NAME: David Graham
ORGANIZATION: Oak Ridge National Laboratory
PROGRAM AFFILIATION: TES
ABSTRACT TITLE: Biogeochemical controls on microbial CO2 and CH4 production in anoxic low-centered polygon soils from the Barrow Environmental Observatory

ABSTRACT: Organic matter buried in Arctic soils and permafrost will become accessible to increased microbial degradation as the ground warms and remains unfrozen for longer periods due to climate change. The rates of organic matter degradation and the proportion of CH4 and CO2 greenhouse gasses released in a potential warming feedback cycle depend on the microbial response to warming, organic matter structure and availability, and the geochemistry of pH and electron transfer in pore water. To adapt and improve the representation of these Arctic subsurface processes in land models, we intensively examined soil organic matter transformations from middle, ridge and trough areas of a low-centered polygon on the Barrow Environmental Observatory (Barrow, Alaska). Significant amounts of iron(II) in organic and mineral soils of the active layer and groundwater indicate anoxic conditions. Unamended incubations of soils using relevant anoxic conditions at -2, +4 or +8 °C produced both CH4 and CO2, with different response curves. CO2 formation followed Monod kinetics with a short initial lag. CH4 production followed exponential kinetics, with a longer lag characteristic of microbial growth and adaptation. Rates of formation for both CH4 and CO2 were substantially higher in microcosms containing organic horizon samples (38-43% total carbon), compared to B horizon samples (17-18% carbon) or permafrost (16-18% carbon) that produced CO2 but not CH4 during incubations.

Measurements of ionic species dissolved in soil water from frozen cores, humic-rich surface water, or groundwater extracted from the middle, ridge and trough in Sept. 2012 indicated low levels of nitrate and sulfate, constraining the role of these alternative electron acceptors in anaerobic respiration. The pH of surface water (4.4) was significantly lower than ground water (5.8 to 6.3). Substantial differences in other ionic species confirm that surface and ground water do not mix rapidly.

Biomass extracted from frozen mineral soil samples or thawed microcosms was analyzed for relative protein abundance using metaproteomics, and numerous peaks were matched to a database of Arctic genome data. Signature proteins from methanogenic archaea were identified in frozen permafrost and active-layer samples. After microcosm incubations, however, methanogenic proteins were found only in active-layer samples, consistent with headspace gas analyses. Therefore, low-centered polygon soil thawing and warming caused increases in microbial biomass and significant changes in microbial composition that determine the composition of greenhouse gas product mixtures. Differential microbial growth and migration through the thawing soil column may be key to changes in microbial population size and activity during prolonged thaw seasons. Microbial biomass production, fermentation, iron reduction and methanogenesis explain most of the C and electron flow in these closed systems.