EGU21-7654
https://doi.org/10.5194/egusphere-egu21-7654
EGU General Assembly 2021

Constraining anthropogenic carbon and excess heat uptake in climate projections

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The North Atlantic and Southern Oceans are major sinks of anthropogenic carbon and excess heat. The Earth system model projections of these sinks provided by the CMIP5 and CMIP6 scenario experiments remain highly uncertain, hindering an effective development of climate mitigation policies for meeting the ambitious climate targets laid down in the Paris agreement. A recent study identified an emergent coupling between anthropogenic carbon and excess heat uptake, highlighting the dominant passive-tracer behavior of these two quantities under high-emission scenarios. This coupling potentially allows for the use of a single observational constraint to reduce these projection uncertainties. As a first step, we investigate the causes of these uncertainties in the Southern Ocean (30°S-55°S) by looking regionally at different contemporary physical and biogeochemical quantities. We find that the variations in model´s contemporary water-column stability over the first 2000 m is highly correlated to both its future anthropogenic carbon uptake and excess heat uptake efficiency. Using an observation-based estimate of contemporary water-column stability, this allows us to reduce the uncertainty of future estimates of (1) the cumulative anthropogenic carbon uptake by up to 50% and (2) the excess heat uptake efficiency by 23%. Our results show that improving representation of water-column stratification in Earth system models should be prioritized to constrain future carbon budget and climate change projections.