Title: Functional Aerobic-Anaerobic Metabolic Heterogeneity within Soils

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Carbon cycling models do not account for organic matter decomposition under conditions where O_2 is limiting. However, the complex physical structure of soils can result in an abundance of anaerobic microsites and associated metabolic gradients even within seemingly aerobic, well-drained soils. If decomposition processes based on alternative electron acceptors are included in carbon cycling models, information is required about 1) the functional extent of soil microenvironments, and 2) how microenvironments are modified by temporal variations in environmental drivers.

Unfortunately the abundance and distribution of metabolically different soil microenvironments is poorly defined. Our approach to resolve this issue is based on the insight that metabolic activity is a progressive consumption of electron acceptors, a feature that can be observed using platinum redox probes. If a suitable number of replicate probes are installed within a soil horizon, then the observed variability is a numerical indicator of microenvironment diversity.

We use the following premises to evaluate and scale outcomes of soil redox metabolic heterogeneity: (1) If structure is the main control on microenvironment heterogeneity, and structure remains constant over time, the variability in redox potentials should be constant. (2) Particle-size distribution and (3) pore network structure are robust predictors of redox variability and thus of the extent to which soil is organized into microenvironments. With these assumption, we characterized the spatial variability of redox potentials by deploying sets of platinum redox probes within standardized soil volumes both in the laboratory and in the field. Redox potentials in both settings were collected over time to capture the effects of seasonal variations in soil temperature and moisture content. Soil structure was parameterized using X-ray computed tomography. We find that metabolic heterogeneity within a soil horizon is minimal when the system is either completely saturated or completely dry (low moisture potentials). High amplitudes of heterogeneity were observed when the system was in transition between those states. Soil pore network structure mainly determines the rates of change and the absolute magnitude, but not the incidence, of redox heterogeneity.

Our data support the hypothesis that episodes of oxygen deprivation may be encountered in “upland” soils. Soil structure data may be useful to constrain the absolute magnitude of anaerobic events, while climatic parameters may serve to predict frequency and duration.