How productive is the Southern Ocean? Results from inverse modeling compared with satellite based estimates.

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The utilization of dissolved nutrients and carbon for photosynthesis in the euphotic zone and the subsequent downward transport of particulate and dissolved organic material strongly affect carbon concentrations in surface water and thus the air-sea exchange of CO_2. Efforts to quantify the downward carbon flux for the whole ocean or on basin-scales are hampered by the sparseness of direct productivity or flux measurements. Here, a global ocean circulation, biogeochemical model is used to determine rates of export production and vertical carbon fluxes in the Southern Ocean. The model exploits the existing large sets of hydrographic, oxygen, nutrient and carbon data that contain information on the underlying biogeochemical processes. The model is fitted to the data by systematically varying circulation, air-sea fluxes, production, and remineralization rates simultaneously. Use of the adjoint method yields model property simulations that are in very good agreement with measurements.

In the model, the total integrated export flux of particulate organic matter (POC) necessary for the realistic simulation of nutrient data is significantly larger than export estimates derived from primary productivity maps. 10 GtC required globally, the Southern Ocean south of 30°S contributes about 3 GtC (33%), most of it occurring in a zonal belt along the Antarctic Circumpolar Current and in the Peru, Chile and Namibia coastal upwelling regions. The export flux of POC for the area south of 50°S amounts to 1±0.2 GtC, and the particle flux in 1000 m for the same area is 0.115±0.02 GtC. Unlike for the global ocean, the contribution of the downward flux of dissolved organic carbon (DOC) is significant in the Southern Ocean in the top 500 m of the water column. Comparison with satellite based productivity estimates (CZCS and SeaWiFS) shows a relatively good agreement over most of the ocean except for the Southern Ocean south of 50°S, where the model fluxes are systematically higher than the satellite-based values by factors between 2 and 5. This discrepancy is significant, and an attempt to reconcile the low satellite-derived productivity values with ocean-interior nutrient budgets failed. Too low productivity estimates from satellite chlorophyll observations in the polar and sub-polar Southern Ocean could arise because of the inability of the satellite sensors to detect frequently occurring sub-surface chlorophyll patches, and to a poor calibration of the conversion algorithms in the Southern Ocean because of the very limited amount of direct measurements.