A reactive transport model including low soil moisture limitations on soil carbon respiration

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Observations have shown that in soils, the rate of carbon respiration is often highly dependent on soil moisture content [1]. However, a consistent, process-based model for this relationship has yet to be implemented in a reactive transport framework. We present the results of soil incubation experiments using samples collected from the East River watershed in Colorado to quantitatively determine the effect of water availability on microbial oxidation of organic carbon. CO_2 concentration and stable carbon isotopes were measured in time series with different soil moisture contents (0, 33%, 66%, and 100%) and depths (0-52 cm, 63-108 cm, 112-165 cm) in incubation experiments. CO_2 concentration results show that for a given soil sample, respiration rates can range between 0.03 to 5.31 μmol CO_2/g soil/day with an increase between 0 and 66% moisture content, and a decrease between 66% and 100%. These variations show agreement with previous observations. Isotope data show a slight decrease in $\delta^{13}C$ for bottom and middle soil samples as time passes, but stay roughly the same for top soils. Little difference in $\delta^{13}C$ (<4‰) is observed in samples at the same depth with different moisture contents compared with samples in different depth (~12‰ between top and bottom).

Using these data, we develop and constrain a novel reactive model relating soil respiration rate to moisture content through division of the total biomass into active vs. dormant pools [2]. Our derivation successfully quantifies the correlation between respiration rate and soil moisture in arid and semi-arid areas, and where little carbon is present in the soil. Integration of this model into the CrunchTope reactive transport software allows us to test this relationship within the context of hydrologic transport and multi-component reactivity.

[1] Howard & Howard (1993). Soil Bio. and Biochem. 25: 1537-1537
[2] Manzoni et al (2014). Soil Bio. and Biochem. 73: 69-83