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Transient simulations of the carbon and nitrogen dynamics in northern peatlands: from the Last Glacial Maximum to the 21st century

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The development of northern high-latitude peatlands played an important role in the carbon (C) balance of the land biosphere since the Last Glacial Maximum (LGM). At present, carbon storage in northern peatlands is substantial and estimated to be 500 ± 100 Pg C (1 Pg C = 10^{15} g C). Here, we develop and apply a peatland module embedded in a dynamic global vegetation model (LPX). The peatland module features a dynamic nitrogen cycle, a dynamic C transfer between peatland acrotelm (upper oxic layer) and catotelm (deep anoxic layer), hydrology- and temperature-dependent respiration rates, and peatland specific plant functional types. Nitrogen limitation down-regulates average modern net primary productivity over peatlands by almost a factor of two. Decadal acrotelm-to-catotelm C fluxes vary between -20 and +50 g C m^{-2} yr^{-1} over the Holocene. Key model parameters are calibrated with reconstructed peat accumulation rates from peat-core data. The model reproduces the major features of the peat core data and of the observation-based modern circumpolar soil carbon distribution. Results from a set of simulations for possible evolutions of northern peat development and areal extent show that soil C stocks in modern peatlands increased by 365–550 Pg C since the LGM, of which 175–272 Pg C accumulated between 11 and 5 kyr BP. Furthermore, our simulations suggest a persistent C sequestration rate of 35–50 Pg C per 1000 yr in peatlands under current climate conditions, and that this C sink could either vanish or turn into a small source by 2100 AD depending on climate trajectories as projected for different representative greenhouse gas concentration pathways.