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Eddy-induced carbon pumping in the Southern Ocean

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Recent studies have shown that the air-sea carbon fluxes in the Southern Ocean display large signals of variability on interannual to decadal timescales (e.g., Le Quéré et al., 2007; Landschützer et al., 2015, Keppler & Landschützer, 2019). However, due to data sparsity, little attention has been paid to mesoscale processes affecting the Southern Ocean carbon fluxes. This region, dominated by zonal fronts and the Antarctic Circumpolar Current, is rich in highly dynamic eddies (Frenger et al., 2015). These eddies have the potential to significantly alter local air-sea carbon fluxes through eddy pumping, where anticyclonic eddies transport carbon downward, allowing for additional oceanic carbon uptake, and cyclonic eddies pump carbon stored at depth upward, resulting in outgassing. Additionally, the strong westerly winds could result in significant eddy-induced Ekman pumping that has the opposite direction and offsets the effect from eddy pumping (Su et al., 2021; Gaube et al., 2015). Thus, identifying the influence of eddies on the Southern Ocean carbon fluxes forms a crucial part in quantifying the global carbon cycle.

Although this region is historically under-sampled, we now have nearly a decade of biogeochemical (BGC) observations from Argo floats deployed as part of the Southern Ocean Carbon and Climate Observations and Modeling project (SOCCOM). Moreover, the Aviso database provides us with eddies detected from satellite altimetry measurements. Together, the two datasets allow us to investigate the vertical structure of the biogeochemistry in Southern Ocean eddies. Here, we co-locate the Southern Ocean eddies with BGC Argo floats to present the composite vertical structure of pH, oxygen, and nitrate inside anticyclonic and cyclonic eddies compared to the mean fields. We conduct this analysis in several subregions with different dominant processes. Our findings enable us to characterize and interpret the influence of mesoscale eddies on the overall Southern Ocean carbon fluxes, including the relative dominance of eddy pumping and eddy-induced Ekman pumping in different subregions of the Southern Ocean.

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