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Groundwater Pathways in a Periglacial Landscape

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Ice-sheet margin environments in continuous permafrost landscapes are the scene of groundwater interactions between the base of the ice mass and through-talik lakes. Such flows mobilize deep ground water in sub-permafrost aquifers and can possibly imply strongly focused groundwater discharge. Such landscapes are therefore of interest for understanding the long-term behavior of deep geological repositories. For that reason, the Canadian, Finnish and Swedish nuclear waste organizations started to study the present day Greenland Ice Sheet, and the contiguous periglacial landscape, as a natural analogue within the frame of the Greenland Analogue Project (GAP). Yet the flat topography of the potential repository site at Forsmark, Sweden, differs strongly from the hilly Greenland landscape that has been studied. This raises the question of how flow dynamics in talik landscapes vary with surface topography and how the GAP results should be used in safety assessments.

To study the groundwater pathways between different taliks and between taliks and the ice sheet, a 25x40km site, located east of Kangerlussuaq, Greenland, has been analyzed through numerical simulations.This study domain comprises seven through-talik lakes and two outlet glaciers. With the computer code DarcyTools, we have solved the coupled mass and energy balance equations for the groundwater, accounting for the expansion of water during freezing and effects of phase change on permeability. After reaching steady state conditions, we applied a bidirectional particle track scheme. The robustness of the results has been tested for various permeability assumptions, a scenario of lower hydraulic potential beneath the ice sheet and a scenario incorporating major deformation zones. Finally, to address the topography issue, we conducted numerical experiments by altering the original elevation model and simulated the hydrogeological dynamics of an increasingly flattened landscape.

The particle traces reveal that not only talik lakes can act as locations for either strict groundwater recharge or discharge, but also that the same lake can concurrently exhibit both behaviors. This dual behavior is indeed observed in five of the seven lakes. The lakes located closest to the ice margin act primarily as discharge locations for the meltwater from the ice sheet, while lakes further away are receiving water from the glacier as well as from each other's. The nature of the connection between lakes depends on their respective elevations and the most elevated lake even discharges water toward one of the glacier. The scenarios with flatter topographies show that smoothing the digital elevation model enhances the influence of the ice sheet on the hydrogeological system and reveals a significant reduction of flow between the lakes.