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Probing mass balance, fluxes, and deep time implications of the surface Earth reactive silica cycle using Si isotopes

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The transport of reactive Si through various surface Earth reservoirs (e.g., global oceans, biosphere, rocks and sediment, and cryosphere) has applied critical controls on the evolution of the atmosphere and ocean chemistry through Earth's history. The Si cycle is intimately linked to that of C, alkalinity, macronutrients, and trace elements through several pathways like silicate mineral weathering, primary production, the biological portion of the ocean carbon pump, and reverse weathering. As an analogue for the mass balance on the surface Earth, examining the vectors or reactions through which dissolved Si enters, is processed, and exits the global ocean leads to a better understanding of the key drivers that couple Si to other cycles over short–term and geological time scales. Summaries of the marine silica cycle have undergone major revisions in the past decade, with an ~50% change in presumed sources and sinks. Some of these paradigm shifts have resulted from using stable and radiogenic Si isotopes to probe specific reaction pathways. For example, cosmogenic 32Si activities in the proximal coastal zone revealed reverse weathering reactions were a major sink of silica in the ocean. To test whether budgets and summaries achieved mass balance, an inverse model was applied to compilations of stable Si isotope ratios in various surface Earth reactive Si reservoirs. Results revealed that silicate mineral weathering releases 19-21 teramoles of Si per year, of which ~10-18 teramoles are sequestered is silica sinks on land (e.g., freshwater diatoms, phytoliths, pedogenic clays). Though there remain gaps in our understanding, results of the modelling effort also revealed that the latest 2021 marine Si summary appears to be in isotopic mass balance and can only be so if reverse weathering reactions were included in the summary. Inverse modeling also led to more insight (and questions) regarding weathering congruency, fractionation factors, and reactions kinetics.