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Flexible hydrological modeling - Disaggregation from lumped catchment scale to higher spatial resolutions

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Based on an international literature review on model structures of existing rainfall-runoff and hydrological models, a generalized model structure is proposed. It consists of different types of meteorological components, storage components, splitting components and routing components. They can be spatially organized in a lumped way, or on a grid, spatially interlinked by source-to-sink or grid-to-grid (cell-to-cell) routing. The grid size of the model can be chosen depending on the application. The user can select/change the spatial resolution depending on the needs and/or the evaluation of the accuracy of the model results, or use different spatial resolutions in parallel for different applications. Major research questions addressed during the study are: How can we assure consistent results of the model at any spatial detail? How can we avoid strong or sudden changes in model parameters and corresponding simulation results, when one moves from one level of spatial detail to another? How can we limit the problem of overparameterization/equifinality when we move from the lumped model to the spatially distributed model?

The proposed approach is a step-wise one, where first the lumped conceptual model is calibrated using a systematic, data-based approach, followed by a disaggregation step where the lumped parameters are disaggregated based on spatial catchment characteristics (topography, land use, soil characteristics). In this way, disaggregation can be done down to any spatial scale, and consistently among scales. Only few additional calibration parameters are introduced to scale the absolute spatial differences in model parameters, but keeping the relative differences as obtained from the spatial catchment characteristics. After calibration of the spatial model, the accuracies of the lumped and spatial models were compared for peak, low and cumulative runoff total and sub-flows (at downstream and internal gauging stations). For the distributed models, additional validation on spatial results was done for the groundwater head values at observation wells. To ensure that the lumped model can produce results as accurate as the spatially distributed models or close regardless to the number of parameters and implemented physical processes, it was checked whether the structure of the lumped models had to be adjusted.

The concept has been implemented in a PCRaster – Python platform and tested for two Belgian case studies (catchments of the rivers Dijle and Grote Nete). So far, use is made of existing model structures (NAM, PDM, VHM and HBV).

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