Dissolved Organic Carbon Support of Respiration in the Dark Ocean

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Recent evidence that dissolved organic carbon (DOC) is a significant component of the organic carbon flux below the photic layer of the ocean (1), together with verification of high respiration rates in the dark ocean (2), suggests that the downward flux of DOC may play a major role in supporting respiration there. Here we show, on the basis of examination of the relation between DOC and apparent oxygen utilization (AOU), that the DOC flux supports ~10% of the respiration in the dark ocean.

The contribution of DOC to pelagic respiration below the surface mixed layer can be inferred from the relation between DOC and apparent oxygen utilization (AOU, µM O_2), a variable quantifying the cumulative oxygen consumption since a water parcel was last in contact with the atmosphere. However, assessments of DOC/AOU relations have been limited to specific regions of the ocean (3, 4) and have not considered the global ocean. We assembled a large data set (N = 9824) of concurrent DOC and AOU observations collected in cruises conducted throughout the world's oceans (fig. S1, table S1) to examine the relative contribution of DOC to AOU and, therefore, respiration in the dark ocean. AOU increased from an average (±SE) 96.3 ± 2.0 µM at the base of the surface mixed layer (100 m) to 165.5 ± 4.3 µM at the bottom of the main thermocline (1000 m), with a parallel decline in the average DOC from 53.5 ± 0.2 to 43.4 ± 0.3 µM C (Fig. 1).

In contrast, there is no significant decline in DOC with increasing depth beyond 1000 m depth (Fig. 1), indicating that DOC exported with overturning circulation plays a minor role in supporting respiration in the ocean interior (5). Assuming a molar respiratory quotient of 0.69, the decline in DOC accounts for 19.6 ± 0.4% of the AOU within the top 1000 m (Fig. 1). This estimate represents, however, an upper limit, because the correlation between DOC and AOU is partly due to mixing of DOC-rich warm surface waters with DOC-poor cold thermocline waters (6). Removal of this effect by regressing DOC against AOU and water temperature indicates that DOC supports only 8.4 ± 0.3% of the respiration in the mesopelagic waters.

These results confirm that DOC makes a small but significant contribution toward the maintenance of respiratory processes in the dark ocean. DOC use accounts for only ~10% of the AOU in mesopelagic waters, indicating that the bulk of the respiration within the mesopelagic zone is supported by the flux of sinking POC. This estimate for the contribution of DOC oxidation to global AOU is supported by the independent findings that net DOC production accounts for ~20% of net community production in the surface ocean (7), that DOC export contributes to 10 % of the export below 500 m (8), and that the total AOU in the deep ocean is in agreement with that expected from the flux of sinking POC (9). It is the DOC accumulating as a function of primary production in the surface ocean, which is exported with overturning circulation, that dominates the DOC fraction of AOU development. Our findings indicate that the POC flux, which appears to be severely underestimated by sediment traps in the mesopelagic zone (10), is much greater than the DOC flux and supports the bulk (~90%) of the respiratory carbon demand in the dark ocean.

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Fig. S1
Table S1

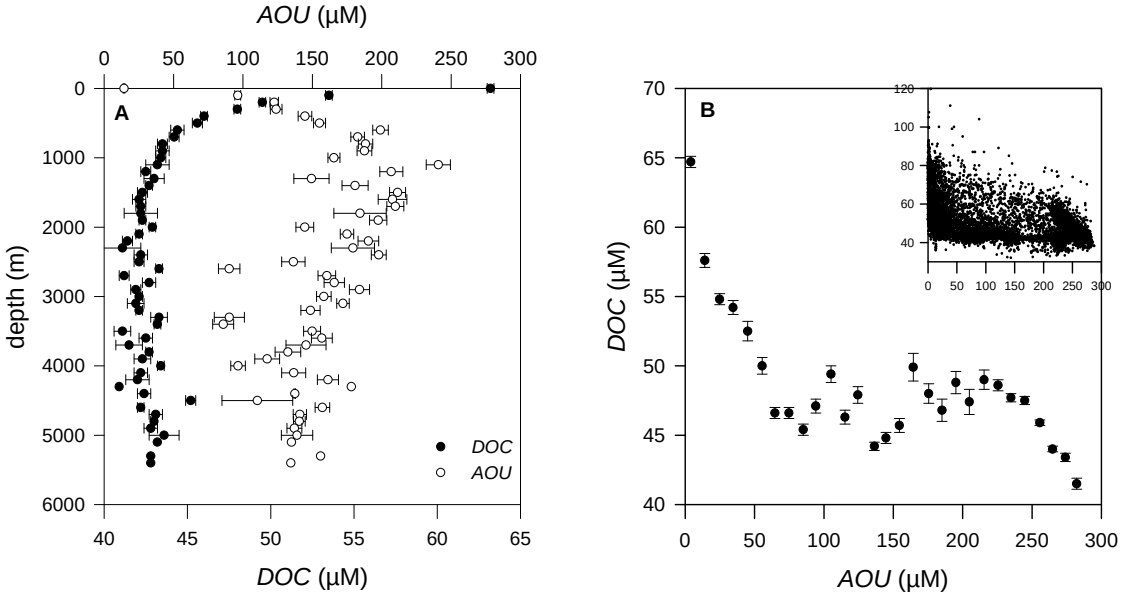

Fig. 1. The depth distribution of the average (mean ± SE of data grouped by 100-m bins, N = 9578) DOC (full circles) concentration and AOU (empty circles) in the ocean (A) and the relation between DOC and AOU in the ocean (B). The symbols represent mean ± SE DOC concentrations of data grouped by 10 µM AOU bins (N = 9824). The inset in (B) shows the relation for the raw data (N = 9824), which is described, in the interval 0 < AOU < 150, by the fitted regression equation DOC = 60.3 (±0.2) - 0.136 (± 0.003) AOU (R^2 = 0.28, P < 0.0001, N = 5541). Multiple regression analysis, also using water temperature (°C) as an independent variable, improves the fit, yielding the equation DOC = 48.0 (±0.2) + 0.81 (±0.01) T - 0.058 (±0.002) AOU (R^2 = 0.69, P < 0.0001, N = 5371). The monotonic decrease of DOC for AOU > 225 corresponds to the oxygen minimum zones of the Arabian Sea, Indian Ocean, and equatorial Pacific Ocean.