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Permafrost degradation as a control on hydrogeological regime shifts in a warming climate

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The degradation of permafrost should cause intensification of subsurface water transport in river catchments. This leads a change in the contribution of groundwater to river flow. Using numerical models, we evaluate hydrogeological regime changes in high-latitude river basins under conditions of ground surface warming. These describe transient heat- and fluid flow coupled to the hydrogeological impacts of phase-changes from ice to liquid water. We consider an idealized sedimentary aquifer system in which groundwater flow is driven by topography, representing a series of small drainage basins in riverine terrain of relatively subdued topography. Various temporal and spatial surface temperature conditions are considered to control the initial permafrost distributions for the simulations. The simulated rates of increase in groundwater contribution to stream flow during and after permafrost thaw, are in the order of magnitude comparable to hydrogeological regime changes over the past decades as reported for several Arctic rivers. The timing and rate of acceleration in groundwater circulation in aquifers at the local scale river basins we consider, are strongly controlled by shifts in aquifer permeability architecture during permafrost degradation. However, the uptake of water into aquifer storage when sub-permafrost hydraulic heads rise, potentially dampens the effect of permafrost degradation on groundwater fluxes by several decades to centuries. In order to evaluate the relative importance of both processes in natural systems, the current hydraulic regime (notably pore pressures) of sub-permafrost aquifer systems as well as patterns of permafrost heterogeneity, taliks and their hydraulic connectivity are insufficiently known.