EGU21-5336
https://doi.org/10.5194/egusphere-egu21-5336
EGU General Assembly 2021

Emergent constraints on the Southern Ocean anthropogenic carbon and heat uptake

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The Southern Ocean south of 30°S, occupying about a third of global surface ocean area, accounts for approximately 40% of the past anthropogenic carbon uptake and about 75% of excess heat uptake by the ocean. However, Earth system models have large difficulties in reproducing the Southern Ocean circulation, and therefore its historical and future anthropogenic carbon and excess heat uptake. In the first part of the talk, we show that there exists a tight relation across two Earth system model ensembles (CMIP5 and CMIP6) between present-day sea surface salinity in the subtropical-polar frontal zone, the formation region of mode and intermediate waters, and the past and future anthropogenic carbon uptake in the Southern Ocean. By using observations and Earth system model results, we constrain the projected cumulative Southern Ocean anthropogenic carbon uptake over 1850-2100 by the CMIP6 model ensemble to 158 ± 6 Pg C under the low-emissions scenario SSP1-2.6 and to 279 ± 14 Pg C under the high emissions scenario SSP5-8.5. Our results suggest that the Southern Ocean anthropogenic carbon sink is 14-18% larger and 46-54% less uncertain than estimated by the unconstrained CMIP6 Earth system model results. The identified constraint demonstrated the importance of the freshwater cycle for the Southern Ocean circulation and carbon cycle. In the second part of the talk, potential emergent constraints for the Southern Ocean excess heat uptake will be discussed.