Biogeochemical Controls on Microbial CO_2 and CH_4 Production Across Polygonal Arctic Soils and Permafrost

David E. Graham[1,3], Jianqiu Zheng[1], Taniya Roy Chowdhury[1,4], Ji-Won Moon[1], Ziming Yang[2], Liyuan Liang[2], Baohua Gu[2], and Stan D. Wullschleger[2,3]

[1] Biosciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

[2] Environmental Sciences Division, Oak Ridge National Laboratory

[3] Climate Change Science Institute, Oak Ridge National Laboratory

[4] Present Address: Pacific Northwest National Laboratory, Richland, WA

Contact: D. Graham (grahamde@ornl.gov)

Abstract

Warmer Arctic temperatures are increasing the annual soil thaw depth and prolonging the thaw season in Alaskan permafrost zones. This change exposes organic matter buried in the soils and permafrost to microbial degradation and mineralization to form CO_2 and CH_4. The proportion and fluxes of these greenhouse gases released into the atmosphere control the global feedback on warming. To improve representations of these biogeochemical processes in terrestrial ecosystem models for the Next-Generation Ecosystem Experiments in the Arctic (NGEE-Arctic) project, we compared physico-chemical properties and microbial activities in soil core samples from three classes of ice-wedge polygons from the Barrow Environmental Observatory in Barrow, AK. High-centered, flat-centered and low-centered polygons represent a gradient of permafrost-affected tundra with increasing water saturation. The soil water potential in high- and low-centered polygon soil layers was determined. Matric potential along with temperature likely explains porewater freezing, gas diffusion and microbial activity.

The temperature-dependent CO_2 and CH_4 production from anoxic soil incubations at -2, +4 or +8 °C identified a significant lag in methanogenesis relative to CO_2 production by anaerobic respiration and fermentation. Proportions of the two greenhouse gases varied substantially across microtopographic positions and soil horizons. The abundance of methanogen signature genes increased during incubations. CH_4 oxidation was observed in microcosms containing soils from all horizons from both high-centered and flat-centered polygons, and prolonged thawing significantly accelerated CH_4 oxidation rates. Comparisons of samples collected across the microtopographic polygonal features address the impacts of water saturation, iron reduction and organic matter content on CH_4 production and oxidation. These combined measurements build process understanding that can be applied across scales to constrain key response factors in models that address Arctic soil warming.