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Response of near-stream surface connectivity to water table dynamics during rainfall events at a small headwater catchment (Luxembourg)

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The controls on non-linear streamflow response to changing streamflow sources during precipitation events are poorly understood. Here, we investigate the linkages between surface saturation development and streamflow under a range of wetness conditions for a forested headwater catchment in Luxembourg. Previous work at this site shows a threshold response in stream discharge to changes in soil moisture. This non-linearity is thought to reflect the development of saturation connectivity that drives streamflow response. Furthermore, the catchment has typically large rainfall-runoff ratios during winter, accompanied by long delays to peak after the onset of rainfall. To better understand controls on these behaviors, we examined the response of near-stream surface saturation development to incident precipitation, discharge, and fluctuating groundwater levels during rain events. Specifically, we sought to test the hypothesis that threshold-like response behavior exists between near-stream surface saturation and discharge, as well as quantify changes in surface saturated zone chemistry to better understand mixing between end-member sources during events. We used ground-based thermal infrared imagery to measure surface saturation development in a 4 by 6 m zone in the riparian area. Imagery collected over several months was analyzed to calculate the proportion of saturated area. Water samples from this saturated riparian area, nearby piezometers as well as discharge were collected for analysis of water isotopes, major cations/anions, and silica concentrations. Data analysis is ongoing but preliminary results indicate that saturation extent exhibits a non-linear, threshold-like response to discharge and antecedent wetness conditions. Surface saturation showed strong hysteresis with near-stream groundwater levels, with saturated areas expanding ahead of increasing groundwater levels. As the proportion of saturated area increased during rainfall events, the saturated riparian are and stream isotope signals became more and more depleted, shifting toward groundwater isotope concentrations during events. Stream conductivity, silica, and chloride concentrations also decreased as the proportion of saturated area increased. This suggests that surface saturation during the hydrograph rise is sourced by rainfall and near-surface sources while under high flow conditions it is dominated by exfiltrating groundwater. The threshold-like response of surface saturation and observed chemistry dynamics suggest that the near-stream saturated zone acts as a collection of many small reservoirs, filling and spilling to contribute to streamflow as a single united source—a size and volume which varies according to event size and antecedent conditions.