Tracing water through a forest root zone

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In river headwaters, much of the water that enters streams first travels through meters of weathered bedrock underlying soils. During dry periods, forests often tap this weathered bedrock to access stored water. To better predict water resources in headwater catchments, a better understanding of the function of water storage in weathered bedrock is needed. Here, I present the results of a field study and tracer experiment directed at tracing the stable isotope composition of waters transiting soils, weathered bedrock, and groundwater, en route to streamflow. In a steep, forested hillslope in Northern California, we used a Vadose zone Monitoring System (VMS) – flexible sensors and samplers pressed against bedrock surrounding an inclined borehole – to extract rock moisture from weathered bedrock and monitor moisture levels at discrete intervals to ~16.5 m depth. Continuous rock moisture measurements build upon previous nuclear magnetic resonance and neutron probe monitoring to identify the timing of progressive wetting and drying to 11.4 m depth in response to the winter-wet, summer-dry Mediterranean climate. During the long, dry summers, tree water uptake occurs at multiple depths throughout the root zone simultaneously, rather than exhausting moisture supplies at shallow depths before extracting deeper rock moisture. By tracking precipitation and vadose zone water isotope composition, isotopically distinct rainfall inputs could be traced up to 4.5 m depth, but these signals attenuate strongly with depth, such that the deeper vadose zone shows small variability and a composition close to the long-term average precipitation input. As a result, the composition of groundwater recharge and thus groundwater fed to streamflow has a relatively consistent composition. A tracer experiment, where deuterated water was injected at 1.75 m depth across a nest of 100 ports overlying the VMS, revealed that plant-accessible and non-accessible water pools in the weathered bedrock mix over the long dry season: the tracer transited downward after multiple dry seasons. Nonetheless, comparison of VMS extracted waters and water stored in the matrix of the weathered bedrock appear to be isotopically distinct. We conclude that deep root water uptake and the interaction of dynamic and non-dynamic water pools within weathered bedrock may pose a strong control on water flowpaths and residence times within unsaturated weathered bedrock.

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