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Multiscale investigation of catchment functioning using environmental tracers: Insights from the mesoscale Attert basin in Luxembourg

S. Wrede (1,2), L. Pfister (1), A. Krein (1), T.A. Bogaard (2), H.H.G. Savenije (2), and S. Uhlenbrook (3)

(1) Centre de Recherche Public - Gabriel Lippmann, Belvaux, Luxembourg, (2) Water Resources Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands (S.Wrede@tudelft.nl / Fax: +31 15-2785915), (3) Department of Water Engineering, UNESCO-IHE, Delft, The Netherlands

Experimental hydrology focuses traditionally on field investigations at smaller spatial and temporal scales and research is driven by small-scale, detailed and complex investigations of densely instrumented research sites. However, to improve operational water management and protection of water resources at the river basin scale, it is necessary to study the hydrological processes across a range of scales. Empirical studies investigating catchment structure and functioning across multiple scales are still rare and urgently needed. Besides geomorphologic and climatic catchment descriptors, environmental tracers have been recognized as a fundamental tool in experimental hydrology to assess the scaling gap, as they provide an independent and integrative perspective of catchment functioning and scaling.

A three year tracer study is being carried out in the Attert river basin in Luxembourg to identify how major controls of runoff generation change across scales and to investigate the spatial and temporal functioning of larger basins. The mesoscale (300 km^2) Attert catchment is located in the Midwestern part of Luxembourg and lies at the transition zone of contrasting bedrock lithology that is a major control for runoff generation: The Northern part is characterized by Devonian schist of the Ardennes massif, while sedimentary deposits of sandstone and marls dominate in the Southern part of the basin. Major hydrochemical tracers including stable water isotopes were grab sampled fortnightly and, where possible, also event-based at 13 nested stream locations ranging in size from 0.5 to 300 km^2 throughout the basin.

Results using Deuterium and a range of hydrochemical tracers confirm the major role of bedrock lithology for runoff response of different geological parts of the basins: Hydrological response of schistose basins is characterized by seasonal variation and a delayed shallow groundwater component originating from a saprolitic zone, sandstone basins exhibit a constant year-round groundwater component with fast rainfall runoff components in parts where saturated surface flow occurs on marly substratum. It also becomes apparent that with increasing scale these highly variable hydrological responses of the small scale converge towards a more integrated response. The scale at which this integration of the response takes place needs to be further investigated.

The analysis of tracer data from the initial year of the study provided insights into the catchment functioning at different spatial scales and confirmed the important role of bedrock geology in this basin. Future research efforts with longer tracer data records will be focusing on the investigation of residence times and will help to constrain process-based hydrological models.