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From Critical Zone to Planetary Habitability: Rethinking Earth's Silicate Weathering Thermostat - *Robert Berner Lecture*

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Silicate weathering is thought to be Earth's long-term thermostat, acting as a negative feedback to climate and supporting habitability over geologic timescales. Since the early kinetic formulations of weathering rates, advances in critical zone field monitoring and reactive transport modeling have refined our understanding of the climatic controls on weathering. In current models, weathering rates reflect the kinetic approach to equilibrium during water-rock interaction, controlled by uplift and erosion, hydrology, temperature, biotic effects, and direct CO_2 regulation of mineral solubility. While these models predict the interactions between climate and tectonic controls and provide mechanistic frameworks for interpreting weathering proxy records, disentangling these controls in field data remains a fundamental challenge. Here I explore how solute production frameworks operate when coupled to geomorphic soil mass-balance models. In this formulation, the persistence of a mobile soil mantle defines a threshold that separates uplift- and climate-controlled weathering regimes. As a result, soil-mantled regions are largely insensitive to climate even where mineral supply rates exceed weathering fluxes, supported by an extended global compilation of soil denudation rates. Consistent with recent reassessments of the long-term carbon cycle, these results suggest that the terrestrial silicate weathering feedback is weaker and more geographically constrained than canonical models assume, with important implications for the net carbon balance of actively eroding terrain. Taken together with emerging evidence for positive redox-based feedbacks in the long-term carbon cycle, these shifts represent a growing paradox: as the individual processes of the long-term carbon cycle become increasingly clear, the apparent robustness of the stabilizing feedback has diminished. I outline testable hypotheses that reconcile this evolving view of the carbon cycle with Earth's sustained habitability.