Modeling aspect controlled formation of seasonally frozen ground on montane hillslopes: a case study from Gordon Gulch, Colorado

The Intergovernmental Panel on Climate Change (2013) warns that high-elevation ecosystems are extremely vulnerable to climate change due to short growing seasons, thin soils, sparse vegetation, melting glaciers, and thawing permafrost. Many permafrost-free regions experience seasonally frozen ground. The spatial distribution of frozen soil exerts a strong control on subsurface flow and transport processes by reducing soil permeability and impeding infiltration. Accordingly, evolution of the extent and duration of frozen ground may alter streamflow seasonality, groundwater flow paths, and subsurface storage, presenting a need for coupled thermal-hydrologic models to project hydrologic responses to climate warming in high-elevation regions. To be useful as predictive tools, such models should incorporate the heterogeneity of solar insolation, vegetation, and snowpack dynamics. We present a coupled thermal-hydrologic modeling study against the backdrop of field observations from Gordon Gulch, a seasonally snow-covered montane catchment in the Colorado Front Range in the Boulder Creek Critical Zone Observatory. The field site features two instrumented hillslopes with opposing aspects: the snowpack on the north-facing slope persists throughout much of the winter season, while the snowpack on the south-facing slope is highly ephemeral. We implemented a surface energy balance and snowpack accumulation and ablation model that is coupled to the subsurface flow and transport code PFLOTRAN-ICE to predict the hydrologic consequences of aspect-controlled frozen soil formation during water years 2013-2016. Preliminary model results demonstrate the occurrence of seasonally-frozen ground on the north-facing slope that directs snowmelt to the stream by way of shallow subsurface flow paths. The absence of persistently frozen ground on the south-facing slope allows deeper infiltration of snowmelt recharge.