How Does Whole Ecosystem Warming of a Peatland Affect Methane Production and Consumption?

Anya Hopple*, Kaitlin Brunik1, Laurel Pfeifer-Meister1, Jason K. Keller2, Glenn Woerndle2, Cassandra A. Zalman2, Paul Hanson3, and Scott D. Bridgham*

1Institute of Ecology and Evolution, University of Oregon, Eugene, OR
2Schmid College of Science and Technology, Chapman University, Orange, CA
3Environmental Sciences Division, Oak Ridge National Lab, Oak Ridge, TN

Contact: ahopple@uoregon.edu

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Peatlands are among Earth’s most important terrestrial ecosystems due to their massive soil carbon (C) stores and significant release of methane (CH4) into the atmosphere. Methane has a sustained-flux global warming potential 45-times greater than carbon dioxide (CO2), and the accuracy of Earth system model projections relies on our mechanistic understanding of peatland CH4 cycling in the context of environmental change. The objective of this study was to determine, under in situ conditions, how heating of the peat profile affects ecosystem-level anaerobic C cycling. We assessed the response of CO2 and CH4 production, as well as the anaerobic oxidation of CH4 (AOM), in a boreal peatland following 13 months of deep peat heating (DPH) and 16 months of subsequent whole-ecosystem warming (surface and deep heating; WEW) as part of the Spruce and Peatland Responses Under Changing Environments (SPRUCE) project in northern Minnesota, USA. The study uses a regression-based experimental design including 5 temperature treatments that warmed the entire 2 m peat profile from 0 to +9°C above ambient temperature. Soil cores were collected at multiple depths (25-200 cm) from each experimental chamber at the SPRUCE site and anaerobically incubated at in situ temperatures for 1-2 weeks. Methane and CO2 production in surface peat were positively correlated with elevated temperature, but no consistent temperature response was found at depth (75-200 cm) following DPH. However, during WEW, we observed significant increases in both surface and deep peat methanogenesis with increasing temperature. Surface peat had greater CH4 production rates than deeper peat, implying that the increased CH4 emissions observed in the field were largely driven by surface peat warming. The CO2:CH4 ratio was inversely correlated with temperature across all depths following 16 months of WEW, indicating that the entire peat profile is becoming more methanogenic with warming. We also observed AOM throughout the whole peat profile, with the highest rates observed at the surface and initial data suggesting a positive correlation with increasing temperature. While SPRUCE will continue for many years, our initial results suggest that the vast C stores at depth in peatlands are minimally responsive to warming and any response will be driven largely by surface peat.