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Legacy effects of climate overshoot scenarios in permafrost-affected regions

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Difficulties to quickly reduce carbon emissions to levels compatible with the long-term goal of the Paris Agreement increase the likelihood of scenarios that temporarily overshoot the respective climate targets. We used simulations with JSBACH, the land surface component of the Max-Planck-Institute for Meteorology's Earth system model MPI-ESM1.2 to investigate the long-term response of the terrestrial Arctic to climate stabilization at such a climate target. In particular, we seek to answer the question whether the state of permafrost-affected soils and the Arctic carbon cycle could converge to different equilibria depending on the climate trajectory that precedes climate stabilization at 1.5°C above pre-industrial levels. To this end, we compare simulations that are forced with the same non-transient atmospheric conditions – corresponding to the 1.5°C-target --, but started from different initial conditions. One simulation was initialized with the conditions before and one simulation with the conditions after a temperature overshoot which follows SSP5-8.5 until the year 2100 subsequent to which the atmospheric conditions are reversed to the 1.5°C-target. Our results reveal that feedbacks between water-, energy- and carbon cycles allow for path-dependent steady-states in permafrost-affected regions. These depend on the soil organic matter content at the point of climate stabilization, which is significantly affected by the soil carbon loss resulting from overshooting the climate target. Here, the simulated steady-states do not only differ with respect to the amount of carbon stored in the frozen fraction of the soil, but also with respect to soil temperatures, the soil water content and even net primary productivity and soil respiration.