A reactive transport model for heterotrophic respiration in soil profiles constrained with laboratory incubations using multiple pulse wetting events

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Soil moisture is a first-order control on the rate of organic carbon respiration, and thus directly links heterotrophy to hydrologic and climatic conditions [1]. Transient, large pulses of CO_2 commonly observed after soil rewetting (a.k.a. the Birch effect [2]) can represent a major component of the total carbon flux from natural landscapes [3]. Despite such dynamic behavior, most models simulate rewetting behavior through empirical relationships that often fail to resolve non-linear responses. Implementing more process-based, predictive relationships in modeling frameworks requires the ability to constrain and validate the approach. Here, we present the results of a 20-day soil incubation experiment of samples collected from a Montane setting in the Rocky Mountains of Colorado, USA. We sampled the soil to a depth of 80cm in 10cm increments and incubated each depth at 10 effective saturations ranging from 10% to 100%. A critical component of the approach was a repeated wet-dry cycle, by which the initial condition of the second wetting event can be constrained. Results show that during the first wetting event, peak respiration rates are up to four times larger than subsueqeunt steady state. The pulse in respiration in the uppermost soil sample (0-10 cm) was roughly half as large in the second rewetting event as compared to the first. In contrast, the rest of the soil profile showed approximately equivalent responses to the two wetting cycles.

We use these incubation results to constrain a process-based reactive transport framework (CrunchFlow), with the addition of a new ability to treat the transition between active and dormant biomass based on soil moisture content, as a means of representing transient Birch behavior. By comparing the model outputs to depth-resolved CO_2 concentrations, we test its ability to accurately simulate soil heterotrophic respiration rates under changing moisture contents, particularly during periodic shifts in soil moisture.

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