

Measuring The F In JGOFS: A New Way To Catch The Rain

by Ken O. Buesseler

Measurements of the flux and composition of the particulate rain that falls through the ocean have been of great interest and importance to JGOFS since its earliest days. The organic particles that sink slowly through the water column represent the major pathway for the rapid removal of carbon from the surface ocean to deeper waters and the sediments. The magnitude of the ocean carbon sink on time scales from years to millennia is ultimately determined by the efficiency of this removal process, the "biological pump."

Recent JGOFS studies suggest that the efficiency of this pump varies greatly with season and latitude as a function of the regional food web and abiotic particle aggregation processes. How accurately can we measure the sinking particle flux, one of the many "F's" that scientists hope to constrain in JGOFS?

Direct collection of sinking particles in the ocean began in the late 1970s with the deployment of sediment traps, open-topped cylinders or cones that act as rain gauges in the water column. They are generally designed to collect, over a period of days or weeks, any particle that sinks into the mouth of the trap. Studies using sediment traps have revolutionized our understanding of the connections between the surface ocean and the depths.

For example, trap studies have showed that a buildup of phytoplankton biomass in the euphotic zone can lead to a direct or delayed increase in the vertical flux of biogenic particles such as fecal pellets, aggregates, molts or shells. During their descent, some of these particles disintegrate or are consumed by zooplankton or by bacteria, which convert their component elements back into inorganic form. This remineralization is critical to the overall efficiency of the removal of carbon and associated elements from the surface ocean. As a general rule, only 5% to 10% of the carbon fixed by phytoplankton sinks out of the surface layer. During specific plankton blooms, however, this export flux can exceed 50% of surface primary production.

Although the overall patterns of particle fluxes that we derive from current trapping methods seem reasonable, it is hard to determine the absolute accuracy of trap flux estimates. My colleagues and I have used thorium 234, a naturally occurring radionuclide that sticks to particles, as a means of measuring carbon removal in particle form. We have found that thorium fluxes in upper-ocean sediment trap samples often differ by as much as three times or more from flux estimates derived from measuring thorium inventories in seawater. Comparisons between different traps deployed at the same time show both agreement and disagreement.

Two U.S. JGOFS reports have been written on the use of sediment traps and the accuracy of their measurements. These reports point out that hydrodynamic forces, such as horizontal currents, have an effect on the particle flux measured in the traps. The reports also note that traps collect grazers that swim into them as well as the sinking debris. For these reasons, among others, it is

difficult to move beyond a first-order estimate of the upper-ocean carbon budget or to clarify the details of the processes responsible for this export. Until we can improve the accuracy of trap measurements, it will be difficult to provide an accurate assessment of the ocean carbon sink that global carbon models and climate predictions require.

In response to this problem, a team at Woods Hole Oceanographic Institution (WHOI) is developing a new sediment trap for upper ocean flux studies. Building upon the expertise gained in deploying floats to study ocean currents, James Price and James Valdes have recently modified a neutrally buoyant drifter to collect sinking particles, thus creating a neutrally buoyant sediment trap (NBST). This team has been working with Deborah Steinberg of Bermuda Biological Station for Research (BBSR), Anthony Michaels of the University of Southern California and Ken Buesseler of WHOI to test the device.

The NBST collection tubes are similar to those used currently in surface-tethered sediment traps, but instead of being attached to a fixed mooring or a cable with drifting surface buoys, the trap is free floating at a predetermined depth. After spending given amount of time at depth, the trap returns to the surface with samples sealed and ready for analysis. The most successful version of the NBST includes active onboard buoyancy control; a one-gram difference in the 20-kilogram package can bring about a 50- to 100-meter shift in deployment depth. After the NBST returns to the surface, it indicates its position with an ARGOS transmitter and a flashing light.

We have tested the trap successfully on two occasions at the U.S. JGOFS Bermuda Atlantic Time-series Study (BATS) site. The data are both exciting and surprising. We found a wide range of compositional and relative flux differences between the NBST and traditional traps. At 150 meters, for example, we found a flux difference of 70% for measurements of particulate organic carbon, 40% for thorium 234, and 60% for fecal pellets. We attribute this relative difference between fluxes to particle sorting, since it is likely that different types of particles have different sinking rates and are thus collected differentially in standard traps.

One of the other surprising findings was that the NBST captured many fewer swimmers than traditional traps do. BATS investigators find, in general, that they pick out more carbon in the form of swimmers than is left behind as the net flux in the surface-tethered sediment traps that they use. With the NBST, however, carbon in the form of swimmers was only 15% of the net flux. We speculate that the swimmers found in traditional traps were actually surfers. They rode the currents that passed horizontally over the traps and were carried into the sample collection tube, which contains poisons to preserve the particles in the sample reservoir.

We hope to develop and test a user-friendly version of the NBST in the near future and to try to replicate these results in a wide range of environments. We are anxious to see whether the results from the early trap studies prove robust and to find out what level of accuracy is possible for constraining the sinking particle flux. As in other fields in the ocean sciences, technological advances can provide new views on an old problem.

In addition to data relevant to ocean carbon cycle questions, NBSTs may ultimately be able to provide information on the temporal and spatial gradients in the flux of many pollutants and compounds of environmental concern. If these new traps prove more accurate than their

predecessors by eliminating the biases caused by hydrodynamic factors and swimmers, we can start to answer some of ocean science's toughest questions about the composition of the particle rain and the flux of carbon into the deep sea.

Editor's note: Ken Buesseler, an associate scientist at Woods Hole Oceanographic Institution, is currently executive scientist of the U.S. JGOFS Planning and Data Management Office.)