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Model-based quantification of hydrological similarity at the hillslope scale

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In the context of hydrological predictions in changing environments, there is an ongoing debate about a suitably general framework to characterize hydrological similarity. Similarity is a gradual and scale-dependent measure that may refer to inherent characteristics such as landscape form, soil types, or wetness state, as well as to related system responses and state changes with respect to their magnitude and dynamics. While it is reasonably self-evident that the combination of comparable physiogeographic characteristics, system states, and hydro-climatological forcing lead to comparable hydrological responses, quantitative understanding of these relationships is scarce.

This paper explores this matter by means of virtual experiments using the spatially explicit hydrological model CATFLOW. We simulate the rainfall response of a forested hillslope marked by fine-textured soils and vertically and laterally draining macropores. Rainfall forcing and hillslope characteristics were varied systematically within realistic ranges, starting from a model setup that has been successfully tested against hydrometric and tracer data.

Dynamical clustering of different response parameters, i.e. grouping according to runoff volume, peak discharge etc., conditional on the input characteristics, then provides a basis for studying hydrological similarity in a quantitative manner. These results provide insights in the conditions under which hillslopes are behaving similarly, and thus improve the understanding of dynamic landscape functions that can be used to guide real-world modelling and monitoring efforts. The complexity of a catchment may be expressed by the number and temporal sequence of different representative hillslopes needed to simulate or observe a catchment's behaviour within a desired level of confidence.