Links between climate, paleogeography and silicate rock weathering: A Cretaceous vs present day comparative study with the GEOCLIM model

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Global models (0D spatial resolution) calculating atmospheric CO_2 and global climate at the geological timescales assume simple linear runoff and exponential temperature dependence of silicate weathering, predicting increasing CO_2 consumption when global climate is getting warmer and wetter. Transposed to the present day world, such laws suggest that CO_2 consumption through silicate weathering is maximum in the equatorial band. These laws heavily impact on predicted partial CO_2 pressure in the past and hence on reconstructed global climate, and might be partially wrong: (a) weathering rates are limited by the development of thick soils, under high temperatures and large runoff (typically equatorial climate) and sustained chemical weathering requires active physical erosion, (b) the simple assumption of increasing runoff with increasing temperature, although valid at global scale, is heavily dependent on the paleogeographic distribution.

Here we propose the definition of new global weathering laws for silicate lithologies accounting for the effect of soils, based on a compilation for large world rivers. A set of weathering laws where CO_2 consumption is made proportional to runoff is calculated for the 5 major biogeographic zones of the Köppen classification, accounting explicitly for the effect of thick soils in equatorial environments. A new world weathering map is produced with a resolution of 0.5° lat ×0.5° long, showing that equatorial environments are not the main CO_2 consumers through weathering, and is compared to previous study. These laws are then exported into the GEOCLIM model (coupling the global biogeochemical model COMBINE to the FOAM GCM) allowing the calculation of the CO_2 partial pressure during the Cretaceous climate optimum (Cenomanian). A study of the sensitivity of the Cretaceous climate system to changes in solid Earth degassing rates is finally proposed.

Reactive transport modeling of reaction fronts

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Reaction fronts define the rates and mechanisms of chemical weathering for a given system with implications for nutrient cycling, long-term regulation of atmospheric CO_2, and in a steady-state system, the rate of formation of soil. The three-million-year old Merced chronosequence has been an ideal field location for successful calculations of field weathering rates. Mineralogical and chemical data from Merced indicate the development of reaction fronts defined by a loss of minerals in the upper part of the older soils. The reaction front extends over at least 3 to 4 m. The meter-scale thickness of the reaction front in this granitic alluvial material contrasts with thinner reaction fronts in other weathering systems, especially those developing on bedrock. For example, reaction fronts on weathering basalt clasts in river terraces in Costa Rica are less than a millimeter in thickness while such fronts on weathering granite in Rio Icacos, Puerto Rico are centimeters in thickness. The steeper Merced weathering gradient implies that weathering is proceeding slower in the unconsolidated alluvium than in the other two systems. In part, the lower and more episodic rainfall at Merced cases pore waters to approach equilibrium more quickly, reducing dissolution rates in the alluvium relative to the the tropical samples. This approach to equilibrium is modeled with the reactive transport code FLOTRAN using a single continuum formulation that ignores the presence of fast pathways in the weathering profile. As expected, model-calculated weathering that uses laboratory dissolution rates occurs more rapidly than weathering in the field. Better correlation between model and field results was sought by changing chemical affinity parameters or reactive surface area parameters. Preliminary results from a simplified mineralogical system have shown that the evolution of the chemical weathering in the Merced chronosequence can be modeled with FLOTRAN, elucidating controls on the thickness and the rate of advance of the reaction front. Future simulations will consider a dual continuum formulation to account for fast pathways.