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Effects of hydrological inputs on the dynamics of permafrost system formation and degradation

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Understanding permafrost dynamics and how this is influenced by hydrological inputs is important in assessing how permafrost systems may affect both surface and subsurface flow systems, and how hydrological and transport mechanisms may impact and be impacted by climate change. In this study, the effects of various hydrological input parameters on the dynamics of a model permafrost system are studied using a three-phase, non-isothermal numerical code.

Previous studies have demonstrated the importance of including three-phase, non-isothermal flow processes in order to better understand permafrost dynamics. Furthermore, results have indicated that warming trends are expected to cause a reduction in temporal and seasonal variability of groundwater discharge into surface water bodies in permafrost environments. In this study, we analyse the effects of hydrological input parameters and how these may influence hydrological feedback mechanisms due to degradation and formation of permafrost. This also further demonstrates the importance of including hydrogeological flow processes in order to better understand the behaviour of permafrost dynamics.

The scenario considered is a two-dimensional cross-section of the subsurface, representing a generic catchment, where liquid water may infiltrate at the surface and discharge along a lateral seepage face boundary, representing subsurface discharge into a lake or river talik. Thereby, effects of hydrological inputs are studied in terms of how they impact the formation and degradation of permafrost. Also, the dynamics of permafrost variation and how this impacts the hydrogeological flow system and its outflow seepage rates to surface water bodies are evaluated. In particular, the effects of warming trends, ambient temperature gradients, and step changes in surface infiltration rates are studied. Results indicate non-linear responses of permafrost formation under imposed ambient temperature trends, which depend primarily on the rate of temperature increase. Also, increased infiltration rates maintained under periodically constant temperatures are shown to effectively degrade or form permafrost, depending on heterogeneity and soil texture.

These results, combined with previous studies, show the necessity in considering the complete three-phase, non-isothermal dynamics when studying the interactions between permafrost and hydrological systems.