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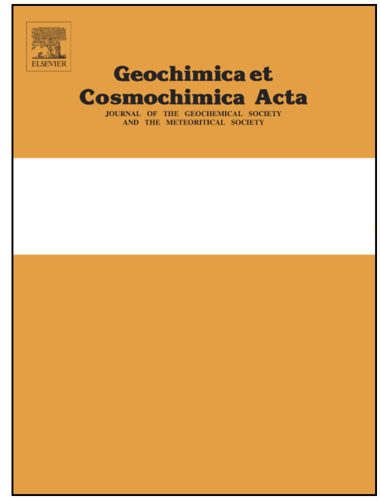

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A microscopic simulation of particle flux in ocean waters: application to radioactive pair disequilibrium.

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Abstract

The biological carbon pump, a fundamental component of the global carbon cycle, is a mechanism comprised of biological processes that transfer large amounts of organic carbon from the upper ocean to the ocean's interior. It sequesters CO_2 for weeks to hundreds or even millions of years through the sinking of a complex mix of biogeochemical material. As particles sink the flux of particulate organic carbon attenuates and only a fraction of the flux reaches the ocean's depth. Quantifying the attenuation of sinking particulate carbon flux is key to assess the amount of carbon sequestered in the twilight zone. Current knowledge of the particle flux attenuation relies on a reduced number of direct measurements, usually fitted to a power law, that tries to describe the result of a large variety of biological, physical and chemical processes involved.

We present a stochastic simulation for particle production, sinking and degradation in the oceans that includes most of the essential ingredients to ultimately describe the sinking carbon flux in the ocean and where all the complex biogeochemical behavior is captured by macroscopic parameters. The algorithm proposed interprets these phenomena probabilistically and is an ideal framework to describe the observed patterns of particle flux attenuation in depth. Particles are randomly produced and degraded with depth-dependent functions, which reproduces the variability of these processes in nature. Hence, the simulation proposed provides a suitable approach to analyse sinking carbon when different particle sizes or speeds are used. Furthermore, production and degradation phenomena are time-dependent, this way their seasonal evolution can be additionally explored and the simulation results in an ideal test-bed for the assessment of both steady and non-steady state situations. In addition, the theoretical formulation proposed provides a simple frame to include particle-metals interactions through adsorption and desorption processes.

In this paper we relate typical parametrizations of the flux attenuation curve to their corresponding degradation rate and propose an alternative parametrization to model the flux degradation function which is negligible at very large depths, therefore producing a constant residual flux, and remains finite in the euphotic zone. This degradation function is implemented in the simulation and applied to estimate the scavenging of the naturally occurring radioisotopes ^{234}Th and ^{210}Po. We use the results to estimate effective adsorption and desorption rate constants for both isotopes. We found that the degradation rate, rather than the half-life, controls the depth at which the parent and daughter reach equilibrium. Thus, this depth is ruled by a combination of the degradation rate and the particle sinking velocity.

Keywords: particle dynamics, carbon attenuation, Martin's curve, adsorption/desorption, ^{210}Po, ^{234}Th

1. Introduction

The Biological Carbon Pump (BCP) is part of the ocean's CO_2 sink and has the potential to remove large amounts of CO_2 from contact with the atmosphere on short time-scales. From 10% (Henson et al., 2011) to 40% (Eppley and Peterson, 1979) of the carbon produced in the euphotic zone (primary production, PP) is exported out of the mixed layer. Nonetheless, only a small fraction of this carbon fixed by photosynthesis reaches the deep-ocean due to the

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