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Stormflow generation: a meta-analysis of field studies and research catchments

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Runoff characteristics are expressions of runoff generation mechanisms. In this study, we want to test the hypothesis if storm hydrographs of catchments with prevailing near-surface flow paths are dominated by new water. We aim to test this hypothesis using published data from the scientific literature.
We developed a classification system based on three runoff characteristics: (1) hydrograph response (HR: slowly or quickly), (2) the temporal source of water that dominates the hydrograph (TS: pre-event vs. event water) and (3) the flow paths that the water takes until it is released to the stream (FP: subsurface vs. surface flow paths). We then performed a literature survey to collect information on these runoff characteristics for small, forested headwater catchments that served as study areas in runoff generation studies and assigned each study catchment to one of the 8 classes. For this purpose, we designed a procedure to objectively diagnose the predominant conceptual model of storm flow generation in each catchment and assess its temporal and spatial relevance for the catchment. Finally, we performed an explorative analysis of the classified research catchments and summarized field evidence.
Our literature survey yielded a sample of 22 research catchments that fell within our defined criteria (small, naturally forested catchments which served as study areas in stormflow generation studies). We applied our classification procedure to all of these catchments. Among them were 14 catchments for which our meta-analysis yielded a complete set of stormflow characteristics resulting in one of the 8 model concepts and were assigned into our classification scheme. Of the 14 classified research catchments, 10 were dominated by subsurface flow paths while 4 were dominated by overland flow. The data also indicate that the spatial and temporal relevance is high for catchments with subsurface flow paths while often weak for surface flow paths dominated catchments.
The catalogue of catchments supports our hypothesis; however, it is afflicted with a relative high degree of uncertainty. Two theories exist that may explain the imbalance between surface and subsurface dominated catchments: (1) the selection of research sites for stormflow generation studies was guided by the leading research question in hydrology, i.e. to address the “old water paradox”, and (2) catchments with prevailing subsurface flow paths are much more common in nature.
In a next step, the proposed catalogue of research catchments allows correlation of environmental characteristics with runoff characteristics to address questions of catchment organization and similarity. However, the successful application and relevance of such an approach depends on the range of conceptual models for which field support exist. Our results prompt us to highlight future research needs: (1) in order to cover a broader range of combinations of runoff characteristics a careful selection of research sites is necessary and (2) propose guidelines for field studies in order achieve higher comparability of resulting conceptual models of research sites and increase the spatial and temporal relevance of the dominant conceptual model.