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Introduction

Why the Southern Ocean is important The oceans are major carbon sink by taking up about 25-30% of the anthropogenic carbon emissions from the atmosphere Quere2016. As a key region, the Southern Ocean contributes about 50% to the global ocean carbon sink Takahashi2012. Due to the sparse spatial and temporal coverage in the Southern Ocean, various observational CO_2 flux products yield large uncertainties Roedenbeck2015. Also modeling results have a large spread Wang2016 and claim the Southern Ocean as a constraint to reduce model uncertainties in future projections Kessler2016.

Southern Ocean observations and demand for models Recent observations suggest pronounced decadal variations in the Southern Ocean carbon sink Roedenbeck2013,landschuetzer2015. However, due to the sparse spatial and temporal coverage of measurement data, it is challenging to discern the dynamics of internally varying processes, which demands for the evaluation with models. Earth system models (ESMs) are a useful tool to analyze processes that contribute to variability. [**?**, **?**] explained the mechanistic processes behind the positive trend in the Southern Annular Mode with a ocean model with atmospheric forcing from reanalysis data. Yet, ESMs, containing a freely evolving coupled atmospheric and ocean component, don't capture the decadal variations suggest by observations Wang2016. Using a large ensemble of simulations with perturbed initial conditions but identical forcing and model allows to separate into the forced signal and internal variability.

What I do and research questions By using a large ensemble simulation based on the Max-Planck-Institute Earth System Model (MPI-ESM), I investigate the variability of the oceanic carbon uptake. I try to answer the following reseach questions:

- What is the modeled internal variability of the Southern Ocean carbon sink?
- How does variability in biological and physical processes influence the carbon sink?

Working hypothesis The Southern Annular Mode (SAM), characterizing the strength and position of the westerly winds, is known to be the dominant mode of climate variability in the Southern hemisphere Thompson2000,Thompson2011. Supposing the strength and position of the westerlies winds as the major reason for climate variability for the Southern Ocean Thompson2000, how does the carbon system respond? Changes in westerly winds alter circulation patterns, which directly effect the carbon sink via the thermal effect, circulation of carbon and biological production.

Revisit processes In this thesis, I revisit the dominant processes leading to extreme trends in the Southern Ocean carbon sink in the biogeochemical model HAMOCC (similar [**?**, **?**]), as individual processes related to changes in winds are already discussed for changes in temperature Takahashi1993,Lovenduski2007, circulation Abernathey2011,Hauck2013,Lauderdale2016,Lovenduski2008 and biology Lovenduski2005,Tagliabue2014,wang2012. [Should I go more in detail here of the findings of these studies? Now I just list them.] This revisit is particularly interesting as other large ensembles of perturbed initial conditions do not capture strong decadal variations in the Southern Ocean carbon sink; whereas MPI-ESM LE does [private communication N. Lovenduski (NCAR) and S. Schlunegger (GFDL), see section **??** for details]. Knowing about the driving processes for strong decadal CO_2 flux trends and the response of the carbon system helps to evaluate the strong trends in MPI-ESM LE and how suitable perturbed initial conditions large ensembles are for studies of internal variability.