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How will groundwater discharge patterns in continuous permafrost regions change in a warming climate?

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Permafrost strongly influences the storage and movement of groundwater in cold regions by confining groundwater flow to the active zone located above permafrost, to the sub-permafrost aquifer located below permafrost or through perennially unfrozen areas known as taliks. Permafrost thaw due to climate warming modifies hydrological processes by increasing hydraulic conductivity by several orders of magnitude and thereby enhances groundwater storage and hydrological connectivity between aquifers and surface water bodies. While data from previous studies reveal increases in Arctic river baseflow, the hydrogeological processes leading to these changes remain poorly understood. Modelling these changes is a challenge partly due to choices in the design and parameterization of the surface boundary conditions. Herein, we develop an improved set of surface boundary conditions for a coupled heat and groundwater flow numerical model that includes dynamic freezing and thawing processes and to simulate the impacts of climate warming on permafrost distribution and the spatial and seasonal patterns of groundwater discharge. Under a range of conditions simulated, we show a spatial shift in groundwater discharge from upslope to downslope and temporal shift towards the winter season due to the formation of a lateral supra-permafrost talik underlying the active layer. These changes only occur once the lateral talik has reached its full lateral extension therefore suggesting that the thickness of the supra-permafrost aquifer is the main driver of the baseflow variations. Parameters such as subsurface permeability, surface slope, recharge rate and recharge seasonality can influence the timing and the magnitude of the temporal and spatial groundwater discharge variations, but the trajectory of spatial and temporal shifts in groundwater discharge remain the same. These insights help explain observed changes in Arctic baseflow and wetland patterns and are important for water resources and ecosystem management.