Simulating groundwater flow, heat transport, and permafrost in cold regions with dynamic-thaw

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Rapid warming and thawing of continuous and discontinuous permafrost is an important component of changes being observed in cold-regions hydrology. Although difficult to observe and measure, subsurface freezing and thawing involve complex feedbacks between the frozen subsurface, groundwater, and surface flow systems. A new numerical groundwater model, SUTRA 3.0, was developed to try and elucidate some of these processes. This code, based on the U.S. Geological Survey SUTRA model for coupled groundwater flow and heat transport, simulates freezing and melting of groundwater, including proportional heat capacity and thermal conductivity of water and ice, decreasing permeability due to ice formation, and latent heat effects. The model code is verified by correctly simulating an analytical solution for ice formation and matching field data from a northern peatland. A Tothian-type hillslope model is used to show the potential influence of groundwater flow in accelerating the rate of permafrost melting.