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Unsteady gypsum cycling may decouple ocean and atmosphere carbon reservoirs

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Of the major ocean ions, calcium and sulfate have the greatest potential to undergo rapid changes in concentration due to the weathering and burial of large gypsum deposits. Here we develop an ocean-atmosphere box model to investigate the influence of unsteady gypsum cycling on oceanic carbon cycling. Model results indicate that weathering or burial of large gypsum deposits can induce long-term changes in ocean pH and the size of the oceanic DIC reservoir without affecting atmospheric pCO_2. On an ALK-DIC cross-plot, this effect is analogous to changing carbonate mineral weatherability. The size of the perturbation is primarily a function of the relative change in oceanic $[Ca^{2+}]$, while the timescale of the ocean's return to steady state depends on the degree to which background gypsum burial responds to changes in the Ca^{2+}-SO_4^{2-} ion product. A system responsive to the ion product is restored over the timescale of sulfate's residence time in the ocean (~10^7 yr), while a system responsive only to tectonic forcing essentially shifts to a new steady state until the opposite gypsum flux is applied. We apply this model to a hypothesized gypsum weathering event in the Eocene (56-34 Ma) by matching the pace and magnitude of simulated gypsum weathering to the Eocene seawater sulfate $\delta^{34}S$ curve. The model outputs suggest that a protracted (~15 Myr) episode of gypsum weathering beginning at 54-53 Ma could have gradually lowered ocean pH by 0.1-0.15 units and the DIC reservoir by ~15-20% by the late Eocene, without affecting pCO_2. The effects of unsteady gypsum cycling could complicate the conversion of pH proxy data to pCO_2 data, as this conversion relies in part on assumptions about oceanic Ca concentration. More broadly, this mechanism may be relevant to interpretations of the oceanic carbon and oxygen isotope records, and to reconstructed changes in oceanic nutrient speciation in deep time.