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Comparing POC export from $^{234}Th/^{238}U$ and $^{210}Po/^{210}Pb$ disequilibria with estimates from sediment traps in the northwest Mediterranean

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Abstract

We compare POC fluxes estimated using $^{234}Th/^{238}U$ and $^{210}Po/^{210}Pb$ disequilibria at the DYFAMED site, northwestern Mediterranean Sea. We also compare the POC fluxes estimated from these two isotope pairs with fluxes below the euphotic zone measured in moored sediment traps. The POC flux at 200 m estimated from ^{234}Th and ^{210}Po deficits and the $POC/^{210}Po$ or $POC/^{234}Th$ on $>70\,\mu m$ filterable particles measured through three seasons (early spring, late spring, summer) ranged from 3.8 to 17.5 mmol $C/m^2/d$ based on $^{234}Th/^{238}U$ and from 4.4 to 7.0 mmol $C/m^2/d$ based on $^{210}Po/^{210}Pb$ disequilibrium. In comparison, sediment trap fluxes of POC at approximately 200 m ranged from 0.2 to 6.0 mmol $C/m^2/d$ over the same interval. Values of $POC/^{210}Po$ and $POC/^{234}Th$ ratios in sediment trap material collected in time series or separated according to settling velocity (SV) were generally lower than values in the $>70\,\mu m$ filterable particles at the same depth. The variation in $POC/^{210}Po$ and $POC/^{234}Th$ in material separated according to SV showed no clear relationship with SV and was controlled more by particle composition and degree of degradation. Both ^{234}Th and ^{210}Po showed sustained deficits in late spring and summer, despite low fluxes recorded in the trap. Lateral processes (transport of particles along isopycnals or intrusion of shelf waters to the site) and violations of temporal assumptions (steady-state vs. non-steady-state) may be responsible for this disparity. Based on the results of this study, we conclude that $^{210}Po/^{210}Pb$ disequilibrium is as valid as $^{234}Th/^{238}U$ as a proxy for estimating POC flux in the ocean.

Keywords: Vertical flux; Thorium; Polonium; Lead; Sediment traps; Mediterranean; DYFAMED

1. Introduction

The export of POC from the surface ocean to depth is an important parameter in global carbon models (e.g., Kwon and Schnoor, 1994). This flux of material plays a key role in sequestering carbon

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from the atmosphere into the deep ocean and marine sediments. Particle-reactive, short-lived natural radionuclides can be used to trace POC flux (e.g., Buesseler et al., 1992a,b; Buesseler, 1998; Cochran et al., 2000; Cochran and Masqué, 2003). Commonly, the disequilibrium of ^{234}Th ($t_{1/2} = 24$ d) with respect to its radioactive parent ^{238}U ($t_{1/2} = 4.5 \times 10^9$ y) in the surface ocean has been used to estimate POC fluxes (see Cochran and Masqué, 2003 for a review). The calculation of POC flux from ^{234}Th deficits is done by multiplying the integrated deficit above a given depth horizon (e.g., the base of the euphotic zone) by the POC/^{234}Th ratio (hereafter POC/Th) on particles settling through that horizon (Buesseler et al., 2006).

Only a few studies have employed disequilibrium in another radionuclide pair, ^{210}Po ($t_{1/2} = 138$ d) and its grandparent ^{210}Pb ($t_{1/2} = 22$ y), to predict POC fluxes despite evidence that ^{210}Po is more closely linked to the cycling of organic material within the plankton than is ^{234}Th (Fisher et al., 1983; Stewart and Fisher, 2003a,b; Stewart et al., 2005). Indeed, ^{210}Po has been shown to correlate with organic carbon and nitrogen in natural sinking particles (Sarin et al., 1999; Kim and Church, 2002; Friedrich and Rutgers van der Loeff, 2002; Murray et al., 2005).

Many of the export flux results from the Joint Global Ocean Flux Study relied on ^{234}Th /^{238}U disequilibria. ^{210}Po and ^{210}Pb activities were measured during some of the same JGOFS studies (EqPac: Murray et al., 2005; Southern Ocean: Friedrich and Rutgers van der Loeff, 2002), and, in some instances, the POC fluxes from both radionuclide pairs were compared. For example, Murray et al. (2005) used both ^{234}Th/^{238}U and ^{210}Po/^{210}Pb disequilibria to determine export fluxes of POC in the JGOFS EqPac study. They estimated POC fluxes based on the radionuclide deficit and the POC/Th or POC/Po ratio on particles collected in drifting traps deployed at the same time as the radionuclide sampling and found that POC fluxes determined from ^{210}Po/^{210}Pb disequilibria were frequently greater than those from ^{234}Th/^{238}U. Other studies have indirectly compared the two isotope pairs (e.g., Shimmield et al., 1995; Kim and Church, 2002; Friedrich and Rutgers van der Loeff, 2002).

Except for the work of Murray et al. (2005), prior efforts to use ^{210}Po as a POC flux proxy generally have not applied it in a manner analogous to that in which ^{234}Th has been used, making a rigorous evaluation of the relative advantages of the two tracers difficult (Verdeny et al., 2005). Here we compare POC fluxes estimated from the water column disequilibrium between isotope pairs, ^{210}Po/^{210}Pb and ^{234}Th/^{238}U, with those measured in sediment traps at the DYFAMED site in the northwestern Mediterranean Sea in order to evaluate these three methods of POC flux estimation. Because the conversion of ^{234}Th or ^{210}Po deficits into POC fluxes requires knowledge of the POC/^{234}Th or POC/^{210}Po ratio of sinking material, we have measured simultaneously the ratios of POC/^{210}Po and POC/^{234}Th in filterable particles (>70 and 1–70 μm) collected by in situ pumps and in sediment trap material collected in time-series mode and in a fashion that separated particles according to settling velocity (SV).

2. Materials and methods

2.1. Sample collection

Samples were collected during three multidisciplinary cruises as part of the MedFlux project at the DYFAMED site (Fig. 1; http://www.msrc.sunysb.edu/MedFlux/). The DYFAMED (DYnamique des Flux Atmospheriques en MEDiterranee, 43°25′N, 7°52′E) site is a French JGOFS time-series station in the Ligurian Sea. This site was chosen because it demonstrates characteristics of an open-ocean setting despite its relative proximity to shore. The site (2300 m

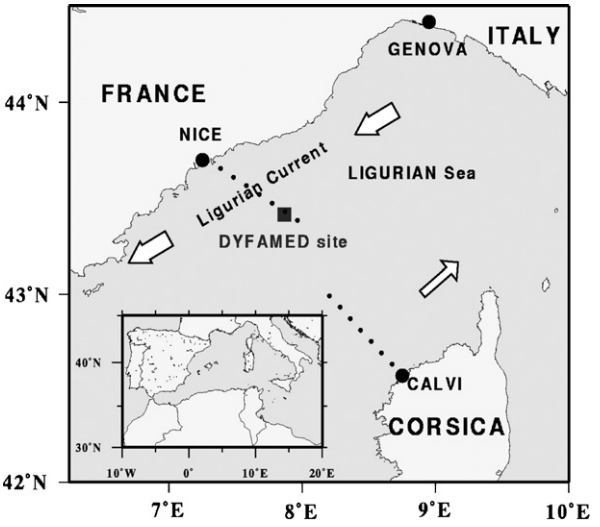

Fig. 1. Map showing location of the DYFAMED site. Arrows indicate direction and relative magnitude of Northern (Liguro-Provencal) Current.