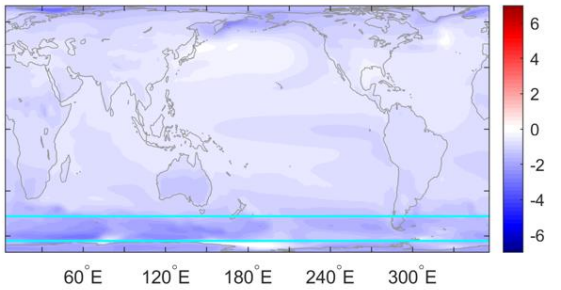

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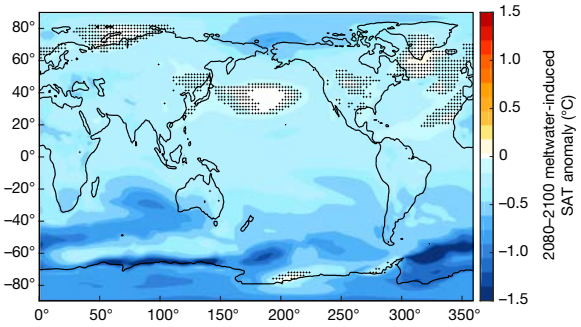

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Effect of Antarctic ice sheet melt in coupled GCM:
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- All studies show more SST cooling on the eastern basins
- Forcing is idealized and/or strong (10s of W/m2)

Does Southern Ocean cooling contribute to SST changes in the subtropics and beyond during the satellite era?

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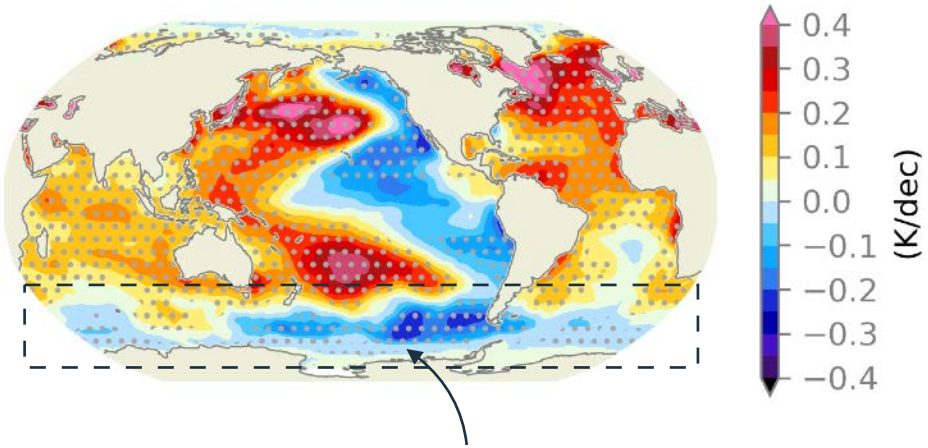
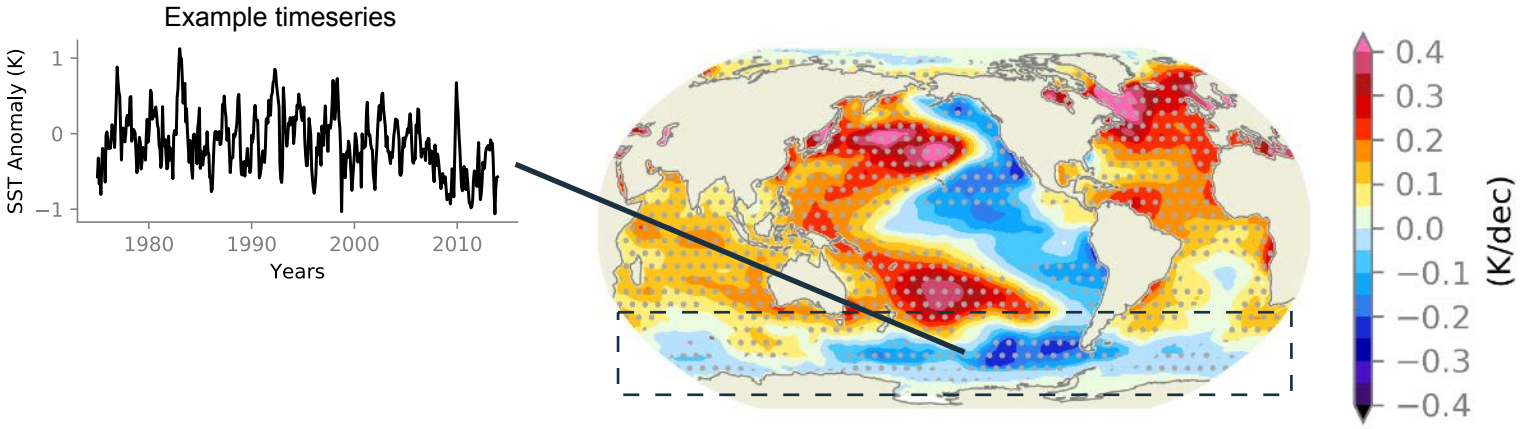


0.3 K/dec SST cooling is equivalent of -0.4 W/m^2 forcing
(not ideal for identifying process…)

Pacemaker setup

- Fully coupled CESM1.1
- 20 ensemble members (branched out from LENS 1st ensemble member at 1975)
- Historical + RCP8.5 forcing

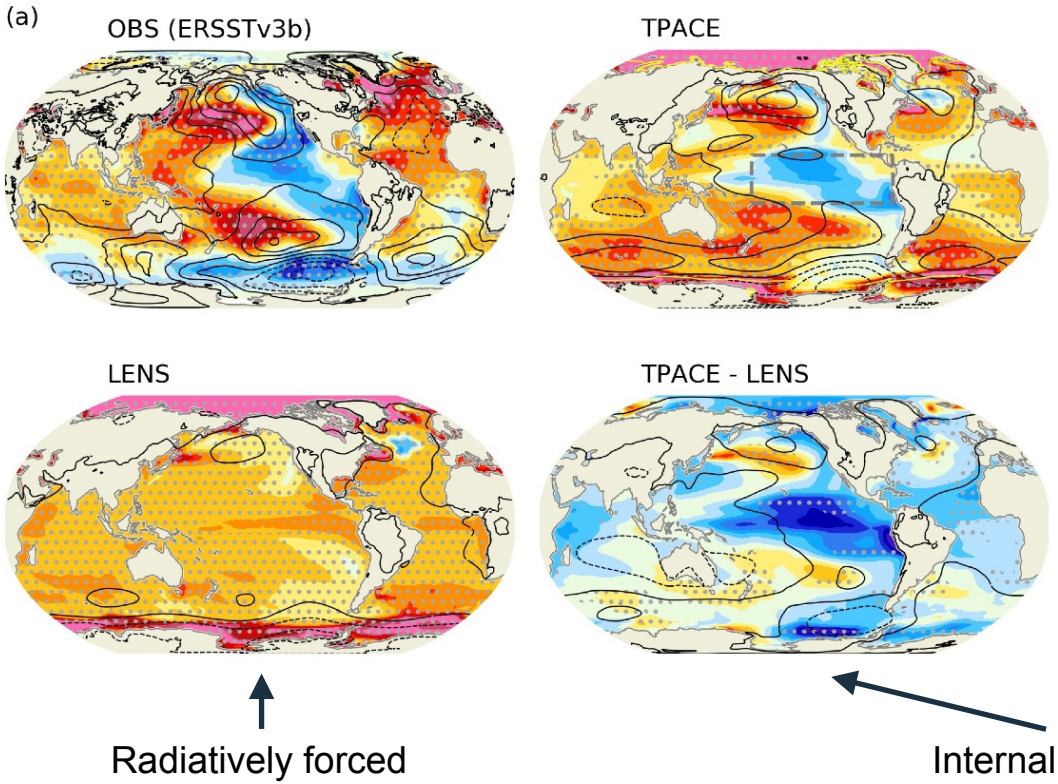


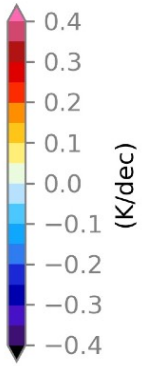
- Southern Ocean SST monthly anomaly is nudged to observations (1975-2013)
- Nudging domain is south of 40 S, with linear buffer zone to 35 S
- In climatological sea ice covered region, SST is nudged to melting temperature (-1.8 C)

Tropical pacemaker experiment results were published by Schneider and Deser (2018).

Kosaka & Xie (2013), Deser et al. (2017)

Ensemble mean surface temperature and sea level pressure trends





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Schneider & Deser (2018); Zhang & Deser (in prep)

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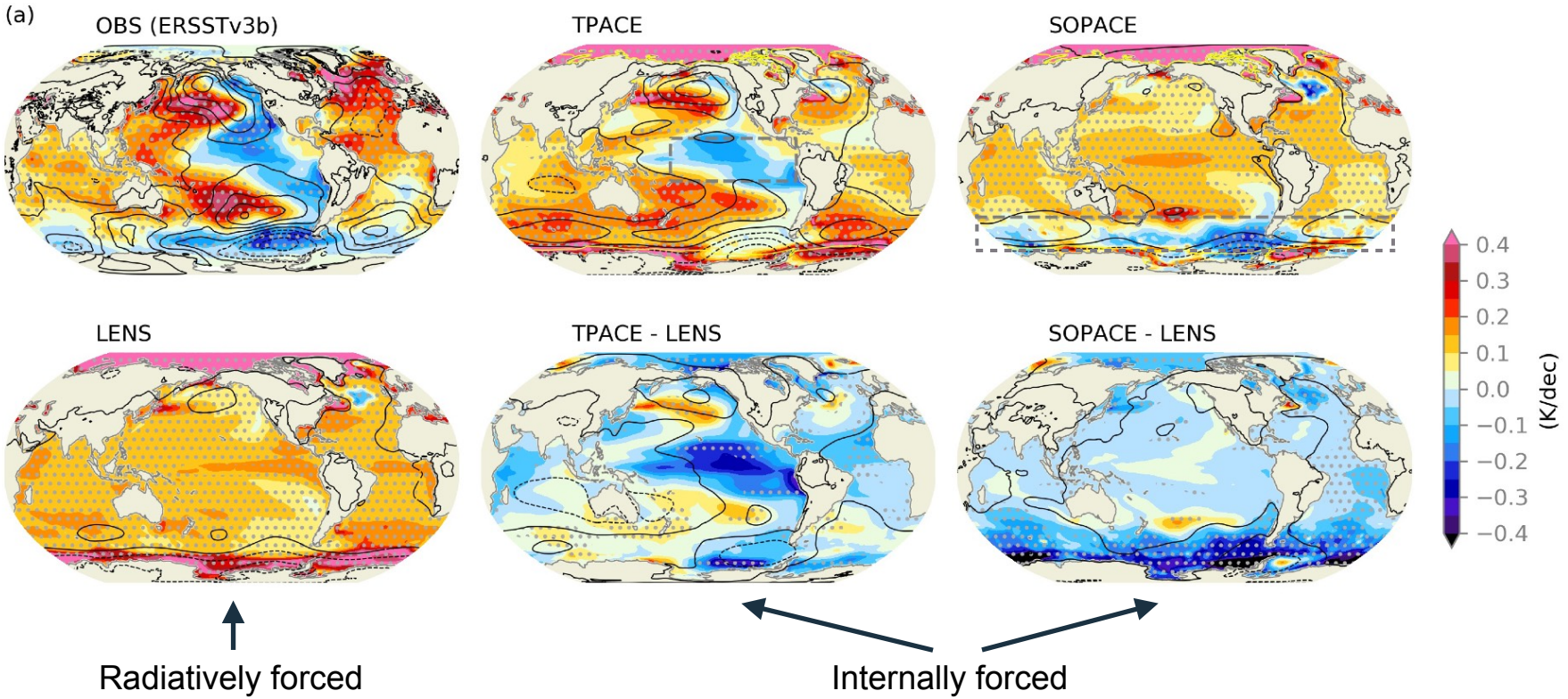

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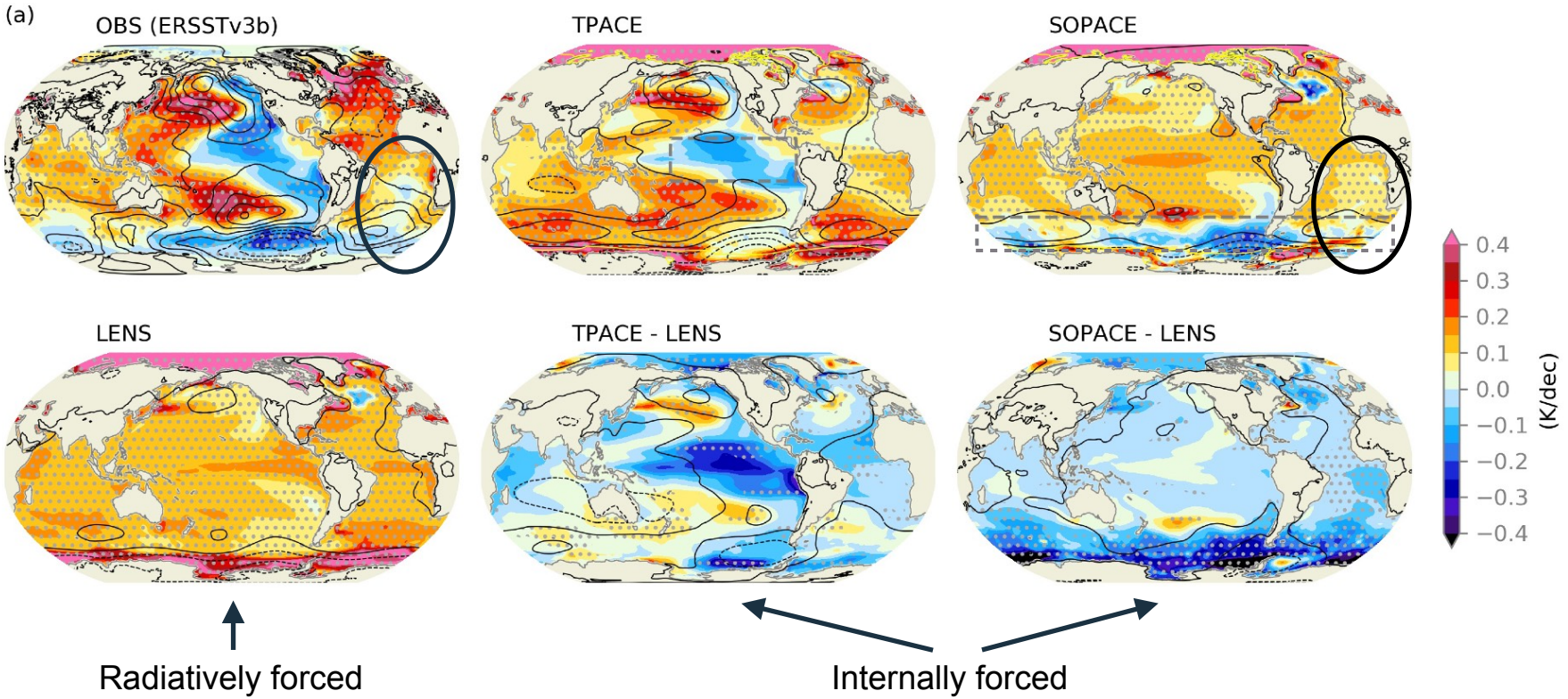

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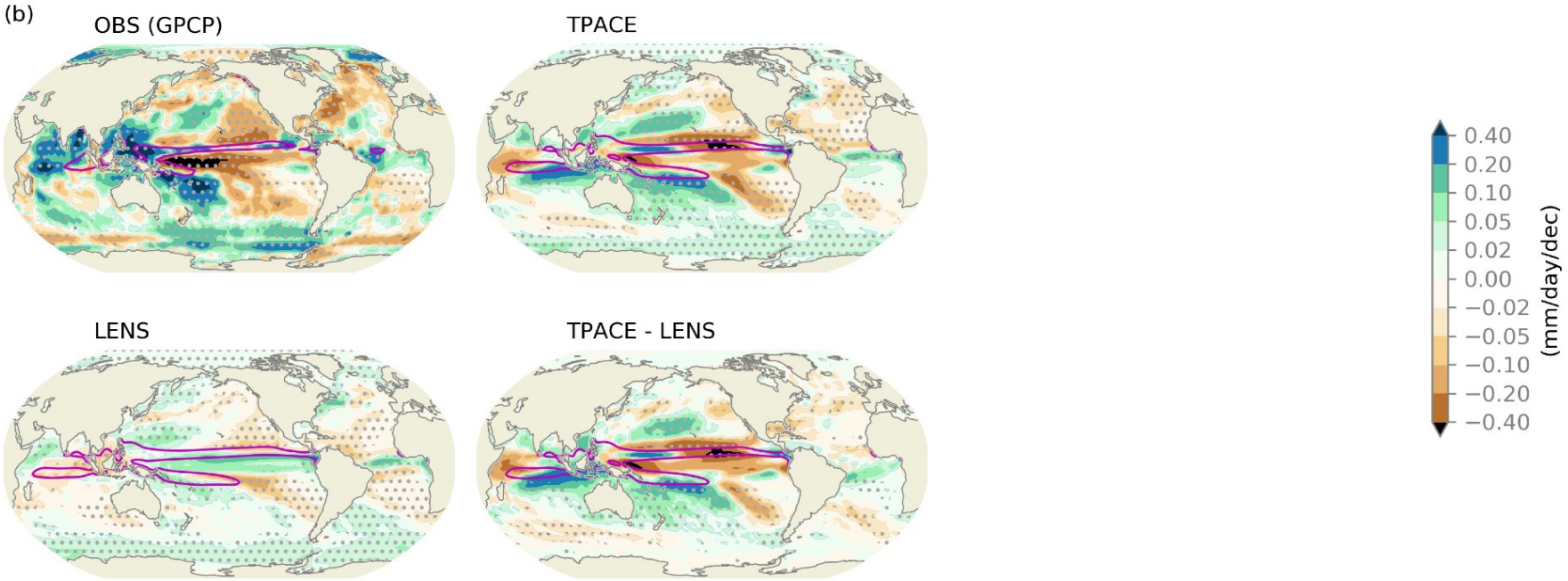

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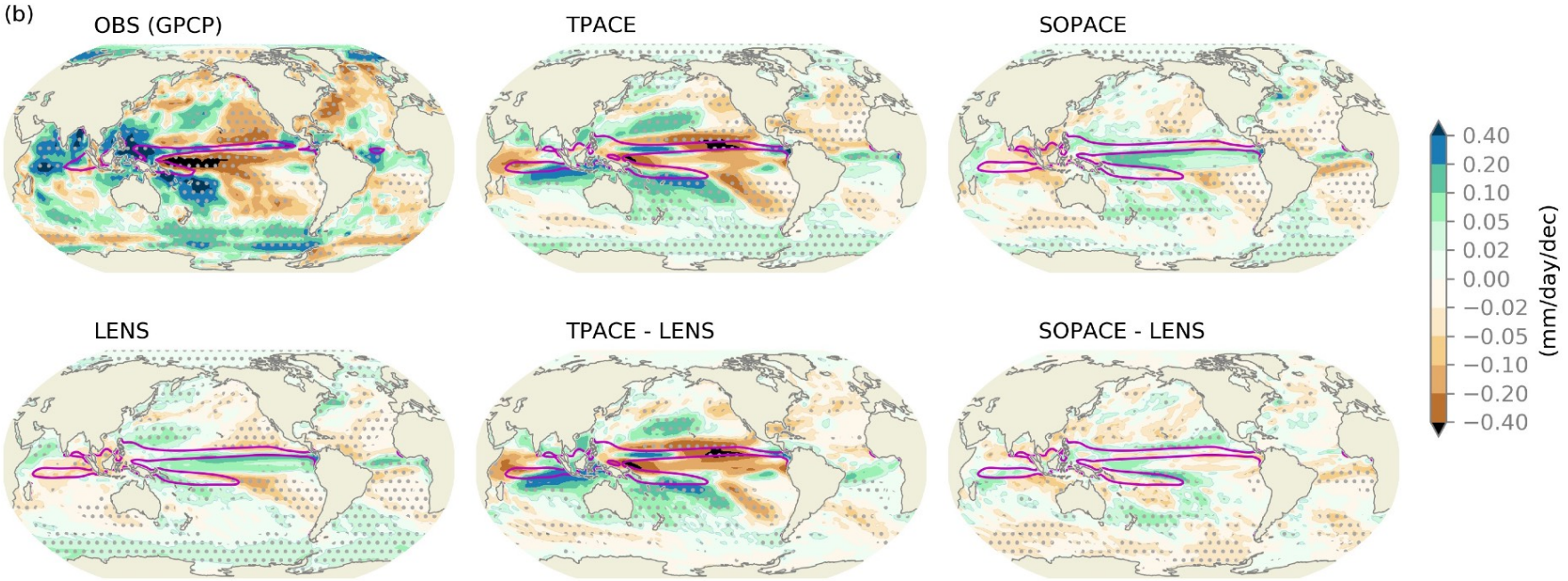

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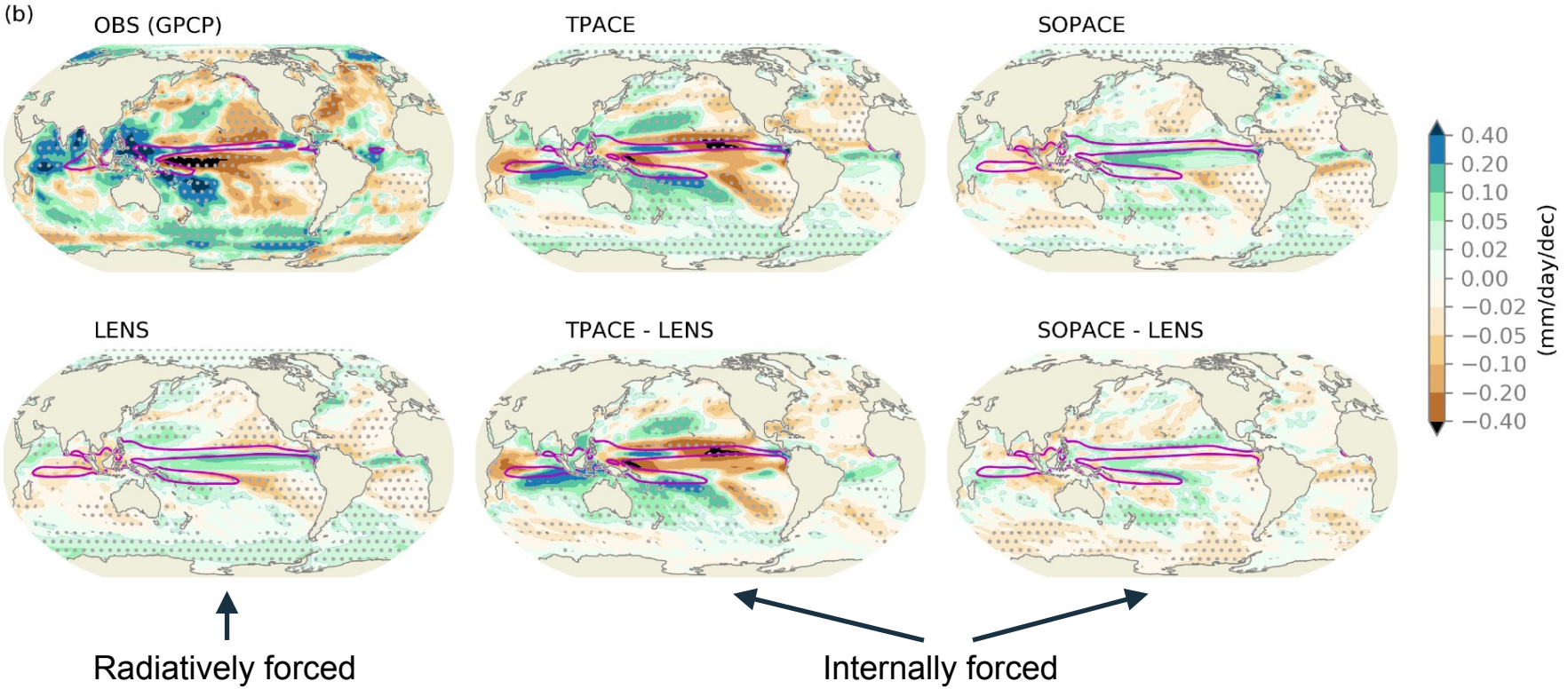

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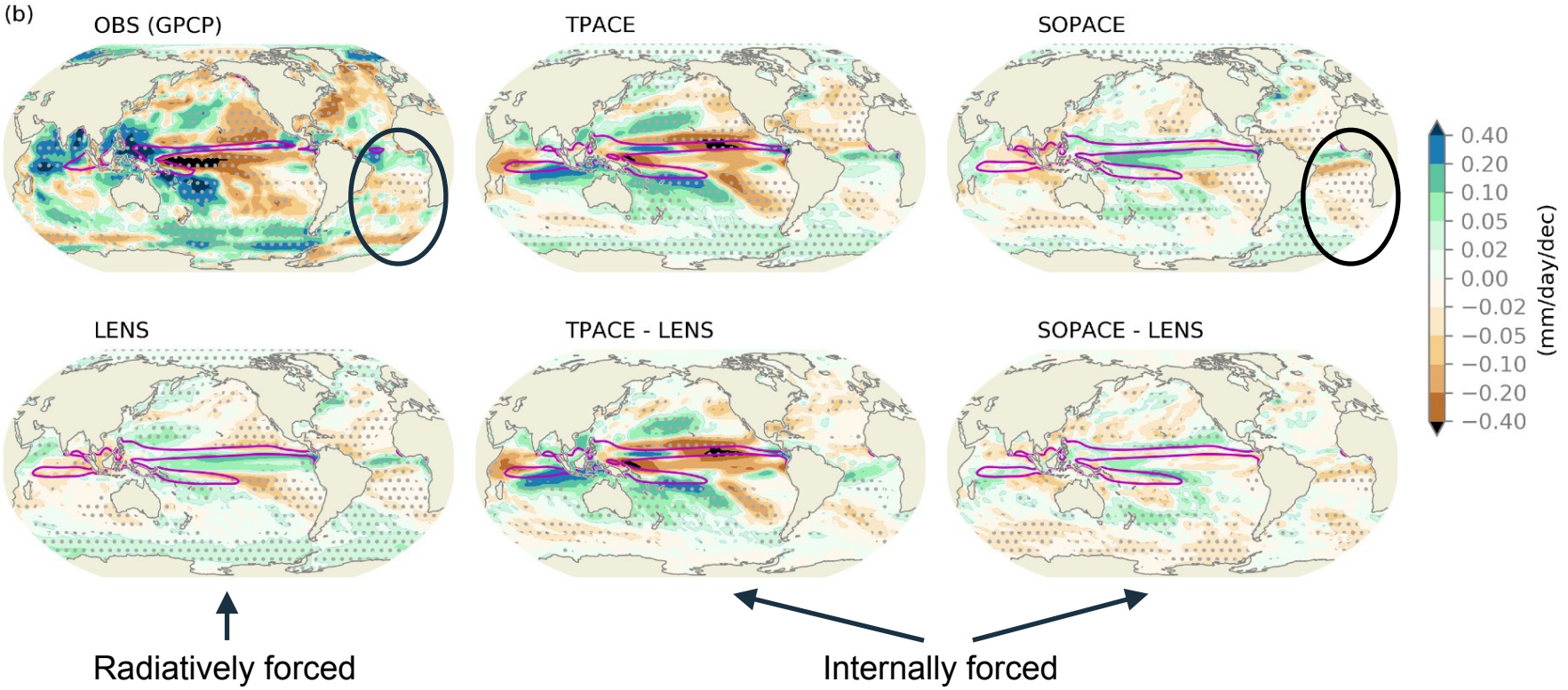

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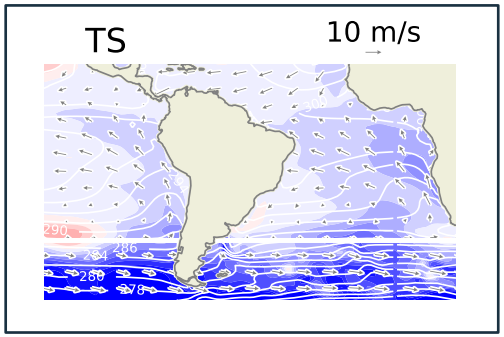
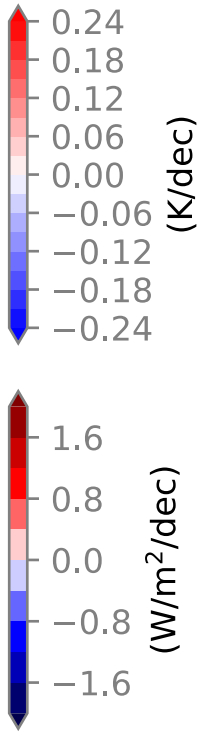
Surface energy budget

Linear trend in SST and surface fluxes





SOPACE (20 ens) ensemble mean linear trend 1979-2013
Contours and vectors show climatological SST and surface winds

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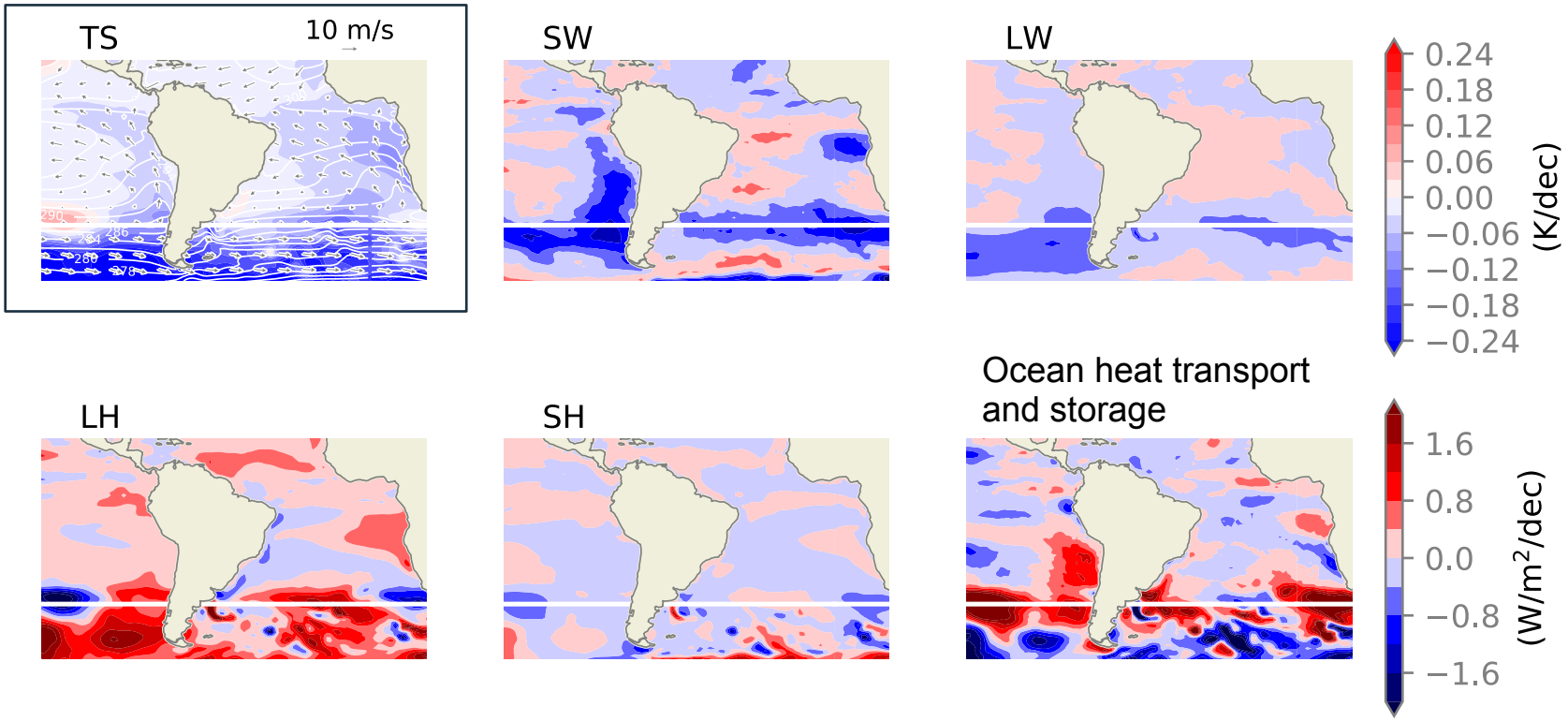

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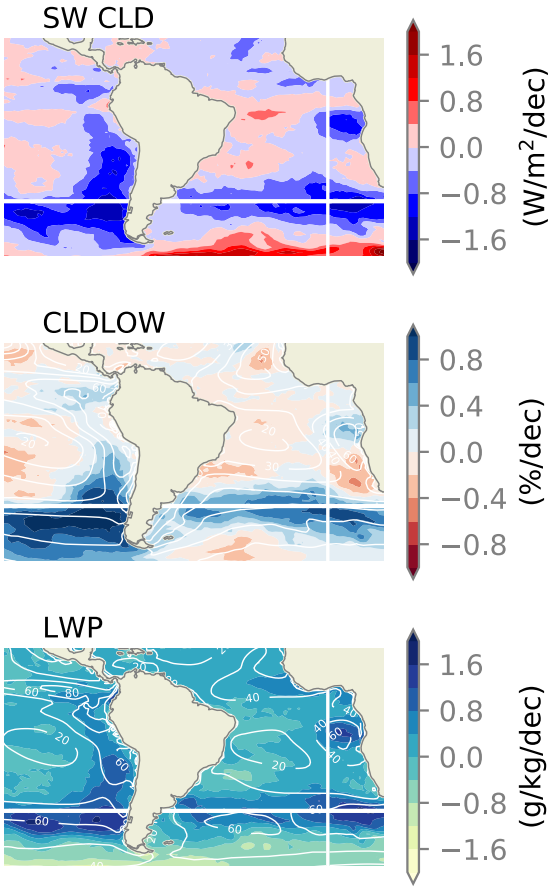
Cooling pattern dominated by cloud changes



- Surface net SW trend is dominated by cloud radiative effect
- Increased low cloud fraction and liquid water path along the eastern Pacific and and Atlantic basins, where climatological values are high

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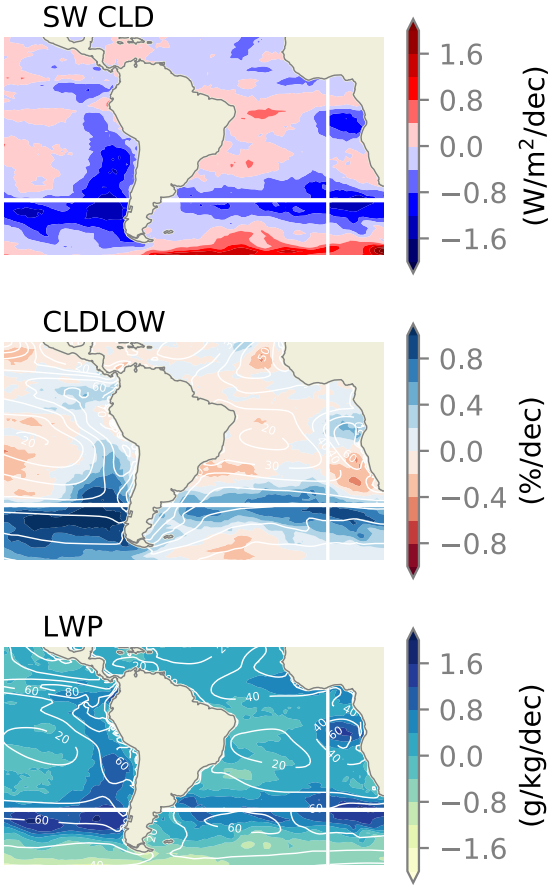

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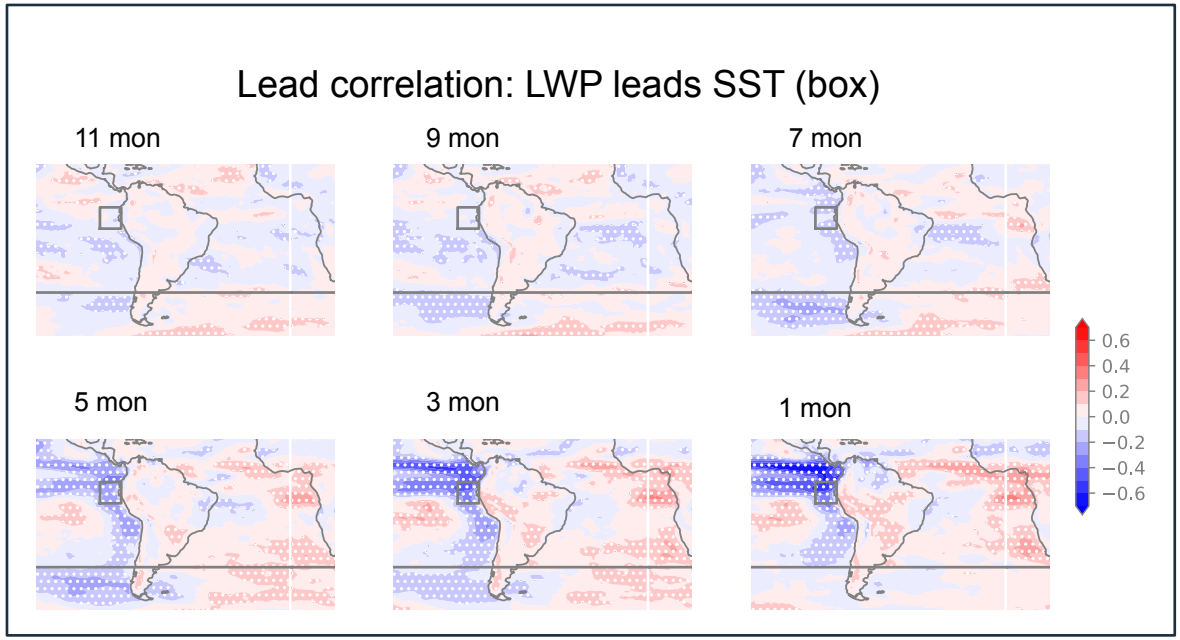

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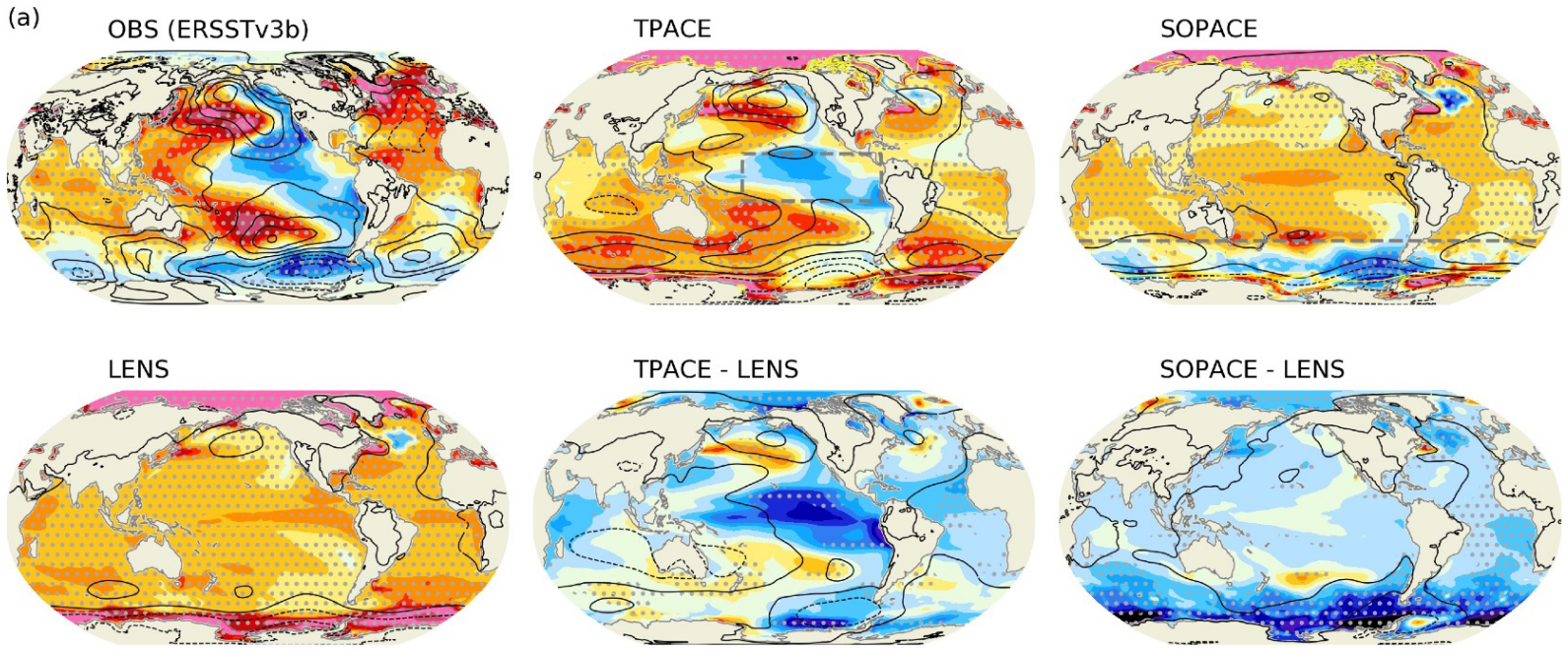

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- An increase in low cloud amount (as opposed to latent heat flux) is found to contribute to the southeastern Pacific and Atlantic cooling

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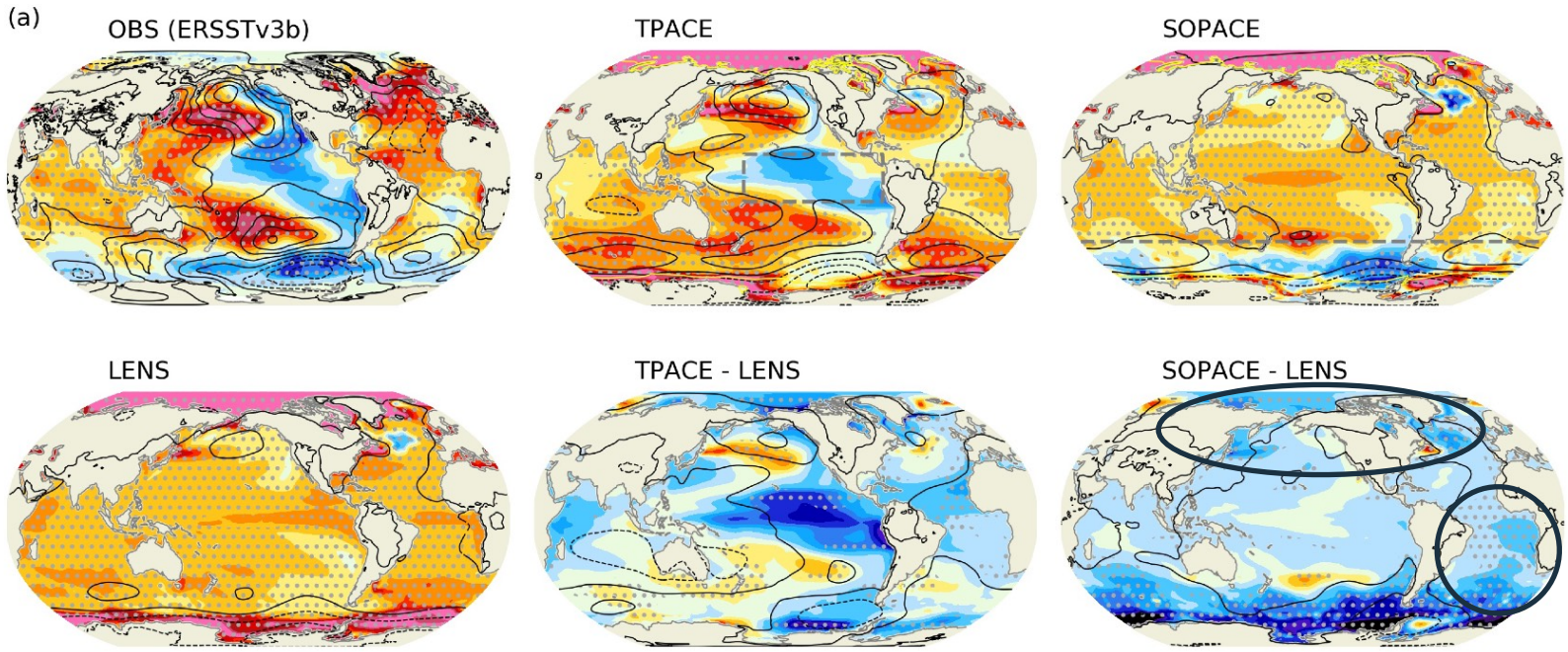

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Additional slides

Diverse ensemble members in SOPACE

#10: **0.59** *

#15: **-0.04** *

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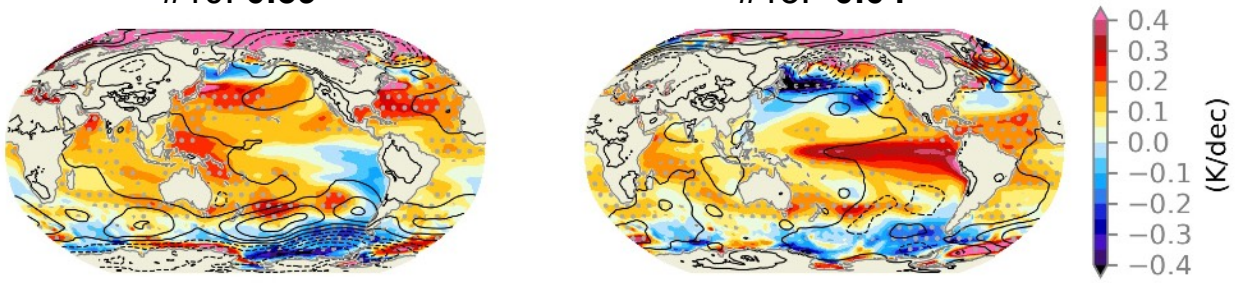
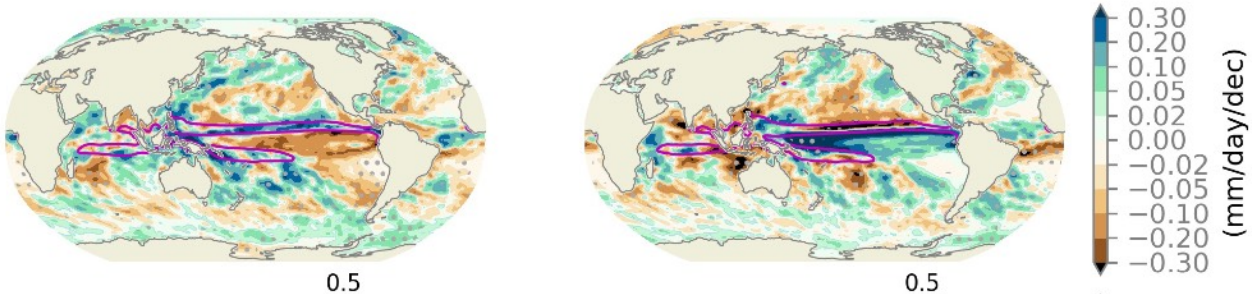
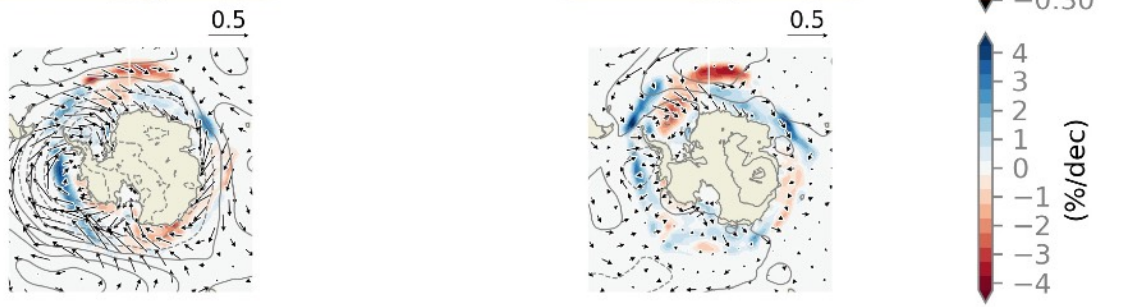


Precipitation trends



Sea ice fraction, sea level pressure, and surface wind trends

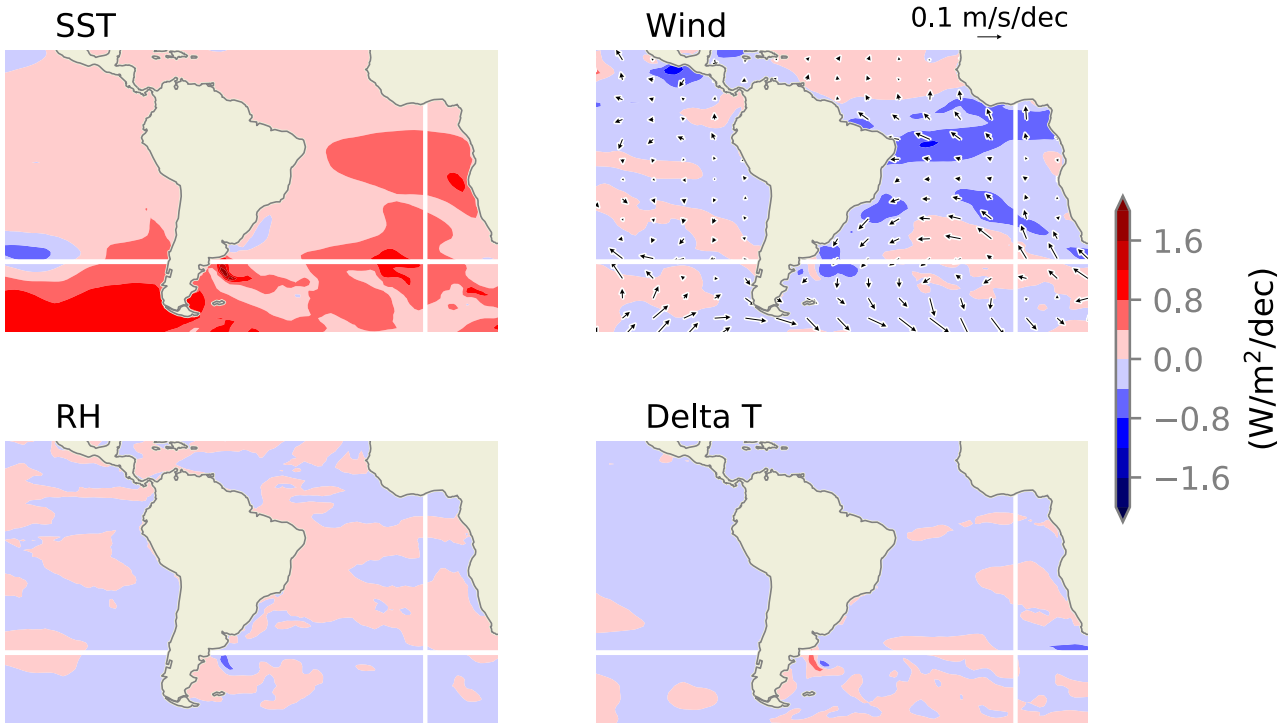


TPACE = Tropical pacemaker (20 ens)
SOPACE = Southern Ocean pacemaker (20 ens)
LENS = CESM Large Ensemble (40 ens)
Stippling indicates trends significant above 95% level

* spatial correlation coefficient with OBS 70S to 70N

Zhang & Deser (in prep)

Decomposing latent heat budget

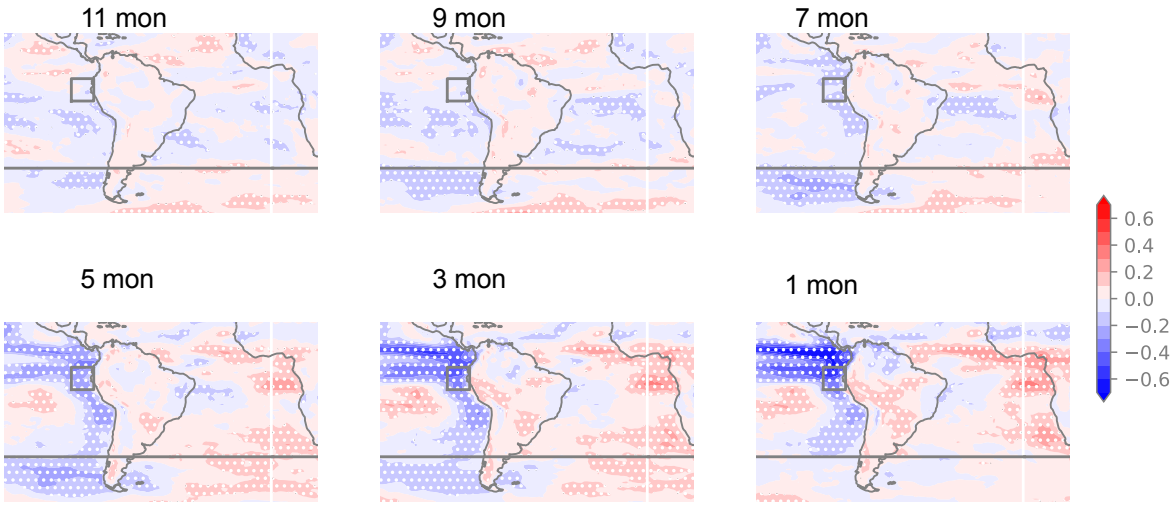


SST and wind terms dominate, and contribute in opposite ways to the latent heat trend that is much weaker than SW CRE.

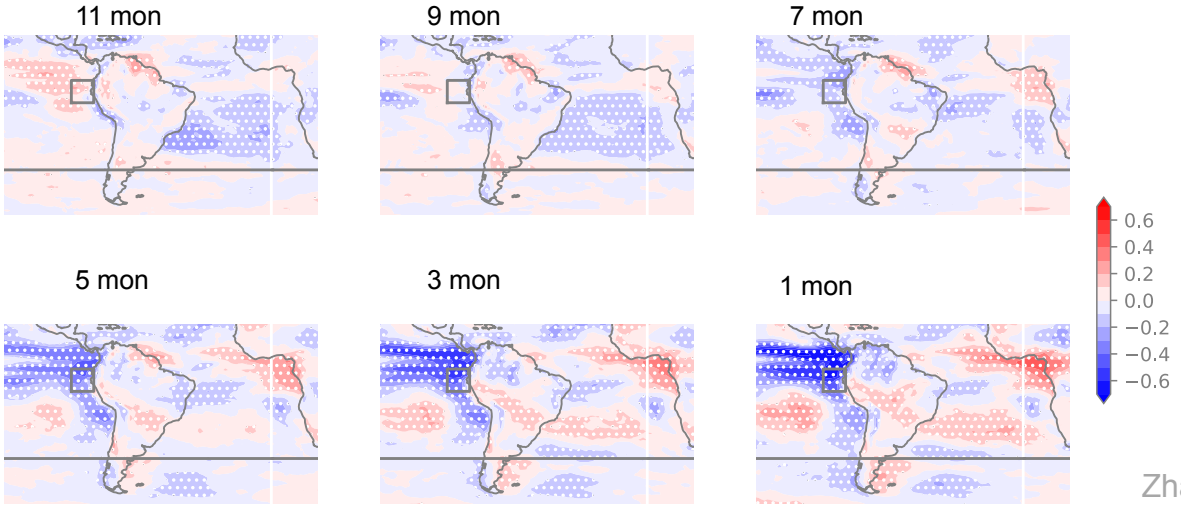
Zhang & Deser (in prep)

Lead correlation: LWP leads TS (box)

SOPACE

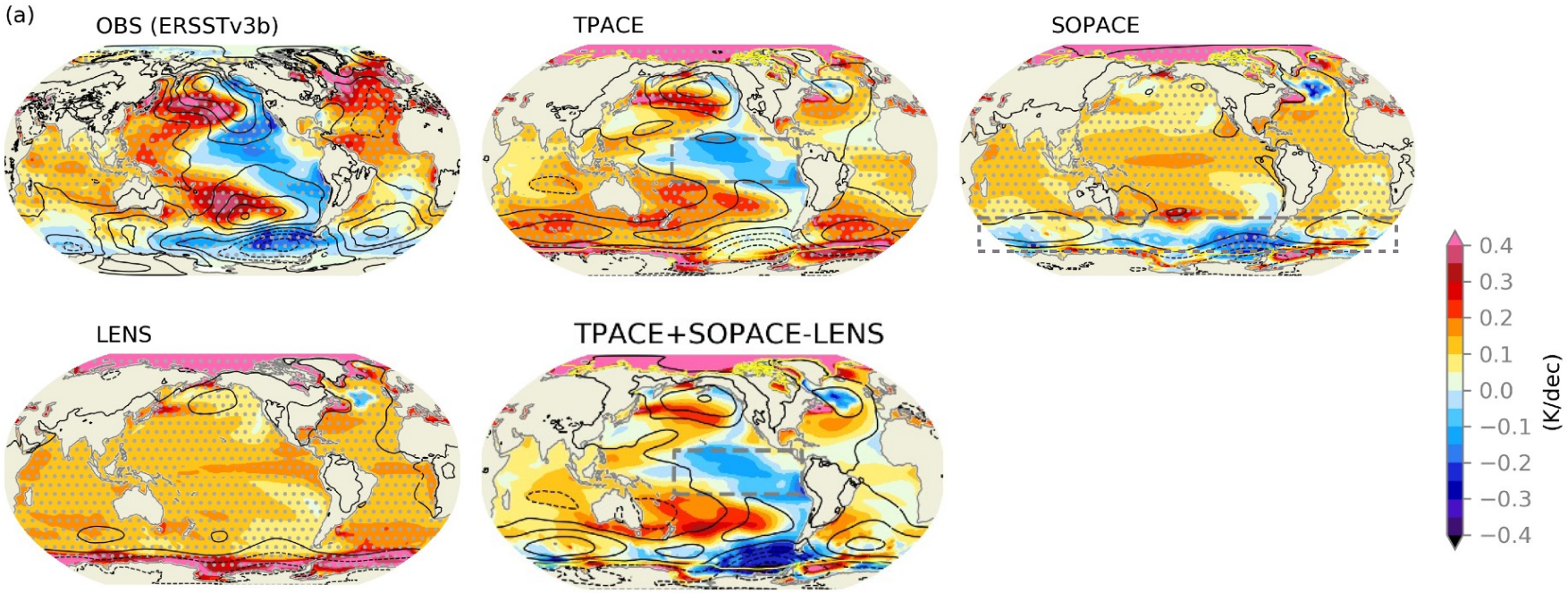


LENS



Zhang & Deser (in prep)

Ensemble mean surface temperature trends



TPACE = Tropical pacemaker (20 ens)
SOPACE = Southern Ocean pacemaker (20 ens)
LENS = CESM Large Ensemble (40 ens)
Stippling indicates trends significant above 95% level

Schneider & Deser (2018); Zhang & Deser (in prep)