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Which information can tracers give on catchment internal processes when used with conceptual models?

Markus Hrachowitz (1), Huub H.G. Savenije (1), Thom A. Bogaard (1), Chris Soulsby (2), and Doerthe Tetzlaff (2)

(1) Delft University of Technology, Civil Engineering and Geosciences, Water Management, Delft, Netherlands (m.hrachowitz@tudelft.nl), (2) University of Aberdeen, School of Geosciences, Aberdeen, UK

Flow generation processes on catchment scale are not yet quite understood. This commonly leads to substantial structural deficiencies and subsequent prediction uncertainties of particularly conceptual hydrological models when calibrated against runoff alone. Additional orthogonal information, such as observations of groundwater fluctuations or tracer response in streams, can help to gain crucial insights into the internal processes of catchments and thus help to reduce misrepresentations of these processes in model structures. However, such orthogonal data are frequently not available or where available, trade-offs have to be made between spatial and temporal coverage as well as temporal resolution.
In this study we use long term (< 16 years) tracer data sets at relatively high resolution (1 week) for three contrasting catchments (~ 2 – 10 km2) in the Scottish Highlands together with parsimonious conceptual models to get a better understanding of catchment internal processes and of how changes in these processes are directly related to variations in external forcings. Furthermore the individual processes and their temporally changing importance are compared for the three catchments in order identify catchment characteristic dependent patterns of change in dominant flow generation and tracer translation processes.
As a first step, owing to the contrasting appearance of the individual catchments, the most suitable out of 50 possible model structures for each catchment was identified in a FLEX-type modeling approach (Fenicia et al., 2008), based on the entire individual observation periods (NSE = 0.85, 0.78 and 0.65). Subsequently, these three model structures were calibrated individually for all n hydrological years of the observation period, for n summer and n winter season as well as for n one year periods classified according to the catchment wetness of these periods, i.e. from the wettest to the driest period. This then allowed assessing the changes in model parameter sets and state variables according to external forcings, giving insights into changes of dominant flow generation processes. Additional information was gained by comparing the modeled hydrographs of the remaining n-1 test or validation periods. The temporal variation in model parameters as well as in modeled average state variables, such as the average moisture content in the unsaturated zone, were then related to several metrics of tracer signatures, e.g. tracer damping (tracerin/tracerout). This allowed a preliminary evaluation of which catchment internal processes tend to dominate the tracer response under which climatic conditions in the three contrasting catchments and of whether catchment specific thresholds could be identified at which the dominant tracer response switches from one to another process.