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Impact of scavenging by nepheloid layers on the distribution of protactinium and thorium isotopes in the ocean

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The isotopes ^{231}Pa and ^{230}Th have long been used as a proxy of past ocean circulation, in particular the strength of the Atlantic Meridional Overturning Circulation. While these tracers are now implemented in many ocean and climate models used for paleoclimate studies, models still struggle to capture important features of their distribution, limiting the systematic and quantitative use of this isotope pair. One reason for this, as is increasingly recognized, is the role of ocean bottom nepheloid layers. These layers contain large amounts of suspended sediments that can scavenge Pa/Th and other tracers such as neodymium. A second reason is the computational expense of spinning-up these tracers to equilibrium in global models, a procedure that requires integrating the model for several thousand years.

To address the first problem, we have implemented a spatially-variable distribution of nepheloid layers in a numerical model of Pa/Th embedded within a coupled physical circulation-biogeochemical model. The nepheloid layer map is estimated by calibrating transmissometer data against concomitant particle concentrations. Our results show that, compared with simulations without a nepheloid layer or a spatially-uniform one, a spatially-variable map leads to a markedly better agreement between the modeled distribution of Pa/Th and GEOTRACES data. To address the second challenge, we have developed a numerical technique that can accelerate spin-up of geochemical tracers in models by over an order of magnitude. We demonstrate the application of this method to systematically tune the scavenging coefficients of the Pa/Th model against GEOTRACES data.