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The Nutrient Status of the Southern Ocean During the Last Ice Age and its Links to the Global Ocean

Daniel Sigman[1], **Roger Francois** (rfrancois@whoi.edu)[2], **Mark Altabet** (maltabet@umassd.edu)[3] & **Scott Lehman** (lehmans@spot.colorado.edu)[4]

[1] Dept. of Geosciences, Princeton University, Princeton, New Jersey, 08544, USA
[2] Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
[3] CMAST, University of Massac, 706 Rodney French Blvd., New Bedford, MA 02744, USA
[4] INSTAAR, University of Colorado, Boulder, CO 80309, USA

Based on our understanding of the modern Southern Ocean, it is possible to use the available paleoceanographic data to craft a revised hypothesis for the glacial Southern Ocean that integrates both the Antarctic and Subantarctic regions into a picture of the global ocean during the last ice age. In this picture, the supply of deep water to the Antarctic surface was less than it is today. Although Antarctic biological export production was lower, nutrient utilization (the ratio of nutrient uptake to nutrient supply) was greater, and the net release of carbon dioxide from the Antarctic was reduced. Lower nutrient concentrations in the Antarctic surface and a possible reduction in Ekman divergence in the glacial Antarctic reduced the lateral transport of nutrients from Antarctic surface water into the Subantarctic. This made the thermocline the dominant source of nutrients to the Subantarctic surface. It also cut off one of the most important modern routes by which the nutrients sequestered in the cold deep ocean are returned to the thermocline and upper ocean, contributing to the apparent glacial increase in the oxygen content of the thermocline while causing a decrease in the oxygen content of abyssal waters.

Two forms of evidence will be presented in support of the above hypothesis. Firstly, paleoceanographic data will be reviewed that address the nutrient status and biological fluxes of the glacial Southern Ocean. Secondly, paleoceanographic constraints on the nutrient and oxygen distributions of global ocean during the last ice age will be discussed, and new results will be presented from a modelling study of intermediate-depth ocean circulation and nutrient chemistry during the last ice age. These results indicate that there are few good alternatives to our Southern Ocean hypothesis to explain the global intermediate-depth nutrient depletion that the available paleoceanographic data appear to require.