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Non-isothermal, three-phase simulations of near-surface flows in a model permafrost system under seasonal variability and climate change

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Permafrost responses in a changing climate can affect hydrological and biogeochemical cycling, ecosystems and climate feedbacks. We show results from recent numerical simulations of permafrost and hydrology interactions, using a non-isothermal, three-phase model of water migration coupled to heat transport for partially frozen porous media. Several porous media textures representing a small-scale subsurface domain are evaluated in terms of how they exhibit control on the formation and continuity/discontinuity of permafrost, together with dynamics of water flow, and subject to both seasonal temperature variability and for an increasingly warmer climate. For all subsurface conditions considered, the main common hydrological signal of permafrost degradation in a warming trend is decreasing seasonal variability of surface water flows. This is determined to be due to deeper and longer subsurface flow pathways with increasing lag times from infiltration, or thawing through subsurface flow to surface water discharge. Further, these results show how physically based numerical modelling can be essential for a quantitative and qualitative improvement of our understanding of how permafrost thawing relates to, and may be detected in, hydrological data. This is advantageous since hydrological data is considerably easier to obtain, may be available in longer time series, and generally reflects larger-scale conditions than direct permafrost observations.