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Quantifying biotic effects on silicate weathering rates in a global dynamic soil model

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On geological time scales the atmospheric CO_2 level is controlled by a negative geological feedback according to the silicate weathering hypothesis [1]. The effects of runoff, temperature, lithology and the biosphere on weathering rates have previously been parameterized empirically [1]-[5], but a global scale process based model that includes all major long term controls such as uplift, erosion and biotic processes has yet to see the light of day (and peer review).

Here, the concept of a simple dynamic model of rock weathering and associated soil accumulation (JIWES - Jena Integrated Weathering and Erosion Scheme) is presented and evaluated with the focus on biotic effects. The model has been set up for a global scale study on the time scale of 1 Ma. It is coupled to a simple global dynamic vegetation model and forced by climatic daily means of precipitation, temperature and radiation. The simulated state of the vegetation hereby affects the balance and fluxes of water and carbon in the soil. The concentration of dissolved elements from weathering processes is described as a state function that depends on the carbon and water balance, and the associated leaching depends directly on the drainage. The model is computationally efficient and needs fewer input data than current state of the art models for catchment scale weathering [6][7] making it suitable for a global scale study on long time scales.

The model approaches steady state after 100 ka simulated time for weathering rates, however, soils still accumulate in some regions after this time leading to a continuous but slight decrease in weathering rates throughout the rest of the simulation. The influence of runoff, lithology, accumulation of secondary minerals and erosion rates on weathering rates is investigated in order to understand under which conditions weathering becomes sensitive to biotic effects. The primary control of weathering rate as the model approaches steady state is erosion rate and thus implicitly uplift rate, since high uplift rates are needed to sustain high erosion rates on long time scales and vice versa. However, the biosphere also plays a profound role, specifically in areas where erosion may be weathering limited. Finally, the global effect of biospheric enhancement of weathering through the formulated controls on carbon and water balance in the model is evaluated by analyzing a desert world scenario in which the vegetation is explicitly omitted from the simulation.

References:

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