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Northern hemisphere peatland carbon cycle dynamics over the Holocene - modelled with the MPI-Earth System Model

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Peatlands of the high northern latitudes store about 450 petagrams of carbon and constitute a significant natural source of methane (CH_4) even though they cover only 3 % of the global land surface. By storing carbon and removing carbon dioxide (CO_2) from the atmosphere, boreal peatlands have globally had a cooling effect on millennial timescales. Undisturbed boreal peatlands are likely to continue functioning as a net carbon sink. On the other hand, these carbon pools might be destabilised in the future since they are sensitive to climate change. Given that processes of peat accumulation and decay are closely dependent on hydrology and temperature, this balance may be altered significantly in the future. As a result, northern peatlands could have a large impact on carbon cycle-climate feedback mechanisms and therefore play an important role in global carbon cycle dynamics.

However, global biogeochemistry models used for simulations of carbon cycle dynamics in past and future climates usually neglect peatland processes. Our approach aims at the evaluation of the feedback of boreal wetlands to climate through fluxes of CO_2 and CH_4 on millennial time scales. For this purpose, we developed a generic model of peatland carbon dynamics which is part of the Max Planck Institute Earth System Model (MPI-ESM) land surface module JSBACH. Carbon accumulation is calculated as the net balance of productivity and decomposition. The key factor is the water table depth which controls decomposition rates. These are more than an order of magnitude lower in anoxic conditions. Model output consists of carbon accumulation rates, peat height, net primary production, fraction of carbon above respectively below water table, CH_4 and CO_2 emissions.

We have conducted a Holocene run (6000 years) of our model of peat dynamics, which we forced with Holocene climate data from a model run with MPI-ESM (Fischer et al.). The distribution of peatlands was determined using a dynamic model of wetland extent (accompanying poster by Stacke et al.), which was coupled to the JSBACH-peat model asynchronously. After these 6000 years, we get total peat storage in the northern high and temperate latitudes (above 45° N) comparable to recent estimates. Additionally, our model gives estimates of CH_4 emissions during the Holocene.

For additional validation on the local scale, we also forced the model with 10 years of observed climate data from specific sites, e.g. the Bakchar Bog near Tomsk, Russia. This enabled the comparison of seasonal dynamics of biomass, net primary production, net ecosystem production, and peat accumulation rates with JSBACH-peat simulation output.