Global Biogeochemical Cycles

The seasonal cycle of nitrogen uptake and nitrification in the Atlantic sector of the Southern Ocean

Mhlangabezi Mdutyana[1,2], Sandy J. Thomalla[2,3], Raissa Philibert[4], Bess B. Ward [5], and Sarah E. Fawcett [1]

[1]Departmentof Oceanography, University of Cape Town, Cape Town, South Africa,

[2]Southern Ocean Carbon and Climate Observatory (SOCCO), CSIR, Rosebank, Cape Town, South Africa,

[3]Marine Research Institute (Ma-Re), University of Cape Town, Cape Town, South Africa,

[4]Hatfield Consultants, Vancouver, British Columbia, Canada,

[5]Department of Geosciences, Princeton University, Princeton, NJ, USA

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Abstract

Net primary production (NPP) fueled by nitrate is often equated with carbon export, providing a metric for CO2 removal to the deep ocean. This “new production paradigm” assumes that nitrification, the oxidation of regenerated ammonium to nitrate, is negligible in the sunlit upper ocean. While surface layer nitrification has been measured in other oceanic regions, very few data exist for the Southern Ocean. We measured NPP, nitrogen (N) uptake, and nitrification in the upper 200 m across the Atlantic Southern Ocean in winter and summer. Rates of winter mixed-layer nitrate uptake were low, while ammonium uptake was surprisingly high. NPP was also low, such that NPP and total N (nitrate+ammonium) uptake were decoupled; we attribute this to ammonium consumption by heterotrophic bacteria. By contrast, NPP and total N uptake were strongly coupled in summer except at two stations where an additional regenerated N source, likely dissolved organic N, apparently supported 30–45% of NPP. Summertime nitrate uptake rates were fairly high and nitrate fueled >50% of NPP, indicating the potential for significant carbon export. Nitrification supplied <10% of the nitrate consumed in summertime surface waters, while in winter, mixed-layer nitrification was on average 16 times higher than nitrate uptake. Despite the near-zero nitrification rates measured in the summer mixed layer, the classically defined f ratio does not well-represent Southern Ocean carbon export potential annually. This is because some fraction of the nitrate regenerated in the winter mixed layer is likely supplied to phytoplankton in summer; its consumption cannot, therefore, be equated with export.