Field observations of rapid midwinter recharge in a seasonally frozen bedrock aquifer

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Under conditions of a changing climate winters are predicated to be warmer and wetter in the northern hemisphere. As a result, midwinter melts and rain on snow (ROS) events have the potential to contribute to groundwater recharge. An understanding of the impacts of repeated freeze-thaw and ROS on groundwater recharge is critical for predicting and managing future groundwater resources in seasonally frozen environments. In particular, fractured rock aquifers have received little attention regarding these processes. To explore the impacts of midwinter melts and ROS on bedrock recharge, a granitic outcrop has been heavily instrumented in Eastern Ontario, Canada over the 2019-2020 winter season. The low-lying outcrop is approximately 10 m X 8 m and the water table resides in the bedrock approximately 3 m below ground surface. Two wells have been drilled to 15 m and 30 m depths. The first well is open and the second has two isolated intervals with pressure transducers and temperature sensors installed in both wells. Three temperature probes have been drilled into the rock outcrop with two installed just beneath the soil to explore if heat transferred from exposed warming rock could melt adjacent frozen soil. Two soil moisture and temperature profiles (5 measurements each) have been installed in the adjacent soil and extend from the surface to the soil-bedrock contact. Finally, a weather station has been installed that measures precipitation, snow depth, air temperature, relative humidity, solar radiation and wind speed. The instrumented area allows for detailed measurements of atmosphere-subsurface interaction that can be used for coupled snowpack and subsurface flow modelling. Preliminary field observations indicate that rapid recharge in the bedrock can take place despite frozen conditions. This is evidenced by sharp drops in groundwater temperature accompanied by rises in water level in response to snowmelt or ROS events. The soil moisture and temperature profiles indicate that shallow (20 cm) soil remains frozen, limiting infiltration from above. However, runoff from the outcrop can flow along the soil-rock contact allowing for infiltration and recharge to occur beneath the frozen layer. These results suggest that areas of exposed rock can be localized hotspots for groundwater recharge when midwinter warming or ROS occurs. This may result in increased recharge to bedrock aquifers during winter months under future climate change scenarios.