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Enhanced greenhouse gas emissions from the Arctic with experimental warming

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Temperatures in the Arctic are projected to increase more rapidly than in lower latitudes. With temperature being a key factor for regulating biogeochemical processes in ecosystems, even a subtle temperature increase might promote the release of greenhouse gases (GHGs) to the atmosphere. Usually, carbon dioxide (CO_2) and methane (CH_4) are the GHGs dominating the climatic impact of tundra. However, bare, patterned ground features in the Arctic have recently been identified as hot spots for nitrous oxide (N_2O). N_2O is a potent greenhouse gas, which is almost 300 times more effective in its global warming potential than CO_2; but studies on arctic N_2O fluxes are rare.

In this study we examined the impact of temperature increase on the seasonal GHG balance of all three important GHGs (CO_2, CH_4 and N_2O) from three tundra surface types (vegetated peat soils, unvegetated peat soils, upland mineral soils) in the Russian Arctic (67˚03' N 62˚55' E), during the course of two growing seasons. We deployed open-top chambers (OTCs), inducing air and soil surface warming, thus mimicking predicted warming scenarios. We combined detailed CO_2, CH_4 and N_2O flux studies with concentration measurements of these gases within the soil profile down to the active layer–permafrost interface, and complemented these GHG measurements with detailed soil nutrient (nitrate and ammonium) and dissolved organic carbon (DOC) measurements in the soil pore water profile.

In our study, gentle air warming ($\sim$1.0 ˚C) increased the seasonal GHG release of all dominant surface types: the GHG budget of vegetated peat and mineral soils, which together cover more than 80 % of the land area in our study region, shifted from a sink to a source of -300 to 144 g CO_2-eq m^{-2} and from -198 to 105 g CO_2-eq m^{-2}, respectively. While the positive warming response was governed by CO_2, we provide here the first *in situ* evidence that warming increases arctic N_2O emissions: Warming did not only enhance N_2O emissions from the known arctic N_2O hot spots (bare peat soils; maximum seasonal release with warming: 87 mg N_2O m^{-2}), but also from the vegetated peat surfaces, not emitting N_2O under present climate. These surfaces showed signs of a hampered plant growth, leading to reduced soil N uptake with warming, indicating that plants are regulating arctic N_2O emissions.

The warming treatment was limited to temperature of air and upper soil surface, and did not alter thaw depth. Nonetheless, we observed a clear increase of all three GHGs deep in the soil profile, and attribute this to downward leaching of labile organic substances from the surface soil and/or plants, fueling microbial activity at depth. Our study thus highlights the tight interlinkage between the surface soil, vegetation, and deeper soil layers, which could lead to losses of all three GHGs, including N_2O, with subtle temperature increase. We therefore emphasize that indirect effects caused by warming, such as leaching processes, as well as arctic N_2O emissions, need to be taken into account when attempting to project feedbacks between the arctic and the global climate system.