A New Age of Radiocarbon: Reactive Transport Models as a Tool for Assessing Soil Carbon Cycling

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Radiocarbon has long been used for estimating the mean residence time of carbon in soils. As a result of the atmospheric "bomb" pulse of ^{14}C from the above ground testing of nuclear weapons, soil radiocarbon data must be interpreted, not in the context of absolute age, but rather with regard to the timescales of carbon in mutltiple soil reserviours. This requires partitioning of total organic soil carbon into "pools" that are often opperationally defined, such as the unique fraction of carbon isolated by density seperations. These efforts have greatly advanced our understanding but have also limited our perspective on soil carbon cycle dynamics. For instance, models implementing the traditional pool structures may lead to underestimation of the reactivity of the so called "passive" pool. Thus, modeling approaches that are less constrained by carbon pool structure may provide novel insights.

In this study, we use the carbon isotope enabled reactive transport model (RTM), CrunchTope, to investigate how assumptions regarding soil reaction networks compare with observations. Specfically, we compared modeled reactions, assumed to provide carbon protection, with synthesized soils data including carbon content and isotopic composition. We focued these analyses on two case studies well suited to the application of RTMs: (1) podzols (or spodisols), which are characterized by complexation, leaching, and precipitation of carbon with metals and (2) erosion/burial systems where physical transport leads to varied soil profile structure and reaction conditions.

First, we parameterized RTM simulations using the best available constraints on reactions including microbially - mediated decomposition; aqueous complexation and precipitation; sorption/desorption; and physcial isolation. Then, we compared the results of long-term simluations (e.g., millenial scale) with observations of bulk and pool based measurements of carbon content and isotopic composition for our case studies. Our results indicate the potential and current limitations of a process-based representation of soil carbon cycling.