

Figure 8.6 (continued)

concentration based on a time-dependent numerical model (Altabet, in prep.) suggest a residence time for suspended PN in the euphotic zone of 2 weeks, a significant fraction of the depletion time for NO_3^- .

In the post-bloom period, the NO_3^- originally present in the euphotic zone has been depleted and any new transport into the euphotic zone from below is completely consumed. $\delta^{15}\text{N}$ for near-surface ocean POM will decrease to the value for $\delta^{15}\text{NO}_3^-$ or lower depending on recycling effects. Our near-surface data cover well the first two phases of the bloom (Figure 8.6) but not this third phase. More recently, a complete $\delta^{15}\text{N}$ time series was obtained for the subtropical Gulf of Eilat showing the 3 expected phases (Figure 8.8). In the winter there is deep convective mixing homogenizing NO_3^- concentrations throughout the water column. In early

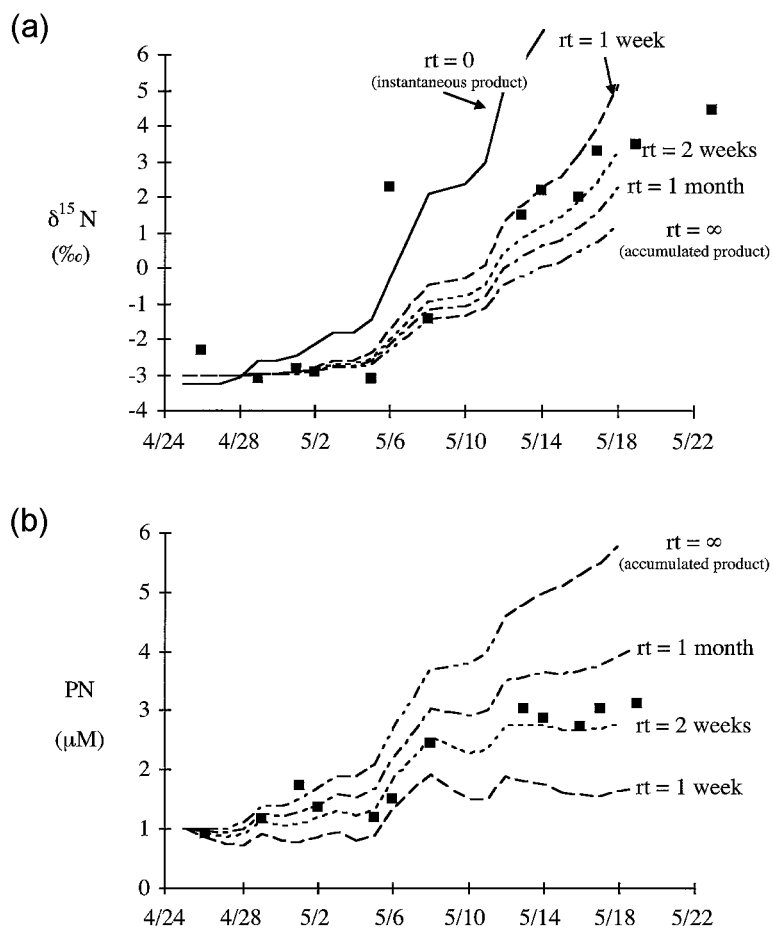
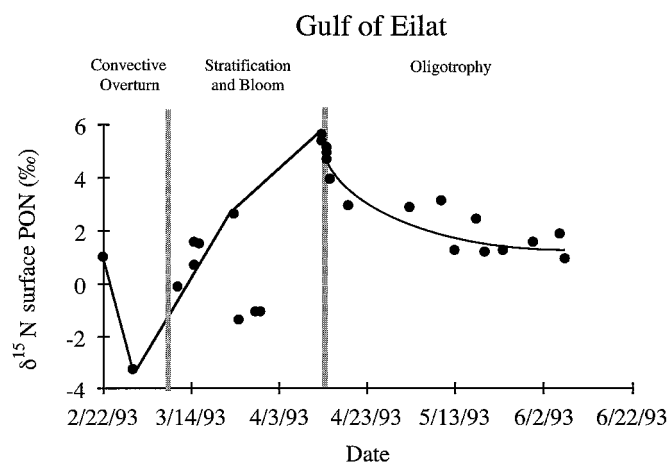


Figure 8.7 Comparison of observations (points) from the JGOFS NABE with simulated results (lines) for different particle residence times (rt). For $rt = 0$ and $rt = \infty$, simulations correspond to the instantaneous and accumulated product eqs. respectively (eqs. 6 and 7). For intermediate values of rt , a numerical model was used (Altabet, in prep.) (a) $\delta^{15}\text{N}$ for suspended PN. (b) Suspended PN concentration. Observed data points are for mixed layer averages.

spring, stratification promotes a phytoplankton bloom, drawing down NO_3^- and raising $\delta^{15}\text{N}$ values. After complete NO_3^- removal, $\delta^{15}\text{N}$ relaxes to lower values probably due to both complete utilization of NO_3^- subsequently transported upward by vertical eddy diffusion and increased N-recycling.

As discussed above, the increasing $\delta^{13}\text{C}$ of near-surface POM during the bloom cannot be attributed to isotopic enrichment of the substrate (Figure 8.6c and d).

Assuming a net photosynthetic fractionation factor of 22‰ (ϵ_p), the observed 2.4% decrease in dissolved inorganic carbon (DIC) during the bloom period would produce only a 0.5‰ increase in $\delta^{13}\text{C}$ consistent with the 0.3‰ increase in $\delta^{13}\text{C}$ for carbonate in sinking particles observed by Rau et al. (1992). Moreover, the 1° temperature increase observed would have had a minor influence on the equilibrium fractionation effect between HCO_3^- and $\text{CO}_2(\text{aq})$. Instead, as observed previously, the photosynthetic fractionation factor appears to vary directly with $[\text{CO}_2(\text{aq})]$. Since there is an apparent greater sensitivity of $\delta^{13}\text{C}$ to $\text{CO}_2(\text{aq})$ than previously observed, Rau et al. (1992) also suggest a role for increasing ‘biological demand’ for CO_2 (on a cellular not community level) with the progression of the bloom. Other factors such as changes in phytoplankton species composition with progression of the bloom (from diatoms to flagellates) may have also influenced $\delta^{13}\text{C}$ values. Increases in $\delta^{13}\text{C}$ during the bloom substantially lead increases in $\delta^{15}\text{N}$ (Figure 8.6) underscoring the independence of their forcing functions.



concentration (Figure 8.10a) is the principal source for sinking particles (Figure 8.9). The reason $\delta^{15}\text{N}$ values for suspended PN increase toward the surface in the upper 50 m is because of the corresponding vertical depletion of nitrate. C/N ratios also show no difference, on average, between sinking particles exiting the euphotic zone (upper 40 to 50 m) and suspended particles within it (Figure 8.10a). The relationship in $\delta^{13}\text{C}_{\text{org}}$, however, is variable with sinking particles being modestly depleted in ^{13}C relative to suspended ones (Figure 8.10b). On average, though, our $\delta^{13}\text{C}$ results agree with those of Rau et al. (1992).

As discussed above, trophic transfers increase $\delta^{15}\text{N}$ on the average of 3.5‰ per step (Minagawa and Wada, 1984; Fry, 1988) and fecal pellets are enriched by 2.2‰ compared to food sources (Altabet and Small, 1990). Either of these processes contributing to the transformation of suspended into sinking particles would raise $\delta^{15}\text{N}$ values. Overall, the data imply that during the bloom the packaging of small, suspended particles into large, sinking ones consisted of relatively short and direct pathways which produced little alteration of organic matter.

These results further indicate that export of organic matter from the euphotic zone occurred relatively efficiently, consistent with the high *f* ratios estimated for this period (Martin et al., 1993). Our floating sediment trap observations occurred just after depletion of silicate in the euphotic zone coincident with a sharp reduction in diatom numbers (Sieracki et al., 1993). We suspect sinking particles were formed primarily by the mass flocculation of diatoms which would account

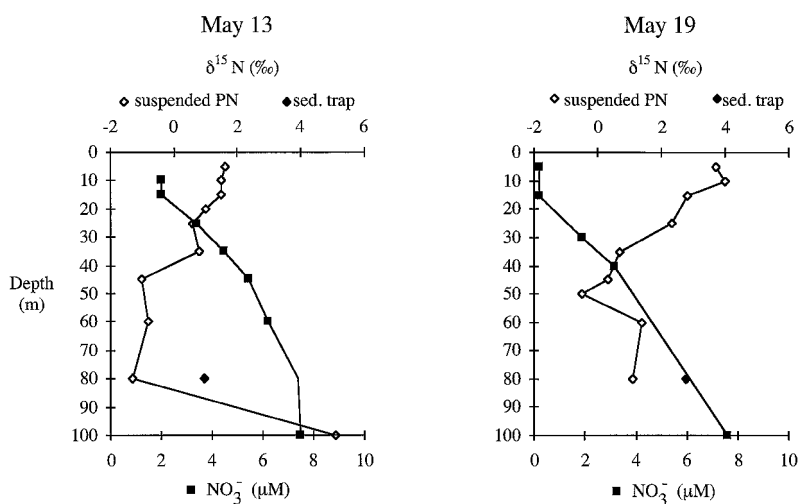


Figure 8.9 Near-surface profiles of NO_3^- concentration and $\delta^{15}\text{N}$ for suspended PN taken on two separate dates during the middle third of the bloom period at the NABE site. $\delta^{15}\text{N}$ values for sinking PN are also shown.

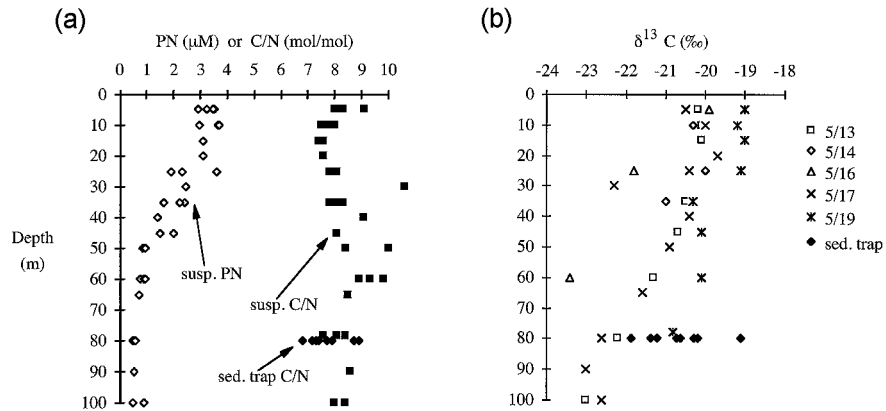


Figure 8.10 (a) Comparison of C/N (mol/mol) for near-surface suspended and sinking POM at the NABE site during the bloom period. These data are from suspended particle profiles and floating sediment trap deployments (24 hr at 80 m) carried out daily to bi-daily from May 12 to May 21, 1989. Suspended PN concentrations are also shown. (b) Comparison of $\delta^{13}\text{C}$ data for floating sediment traps and suspended POC profiles.

for the $\delta^{15}\text{N}$ and C/N results. Such a phenomenon has been directly observed in coastal waters (Alldredge and Gotschalk, 1989). The $\delta^{13}\text{C}$ results could be accounted for if the flocculating diatoms and associated extracellular material were enriched in lipid material (which is low in $\delta^{13}\text{C}$ relative to proteins and carbohydrates). However, higher C/N ratios for sinking particles would then be expected.

8.7.3 COMPARISON OF NEAR-SURFACE AND 1000 M ISOTOPIC SIGNALS

It is clear that the strong near-surface bloom signals in $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ are rapidly carried into the deep ocean by large, fast-sinking particles. Even the near-surface difference in phase between the ^{15}N and ^{13}C isotopic signals is manifest at depth (Figure 8.11). However, significant modification of the $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ signals appears to have occurred between the euphotic zone and the shallowest moored trap (see Figure 8.12 for a close comparison). The near-surface $\delta^{15}\text{N}$ time series has nearly twice the amplitude as observed for deeply sinking particles at 1000 m (12 vs. 6‰) and both a lower minimum and higher maximum (further modifications below 1000 m will be discussed below). A similar comparison is apparent for the $\delta^{13}\text{C}$ time series.

Important clues for explaining these differences are the persistently high $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values at 1000 m during fall and winter and the extended period of decreasing $\delta^{15}\text{N}$ at 1000 m during the early bloom period (April to May). Deep

