The Effect of Permafrost Thawing and Thermokarst on Vegetation and Ecosystem Carbon Cycling in Alaskan Tundra

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Up to 450 billion tons of soil carbon (C) are estimated to be stored in high latitude ecosystems (Gorham, 1991). This quantity represents almost a third of the soil C stored in terrestrial ecosystems globally, and is several orders of magnitude greater than current annual anthropogenic CO₂ emissions. Latitudinal gradients of soil C, field experiments, and laboratory incubations all show that soil C cycling in these northern ecosystems is likely to be strongly influenced by the effect of cold temperatures on rates of decomposition of soil organic matter (Kirschbaum, 2000). This ‘old’ soil C, climatically protected from microbial decomposition in frozen or waterlogged soil, has been accumulating in these ecosystems throughout the Holocene since retreat of the last major ice sheets.

Climate change scenarios predict that the greatest magnitude of warming will occur at high latitudes. This predicted warming is supported by observational evidence over the last 25 years and is associated with warmer ground temperatures, permafrost (permanently frozen soil) thawing, and thermokarst (ground subsidence as a result of ground ice thawing) (ACIA, 2004). Thermokarst has the potential to alter ecosystem C cycling by changing the vegetation structure and growth rates, and by altering soil microbial decomposition rates. Together, these changes can alter the balance of C cycling processes in these ecosystems and cause feedbacks to climate change. We are testing how microelevation as caused by ground subsidence can be used as a predictive variable for ecosystem carbon fluxes and patterns of vegetation following permafrost thawing. We used high-precision GPS to quantify centimeter scale differences in surface topography and related these to measurements of ecosystem net carbon exchange (Figure 1). Developing regression relationships allows us to scale measurements of carbon exchange across larger spatial scales based on microtopography.

References

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Figure 1. Map showing microelevation of a permafrost study plot where ground is locally subsided. Scale is in units of meters to an arbitrary baseline.