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Potential inflow of sub-glacial groundwater to proglacial lakes along the western margin of the Greenland Ice Sheet

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In the Kangerlussuaq area, West Greenland, the proglacial area stretching from the margin of the Greenland Ice Sheet (GrIS) to the coast was covered by the GrIS during the last glacial maximum (LGM). Comparison of radiocarbon dates of shallow lake sediments and moraines suggest lake development to occur shortly after the retreat of the ice-sheet margin. At present day, permafrost is approximately 300 m deep near the ice-sheet. Taliks penetrating the thickness of the permafrost are believed to occur underneath lakes large enough to provide sufficient thermal insulation. Nevertheless, observations have shown that a small lake (radius of 30 m, maximum depth 3.5 m) after partial lake drainage, refilled itself within a few months. Considering heat conduction only, a thermal through talik is unlikely; however, we hypothesize that advective heat flow by groundwater discharge could have resulted in conditions that have locally hampered permafrost development after retreat of the GrIS.
Regions in front of an ice sheet are subject to high hydraulic head gradients if the ice-base is under pressure melting, and groundwater flow paths can extent into the proglacial area where upwelling to the surface can potentially occur via localized high permeable zones. Lakes forming immediately after ice retreat may be connected to a deep aquifer system, hydraulically linking the sub-glaical and proglacial domains while permafrost is forming around these lakes. Whether the connection to the subpermafrost aquifer gets cut off, is subject to the size of the lake, the lake bottom temperature, the mean annual air temperature and the rate of groundwater discharge into the lake.
In this study, we aim to improve our understanding of the occurrence of groundwater flow in permafrost covered areas by numerical modeling of coupled transient heat and fluid flow. We developed a 2D regional- scale hydrogeological model of an ice sheet covered area from which the ice retreats starting from the end of the LGM to its present position. In the forefield of the ice-sheet we mimic lake formation. In this way, we study the possibility of the development of through taliks due to advective heat flow through groundwater discharge.
Results show that due to high hydraulic head gradients, the proglacial area is subject to groundwater discharge. During the freezing process, groundwater discharges preferentially through taliks underneath lakes. Some of them remain open over the period since the LGM, whereas a conduction only model with the same settings would not show a through talik.
The comparison of a model of a single lake with a high hydraulic head, as it can be found in front of an ice sheet with a model without fluid flow, reveals that the through talik freezes down within a few hundred years, whereas in the same setting but with consideration of advective heat flow due to subsurface flow, the through talik can persist.