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Top-down methodology for rainfall-runoff modelling and evaluation of hydrological extremes

Patrick Willems
KU Leuven, Hydraulics division, Civil Engineering, Leuven, Belgium (patrick.willems@bwk.kuleuven.be, +32 16 321989)

A top-down methodology is presented for implementation and calibration of a lumped conceptual catchment rainfall-runoff model that aims to produce high model performance (depending on the quality and availability of data) in terms of rainfall-runoff discharges for the full range from low to high discharges, including the peak and low flow extremes. The model is to be used to support water engineering applications, which most often deal with high and low flows as well as cumulative runoff volumes. With this application in mind, the paper wants to contribute to the above-mentioned problems and advancements on model evaluation, model-structure selection, the overparameterization problem and the long time the modeller needs to invest or the difficulties one encounters when building and calibrating a lumped conceptual model for a river catchment.

The methodology is an empirical and step-wise technique that includes examination of the various model components step by step through a data-based analysis of response characteristics. The approach starts from a generalized lumped conceptual model structure. In this structure, only the general components of a lumped conceptual model, such as the existence of storage and routing elements, and their inter-links, are pre-defined. The detailed specifications on model equations and parameters are supported by advanced time series analysis of the empirical response between the rainfall and evapotranspiration inputs and the river flow output. Subresponses are separated and submodel components and related subsets of parameters are calibrated as independently as possible. At the same time, the model-structure identification process aims to reach parsimonious submodel-structures, and accounts for the serial dependency of runoff values, which typically is higher for low flows than for high flows. It also accounts for the heteroscedasticity and dependency of model residuals when evaluating the model performance.

It is shown that this step-wise model structure identification method does not lead to higher accuracy than the traditional approach when evaluated using common statistical criteria like the Nash-Sutcliffe efficiency. The method is, however, favourable to produce a well-balanced calibration obtaining accurate results for a wide range of runoff properties: total flows, quick and slow subflows, cumulative volumes, peak flows, low flows, frequency distributions of peak and low flows, changes in quick flows for given changes in rainfall. It furthermore is shown that model performance evaluation procedures that account for the flow residual serial dependency and homoscedasticity are preferred. Explicit evaluation of model results for peak and/or low flow extremes and changes in these extremes make the models useful for impact investigations on such hydrological extremes.

References:

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