Coupled Long-Term Experiment and Model Investigation of The Differential Response of Plants and Soil Microbes in a Changing Permafrost Tundra Ecosystem

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Project Abstract:
There are 1460-1600 billion tons of soil carbon in the northern circumpolar permafrost region, more than twice as much carbon than in the atmosphere. Understanding the magnitude, rate, and form of greenhouse gas release to the atmosphere is crucial for predicting the strength and timing of this carbon cycle feedback to a warming climate. Here we report results from an ecosystem warming manipulation where we increased air and soil temperature, and degraded the surface permafrost. We used snow fences coupled with spring snow removal to increase deep soil temperatures and thaw depth (soil warming) and open top chambers to increase growing season air temperatures (air warming). The soil warming treatment has successfully warmed soils by 2-3ºC in winter, has increased growing-season depth of ground thaw by up to 50%, and has degraded an increasing amount of surface permafrost each year of the project. We have subsequently manipulated the surface water table that together with warming influences air and deep soil temperatures, permafrost, and soil moisture conditions that are primary drivers of tundra ecosystem carbon balance across the Arctic landscape. Here we report new measurements of ground subsidence as a metric of change in ground ice in response to permafrost thaw. To determine the impact of subsidence on permafrost thaw and soil carbon, we quantified subsidence using high-accuracy differential GPS over the course of the experiment. With permafrost temperatures already near 0°C, almost 11 cm of subsidence was observed in control plots over 9 years. Experimental air and soil warming increased the amount of subsidence five-fold and also created inundated microsites as the subsided soil surface was closer to the water table. Across treatments, the loss of ground ice was responsible for 85-91% of the subsidence, while 9-15% of the subsidence was linked to the loss of organic matter. Accounting for subsidence, permafrost thaw was 19% (control) and 49% (warming) deeper than active layer thickness measurements alone would have indicated. This corresponds to 37% (control) and 113% (warming) more carbon in the newly thawed active layer as compared to the beginning of the experiment. Ground subsidence that results in greater amounts of thawed carbon and wetter soils are not well represented by current biogeochemical models. Improved model structure that includes the physical subsidence of ground, or parameterizations that capture such effects, may be needed in order to capture the non-linear dynamics revealed by this unique long-term experiment.