**TES Program**

# The impact of permafrost carbon loss on the carbon balance of an experimentally warmed tundra ecosystem

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New estimates place 1330-1580 billion tons of soil carbon in the northern circumpolar permafrost zone, more than twice as much carbon than in the atmosphere. Permafrost thaw and the microbial decomposition of previously frozen organic carbon is considered one of the most likely positive feedbacks from terrestrial ecosystems to the atmosphere in a warmer world. 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 eight years of an ecosystem warming manipulation —the Carbon in Permafrost Experimental Heating Research (CiPEHR) project—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 25-50%, and has degraded an increasing amount of surface permafrost each year of the project. The treatment has lead to the development of continuously thawed soil layers deep within the profile that remain above zero even during the cold winter. Surface subsidence as a result of permafrost thaw previously had increased surface soil moisture and reduced the distance from the soil surface to the water table. These unfrozen layers have led to threshold changes in surface moisture that is normally perched on the permafrost table, with thaw breakthroughs drying the soil surface, at least periodically, during the growing season. We showed that experimental warming that caused permafrost degradation led to a two-fold increase in carbon uptake by the ecosystem during the growing season. Warming also enhanced growing season and winter respiration, which, in part, offset growing season carbon gains. This was in part due to more old carbon released by soil warming both during the growing season and the winter. Assimilating experimental data into an ecosystem model indicated that parameter adjustment was needed for the model to simulate carbon cycle dynamics under experimental warming. In particular, parameters for light use, gross primary production allocation, as well as transfer coefficients from litter to soil pools showed the greatest change, suggesting that there was acclimation in ecosystem behaviour in response to warming.