Coupling Peat Decomposition and Metagenomics to Incorporate Molecular Scale Processes into Climate Models

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The goal of this project is to investigate changes in the structure of dissolved and solid phase organic matter, the production of CO_2 and CH4, and the composition of decomposer microbial communities in response to the climatic forcing of environmental processes that determine the balance between carbon gas production versus storage and sequestration in peatlands. Cutting-edge analytical chemistry and next generation sequencing of microbial genes has been applied to habitats at the Marcell Experimental Forest (MEF), where the US DOE's Oak Ridge National Laboratory and the USDA Forest Service are constructing a large-scale ecosystem study entitled, "Spruce and Peatland Responses Under Climatic and Environmental Change"(SPRUCE). Our study represents a comprehensive characterization of the sources, transformation, and decomposition of organic matter in the S1 bog at MEF. Multiple lines of evidence point to distinct, vertical zones of organic matter transformation: 1) the acrotelm consisting of living mosses, root material, and newly formed litter (0-30 cm), 2) the mesotelm, a mid-depth transition zone (30-75 cm) characterized by labile organic C compounds and intense decomposition, and 3) the underlying catotelm (below 75cm) characterized by refractory organic compounds as well as relatively low decomposition rates. These zones are in part defined by physical changes in hydraulic conductivity and water table depth. O-alkyl-C, which represents the carbohydrate fraction in the peat, was shown to be an excellent proxy for soil decomposition rates. The carbon cycle in deep peat was shown to be fueled by modern carbon sources further indicating that hydrology and surface vegetation play a role in belowground carbon cycling. We provide the first metagenomic study of an ombrotrophic peat bog, with novel insights into microbial specialization and functions in this unique terrestrial ecosystem. Vertical structuring of microbial communities closely paralleled the chemical evolution of peat, with large shifts in microbial populations occurring in the biogeochemical hotspot, the mesotelm, where the highest rates of decomposition were detected. Stable isotope geochemistry and potential rates of methane production paralleled vertical changes in methanogen community composition to indicate a predominance of acetoclastic methanogenesis mediated by the Methanosarcinales in the mesotelm, while hydrogen-utilizing methanogens dominated in the deeper catotelm. Preliminary evidence suggests that the availability of phosphorus limits the microbially-mediated turnover of organic carbon at MEF. Prior to initiation of the experimental treatments, our study provides key baseline data for the SPRUCE site on the vertical stratification of peat decomposition, key enzymatic pathways, and key enzymatic pathways.