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Permafrost–ice-sheet interactions during the Quaternary

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Permafrost influences a number of processes which are relevant for local and global climate. For example, it is well known that permafrost plays an important role in global carbon and methane cycles. Less is known about the interaction between permafrost and ice sheets. We recently included a permafrost module in the Earth system model CLIMBER-2 to explore the coupled Northern Hemisphere (NH) permafrost–ice-sheet evolution during the Quaternary.
The model has been shown to perform generally well at reproducing present-day permafrost extent and thickness. Modelled permafrost extent at the Last Glacial Maximum (LGM) agrees well with reconstructions and previous modeling estimates.
In a previous study we showed that over the last glacial cycle permafrost has a relatively modest impact on simulated NH ice sheet volume except at LGM, when including permafrost increases ice volume by about 15 m sea level equivalent in our model. This is explained by a delayed melting of the ice base from below by the geothermal heat flux when the ice sheet sits on a porous sediment layer and permafrost has to be melted first. Permafrost affects ice sheet dynamics only when ice extends over areas covered by thick sediments, which is the case at LGM.
In transient model simulations of the “40 kyr world” of the early Pleistocene we show that when all continents are covered by a thick sediment layer the response of ice volume to the obliquity component of orbital forcing is enhanced while the response to precession is dampened.
We therefore argue that permafrost could have played a role for ice sheet evolution when all continents were covered by a thick sediment layer, as was likely the case in the early Pleistocene before the sediment layer was gradually eroded by expanding ice sheets over parts of northern Canada and Scandinavia.