NGEE Arctic: Biogeochemical controls on microbial CO_2 and CH4 production in polygonal soils from the Barrow Environmental Observatory

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Organic matter buried in Arctic soils and permafrost will become accessible to increased microbial degradation as the ground warms due to climate change. The rates of organic matter degradation and the proportion of CH4 and CO_2 greenhouse gasses released in a potential warming feedback cycle depend on the microbial response to warming, organic carbon structure and availability, the pore-water quantity and geochemistry, and available electron acceptors. To adapt and improve the representation of these Arctic subsurface processes in terrestrial ecosystem models for the NGEE Arctic project, we examined soil organic matter transformations from elevated and subsided areas of low- and high-centered polygons from interstitial tundra on the Barrow Environmental Observatory (Barrow, AK).

Significant amounts of iron(II) ions in organic and mineral soils of the active layer in low-centered polygons indicate anoxic conditions in most soil horizons. Unamended, anoxic incubations of soils at -2, +4 or +8 °C produced both CH4 and CO_2, with different response curves. CO_2 formed rapidly while CH4 production increased slowly after an initial lag, consistent with field measurements previously reported by other groups. This lag correlates with an increase in microbial biomass and the accumulation and consumption of acetate, the primary substrate for methanogenesis. Rates of formation for both CH4 and CO_2 were substantially higher in microcosms containing active layer O horizon (38-43% total carbon) compared to B horizon (17-18% carbon) samples. Only traces of CH4 were released from permafrost during incubations, although CO_2 was continually produced by fermentation and anaerobic respiration. The ratio of CO_2 to CH4 produced decreased with increasing temperature. The temperature threshold for methanogenesis and dynamic time course of CH4 production indicate that a constant Q10 relationship is not adequate to explain temperature effects from -2 to +8 °C in the low-centered polygons. Physicochemical data from this experiment are available online at DOI:10.5440/1124197.

In contrast to the low-centered polygon incubations representing in situ water-saturated conditions, microcosms unsaturated high-centered polygon samples displayed lower carbon mineralization as either CH4 or CO_2. In these experiments, the elevated and oxic center samples produced negligible CH4, while the mineral horizon of subsided, anoxic trough samples released an increasing proportion of CH4 at 8 °C.