Differential movement of solid phases: A case study of soil organic carbon storage

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Soil organic matter represents a vast reservoir of reactive carbon, which supports heterotrophic resipiration, regulates the productivity and resiliance of soils, and contributes to the long-term weathering of primary minerals [1]. This broad range of characteristic timescales over which soil carbon plays an active role suggests that model representation of organic carbon reaction networks in reactive transport frameworks may significantly influence a variety of predictive capabilities. Notably, recent efforts have emphasized the ability to simulate the 'age' or radiocarbon content of carbon compounds in open-throughflowing soil profiles using complex reactive networks encompasing sorption, microbial respiration, complexation, fluid and gas phase transport [e.g. 2]. Notably, the extent to which these approaches have successfully generated 'old' soil carbon has been predicated on the representation of a carbon phase which may be retained within the model domain on timescales of the solid porous media, rather than those of rapidly moving fluids and gases. Introduction of an organic carbon phase with realistic solid transit times through soils inherently requires the use of either a kinetically limited sorption or aggregation pathway, which at present is not well described, or burial of a solid phase organic carbon represending the collective inputs of roots, litter and solid phase deposition at the surface boundary. While the latter approach is straightforward, it presents the complicating condition that the entirety of the soil phase soil column is then subject to a downward velocity, which contradicts the representation of parent rock supplying fresh, unweathered material to the base of an actively developing soil profile.

In total, this contradiction points to the necessity for treatment of differential rates of motion of individual solid phases across the model domain in order to represent the coupled behavior of soil development and organic carbon storage over the timescales of weathering profiles. In the present study we present a novel set of simulations utilizing the CrunchFlow open source software modified to include this capability, and illustrate the simulated development of soil chronosequences driven by the availability of solid phase organic carbon delivered from the soil surface to the active weathering front.

[1] Lawrence et al. (2014) Geochim. Cosmochim. Acta
[2] Riley, W.J. et al. (2014) Geosci. Model. Dev.