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Experiments with a conceptual distributed hydrological model: impact of cell size, parameter regionalization and routing method

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In recent years, extensive studies have been carried out to develop distributed conceptual or process based hydrological models that represent spatial the hydrological phenomena in a river basin. The process of building a distributed hydrological model is considered to be a complex problem; such models require identification of large number of parameters, spatial discretization, and optimal routing scheme for the integration of the surface flow.
This research analyses three main areas of model calibration and validation performance of a distributed hydrological model, with the HBV-type submodels. Firstly, the variations in spatial resolution due to a change in grid size (500m, 1, 2and 4km) are considered. Secondly, two parameterization methods are evaluated: one assuming that all parameters have the same values, and the other one allowing all parameters to vary across the grid. Thirdly, we analysed the influence of the model structure: the description of the upper zone runoff generation process was varied, and the two different routing models, Muskingum-Cunge and a simple lag function (MAXBAS).
The case study considered is in Jiboa River in El Salvador with the area of 432 km2 including a lake of 70 km2. Two and a half year of hourly data (6/2012-11/2014) were used; the first year and a half were used for the calibration, and the last year was used for validation. The main purpose of the model is flood modeling and forecasting.
HBV96 Model structure was used with different superficial runoff generation subroutines using Hapi Python framework (https://github.com/MAfarrag/HAPI) for building hydrological models. Hapi is a framework for building raster-based conceptual distributed hydrological models, where computations are performed on a pixel by pixel basis; it also enables multiscale modeling and thus suitable for simulation ranges from coarse scale to relatively fine resolution. Meteorological data (precipitation, evapotranspiration, and temperature) data can be supplied in the form of gauges inputs or as raster data. Hapi basic setup uses HBV96 as a conceptual model to represent the hydrological processes within a cell, and Muskingum-Cunge scheme for routing between cells.
The calibration process was carried out in three steps: (1) pre-calibration of the model using genetic algorithm to explore model performance with parameter values within the initial limits; (2) one-at-a-time (OAT) sensitivity analysis of the model, and redefining parameter search space; (3) model calibration using harmony search algorithm. Performance was measured by the root mean square error.
Results show the following: a) conceptual distributed model performs better, if compared to lumped model; b) the choice of an appropriate spatial discretization mainly depends on spatial resolution of input data, runoff generation process and dominant hydrological process; c) model performance improved with increasing resolution to 2 and 1km2 and decreased with finer resolutions; d) very slight performance improvement gained by considering spatially distributed catchment characteristics (parameters); e) the use of the Muskingum routing method results in performance drop with finer resolutions to maintain stability of the computations with hourly time step temporal resolutions .
The study allows for developing practical recommendations for the model use in real-life situations.