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Future permafrost degradation positively enhances Arctic ecohydrological processes

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Permafrost is considered vulnerable to increasing temperatures. Air temperatures over the Arctic have indeed increased considerably over the last century. Most climate models project that the warming will continue, enhancing permafrost degradation. The degradation of permafrost has the potential to initiate numerous feedbacks, predominantly positive, in the Arctic climatic, hydrological, and biogeochemical processes. For instance, the Arctic terrestrial evapotranspiration during summer season tends to overpass precipitation of the period. The unbalance of water budget seems to be offset by permafrost contribution. A considerable amount of soil carbon cumulating within the permafrost is also released with permafrost degradation. However, it is still uncertain on how much amount of soil carbon will be released. Furthermore, the largest uncertainty is on the magnitude of permafrost degradation under the future climate change. Therefore, the major purpose of this study is to reduce the uncertainties relating to permafrost degradation and then is to assess influences of permafrost dynamics on ecohydrological processes.

A land surface model CHANGE, including hydrological and biogeochemical processes, was applied to the pan-Arctic terrestrial region over the period 1901-2100. For exploring the influence of permafrost dynamics on ecohydrological processes in the future, outputs from four scenarios (RCP 4.5, 6.0, and 8.5) of three GCMs (MIROC, CCSM4, and HadGCM2) were used for the simulation of CHANGE.

Permafrost positively degraded with temperature warming. By 2091–2100, permafrost extent was decreased 30–75% and active layer thickness increased about 55–125 cm, compared to 1991–2010. Evapotranspiration (ET) and net primary productivity (NPP) also increased about 15–55%. However, higher ET resulted in soil dryness. On the other hand, the increased NPP enhanced soil organic matter, which increased soil water-holding capacity and limited soil warming due to its insulation effect. The model also predicted a cumulative efflux of 50–120 Gt C of permafrost carbon to the atmosphere by 2100. The thaw and decay of permafrost carbon is irreversible and amplify surface warming to initiate a positive permafrost carbon feedback on climate. On the other hand, the conditions implicated to permafrost degradation tended to keep summertime ET and NPP relatively high.