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The fate of carbon and nutrients exported out of the Southern Ocean

Judith Hauck, Andrew Lenton, Richard Matear, and Clothilde Langlais
Alfred Wegener Institute, Marine Biogeosciences, Bremerhaven, Germany (judith.hauck@awi.de)

Subduction and formation of mode water transports nutrients and carbon from the Southern Ocean (SO) to upwelling regions where they are reventilated. While it has been long recognized that this process sustains a significant part of the low-latitude primary productivity, it is less clear what these pathways mean for the global carbon cycle. The fate of carbon and nutrients exported out of the Southern Ocean and the timescales associated with its reventilation, are critical to understanding current and future global carbon budgets and this is the focus of our study.

We use ocean biogeochemical simulations driven with reanalysis data. We focus on the upper ocean response in the present day climate. Importantly, the time-scale of carbon sequestration is much longer for the biological than for the physical carbon pump. 90% of the reventilation of SO carbon taken up by the physical pump occurs within 200 years, which is broadly consistent with the literature, while over the same timescales only 50% of the carbon taken up by the biological pump is reventilated. This can be explained by the sinking of particles to greater depths and its subsequent remineralization into waters with longer reventilation timescales. In today's climate, carbon sequestration occurs in the SO by the biological pump, whereas the physical pump releases carbon to the atmosphere

If no macronutrients were utilized in the Southern Ocean, primary productivity north of 40°S would increase by 2.9 PgC yr-1 (10%). In other words, only 40% of Southern Ocean productivity would be compensated outside of the Southern Ocean on a 200 year timescale.

Given the diversity of projections of physics and productivity in the Southern Ocean, these considerations set the stage for discussing global implications and feedbacks by recent and projected future changes in the Southern Ocean carbon pumps due to global warming and strengthening of winds.