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On the influence of sediment resuspension on deep-ocean Pa-231 and Th-230 cycling: Roles of turbulent mixing and differential scavenging

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The naturally-occurring particle-reactive radionuclides protactinium-231 (^{231}Pa) and thorium-230 (^{230}Th) are used as tracers of a variety of oceanic processes, both at present and in the past. Most notably, the sediment ^{231}Pa/^{230}Th ratio has been used to infer changes in the Atlantic Meridional Overturning Circulation over the last (de)glaciation. However, recent measurements along the U.S. GEOTRACES North Atlantic transect (GA03) revealed two features which are at odds with current understanding about ^{231}Pa and ^{230}Th behaviour in the ocean: (i) a sharp decrease in dissolved ^{231}Pa and ^{230}Th activities with depth below 2000-4000 m and (ii) very large particulate ^{231}Pa and ^{230}Th activities near the bottom, at a number of stations between the New England continental shelf and Bermuda. Concomitant measurements of particulate matter concentration and potential temperature showed that both features are associated with the benthic nepheloid layer (BNL) and the bottom mixed layer (BML) that are present at these stations.

Here we develop and apply a simplified model of the exchange of particles, ^{231}Pa, and ^{230}Th between the BNL and the upper sediment, to explore the extent to which the radionuclide anomalies observed near the bottom at a number of GA03 stations can be explained by local sediment resuspension. We find that the model can broadly reproduce the observed anomalies at two stations where samples for radionuclide analyses were collected near the seafloor. Sensitivity tests with the model show that the ^{231}Pa/^{230}Th ratio of particles in the BML and the sediment varies by a factor of 3 as the sediment resuspension rate fluctuates within a range consistent with observational estimates. The modelled variability is comparable to the spatial variability of ^{231}Pa/^{230}Th of suspended particles in the modern North Atlantic and to the variability of Atlantic sediment ^{231}Pa/^{230}Th records across the last (de)glacial period. Two factors are found to contribute to the modelled sensitivity of the sediment ^{231}Pa/^{230}Th to sediment resuspension rate: the vertical turbulent mixing in the BML and the differential scavenging intensity of Pa and Th due to variation in particle concentration. Overall, our study indicates that the exchange of material between the BNL and the upper sediment can affect the particulate ^{231}Pa/^{230}Th ratio in the bottom water and the sediment, which may complicate the use of sediment ^{231}Pa/^{230}Th as a palaeoceanographic

tracer.