On the remote impact of observed Southern Ocean cooling

A pacemaker study

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Observed SST trend during satellite era (1979-2013)

ERSSTv3b

LENS = CESM Large Ensemble (40 ens)
Stippling indicates trends significant above 95% level
Observed SST trend during satellite era (1979-2013)

- SST trend shows strong zonal asymmetry in the Pacific
- The Pacific sector of the Southern Ocean shows significant SST cooling
- Cooling trend is absent in the anthropogenic forced SST response in CESM, suggesting a role internal variability plays in shaping the observed pattern
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Teleconnection processes
(Not a comprehensive list…)

ERSSTv3b

Tropics —> Extratropics

Hadley Cell

Atmospheric Rossby Waves
(e.g. Tropical Pacemaker,
Schneider and Deser, 2018)
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Stochastic atmospheric forcing
(e.g. seasonal footprinting mechanism)

Thermohaline circulation

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Hadley Cell

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

Ocean Gyre/Subtropical Cell

Wind-SST-Evaporation feedback

Clouds

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

Thermohaline circulation

Southern Ocean Pacemaker
Southern Ocean’s effects on global SST pattern
(Idealized and/or strong forcing experiments)

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

Hwang et al. (2017)
Southern Ocean’s effects on global SST pattern

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Decreased insolation over southern extratropics in coupled GCM:
Equilibrium response of SST pattern shows zonal asymmetry; tropical response is damped by sub polar ocean heat uptake

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Kang et al. (2019)
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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?

0.3 K/dec SST cooling is equivalent of -0.4 W/m² forcing (not ideal for identifying process…)

Southern Ocean Pacemaker
Pacemaker setup

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

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

- 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).
Ensemble mean surface temperature and sea level pressure trends

TPACE = Tropical pacemaker (20 ens)
SOPACE = Southern Ocean pacemaker (20 ens)
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Schneider & Deser (2018); Zhang & Deser (in prep)
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Radiatively forced
Internally forced

Schneider & Deser (2018); Zhang & Deser (in prep)
Ensemble mean surface temperature and sea level pressure trends

(a) OBS (ERSSTv3b)  TPACE  SOPACE

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Ensemble mean precipitation trends

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Ensemble mean precipitation trends

(b) OBS (GPCP)       TPACE       SOPACE
LenS                TPACE - LENS    SOPACE - LENS

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

Zhang & Deser (in prep)
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Zhang & Deser (in prep)

Xiyue (Sally) Zhang, CFMIP 2019
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 Atlantic basins, where climatological values are high

SW CLD

CLDLOW

LWP

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Contours show climatology

Lead correlation: LWP leads SST (box)

Zhang & Deser (in prep)
Xiyue (Sally) Zhang, CFMIP 2019
• We conducted a pacemaker experiment to study the impact of Southern Ocean cooling during the satellite era (1979-2013) in CESM:
  - South Atlantic SST trend pattern is consistent with observation
  - The observed SO cooling’s overall contribution to tropical SST and precipitation trends is limited
  - 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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Additional slides
Diverse ensemble members in SOPACE

Temperature and sea level pressure trends

Precipitation trends

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

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* 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

LENSS

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