Large ensemble ESM simulations reproduce decadal trends in the Southern Ocean carbon sink

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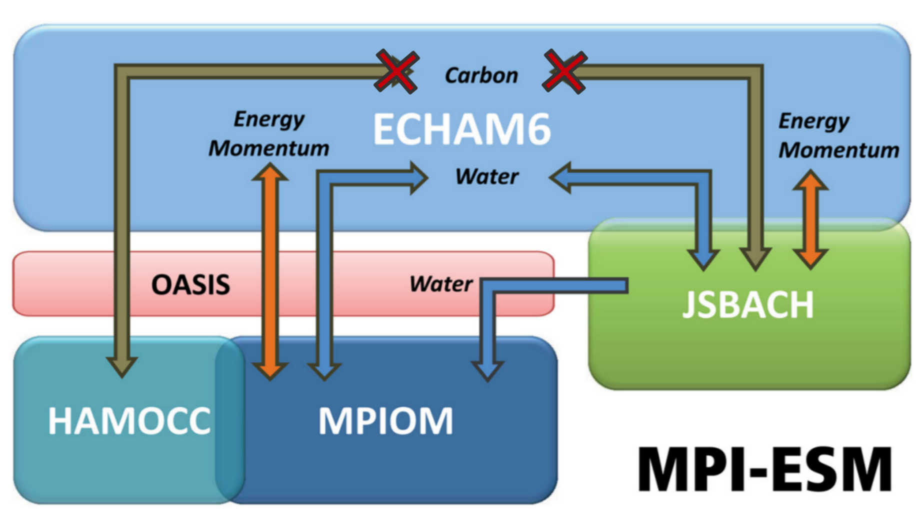
Introduction

Observations-based estimates report large decadal variations in the Southern Ocean carbon sink [LeQuere et al. 2007, Landschützer et al. 2015]. Sparse observational data lack the ability to show the dynamics of internally varying processes, which demands for the evaluation with models. Forced ocean models reproduce this internal variability. However, all coupled earth-system-models fail. By analyzing a historical large ensemble of 100 simulations based on Max Planck Institute's Earth System Model (MPI-ESM), we assess modeled internal variability of the Southern Ocean carbon sink.

Here we analyze what drives internal variability and focus on negative trends in the Southern Ocean carbon sink which are unforeseen just from atmospheric forcing alone.

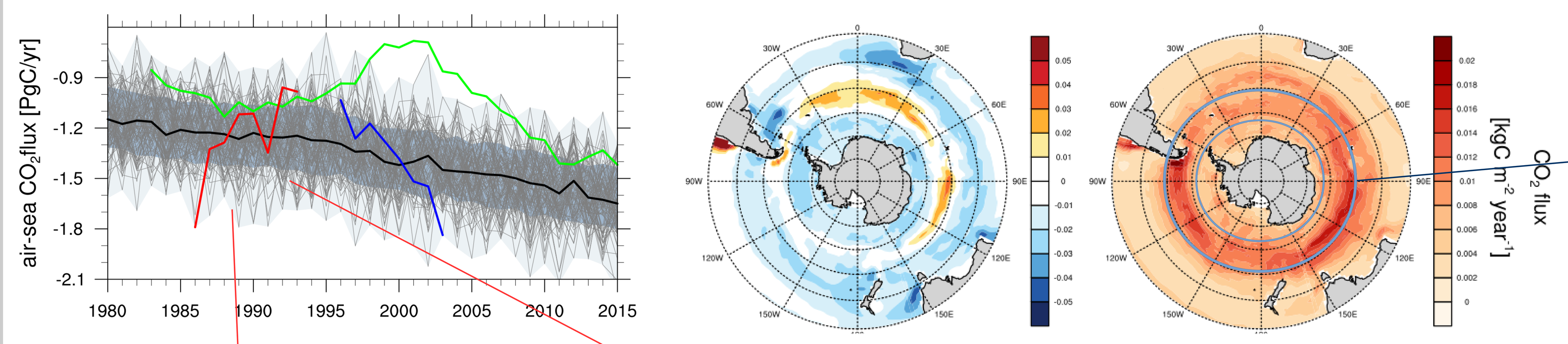
Methods

We use MPI-ESM1.1 with a prognostic carbon cycle. The 100 ensemble members had slightly different initial conditions from the pre-industrial control run and are subject to historical forcing from 1850 to 2005 and extended under the RCP4.5 scenario to 2100.



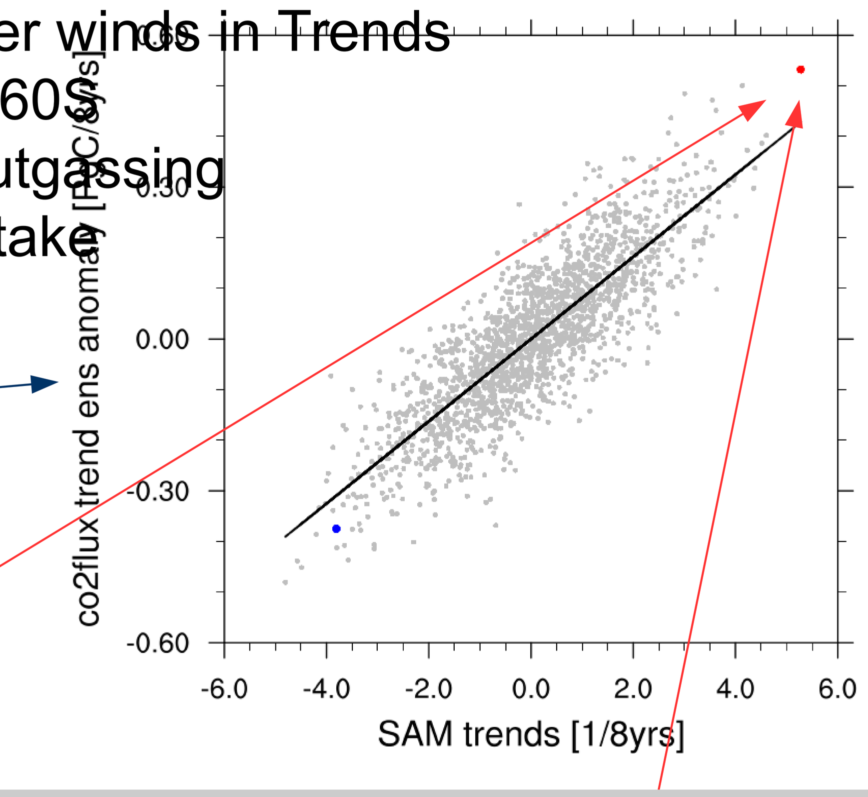
Internal Variability of the Southern Ocean carbon sink

- Largest internal variability in outgassing area
- Internal decadal variability ±0.4 PgC
- Detection of negative decadal carbon sink trends similar to [Landschützer et al. 2015]



Winds drive internal variability .

- Opposing response to weaker winds in Trends
- area of largest variability 50-60S
- Stronger winds drive CO2 outgassing
- Weaker winds drive CO2 uptake

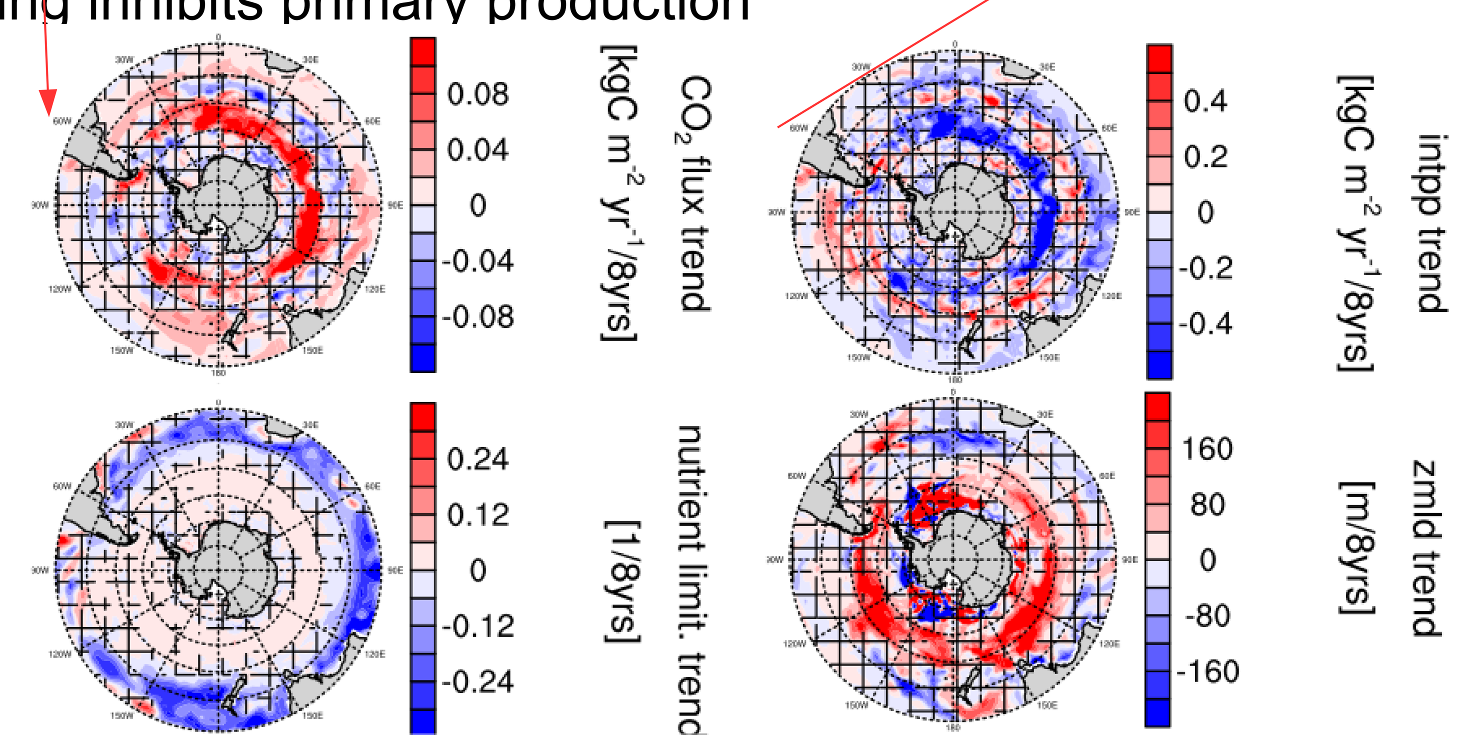


Conclusions

- Southern Ocean carbon sink variability driven by winds
- Intensified winds decrease carbon sink via increased upwelling and decreasing primary production due to light limitation from deep mixing
- Decadal Southern Ocean carbon sink trends similar to 1990s and 2000s reproducible in coupled ESM

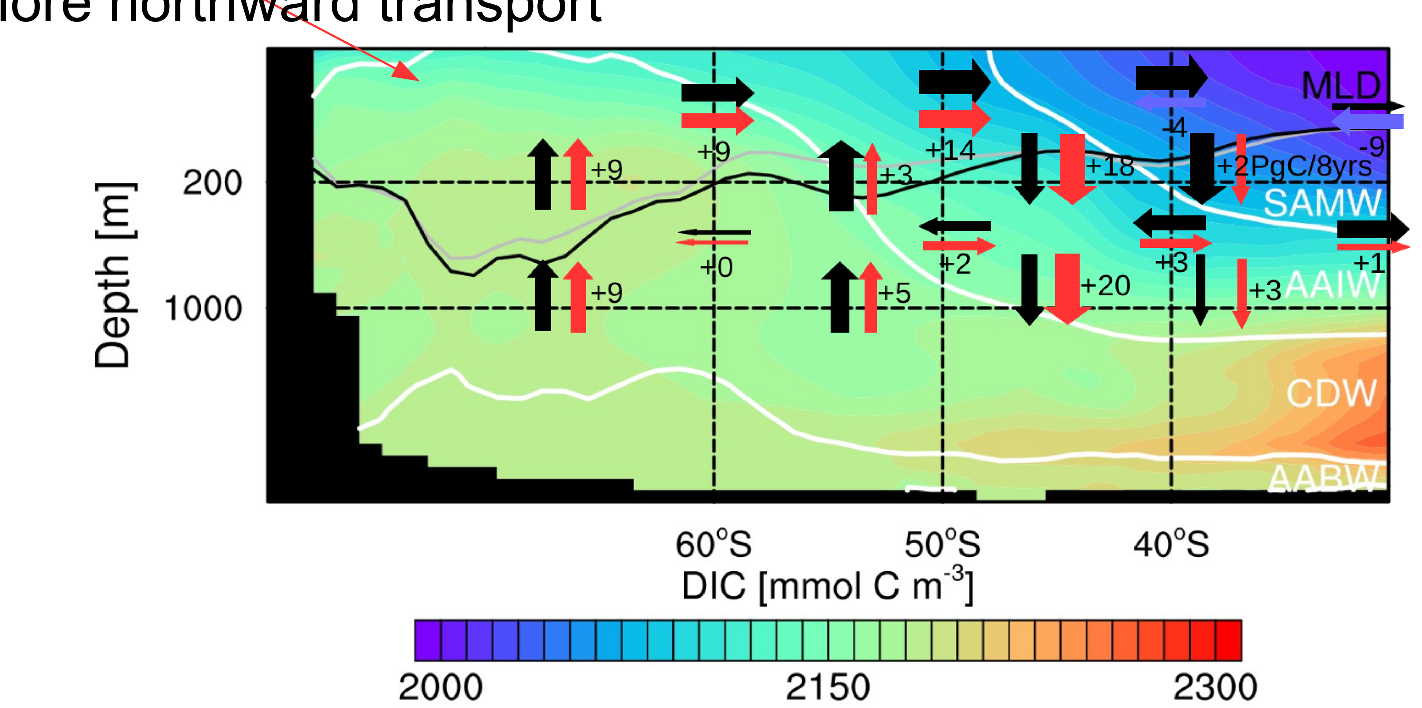
Trends in biology

- Opposing summer trends in CO2flux and primary production
- No change in nutrient limitation
- Deeper mixing inhibits primary production



Trends in circulation

- Similar to [DeVries et al. 2017]
- Intensified upper-ocean overturning circulation
- More upwelling of carbon-rich deep waters
- More northward transport



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