Title: Toward a predictive understanding of environmental perturbations in regulating greenhouse gas release in northern peatlands

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Project Abstract:

Our project goal is to develop a mechanistic understanding of how environmental disturbance (warming, eCO_2, drought, plant community shifts) regulates microbial communities, soil organic matter(SOM) decomposition and greenhouse gas emission rates and ratios from peatlands. Our team has compiled a 7-year time series of the concentrations and isotopic composition ($\delta^{13}C$ and $\delta^{14}C$) of major carbon species (solid peat, porewater CO_2 and CH_4, dissolved organic carbon), metabolites, enzyme activities, and microbiomes in the experimentally warmed SPRUCE peatland which includes experimental manipulation of CO_2(eCO_2).

Warming induced changes in the plant community and resulting organic matter inputs were correlated with increasing CO_2 and CH_4 production. Lipids significantly increased with both temperature and eCO_2, and lipids/sugars were also a significant predictor of CH_4/CO_2 ratio, suggesting that a shift towards increasing abundance of shrubs will further promote methanogenic conditions. Mass-balance modeling of isotopic data revealed increases in solid peat-supported respiration in heated plots over time and relative to ambient enclosures. The following contrasts were observed in the ambient vs. eCO_2 enclosures: $\delta^{13}CH_4$ is significantly more depleted, CH_4/CO_2 concentrations are marginally greater, and $DI^{14}C$ was depleted relative to the controls in the eCO_2 plots. Peat microbial communities appeared stable over 7 years; however, only limited replication was possible due to the destructive nature of soil coring. Thus, we developed methods for higher frequency sampling of planktonic microbial communities in porewater and observed a significant decline in diversity along with a substantial shift in community composition with warming. Finally, we investigated the response/recovery of microbial community enzyme activity to a generational drought in summer of 2021; while no response was observed in hydrolase activity, phenol oxidase activities were elevated in warmer and drier soils during the drought.

Our results suggest that as climate forcings worsen, peatland systems will become increasingly methanogenic, resulting in a positive feedback loop that exacerbates climate warming. We are just beginning to see statistically significant changes in microbial community dynamics and a stimulation in the respiration of ancient catotelm peat C, deposited under prior climate(cooler) conditions. Shifts in microbial diversity and community composition point to a loss of stability with warming, with potentially dramatic implications for ecosystem functioning. The apparent destabilization of the large peat C reservoir has substantial implications for

peatland-climate feedbacks. After a ~5 year lag, we also observe a significant influence of eCO_2 on the reactants and products of organic matter mineralization suggesting a synergistic effect between temperature and eCO_2.

References:

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