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Carbon cycle responses to step-changes in weathering: investigating the long-term fate of $\delta^{13}C$

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Variations in CO_2 and $\delta^{13}C$ in the atmosphere and ocean are recorded in ice cores and ocean sediments over the past 800 thousand years (kyr). Despite decades of research, mechanisms driving these variations during different time intervals are not fully understood. On multi-millennial, glacial-interglacial timescales, imbalances between the weathering input from the geologic reservoir to and removal from the combined atmosphere-ocean-land-reactive ocean sediment reservoir back to the geologic reservoir have strong influences on CO_2 and $\delta^{13}C$ and cannot be neglected. However, studies are missing that systematically investigate the effect of changes in weathering fluxes on carbon and $\delta^{13}C$ in the atmosphere and ocean.

Here, we use the Bern3D Earth system model of intermediate complexity to perform idealized, 100 and 500 kyr long simulations. The weathering fluxes of alkalinity, nutrients, carbon, and carbon isotopes are changed in a step-wise manner. The Bern3D includes a dynamic 3-dimensional ocean circulation-carbon cycle model coupled to an energy-moisture balance atmosphere and a sediment module. Burial fluxes of $CaCO_3$, organic matter, and opal are explicitly simulated. The aim is to understand related changes in carbon inventories and $\delta^{13}C$ in the atmosphere and ocean. We quantify the contribution to the carbon and carbon isotopic perturbations from imbalances in the burial-weathering cycles and highlight the role of vertical gradients in $\delta^{13}C$ in the ocean.

First results show that generally, imbalances in the $CaCO_3$ burial-weathering cycle dominate changes in the carbon budget while isotopic perturbations are dominated by changes in the burial-weathering cycle of organic carbon. In all simulations, the $\delta^{13}C$ perturbation in the ocean is spatially heterogeneous. The spatial gradients affect the isotopic signatures of the $CaCO_3$ and organic carbon burial fluxes and thereby the removal timescales of isotopic perturbations [1]. The results from our simulations with step-changes in weathering fluxes will provide valuable insight into the long-term cycling of carbon and carbon isotopes, underlying processes, and timescales.

[1] Jeltsch-Thömmes, A., and F. Joos (2020), Modeling the evolution of pulse-like perturbations in atmospheric carbon and carbon isotopes: the role of weathering-sedimentation imbalances, Climate of the Past, 16(2), 423–451, doi:10.5194/cp-16-423-2020.