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# A bottom-up approach to derive the closure relation for modelling hydrological fluxes at the watershed scale

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Physically-based hydrological modelling could be considered as an ideal approach for predictions in ungauged basins because observable catchment characteristics can be used to parameterize the model, avoiding model calibration using discharge data, which are not available. Lumped physically-based modelling at the watershed scale is possible with the Representative Elementary Watershed (REW) approach. A key to successful application of this approach is to find a reliable way of developing closure relations to calculate fluxes from different hydrological compartments in the REWs. Here, we present a bottom-up approach as a generic framework to identify the closure relations for particular hydrological processes that are scale-independent and can be directly parameterized using the local-scale observable REW characteristics. The approach is illustrated using the Hortonian runoff as an example.

This approach starts from developing a physically-based high-resolution model describing the Hortonian runoff mechanism based on physically-based infiltration theory and runoff generation processes at a local scale. This physically-based model is used to generate a synthetic discharge data set of hypothetical rainfall events and HRUs ($6 \bullet 10^5$ scenarios) as a surrogate for real-world observations. The Hortonian runoff closure relation is developed as a lumped process-based model, consisting of the Green-Ampt equation, a time-lagged linear reservoir model, and three scale-transfer parameters representing the processes within REWs. These scale-transfer parameters are identified by calibrating the closure relations against the synthetic discharge data set for each scenario run, which are, in turn, empirically related to their corresponding observable REW properties and rainstorm characteristics. This results in a parameter library, which allows direct estimation of scaling parameter for arbitrary REWs based on their local-scale observable properties and rainfall characteristics, potentially avoiding calibration.

The Hortonain runoff closure relation is evaluated using field discharge observations from 16 $km^2$ catchments in the French Alps. The catchments are disaggregated to 60 REWs. Scaling parameters for each REW are derived from the parameter library. Discharge is simulated from individual REWs, routed over the stream network, and summed at the catchment outlets to obtain the catchment-scale responses. The results show that our closure relation is capable of reproducing the observed hydrograph and discharge volume without calibration, i.e. Nash-Sutcliffe index up to 0.8, 10% errors in discharge volume. Our closure relation outperforms a simple lumped rainfall-runoff model that does not have scaling components. A brute-force calibration for an optimal local-scale REW observable (i.e. saturated hydraulic conductivity; $K_s$), using a constant pre-factor for all REWs, however significantly improves the prediction. The calibrated $K_s$ values are comparable to the local-scale observations in the study catchment, implying that calibration may be unnecessary if the local-scale observable REW properties can be correctly estimated. The bottom-up approach for derivation of closure relation, including the parameter estimation scheme, in this study is robust and shows promising applicability for the REW-based models.