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Can the gradient method improve our ability to predict soil respiration?

Claire Phillips (1), Nicholas Nickerson (2), and Dave Risk (3)

(1) Dept of Crops and Soil Science, Oregon State University, Corvallis, OR, United States (claire.phillips@oregonstate.edu), (2) Forerunner Research Inc., Dartmouth, Nova Scotia, Canada (nick@forerunnerresearch.ca), (3) Dept of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia, Canada (drisk@stfx.ca)

Soil surface flux measurements integrate respiration across steep vertical gradients of soil texture, moisture, temperature, and carbon substrates. Although there are benefits to integrating complex soil processes in a single surface measure, i.e. for constructing soil carbon budgets, one serious drawback of studying only surface respiration is the difficulty in generating predictive relationships from environmental drivers. For example, the relationship between depth-integrated soil respiration and temperature measured at a single discreet depth (apparent temperature sensitivity) can bear little resemblance to the temperature sensitivity of soil respiration within soil layers (actual temperature sensitivity). Here we present several examples of how the inferred environmental sensitivity of soil respiration can be improved from observations of CO_2 flux profiles in contrast to surface fluxes alone. We present a theoretical approach for estimating the temperature sensitivity of soil respiration in situ, called the weighted heat flux approach, which avoids much of the hysteresis produced by typical respiration-temperature comparisons. The weighted heat flux approach gives more accurate estimates of within-soil temperature sensitivity, and is arguably the most theoretically robust analytical temperature model available. We also show how soil drying influences the effectiveness of the weighted heat flux approach, as well as the relative activity of discreet soil layers and specific soil organisms, such as mycorrhizal fungi. The additional information provided by within-soil flux profiles can improve the fidelity of both probabilistic and mechanistic soil respiration models