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Abrupt thaw enhances annual global warming potential of an actively degrading permafrost peatland

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Global scale warming has led to permafrost thaw, which may release large amounts of carbon to the atmosphere as CO_2 and CH_4, potentially accelerating global warming (i.e. a positive feedback). However, uncertainty in the mechanisms controlling carbon mineralization is compounded by concurrent changes in soil hydrology associated with permafrost thaw. Thawing permafrost can lead to surface water accumulation in some areas and seasonal or permanent soil drying in areas where permafrost thaw opens up new channels of water to penetrate into the groundwater system. The complexity of the hydrologic response to permafrost thaw increases the challenge in generating reliable estimates of the permafrost carbon climate feedback. Furthermore, limited observational data exist to i) quantify the effects of permafrost thaw on net tundra carbon budgets, particularly on an annual basis, and ii) as well as constrain the underlying processes governing carbon release under aerobic and anaerobic conditions.

Here, we investigated how changes in local hydrology affects CO_2 and CH_4 release from permafrost soils by establishing a field gradient study in northern Norway (69 N), where recent abrupt degradation of permafrost created thaw ponds in palsa-mire ecosystems. The site exhibits a natural gradient of permafrost thaw, which also corresponds to a strong hydrological gradient (i.e. dry palsas with intact permafrost, seasonally inundated thaw slumps, and thaw ponds). Since 2017, we have used a range of manual and automated techniques to measure changes in vegetation, soil and water microclimate, biogeochemistry, and soil CO_2 and CH_4 concentrations and efflux across the permafrost thaw gradient.

Our preliminary results show that abrupt permafrost thaw and landscape subsidence – both intermediate slumping and thaw pond formation – increase net annual carbon loss from this type of subarctic wetland. Permafrost thaw approximately doubles CO_2 emissions from thaw slumps compared to vegetated or soil palsas. Furthermore, CH_4 release greatly increased across the permafrost thaw gradient. While vegetated palsas were small sinks of atmospheric CH_4 during the growing season, permafrost thaw slumping and pond formation led to a dramatic increase in CH_4

efflux compared to bare palsas. In contrast, bare soil palsas on were the most important source of N_2O. Soil profile CO_2 and CH_4 concentrations in thawed permafrost plots were overall highly enriched relative to palsa profiles, reflecting soil conditions with inundated pore space and low oxygen availability along the permafrost thaw gradient. We therefore conclude that abrupt thaw will increase annual carbon loss in subarctic palsa wetlands.