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Hortonian runoff modeling with the Representative Elementary Watershed approach: identifying and testing the closure relation with observed watershed characteristics.

We develop a catchment-scale process-based rainfall-runoff modeling framework based on the Representative Elementary Watershed (REW) approach. Our focus is on the identification of a physically-based process conceptualization (closure relation) at the REW scale for Hortonian runoff fluxes, using observable inputs and parameters at the local (point) scale. The closure relations are developed, consisting of the Green-Ampt equation, a time-lagged linear reservoir model and the scale-transfer parameters representing the processes and heterogeneities within REWs. These parameters are identified using the synthetic rainfall-runoff response data set consisting of an extensive set of REWs and rainstorms (65,000 scenarios) generated by a physically-based high-resolution model. Calibration of the closure relations against this data set results in, for each scenario run, three scale-transfer parameters, which are, in turn, related to their corresponding observable REW properties, and rainstorm characteristics. This results in a large database. In this way, when applying the closure relations to arbitrary REWs, the scale-transfer parameters in the closure relations can be directly estimated with known point-scale observable REW properties and rainfall characteristics based on the information retrieved from the database. The inverse distance weighted interpolation method in the parameter space is used for the parameter estimation. Discharge is simulated for each REW and aggregated to derive the hydrologic responses of the catchment.
The approach is evaluated using data from 30 rainstorms for 3 catchments (0.5, 4, 12 km^2) in the French Alps. The catchments are disaggregated to 60 REWs according to geomorphology, with an area of approximately 2 km^2. Parameters and boundary conditions are estimated from field observations (i.e. rain, vegetation, soil parameters) or using a simple soil water balance model (i.e. antecedent soil moisture). Discharge from individual REWs is routed over the drainage network using the Manning's equation and summed at the catchment outlets to obtain the catchment-scale responses. The results show that our model is capable of simulating the discharge with a Nash-Sutcliffe index up to 0.8 without calibration and yield the better predictions compared to the closure relations that do not use the scale-transfer parameters (i.e. complete lumped model). The model performance decreases with catchment size due to uncertainties in inputs and parameters. Our modeling framework provides a building block for large-scale semi-distributed physically-based modeling.