Modeling carbon dynamics in arid soils: Insights from the Mojave Desert

JENNIFER V. MILLS[1*], GREGORY E. MAURER[1], RONALD AMUNDSON[1], AND LAURA N. LAMMERS[1]

[1] Department of Environmental Science, Policy, and Management, 130 Mulford Hall, University of California, Berkeley, CA 94720, USA (*correspondence: jennifer.mills@berkeley.edu)

Understanding how soil carbon stocks will respond to both long-term climate change and shorter-term perturbations from land use change is imperative for effective climate change mitigation policy. While arid soils contain relatively low levels of organic C, they store vast amounts of inorganic C in the form of pedogenic carbonate (~35% of global soil C stocks). Previous modeling efforts have successfully simulated the long-term accumulation (10^4-10^6 year timescales) of pedogenic carbonate, but the short-timescale dynamics of the soil carbonate system and complex couplings to soil organic C cycling, plant and microbial activity, environmental forcings, and nuanced mineral reaction kinetics that ultimately regulate the fate of soil inorganic C remain poorly understood.

Here we attempt to constrain how the total soil C reservoir in arid systems will respond to perturbations through a coupled field and modeling study of soils from the Mojave Desert. We report over one-year of in-situ observations of micro-meterological and soil conditions (including continuous measurements of soil water content, temperature, and CO_2 concentrations to 125cm depth) from a series of soils along a climate/elevation gradient. We use these observations and data from ex-situ geochemical analyses to parameterize a reactive transport model of soil C cycling using the Hydrus/HPx suite of codes. We particularly focus on developing representations of the biotic-abiotic feedbacks that dominate geochemical dynamics in these water-limited ecosystems. Such tight couplings between soil CO_2 and abiotic parameters are observed that depth-dependent CO_2 concentrations are remarkably well-described (R^2>0.90) by simple multiple linear regressions of depth, temperature, and water content. Interestingly, the CO_2 response to rainfall events propagates deeper into the soil (with a temporal lag of hours to days) than coexisting changes in water content and temperature would predict. We discuss these findings in the context of incorporating plant and microbial community responses to soil conditions and associated root exudate / CO_2 production into our C cycle model.