The impact of biology on decadal decreasing trends of carbon sink in the Southern Ocean

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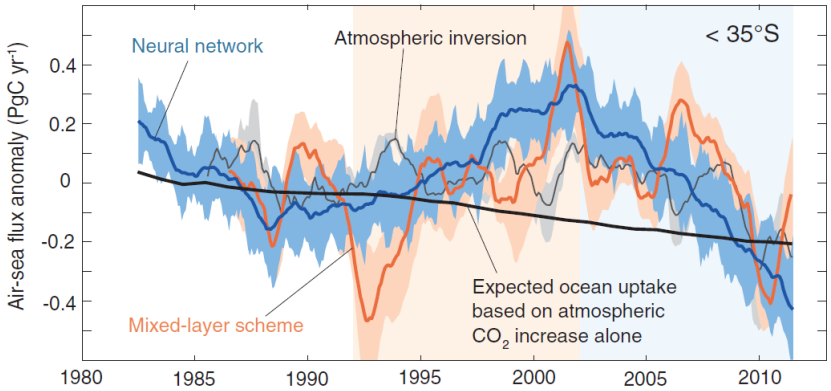
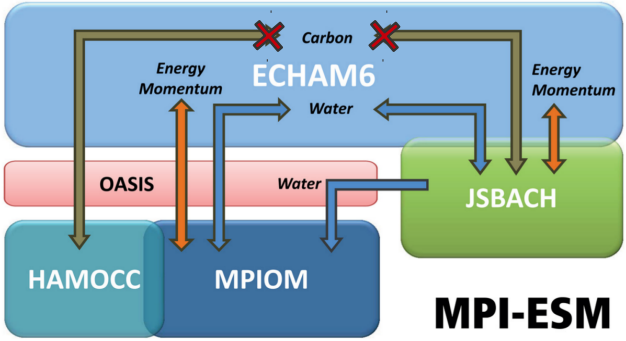
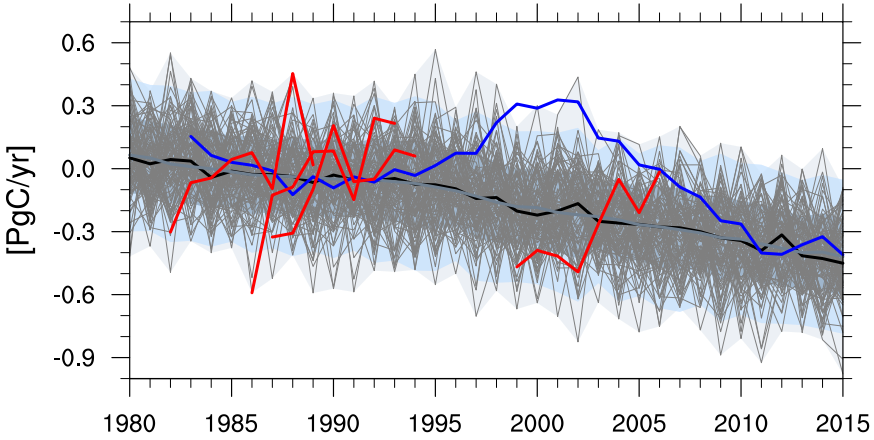
Observations [Landschützer et al., 2015] show anomalous outgassing decadal trend in the Southern Ocean Carbon Sink in the 1990s.



Decadal trends of internal variability were not yet explored in coupled earth system models. We use initially perturbed 100-member ensemble simulation to assess the variability of the Southern Ocean carbon sink and its underlying processes.



We find positive decadal trends in the Southern Ocean carbon sink similar to observations in the 1990s [Landschützer et al., 2015].



Internal Variability of CO_2flux and primary production show similar patterns, have highest values at 45-60°S south and appear in same locations.

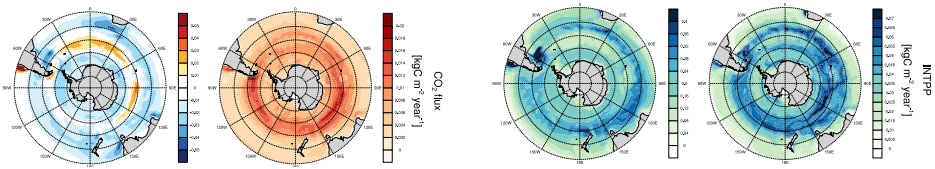


Figure: Southern Ocean CO_2flux where negative values indicate ocean uptake (1^{st}) and primary production (2^{nd}): ensemble median (left) as forced signal and ensemble standard deviation (right) as internal variability [Deser et al., 2012]

There are significant correlations of trends in CO_2flux,primary production and mixed-layer depth.

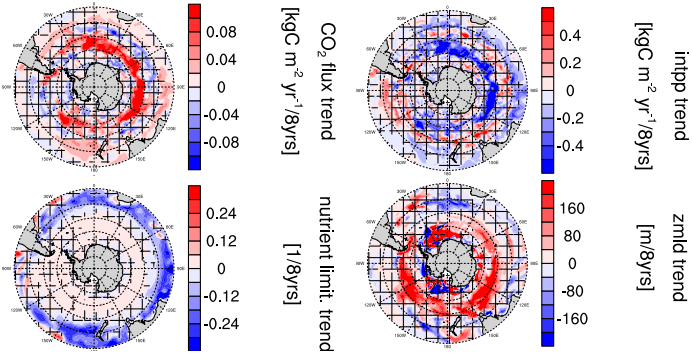


Figure: Southern Ocean austral summer trends per per 8 years: CO_2flux (top left), vertically integrated primary production (top right), nutrient limitation (bottom right) and mixed layer depth (bottom left); hatched areas indicate where trends were below 5% significance

The decline in primary production at 50-60°S is caused by reduced stability of the water column due to turbulent wind mixing[Sverdrup, 1953]

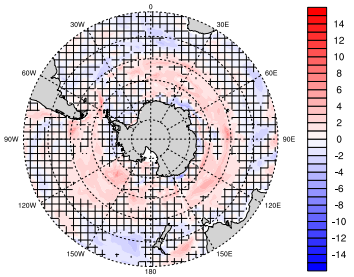


Figure: Trends in [m/8yrs] of average depth of vertical diffusivity due to wind (right); hatched areas indicate where trends were below 5% significance

Water column stability is further decreased by cold upwelling water. This enhances the mixing power of the strengthening winds to pull phytoplankton deeper into the darker ocean.

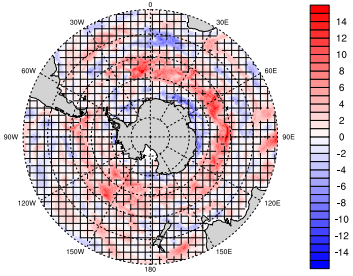


Figure: Trends in [m/8yrs] for phytoplankton average depth; hatched areas indicate where trends were below 5% significance

Deeper winter mixing delays primary production blooms in austral spring and lowers productivity all over the summer.

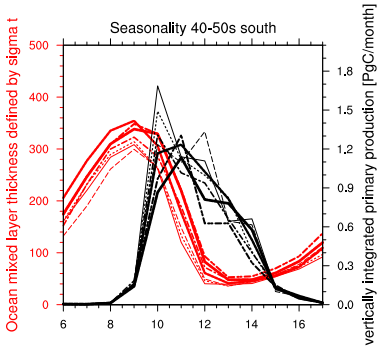


Figure: Seasonality of vertically integrated primary production (black) and mixed layer depth (red) at 50-60°S over 8 years; thicker lines are later years

Primary production decreases S30s because of nutrients, increases S40s because of temperature effect and stratification, decreases S50s because of instability.

Anomalous outgassing trends in the Southern Ocean Carbon Sink can be explained by changes in primary production induced by changes in climate. We could not determine a ratio of summer primary production trend towards yearly upwelling trend.

Discussion on previous studies show different response of biology to increasing winds than other models which are in contrast to HAMOCC iron-limited.

[Lovenduski et al., 2008]
[Wang and Moore, 2012]
[Hauck et al., 2013]

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