Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.28231

Insights from simulating trace elements and their isotopes in Earth system models

FRERK PÖPPELMEIER AND PIERRE TESTORF
University of Bern

Trace elements and their isotopes serve as essential tools to advance our understanding of biogeochemical processes and oceanic circulation dynamics. However, interpreting these tracers remains inherently challenging due to their (direct or indirect) sensitivity to both processes, which often rely on a range of assumptions. This issue is further exacerbated when reconstructing past conditions from marine sediments, as assumptions valid for today's ocean may not hold under past environmental conditions. These challenges can be overcome by implementing trace elements and their isotopes in Earth system models, which provide a coherent analytical framework. Here, we demonstrate this potential by employing the Bern3D model of intermediate complexity. The reduced computational costs of this model allow for simulating elements with marine residence times spanning millennia and isotope systems that only reach equilibrium on timescales of glacial-interglacial cycles. The Bern3D model is equipped with a large suite of isotope tracers, including carbon, neodymium (Nd), beryllium, protactinium (Pa), and thorium (Th) isotopes as well as additional trace elements, such as noble gases, N_2O, and chromium. Through two examples, we illustrate how new insights can be gained with this approach: First, Nd isotopes, which act as diagnostic marker for water mass provenance, have long faced uncertainties regarding global sources and sinks to the ocean, both in magnitude and distribution. Through modeling efforts, these are now more robustly constrained, revealing that during past climate and ocean states, Nd concentrations varied substantially on a regional scale. This challenges the prior assumption of constant Nd concentrations, with critical implications for interpretations of reconstructed Nd isotopes. Second, by explicitly simulating Pa and Th dynamics in the model, we are able to disentangle the influences from physical transport and scavenging by settling particles on tracer concentrations. We find that even in the Atlantic, where kinematic processes were previously assumed dominant, effects of physical transport and particle scavenging are in a delicate balance. This implies the necessity of accounting for spatiotemporal variations in both mechanisms when interpreting Pa/Th proxy data.