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Physiographic controls on thresholds and non-linearity in rainfall-runoff transformations

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Thresholds are critical points in time or space that eventually express a rapid change in runoff behavior. They have gained increasing attention in recent years. Two types of thresholds are existing: storage and intensity controlled thresholds. Most threshold studies focused on individual catchments which lead to difficulties in identifying the combinations of hydro-climatic and physiographic factors that control catchment thresholds and non-linearities in rainfall-runoff transformations, as well as differences between catchments. The individual influence of the boundary conditions remains poorly understood. Here, we employ a data set from the Alzette River basin in Luxembourg (Europe). While the climatic conditions are similar throughout the basin, the lithology of individual sub-catchments varies remarkably. We find clean and mixed combinations of distinct geologies: schists, marls, sandstone, dolomite, and limestone. We focus on the role of storage thresholds. The filling of catchment storage plays a critical role on the runoff response and stable isotopes signatures in stream water in the Alzette basin. On seasonal scale the geology leads to distinct non-linearity in the flow duration curve. These changes in the flow duration curve indicate a storage threshold exceedance within a distinct geology that changes streamwater stable isotope behavior. In the catchment with the lowest permeability (e.g. 100% schist), a storage threshold changes the runoff response from a single to a (delayed) double peak hydrograph. On event scale the different geologies control the relation between storage filling and threshold response and the shape of the non-linear relationship between rainfall and runoff. The use of various catchments within the same hydro-climatic region allows a better description of the influence of physiographic properties on thresholds in the rainfall-runoff response. Better understanding of individual influences will further improve our understanding of the interplay between climate, topography, soils, vegetation, and geology on thresholds and non-linearity in rainfall-runoff response in catchments.