The evolution of land plants and silicate weathering

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We test the impact of some established and recent theories regarding plant enhanced weathering by coupling a one-dimensional vapor transport model to a reactive transport model of silicate weathering. In this coupled model, we evaluate: 1) the role of evolutionary shifts in plant transpiration in enhancing silicate weathering by increasing downwind transport of water vapor to continental interiors; 2) the importance of plant biomass (namely deep roots) and their associated microbial communities in increasing soil CO_2 and weathering zone length scales; and, 3) the joint effect of both processes on weathering rates.

The hydrologic balance for these models is framed by energy/supply constraints calibrated for minimally vegetated-, vascular plant forested-, and angiosperm-worlds. We find that increased transpirational fluxes and downstream vapor recycling doubles weathering fluxes when a minimally vegetated (pre- Devonian) scenario is contrasted to deep-rooted vascular plants (Devonian-Carboniferous). This effect increases to 2.3 for enhanced transpiration scenarios linked to angiosperm dominated ecosystems (late Cretaceous and Cenozoic). We also show that the dominant increase in silicate weathering fluxes occurs when deep-rooted vascular plants colonized the planet, which would have increased weathering fluxes due to thermodynamic effects caused by increased soil pCO_2 by a factor of 3.7 to 6.9, with the higher rates occurring in actively eroding landscapes. Angiosperm seed plants then compound this effect further by up to 14 percent. Our relative changes in weathering fluxes caused by land plant evolution are higher, but of a similar magnitude, than those used in existing carbon cycle models. The largest increase in feedback strength is posited to have occurred in the late Devonian and Carboniferous due to deep-rooted plant evolution and concurrent establishment of subsurface microbial respiration increasing maximum solute concentrations, and to a lesser extent when angiosperms became the dominant vegetation in the Cenozoic.

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