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Snow and Landscape Controls on Recharge and Groundwater Flux to Streams

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Understanding mountain hydrology is complicated by the tight coupling of snow processes, vegetation and topography, while the importance of groundwater in these systems and its sensitivity to climate remain uncertain. In this framework, spring snowmelt is one of the major sources of recharge. To address challenges, we combine snow observations across spatial and temporal scales, groundwater gas tracers, and an integrated hydrologic model of the East River, CO to explore stream water source, depth of hydrologically active groundwater, and first-order controls on recharge as well as baseflow age distributions. Use of Lidar-derived snow water equivalent allows us to implicitly account for nuances in storm patterns, snow redistribution processes related to wind and avalanche, and capture high elevation snowpack accumulation and persistence important for water resources. Results indicate 35% of streamflow comes from groundwater to independently validate Carroll et al. (2018) assessment using end-member mixing analysis. We find groundwater flow to streams remains stable across the multi-decadal simulation (water years 1987-2018) despite variability in snow accumulation and melt. While there is stability in simulated groundwater flow volumes, the relative contribution of groundwater to streams varies considerably (21-52%) as a function aridity and the tight coupling between basin-scale ET and interflow. During low snowpack years, ET/P increases at the expense of lateral flow through the soil zone. Resilience of groundwater volumetric flux is dictated by changes in groundwater storage. The responsiveness of groundwater storage to snow accumulation occurs because the majority (~53%) of groundwater moves through the permeable alluvium and shallow fractured bedrock that are relatively well connected to surface water input from snowmelt. The remaining groundwater component, however, moves through deeper fractured bedrock and steeply dipping sedimentary strata, with drier scenarios lowering water table depths and extending circulation downward. Our results support the hypothesis presented by (Carroll et al., 2018) that the upper subalpine focuses groundwater recharge in mountain systems. However, we find that while coupled seasonal vegetation and snow dynamics are particularly important in the lower reaches of the basin, the dominant control on maximum recharge in/above the upper subalpine is topographical. Lastly, baseflow ages derived from gas tracers (SF_6, CFCs) and numerically generated particle tracking independently agree that median age of groundwater discharging to streams is approximately 10 years with numeric modelling highlighting the importance geologic structure driving deeper flow paths and older travel times. We conclude that deeper groundwater is an important component of mountain hydrology and should be explicitly included in water budgets for improved predictive capability.

Reference:

Carroll, R. W. H., Bearup, L. A., Brown, W., Dong, W., Bill, M., & Willlams, K. H. (2018). Factors controlling seasonal groundwater and solute flux from snow-dominated basins. *Hydrological Processes*, *32*(14), 2187–2202. http://doi.org/10.100[2]/hyp.1[3]151