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Quantifying Lithogenic Inputs to the Ocean from the GEOTRACES Thorium Transects in a Data-Assimilation Model

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The long-lived thorium isotope ^{232}Th is a primordial component of continental crust, and is delivered to the global ocean in lithogenic material. Its primary sources include dissolution from aeolian dust in the surface ocean and inputs from shelf sediments along continental margins, and it is lost from the water column by scavenging onto particulate matter. The radiogenic isotope ^{230}Th shares the same removal processes but its only source is the uniform decay of Uranium-234. The ^{232}Th-^{230}Th isotope system can therefore be used to jointly constrain source and sink processes and infer lithogenic trace element inputs. While this tool has been applied at select locations, a systematic global analysis has not been conducted to date. Here we employ a data-assimilation model of the oceanic ^{230}Th and ^{232}Th cycles to extract process information from the GEOTRACES transect data collected from all ocean basins. We first model the relatively simple ^{230}Th isotope to constrain scavenging rates. We find that reversible scavenging onto particulate organic carbon is sufficient to explain the large-scale ^{230}Th distribution, but strong scavenging onto iron and manganese oxides is required to explain ^{230}Th depletion around hydrothermal vents. We then conduct an ensemble of ^{232}Th model optimizations that test different patterns of dust supply and solubility, and different parameterizations of benthic lithogenic sources. We find that the aeolian ^{232}Th supply is consistent with inferences made from the Aluminum dust tracer in previous work – the Atlantic Ocean receives the majority of aeolian ^{232}Th, and dust solubility increases approximately tenfold in regions of low dust deposition. Our model suggests that there must be ubiquitous benthic resuspension of lithogenic matter into bottom waters to sustain deep ^{232}Th concentrations, with enhanced rates along continental shelves that explain mid-depth maxima in the ^{232}Th distribution. Combined with observed ratios of soluble iron (Fe) to ^{232}Th in aeolian and benthic lithogenic material, our results can help constrain different Fe supply pathways to the global ocean.