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Characteristics of sinking particles in the upper ocean at the Porcupine Abyssal Plain

Jennifer Riley, Richard Sanders, and Eric Achterberg
(Jennifer.Riley@noc.soton.ac.uk)

Sinking particles play an important role in the biological carbon pump, transferring carbon from the surface to the deep ocean. Data from deep ocean sediment traps suggest biominerals influence particle settling velocity, by increasing their density. However it is unclear whether this biomineral facilitated sinking applies to the upper ocean and if shape also plays a critical role on the rate at which particles sink. Measurements of particle settling velocity, density and drag were made in order to determine their influences on the particle sinking rate in the upper water column. Samples were taken during a cruise in summer 2009 from the Porcupine Abyssal Plain (PAP site) in the northwest Atlantic.

Particles were collected from the base of the mixed layer (approximately 50m) using the Marine Snow Catcher. This instrument samples 100L of water and collects any settling particles in a 5L base chamber over 2 – 3 hours. After settling, the top 95L of water was drained off and any particles collected in the base chamber were transferred to the lab. Particles were individually picked using a Pasteur pipette and subdivided, into categories on the basis of appearance. Settling experiments were conducted in a 2L glass measuring cylinder filled with surface sea water, kept at a constant temperature of 15˚C. After each experiment particles were preserved individually in buffered formalin for high quality image analysis back on land. Calculations of both excess density and drag were undertaken using data from microscopic measurements.

Five main particle categories were identified; (1) diffuse fluff aggregates, (2) dense fluff aggregates, (3) centred particles (fluff aggregated around a central biomineral test), (4) organisms (biomineralising protists including foraminifera) and (5) calcareous tests. Statistical analysis suggested a significant difference in the rate at which the centred and calcareous particles sank (approximately 248 m day^{-1} and 1070 m day^{-1}respectively) in relation to the other classes (142 – 184 m day^{-1}). Excess densities and drag coefficients were respectively; 0.015 g cm^{-3} and 126, for organisms, 0.044 g cm^{-3} and 204 for centred particles and 1.68 g cm^{-3} and 1823 for calcareous tests.

To determine whether particle density or drag, governs settling velocity, calculations were made of how typical (defined using averaged values from the observed data) sinking speeds vary with, (1) excess density and (2) drag coefficient. Comparison of the observed and typical particle characteristics suggested the differences observed in excess density were too small to account for the variation in measured sinking speed. However the change in calculated drag was larger than required to account for the observed variation in settling velocity.

The results imply it is the process of aggregate formation and the resulting particle shape that has the greatest influence upon the rate at which particles sink in the upper ocean. This contrasts with the deep ocean ballast hypothesis, which suggests the incorporation of biominerals into aggregates influences particle sinking speeds.