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Future climatic suitability of permafrost peatlands in Europe and Western Siberia

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Human-induced climate change during the 21st century is expected to thaw large expanses of permafrost peatlands - one of Earth's largest terrestrial carbon stores. Whilst frozen, peatland carbon fluxes are inhibited by cold temperatures, but emissions of carbon dioxide (CO_2) and methane (CH_4) are expected to substantially increase post-thaw. Peatland permafrost is often characterised by the presence of frost mounds, termed palsas/peat plateaus, or by ice-wedge polygons in more northerly regions. The spatio-temporal dynamics of future permafrost peatland thaw remain highly uncertain due to incomplete mapping of their modern distribution, the insulating properties of organic soils, and the variation in model projections of future climate.

Here, we present simulations of the modern and future climate envelopes of permafrost peatlands in Europe and Western Siberia. We collated > 2,000 site observations from across the northern hemisphere to quantify the modern distributions of palsas/peat plateaus and polygon mires. We fitted novel climate envelope models by relating landform distributions to modern climate data. We forced our climate envelope models with decadal projections of future climate under four Shared Socioeconomic Pathway (SSP) scenarios from 2020–2090, taken from an ensemble of 12 general circulation models included in the Coupled Model Intercomparison Project 6 (CMIP6). We then combined our simulations with recent soil organic carbon maps to estimate the total peat carbon stocks that may be at risk from future losses of suitable climate space.

Our simulations indicate that permafrost peatlands in Europe and Western Siberia will soon surpass a climatic tipping point under scenarios of moderate-to-high warming (SSP2-4.5, SSP3-7.0, and SSP5-8.5). We show that permafrost peatlands in Fennoscandia currently exist under warmer, wetter climates than those in Western Siberia. Our projections suggest that Fennoscandia will no longer be climatically suitable for peatland permafrost by 2040. Projected climate space losses by

2100 under these scenarios would affect peatlands containing 37.0–39.5 Gt carbon in Europe and Western Siberia (equivalent to twice the amount of carbon stored in European forests). Under a scenario with strong climate change mitigation (SSP1-2.6), our analyses show that permafrost peatlands storing 13.9 Gt carbon in the northernmost parts of Western Siberia would remain climatically supported by the 2090s. These results indicate that the rate and extent of 21st century permafrost peatland thaw will be determined by near-future socioeconomic developments.