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Observation-based modelling of permafrost carbon fluxes with accounting for deep carbon deposits and thermokarst activity

Thomas Schneider von Deimling (1), Guido Grosse (1), Jens Strauss (1), Lutz Schirrmeister (1), Anne Morgenstern (1), Sibyll Schaphoff (2), Malte Meinshausen (3), and Julia Boike (1)

(1) Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Periglacial Research Unit, Potsdam, Germany, (2) Potsdam Institute for Climate Impact Research, Potsdam, Germany, (3) School of Earth Sciences, The University of Melbourne, Victoria, Australia

With rising global temperatures and consequent permafrost degradation a part of old carbon stored in high latitude soils will become available for microbial decay and eventual release to the atmosphere. To estimate the strength and timing of future carbon dioxide and methane fluxes from newly thawed permafrost carbon, we have developed a simplified, two-dimensional multi-pool model. As large amounts of soil organic matter are stored in depths below three meters, we have also simulated carbon release from deep deposits in Yedoma regions. For this purpose we have modelled abrupt thaw under thermokarst lakes which can unlock large amounts of soil carbon buried deep in the ground.

The computational efficiency of our 2-D model allowed us to run large, multi-centennial ensembles of differing scenarios of future warming to express uncertainty inherent to simulations of the permafrost-carbon feedback. Our model simulations, which are constrained by multiple lines of recent observations, suggest cumulated CO_2 fluxes from newly thawed permafrost until the year 2100 of 20-58 Pg-C under moderate warming (RCP2.6), and of 42–141Pg-C under strong warming (RCP8.5). Under intense thermokarst activity, our simulated methane fluxes proved substantial and caused up to 40 % of total permafrost-affected radiative forcing in the 21st century. By quantifying CH4 contributions from different pools and depth levels, we discuss the role of thermokarst dynamics in affecting future Arctic carbon release.

The additional global warming through the release from newly thawed permafrost carbon proved only slightly dependent on the pathway of anthropogenic emission in our simulations and reached about 0.1°C by end of the century. The long-term, permafrost-affected global warming increased further in the 22nd and 23rd century, reaching a maximum of about 0.4°C in the year 2300.