Determining the Drivers of Redox Sensitive Biogeochemistry in Humid Tropical Forests

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The availability of soil oxygen (O_2) and associated redox dynamics are key drivers of carbon and nitrogen cycling and greenhouse gas emissions in tropical forests. However, few studies have measured soil oxygen availability, and even fewer have related this to greenhouse gas fluxes over time and space. Improved mechanistic understanding of the relationship between soil O_2 concentrations and greenhouse gas dynamics will improve Earth systems models. In this study, we are using field and laboratory experiments in the Luquillo Experimental Forest, Puerto Rico, to develop a mechanistically derived redox component for the Community Land Model (CLM4). We are using empirical and modeling efforts to improve the prediction of carbon, nitrogen, and phosphorous cycling and greenhouse gas dynamics in space and time. Our research tests the following hypotheses: 1) Soil O_2 concentrations vary as a function of soil texture, slope position, and rainfall in humid tropical forests; 2) The spatial and temporal dynamics of soil O availability can be used to predict patterns in redox sensitive biogeochemical processes; and 3) Hot spots and hot moments in greenhouse gas fluxes are derived primarily from high substrate availability and secondarily from soil O_2 availability.

We installed a sensor field using galvanic O_2 sensors (Apogee Instruments) and time-domain reflectometry (for moisture and temperature, Campbell Scientific) along topographic gradients in a lower montane wet tropical forest in Puerto Rico. Seven sensors of each type were installed at 12 cm depth along a ridge to valley catena; the entire catena transect was replicated five times. Within the sensor field we also installed three automated gas flux chambers randomly located in each topographic zone (ridge, slope and valley). A Cavity Ring-Down Spectroscopy (CRDS) gas analyzer is being used to measure pseudo-continuous fluxes of CO_2, N_2O, and CH_4. Our preliminary results showed that soil O_2 concentrations decrease from ridges to valleys along topographic gradients. Average O_2 concentrations on ridges were significantly higher than those in valleys. Moreover, soil volumetric water content in upland valleys was significantly higher than those on ridges. Both ridges and slopes produced higher CO_2 fluxes than valleys ($P<0.05$). Daily CH_4 emissions went up to ~2000 g CH_4 $ha^{-1}d^{-1}$ for valleys, which released significantly higher CH_4 than ridges and slopes. Soil nitrous oxide (N_2O) oscillated between negative and positive values across all treatments with all values mostly less than 4 g N_2O $ha^{-1}d^{-1}$. Our preliminary results suggest that soil O_2 and associated redox dynamics are an important driver of gas fluxes. We also report very high CH_4 emissions from valley soils suggesting that these upland soils are large net CH_4 sources.