surface waters should turn over at least once per week.

In summary, is likely that the input of non-biogenic NO_3-N and NH_4-N derived from continental ice is probably insignificant in the overall nitrogen budget for epipelagic Antarctic seas although enrichment from melting ice may be locally important. It is further likely that the biogenic input of NH_4-N (from zooplankton and nekton excretion) far outweighs NH_4-N inputs from continental ice, and the calculated rapid turnover rate for NH_4-N suggests that ammonium could conceivably limit the rate of primary production in the Southern Ocean.

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PARKER *ET AL.* REPLY—We too are concerned that data may be too limited and assumptions too many to draw fixed conclusions. We agree with Biggs' calculations for both NO_3^- and NH_4^+ contributions to the Southern Ocean. However, the calculations were based on mean values, assuming uniform mixing to a depth of 50 m. Yet icebergs are not distributed uniformly through time and space, nor are their nitrogenous contents uniform. Regretting our selection of El-Sayed's published data which cited μg l^{-1} rather than the correct μg-atm l^{-1} for NO_3-N, we note that the ranges of concentrations vary widely such that icebergs might well be found in ocean waters well below the concentration levels reflected by the mean ice values. Since our report, we have completed over 1,000 analyses of glacial ice and find values ranging to 525 μg NO_3-N l^{-1} (~37 μg-atm) and to 260 μg NH_4-N l^{-1} (~19 μg-atm). Also Robe[1] has estimated that icebergs melt primarily in the upper 20 m of water. These points could bring about higher fixed nitrogen contents in surface water at least locally. Indeed, we reported in a note added in proof in our original paper that we found icebergs with "concentrations near our estimates and that a concentration gradient occurs, descending with increasing distance from an iceberg". Chlorophyll content was several times higher in surface water adjacent to that same iceberg when compared with water approximately 2.0 km downwind from the same iceberg. These studies were preliminary and were conducted in McMurdo Sound involving icebergs which probably originated from the Ross Ice Shelf, the nitrogenous composition of which is unknown. We therefore assert that the overall question of whether nutrients from icebergs or ice shelves play a major part in the productivity of the Southern Ocean remains moot, and that the probability of icebergs enhancing productivity of surface waters locally or seasonally on a wider scale cannot be dispelled from the available data, assumptions and calculations. We plan a more extensive test of our thesis during the coming austral summer.

With respect to Bauer's comments, we also agree with the calculations for lack of other information to contradict the numerous assumptions made. However, we question whether NO can be destroyed photochemically in polar regions during winters when solar radiation is essentially absent for periods of up to several months. Assuming the maximum angle of 23.5° for the Sun at winter solstice, we calculate that solar radiation will be absent to an altitude of >100 km for more than 5 months. More specifically, disregarding the minor components of scattering and refraction, we calculate the following approximate altitudes above sea level at the geographic poles which will not receive direct sunlight: at the winter solstice, 575 km; ±30 d from winter solstice, 439 km; ±45 d from winter solstice, 300 km; ±60 d from winter solstice, 156 km; ±75 d from winter solstice, 46 km; ±90 d from winter solstice, 0.278 km. These values are only slightly lower when we recalculate values using the upper periphery of the Sun instead of the centre.

Therefore, if Bauer's mean transport time for NO from 70–90 km to 40–50 km is correctly estimated at a few weeks, there is ample time during the polar night for aurora-fixed nitrogen to reach the Earth's surface without photodestruction. Even with early spring and late autumn, much of the UV radiation will be removed by the thick layer of ozone through which the Sun's rays must penetrate to reach the polar region. We assert that, based on our data for a 100-m South Pole core, the periodic fluctuations in NO_3^- concentrations cannot be simply explained by a model using galactic cosmic rays as a major mechanism for explaining the source of NO_3^- in Antarctic snow.

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EL-SAYED COMMENTS—The above authors quoted data included in my Tables 1 and 2 which appeared in Balech *et al.*[1]. Unfortunately the units of nutrient concentrations were incorrectly printed as μg l^{-1}. However, the maps in that folio showing surface phosphates and silicates (but not the nitrates and nitrites) were correctly given in μg-atm l^{-1}. This table appeared in ref. 2 with the concentration units given in μg-atm l^{-1}. Except for the misprint in this folio, all my nutrient data are always given in μg-atm l^{-1} (see refs 3–6, 7). Reference to these other publications would immediately have pointed to the misprints in the units given in ref. 1.

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Carbon isotope fractionation in biological material

STABLE, rather than radioactive, tracers are being used in metabolic studies, and Lyon and Baxter[1] have reported "natural baseline" carbon isotope ratios from human tissue samples. The use of natural isotope ratios is also an area of active research interest because of the ecological and palaeoecological significance of carbon isotope discrimination in higher plant photosynthesis[2]. These botanical and ecological studies provide information which may clarify and illuminate some aspects of the above report.

The ^{13}C/^{12}C ratios, expressed as δ^{13}C against PDB, for land plants generally range from −8‰ to −32‰ (ref. 3) rather than the −24‰ to −29‰ reported[1], and are distinctly bimodal near −13‰ and −27‰. These two modal clusters represent the two major photosynthetic systems (C_4 and C_3, respectively) which discriminate differently, and diagnostically, against the carbon isotopes. The mechanism for this discrimination is quite