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A new framework to quantify carbon cycle perturbations using trace metal isotopes

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Reconstructing the environmental consequences of large carbon additions in the past has the potential to improve our understanding and prediction of how the Earth system will respond to human carbon emissions. However, uncertainties over the scale and timing of external carbon additions during past carbon emission events limit quantitative knowledge gained from the geological record. The metals Sr, Os, Li and Ca are essential proxies for changes in volcanic activity and terrestrial weathering rates, and thus for major causes of pre-industrial carbon emission and sequestration, because their isotopic compositions in old continental crust and Earth's mantle differ significantly. So far, box models and equilibrium-state equations have been the only method to quantitatively relate weathering-derived and magmatic input fluxes to trace metal concentrations and isotopic ratios preserved in ancient sediments. This approach results most commonly in a first order estimate of emitted carbon or weathering changes, but it does not account for the effect of climate feedbacks on metal sources and sinks and associated variations in the residence time of these metals in the ocean. Particularly during fast carbon emissions (e.g. Cenozoic hyperthermals, Oceanic Anoxic Events), the processes which added isotopically traceable metals to the oceans also enchained environmental changes which would have affected metal cycles and residence times, resulting in significant alterations of the recorded isotopic excursion in marine sediments. To disentangle the signals of causes and consequences of environmental change recorded by trace metal isotopes, we simulated various coupled carbon and metal cycle perturbations in the 3D Earth system model of intermediate complexity cGENIE, now containing the first representation of isotope-enabled trace metal dynamics. Here, we present a resulting extended framework to reconstruct metal and carbon fluxes from the geological trace metal record during periods of environmental change.