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Reply to the comment by Jackson

Recent simulations of the cycle of organic matter in the ocean with general circulation models suggest that most of the downward transport is in a dissolved form (Najjar 1990; Bacastow and Maier-Reimer 1991; Najjar et al. 1992). Particle remineralization below the euphotic zone in these models is treated in a highly simplified form. Both the fraction of the export production that is sinking particulate matter and the remineralization length scale of this particulate matter are spatially invariant. In his comment concerning zooplankton and their relationship to the particle flux below the euphotic zone, Jackson (1993) suggests that the assumption of a constant remineralization length scale is important with regard to the conclusions of these modeling studies. In particular, he suggests that a shorter remineralization length scale in regions of higher productivity (where animal populations are greater) would improve simulation of the nutrient distribution.

We disagree. In one of our simulations where all export production is in the form of sinking particulate matter that is remineralized below the euphotic zone with a length scale consistent with sediment trap observations (Martin et al. 1987), we found that nutrients become "trapped" below the euphotic zone in regions of shallow upwelling, such as the eastern equatorial regions of the Pacific and Atlantic Oceans. This trapping is a positive feedback between new production, remineralization, and the upward flux of nutrients; it is discussed in detail by Najjar et al. (1992). Nutrient trapping becomes more pronounced with a shorter length scale for remineralization. We see no evidence for nutrient trapping in the real ocean, at least to the degree found in this simulation, and conclude that the new production of the equatorial upwelling zones cannot be leaving the euphotic zone primarily as sinking particles which are regenerated in the upper few hundred meters. Including dissolved organic matter in our model improves the simulation of the nutrient distribution because it eliminates nutrient trapping.

The remineralization length scale used in our model is based on data from the oligotrophic subtropical Pacific (Martin et al. 1987). Including a spatially varying remineralization length scale which decreases with increasing productivity (as suggested by Jackson) would only reinforce our conclusions, because nutrient trapping would then be greater in the more productive upwelling regions.

The explosion of studies on techniques for measuring dissolved organic matter in the ocean has forced us to reconsider the conclusions of our modeling studies. The measurements of dissolved organic N and C by Suzuki et al. (1985) and Sugimura and Suzuki (1988), to which the modeling studies gave support, have been very difficult to reproduce by other investigators. More importantly, Suzuki (1993) has recently retracted the 1985 and 1988 papers. If dissolved organic matter cannot cure the nutrient trapping problems in the models, then what can? A likely place to look is in the circulation model itself. If equatorial upwelling in the model is higher than observed, it can cause nutrient trapping. The general circulation models that have been used to study organic matter cycling have horizontal resolution of four or five degrees, which is clearly too coarse to properly resolve the important features of tropical ocean circulation. Another possibility is that the particle flux length scales as measured by sediment traps are too short, which is reasonable given the difficulty of measuring the sinking flux of particles in the ocean.

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