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Multi-objective combined simulation-optimization of Lake Tana multi reservoir system, Ethiopia, using two different generalized reservoir system operation models

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Finding optimal management strategies can be a challenging task when water resources systems serve multiple contrary goals. Reasonable trade offs among these goals has to be found. Multi-objective optimization (MOO) is able to obtain a so called Pareto front containing multiple trade off solutions (Pareto optimal solutions). An attractive and powerful MOO method is multi-objective combined simulation-optimization (MOCSO). Generally MOCSO model consists of mainly two components, a simulation model and a multi-objective optimization algorithm. Generalized reservoir system operation models (GRSOM) are commonly used as simulation models in water resources planning and management of multi-reservoir systems. The purpose of the GRSOM in MOCSO is to simulate a specific management in order to evaluate the objective functions for the multi-objective optimization algorithm. As the distribution of water in reservoir system is affected by the particular operation of the GRSOM model, the choice of the simulation model is a crucial step in MOCSO setup which may significantly affect the obtained results.
In a case study of Lake Tana sub basin (Ethiopia) two MOCSO models are compared. The general reservoir operation simulation models HEC-5 and OASIS (Operational Analysis and Simulation of Integrated Systems) are combined with the Multi-Objective Covariance Matrix-Adaptation Evolution Strategy (MO-CMA-ES). HEC-5 is a pure simulation model which computes the distribution of water in the system sequentially and serially from upstream to downstream following an given algorithm. OASIS, a simulation-optimization model, incorporates a linear or nonlinear solver which distributes the water sequentially in the system according to objective function defined by the decision maker.
Lake Tana is the largest fresh water lake in Ethiopia. Its water resources are controllable due to the Chara Chara weir. For hydropower production water is directly diverted from Lake Tana to Belles sub-basin. Upstream of Lake Tana four multi-purpose reservoirs are built or under construction. Two objectives are considered: the minimization of water supply deficit and maximization of hydropower production. The upper- and lower rule curves of all reservoirs are subject to simultaneous optimization, enabling an integrated management.
In two scenarios, differing in the required hydropower production, the resulting Pareto fronts indicate that the performance of the HEC-5-MOCSO model is inferior to the OASIS-MOCSO model. All management strategies obtained with OASIS-MOCSO are able to produce more hydropower while causing less deficit in water supply. Obtained conservation- and buffer rule curves of OASIS-MOCSO show less variation than those of HEC-5-MOCSO and cover a smaller fraction of available reservoir storage. This indicates that the mixed integer solver engine in OASIS allows an more flexible management and more integrated operational mode of the multi-reservoir system compared to HEC-5.