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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 seven 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. We showed that experimental warming that caused permafrost degradation led to a two-fold increase in C uptake by the ecosystem during the growing season. Increased C uptake was mirrored in aboveground plant biomass changes measured by non-destructive point intercept sampling, with much of the increase due to growth of the dominant tussock-forming sedge *Eriophorum vaginatum*. Warming also enhanced growing season and winter respiration, which, in part, offset growing season C gains. This was in part due to more old carbon released by soil warming both during the growing season and the winter. Carbon exchange observations also pointed to an unexplained pattern in the air+soil warming treatment that became magnified over the course of the experiment. Each type of warming manipulation applied alone stimulated the biological processes that drive ecosystem C uptake and release. But, there was a negative interaction such that C exchange rates for the treatments together were in between the magnitudes observed for each warming treatment alone. This negative interaction was also observed in the direct measurement of aboveground plant biomass and in the patterns of soil N availability pointing towards some soil-mediated mechanism driving the interaction.