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A Monte Carlo approach to water management

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Common methods for making optimal decisions in water management problems are insufficient. Linear programming methods are inappropriate because hydrosystems are nonlinear with respect to their dynamics, operation constraints and objectives. Dynamic programming methods are inappropriate because water management problems cannot be divided into sequential stages. Also, these deterministic methods cannot properly deal with the uncertainty of future conditions (inflows, demands, etc.). Even stochastic extensions of these methods (e.g. linear-quadratic-Gaussian control) necessitate such drastic oversimplifications of hydrosystems that may make the obtained results irrelevant to the real world problems. However, a Monte Carlo approach is feasible and can form a general methodology applicable to any type of hydrosystem. This methodology uses stochastic simulation to generate system inputs, either unconditional or conditioned on a prediction, if available, and represents the operation of the entire system through a simulation model as faithful as possible, without demanding a specific mathematical form that would imply oversimplifications. Such representation fully respects the physical constraints, while at the same time it evaluates the system operation constraints and objectives in probabilistic terms, and derives their distribution functions and statistics through Monte Carlo simulation. As the performance criteria of a hydrosystem operation will generally be highly nonlinear and highly nonconvex functions of the control variables, a second Monte Carlo procedure, implementing stochastic optimization, is necessary to optimize system performance and evaluate the control variables of the system. The latter is facilitated if the entire representation is parsimonious, i.e. if the number of control variables is kept at a minimum by involving a suitable system parameterization. The approach is illustrated through three examples for (a) a hypothetical system of two reservoirs performing a variety of functions, (b) the water resource system of Athens comprising four reservoirs and many aqueducts, and (c) a human-modified inadequately measured basin in which the parameter fitting of a hydrological model is sought.