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Coping with high reliabilities in multi-objective optimizations of multi-purpose reservoir systems

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Reservoir systems responsible for potable water supply have commonly to be operated to meet the demands with an occurrence-based reliability higher than 99% (in contrast, the reliability e.g. of irrigation water supply may less than 90%). This requirement is not fully met in most studies which use single- or multi-objective optimization techniques for the optimization of reservoir operation problems. For dealing with very high reliabilities, long time series of several thousand years may be necessary for resilient calculations of those reliabilities using a Monte Carlo approach. However, unreasonable computational costs are the consequence. Thus, in many studies formulations of objective functions have so far been restricted to formulations that minimize an expected value or variance between various demands and the according deliveries.

In this study we present a new approach to enable the explicit formulation of the reservoir performance by means of reliability in objective functions. A simulation based multi-objective optimization method is introduced that theoretically allows for highly efficient and robust optimization of operating rules over time periods of several thousand years. The technical framework of the approach comprises (i) a multivariate time series model, (ii) a new Monte-Carlo recombination technique that is capable of shortening the time series with little small loss of information (iii), a reservoir model coupled with an evolutionary optimization strategy using a box constraint handler and decision variable coding technique for constraint free optimization and (iv) a validation step. In a real case application, the multi-purpose multi-reservoir system Klingenberg – Lehnmühle – Rauschenbach (Germany) is optimized to meeting a reliability of supply in three levels of supply, ranging from 99% to 99,95%, as well as for minimizing pumping costs and to preserve water quality. It is shown that the new approach is capable of providing a resilient Pareto-front with a broad range of compromises between achievable reliabilities and the other two objectives.