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Moist energy balance constraints on the sensitivity of the silicate weathering feedback over the Phanerozoic

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Geologic and geochemical evidence of the Earth system's response to carbon cycle perturbations throughout the Phanerozoic suggests a variable silicate weathering feedback under different climate states. Coincident with increasing land area and solar irradiance, as well as evolutionary trends in terrestrial and marine ecosystems, carbon isotope excursions have decreased in amplitude over the Phanerozoic, implying unidirectional modulation of the stability of the geologic carbon cycle. Importantly, silicate weathering on land acts as the primary carbon removal mechanism from the ocean-atmosphere system, notwithstanding other substantial sinks including seafloor weathering and organic carbon burial. As such, the strength of the coupling between atmospheric CO_2 levels, climate, and silicate weathering is hypothesized to play an important role in setting the thermostat of the Earth system. Here, we quantitatively assess the relative contribution of paleogeographic changes and land plant evolution on setting the strength of the terrestrial silicate weathering feedback using a modeling framework that explicitly links the influence of changes in Earth's energy budget to the hydrologic cycle.

We implement paleogeographic data and proxy-derived CO_2 estimates in a zonally resolved moist energy balance model of the hydrologic cycle coupled to a one-box model of the geologic carbon cycle. Our forward model advances investigations of the silicate weathering feedback by producing latitudinally distributed predictions of temperature and hydrologic cycle parameters over the Phanerozoic. Within this framework, we compare the recovery of the geologic carbon cycle from perturbations under various climate states and paleogeographic configurations. Our approach quantitatively links Earth's energy, water, and carbon budgets to understand long-term climate change, providing a new framework for disentangling the co-evolution of the water and carbon cycles through geologic time.