A Radioisotope-Enabled Reactive Transport Model for Deep Vadose Zone Carbon

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Project Abstract: In upland forested hillslopes such as the East River watershed, roots extend well beneath the classically defined soil layer into partially weathered, unsaturated rock to access both water and nutrients. Yet current carbon cycle models rarely extend below shallow soils, and the contribution of this deeper subsurface nutrient cycling to carbon stocks and fluxes is virtually unknown. In the Eel River watershed of Northern California, a team of SFA collaborators have successfully installed a novel Vadose zone Monitoring System (VMS) consisting of a pair of sub-horizontal bore holes instrumented with flexible plastic sleeves which allow sampling of fluids draining through the partially saturated shale weathering profile, as well as gas sampling ports, moisture and temperature sensors. Using this unique instrumentation, a DOE-SBR exploratory project (PI Druhan, DE-SC0019198) is now constraining carbon stocks and fluxes as an analog to the hillslopes of the East River, which is similarly underlain by a shale lithology and hosts mature forest ecosystems. These data provide new evidence that approximately 30% of net CO_2 flux from the terrestrial environment to the atmosphere is sourced many meters below the soil layer (see A. Tune student poster for further details). Critically, the exploratory DOE-SBR grant has now shown that this CO_2, though produced many meters below the soil, is radiocarbon modern. Thus, in total, this work indicates that modern carbon is being delivered rapidly to the deep subsurface, likely as a result of deep rooting zones, and this previously undocumented carbon cycle is a substantial component of the CO_2 generated in the terrestrial environment. To extend these results, we have constructed a radioisotope-enabled version of the CrunchTope software which is now benchmarked as part of the exploratory proposal awarded to Dr. Druhan (Druhan et al., 2020). The new model is capable of simultaneous and explicit simulation of the three isotopes of carbon including both stable isotope fractionation and radioactive decay. Through this advanced modeling capability, the rates of carbon oxidation, contribution to weathering and thus the development of soils and sustainability of forest ecosystems will be embedded within an adaptive and predictive model framework.

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