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Decadal variations of the Southern Ocean carbon sink are driven by the state and the phase of the climate system

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Recent observations and modeling studies suggest pronounced decadal variations in the Southern Ocean (SO) carbon sink attributable to natural processes. As of now, neither observations, nor single realizations of Earth system models (ESMs) can provide a conclusive quantitative representation of natural climate variability and its role for the SO carbon sink. Large ensembles based on ESMs are becoming standard tools for discerning internal variability and the underlying mechanisms. In the Max Planck Institute-ESM Grand Ensemble (MPI-ESM GE) based on 100 historical and future simulations we find strong decadal positive and negative trends in the global ocean carbon uptake dominated by the SO. Our recent study (Li and Ilyina, GRL, 2018) shows that the strong negative trends are also found in future projections, despite the overall growing ocean carbon sink under rising atmospheric CO_2. Here we examine the drivers and signatures of internal variability of the SO carbon sink from 1980 to 2005.

In the MPI-ESM GE, decadal internal variability, i.e. variability driven by natural processes in the climate system, expressed as standard deviation of decadal differences (0.19 PgC/yr/decade) is stronger than the forced decadal climate signal (-0.14 PgC/yr/decade). Decadal internal variability is largest in the upwelling areas of the SO at 50-60°S.

The relationship between CO_2 flux and the Southern Annular Mode suggest two regimes in the SO carbon sink: Stronger southward-shifting winds lead to a weakening of the carbon sink by enhancing the oceanic meridional overturning circulation, whereas weaker northward-shifting winds strengthen the carbon sink by weakening the overturning circulation.

Furthermore, tele-connections from the central tropical pacific affect the SO carbon sink. The Tripole Index for the Interdecadal Pacific Oscillation (TPI IPO) leads strong trends in the SO carbon sink by 4-7 years.

These regional and remote drivers of decadal variations of the SO carbon sink will be presented and evaluated in the context of the MPI-ESM GE output and the SOM-FFN observational product.