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Quantification of physical weathering rates using thermodynamics

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Physical weathering plays an important role in the global rock cycle in that it breaks up primary rock, thereby increasing the surface area for chemical weathering and providing the substrate for soil formation. We use a simple, thermodynamics based approach to quantify magnitudes of weathering, their spatial variation across climatic regions and their sensitivity to climatic change. Our approach is based on the primary driver of physical weathering: periodic heating and cooling. These heat fluxes and associated temperature gradients are used by different processes to perform work on rock material and cause physical weathering. Similarly to a heat engine, the maximum amount of work available for physical weathering is related to the rates of entropy production that are associated with the heat transport.

We used a global land surface model that simulates soil heat diffusion and temperature profiles to calculate rates of entropy production and estimate the maximum amount of physical work available for weathering processes. We find that (a) the spatial variations are plausible, (b) freeze-thaw cycles enhance available work substantially, and that (c) the available work decreases with increasing atmospheric concentrations of carbon dioxide. We conclude that this thermodynamic approach is a very promising start to a simple yet fundamental quantification of physical weathering rates in an Earth system context.