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Modeling the marine chromium cycle with an EMIC: Constraining global-scale processes

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The chromium (Cr) cycle received growing attention over the past decades motivated by its potential as a tracer of marine oxygenation and biological productivity. The different chemical properties of its two main oxidation states, Cr(III) and Cr(VI), shape the global Cr distribution in the oceans. Yet, anthropogenic contaminations of rivers and coastal environments, insufficient knowledge about the redox behavior in the open ocean as well as in oxygen minimum zones, and the possibility of yet unrecognized Cr sources from sediments complicate the understanding of the marine Cr cycle.

We therefore implemented the two oxidation states of Cr in the Bern3D Earth system model of intermediate complexity (EMIC), in order to gain an improved understanding on the mechanisms that modulate the spatial distribution of Cr in the ocean. Parametrizations include the relatively well-defined sources associated with dust and river input, along with the recently characterized benthic flux. These are balanced by reversible scavenging, which ultimately leads to burial in the underlying sediments. Further, we implemented redox transformations between both oxidation states.

We exploit the computational efficiency of the Bern3D model to explore a large range of parameters and compare these simulations to a comprehensive observational database. This yields important constraints on the mean ocean residence time of Cr and the magnitude of the benthic Cr flux, which converge to 6 kyrs and 0.1-0.2 nmol/cm^2/yr, respectively, for the simulations with best model-data agreement. In these simulations, the total flux of Cr entering the ocean is dominated by the benthic one followed by the riverine flux and a minor contribution from dust. The simulated Cr distribution is characterized by two pronounced and globally consistent features, a vertical increase in concentration and an accumulation of deep water Cr with water mass age, both in good agreement with observations.