Dependence of cloud feedback on Southern Ocean salinity

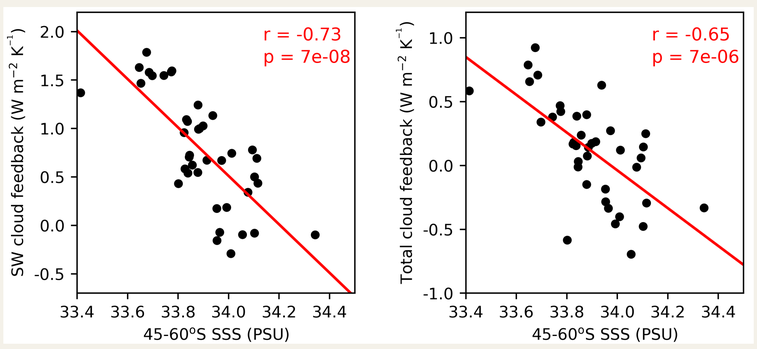
Maofeng Liu[1], Brian Soden[1], Gabriel Vecchi[2], Haozhe He[1], Chenggong Wang[3]

1. Rosenstiel School of Marine, Atmospheric and Earth Science, University of Miami, Miami, FL
2. Department of Geosciences and High Meadows Environmental Institute, Princeton University, Princeton, NJ
3. Program in Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ

Background

1. The uncertainty in effective climate sensitivity (ECS) directly projected by climate models has remained persistently unchanged for the past four decades.
2. Cloud feedback is a primary source of this uncertainty in ECS. Therefore, reducing the inter-model spread in cloud feedback is important for constraining ECS.
3. The cloud feedback spread among climate models has been traced to various sources. Here, we propose a new perspective that links the cloud feedback & ECS spread to Southern Ocean (SO) salinity.

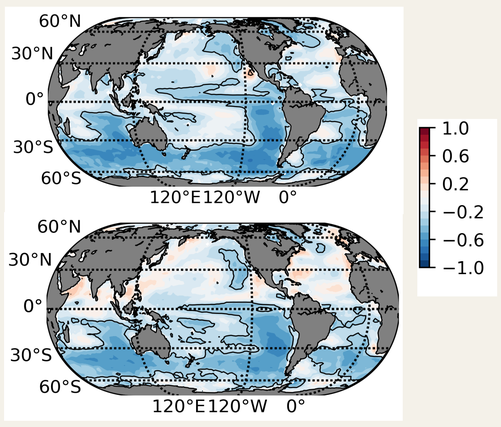
Statistical link between cloud feedback and salinity



There is a significant anti-correlation between global-mean shortwave(SW) cloud feedback and 45-60ºS sea surface salinity (SSS) from the abrupt-4XCO2 experiments from a set of 40 CMIP6 climate models.

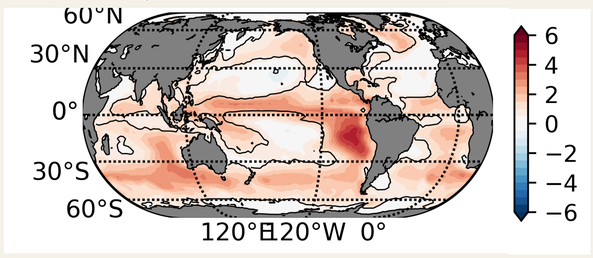
SW cloud feedback

cloud feedback



The regional correlation above between regional cloud feedback and 45-60ºS SSS is significant not only in the local Southern Ocean, but also in subtropical oceans, especially the Southeastern Pacific.

The map of the regional contribution to the inter-model spread of global-mean SW cloud feedback



This map suggests that oceans with strong correlation between SSS and SW cloud feedback are also regions with large contributions to the model spread of cloud feedback.

The proposed logic chain to understand the link

Ocean salinity

↓

Southern Ocean heat uptake

↓

Sea surface temperature & estimated inversion strength

↓

(SW) cloud feedback

↓

Climate sensitivity

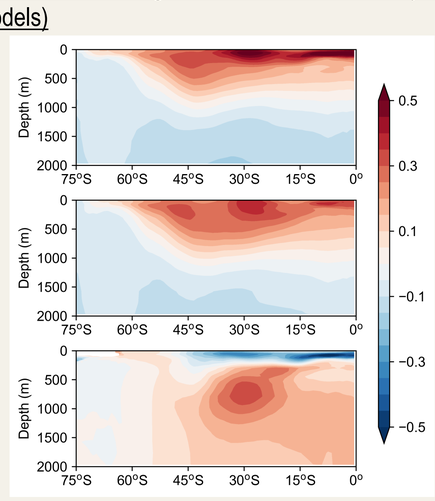
Salinity impact on SO heat uptake

Density difference between models with highest and lowest SO salinity models (highSSS and lowSSS models)

total density difference

density difference due to salinity

density difference due to temperature



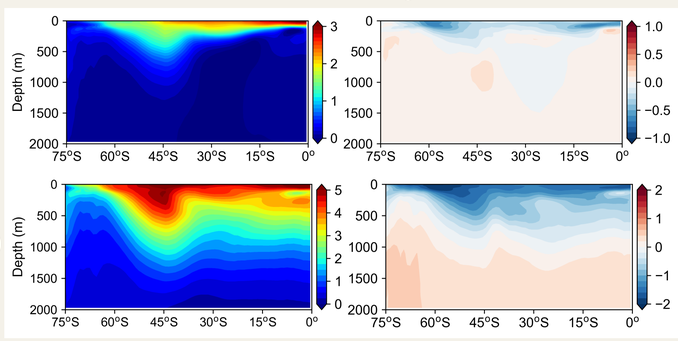
Models's difference in SO density/stratification is dominated by salinity.

ocean warming

warming difference between highSSS and lowSSS

yr5-20

yr131-150



highSSS models produce deeper ocean warming compared to lowSSS, leading to a lower surface warming.

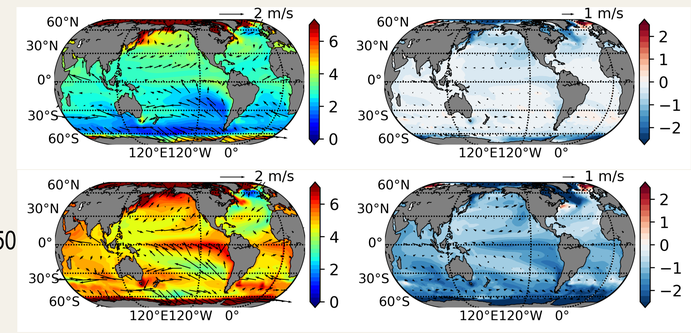
Difference in heat utpake further impacts SST/EIS

Surface warming

warming difference between highSSS and lowSSS

yr5-20

yr131-150

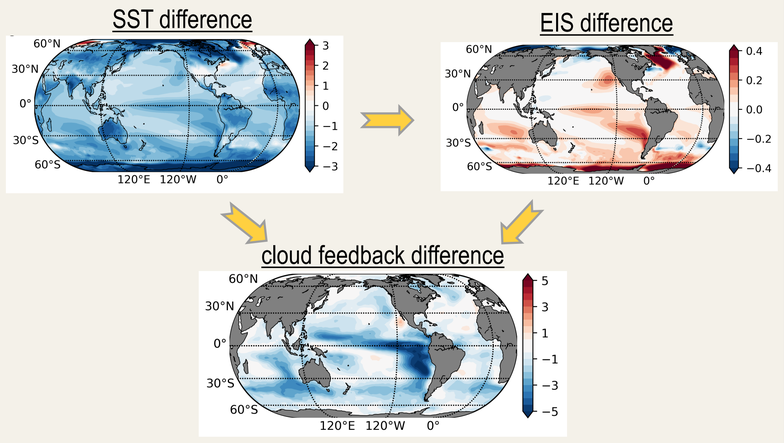


Difference in local SO surface warming due to salinity is further extended to subtropics by climatological surface winds.

SST difference

EIS difference

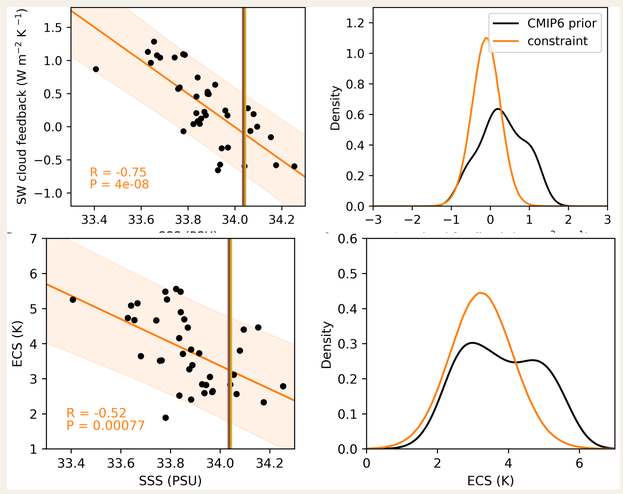
cloud feedback difference



Emergent constraint

SW cloud feedback

ECS

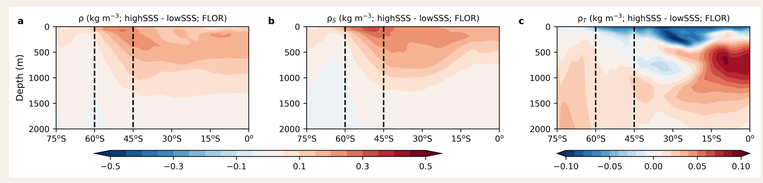


The emergent constraint argues against high-ECS models.

model experiments

The GFDL FLOR model is nudged with SO salinity from highSSS and lowSSS CMIP6 models, respectively; the two are compared to shed light on salinity impact.

Density difference between highSSS and lowSSS

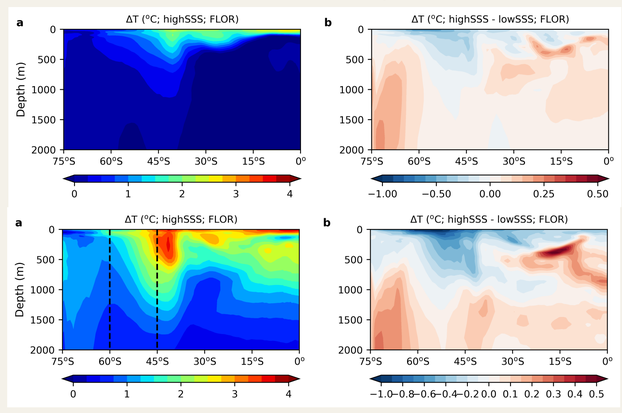


ocean warming

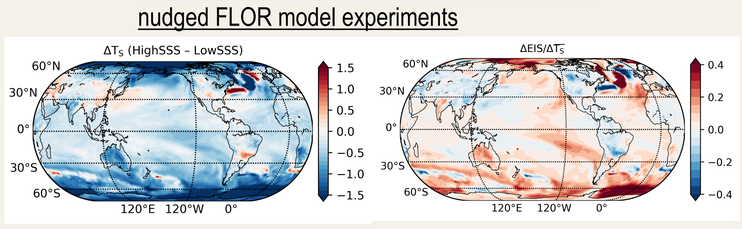
warming difference between highSSS and lowSSS

yr5-20

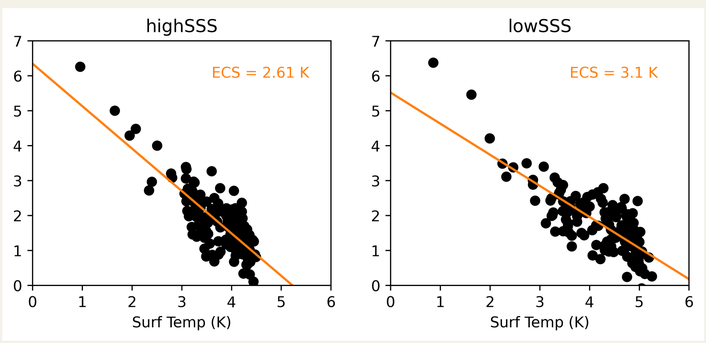
yr131-150



SST and EIS difference between the two salinity-nudged FLOR model experiments



ECS in salinity-nudged FLOR model experiments



Conclusion

1. There is a significant link between Southern Ocean salinity and (SW) cloud feedback among CMIP6 climate models.
2. This link may be attributed to salinity impact on ocean density. Models with higher SO salinity have lower stratification and therefore a deeper ocean warming under CO2 forcing.
3. This deeper warming leads to lower surface warming, which is seen not only in local SO but also in remote subtropics due to climatological surface winds.
4. This difference SST warming pattern and corresponding EIS pattern may contribute to the cloud feedback difference among climate models.
5. The emergent constraint based on ocean salinity observations argues against models with large cloud feedback and high ECS, suggesting that fresh biases in SO may be an important source of uncertainties in simulating climate sensitivity.

Contact

Maofeng Liu

Email: mxl1744@earth.miami.edu