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Reshuffling of Nutrients in the Southern Ocean

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Deep waters upwell in the Southern Ocean, replete with nutrients. Some of these nutrients enter lighter mode and intermediate waters (MIW), fueling upper ocean productivity in the otherwise nutrient depleted (sub)tropical waters. However some of the upwelled nutrients are retained in the Southern Ocean or leak into denser bottom waters (AABW), making them unavailable for upper ocean productivity. Despite its fundamental importance for the global ocean productivity, this "reshuffling" of nutrients between Southern Ocean water masses, and its driving forces and temporal variability, have not been quantified to date.

We analyze the globally major limiting macronutrient, nitrate (NO_3), using the results of a data-assimilating coupled ocean-sea-ice and biogeochemistry model, the Biogeochemical Southern Ocean State Estimate (B-SOSE), for the years 2008 – 2017. Using a water mass framework, applied to five day averaged SOSE output south of 30^{o}S, we quantify the processes controlling NO_3 inventories and fluxes. The water mass framework enables us to assess the relative importance of physical processes (such as surface buoyancy fluxes and diapycnal mixing) and biogeochemical processes (such as productivity and remineralization) in driving the transfer of NO_3 from upwelling deep waters (CDW) to MIW and AABW, and its interannual variability.

Our results show that two thirds of the NO_3 supplied to MIW occurs through lightening, or transforming, of CDW waters during the course of the overturning circulation. The other third of the NO_3 supplied to MIW occurs through upward mixing of NO_3 from NO_3-enriched CDW. This means that physical processes determine the mean MIW NO_3 content. Biology does not have a net effect on MIW NO_3: while biological uptake draws down the MIW concentration of NO_3 near the surface, remineralization of organic matter compensates for this MIW loss below the surface. Also, we find that the productivity in the subtropical waters south of 30^{o}S is fed through both, the canonical upward mixing of NO_3 through the thermocline, and through the near surface supply from MIW. Thus, again, water mass transformation is playing a large role in nutrient distributions.

In ongoing work, we assess the drivers of variability of the reshuffling of NO_3 between water masses and their potential sensitivity to climate change.

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