Estimating thorium-234 partition coefficients by inverse modeling

GUILLAUME LE GLAND[1*], OLIVIER AUMONT[2] AND LAURENT MÉMERY[3]

[1]Institut de Ciències del Mar, CSIC, Barcelona, Spain (*correspondence: legland@icm.csic.es)
[2]LOCEAN, Institut Pierre Simon Laplace, Paris, France (olivier.aumont@ird.fr)
[3]LEMAR, Institut Universitaire Européen de la Mer, Plouzané, France (laurent.memery@univ-brest.fr)

Thorium-234 (^{234}Th), an insoluble radio-isotope scavanged by marine particles, can be used as a proxy of the biological carbon pump (BCP).

Thorium-234 observations can constrain biogeochemical models, but a necessary first step is to estimate the poorly known partition coefficients, representing the affinity of ^{234}Th for each particle type. In our study, we estimated the partition coefficients for five particle types, differing in size and chemical composition, by fitting a ^{234}Th model to a dataset, a process called "inverse modeling". Our 3D time-dependent model is based on the ocean general circulation model NEMO-OPA and the particle concentrations of a biogeochemistry model coupled with NEMO: PISCES v2. Our global dataset contains more than 5000 ^{234}Th observations, including GEOTRACES data.

Surface partition coefficients are estimated between 0.79 and 16.7 x 10^6. Biogenic silica has the smallest partition coefficients. Small particulate organic carbon and lithogenic dust have the largest. Thorium-234 observations at depth cannot be recovered without adding an extra degree of freedom, allowing the model partition coefficients to increase by one order of magnitude from surface to 1000 m deep. Some horizontal biases in PISCES particle distributions can also be identified.

In our time-dependent global 3D model, the biases introduced by three common assumptions made in BCP studies can be quantified. First, using the C:^{234}Th ratio of large particles alone leads to an overestimation of carbon export at the base of the euphotic layer, by up to a factor 2, especially in subtropical gyres where large particles are scarce. Furthermore, assuming steady state and neglecting transport by advection and diffusion can bias fluxes by as much as 50%, especially at high latitudes and in upwellings, with a sign and intensity depending on the season.