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Reservoir optimisation using El Niño information. Case study of Daule Peripa (Ecuador)

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The optimisation of water resources systems requires the ability to produce runoff scenarios that are consistent with available climatic information. We approach stochastic runoff modelling with a Markov-modulated autoregressive model with exogenous input, which belongs to the class of Markov-switching models. The model assumes runoff parameterisation to be conditioned on a hidden climatic state following a Markov chain, whose state transition probabilities depend on climatic information. This approach allows stochastic modeling of non-stationary runoff, as runoff anomalies are described by a mixture of autoregressive models with exogenous input, each one corresponding to a climate state. We calibrate the model on the inflows of the Daule Peripa reservoir located in western Ecuador, where the occurrence of El Niño leads to anomalously heavy rainfall caused by positive sea surface temperature anomalies along the coast. El Niño – Southern Oscillation (ENSO) information is used to condition the runoff parameterisation. Inflow predictions are realistic, especially at the occurrence of El Niño events. The Daule Peripa reservoir serves a hydropower plant and a downstream water supply facility. Using historical ENSO records, synthetic monthly inflow scenarios are generated for the period 1950-2007. These scenarios are used as input to perform stochastic optimisation of the reservoir rule curves with a multi-objective Genetic Algorithm (MOGA). The optimised rule curves are assumed to be the reservoir base policy. ENSO standard indices are currently forecasted at monthly time scale with nine-month lead time. These forecasts are used to perform stochastic optimisation of reservoir releases at each monthly time step according to the following procedure: (i) nine-month inflow forecast scenarios are generated using ENSO forecasts; (ii) a MOGA is set up to optimise the upcoming nine monthly releases; (iii) the optimisation is carried out by simulating the releases on the inflow forecasts, and by applying the base policy on a subsequent synthetic inflow scenario in order to account for long-term costs; (iv) the optimised release for the first month is implemented; (v) the state of the system is updated and (i), (ii), (iii), and (iv) are iterated for the following time step. The results highlight the advantages of using a climate-driven stochastic model to produce inflow scenarios and forecasts for reservoir optimisation, showing potential improvements with respect to the current management. Dynamic programming was used to find the best possible release time series given the inflow observations, in order to benchmark any possible operational improvement.