The Impact of a Changing Permafrost Tundra Ecosystem on Dissolved Organic Carbon Age and Concentration in Surface and Groundwater in a Long-Term Experiment

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Project Abstract: New estimates place 1440-1600 billion tons of soil carbon in the northern circumpolar permafrost zone, 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, increased growing-season depth of ground thaw by up to 200%, and degraded an increasing amount of surface permafrost each year of the project. The primary drivers of the tundra ecosystem carbon balance across the Arctic landscape, air temperature, deep soil temperature, permafrost extent, and soil moisture were manipulated as a result of experimental warming. The water table was also altered, as the ground surface subsided below the top of the water table in some plots and along with increased thaw resulted in for deeper, older layers of the soil profile to become saturated with surface water perched on the permafrost. Here we report measurements of long-term dissolved organic carbon (DOC) leaching as a metric of changes in ecosystem carbon storage. Warming increased carbon exchange with soil water, increasing DOC concentrations in warmed plots by an average of 130% to 93mg/L in warmed plots as compared to 40mg/L in control plots. There was also an observed depletion in DOC-$\Delta^{14}C$ with warming, with $\Delta^{14}C$ values as low as -320‰. This value corresponds to a mean radiocarbon age of ~3,000 years, but actually is likely to represent a mix of modern and much older, permafrost C. The oldest DOC mixtures were located in deeply thawed, warmed tundra whereas younger carbon from freshly decayed soils and plants was present in less deeply thawed portions of the tundra. Permafrost carbon with values as low as -200‰ was also detected in surface water downstream from the experimental site, particularly after large rain events. These findings indicate that permafrost carbon is vulnerable to leaching and is likely to enter aquatic ecosystems following mobilization from terrestrial permafrost soil. This process is irreversible and likely to further exacerbate climate change.