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Conceptual hydrologic models: internal dynamics and realism

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Conceptual hydrologic models, such as rainfall-runoff models (RRMs), are simplified representations of real-world systems. Conventionally, their performance and predictive capability is evaluated through pair-wise comparison of simulated and observed streamflow (i.e. aggregated response of the catchment system), accompanied by uncertainty and/or sensitivity analysis of model parameters (or other model components) presented as uncertainty bounds on model output. Many studies have shown the insufficiencies of the conventional approach for evaluating the 'model realism', i.e. how consistent the model behaviour (and not only the output) is with our understanding of reality. Therefore, it is still a valid and crucial question to ask whether we are "getting 'right'—as a matter of fact 'good'—answers for the right reasons". Even in the case of lumped RRMs, hydrologic processes such as interception, infiltration and runoff generation are represented as model components (i.e. fluxes and stores), averaged on the catchment level (i.e. aggregating in space and time). However, in evaluating the performance of such models, the internal behaviour is ignored and the assessment is only based on the model output.

In this study, we investigate the internal dynamics of a number of widely-used conceptual RRMs. We first demonstrate how various RRMs can produce similar results (i.e. within a narrow range of model error) for a given catchment through distinct internal behaviours—also known as the problem of equifinality. To this end, an ensemble of 1 million model runs is performed for each model structure. We developed a technique (called Flux Mapping) to visualise the internal dynamics of runoff generating fluxes of the models. We discuss that Flux Mapping is a powerful tool for hypothesis testing and evaluating model realism, providing a possibilistic framework for assessing the model internal behaviour and its capability for process-representation. We also argue that hydrologic analyses such as baseflow separation of the observed hydrograph are useful add-ons to Flux Mapping for improving the model realism. While easy to implement, baseflow separation techniques are effective to diagnose and reject 'unrealistic' model internal behaviours, and consequently reduce the modelling uncertainty.