Characterizing the Role of Snow for Liquid Water Storage and Transmission: A Ground-Based Remote Sensing and Modeling Sensitivity Analysis

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ABSTRACT

Streamflow response in headwater catchments is highly sensitive to the hydrologic connectivity of hillslopes to streams during spring snowmelt. Despite strong evidence at point- to plot-scales of flow paths creating lateral connectivity within an alpine snowpack, meltwater is commonly assumed to infiltrate vertically through the snowpack. Hydrologic models only treat the horizontal (downstream) routing of water once released from the snowpack and/or soil column. This assumption limits our ability to represent the full dynamic nature of hydrologic connections in snow-dominated mountainous headwaters. Thus, the goal of this study is to assess the mechanisms that control the spatiotemporal distribution of liquid water in an alpine snowpack during the spring snowmelt season. We utilize terrestrial laser scanning (TLS), ground penetrating radar (GPR), and manual observations to map the seasonal dynamics of snow depth, snow water equivalent (SWE), and within-snow liquid water content (LWC). We compare these observations to point-scale parameter sensitivity analyses with a modular snow model (SUMMA). The results show high spatial variability of LWC in an alpine snowpack during snowmelt. Statistical analyses show LWC is most highly correlated to snow depth (coefficient of determination = 0.62). However, including the distance to bare soil and topographical slope slightly improved the coefficient of determination (coefficient of determination = 0.67). While hydrologic models have the flexibility to simulate many of the observed dynamics in snowpack liquid water storage, model simulations using previously published parameter ranges always underestimated the high liquid water storage at one of the three sites. This is likely a result of current model structures that lack capabilities for surface ponding of water within a snowpack or surface runoff laterally through a snowpack. Our slope-scale characterization of the spatiotemporal distribution of in-snow LWC, together with a model-based sensitivity assessment, will inform future efforts in hydrologic model development and catchment observations.

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