Geophysical Research Abstracts,
Vol. 11, EGU2009-7829, 2009
EGU General Assembly 2009

Stochastic reservoir optimisation using a multi-objective genetic algorithm and conditioning inflow on El Niño information

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Management policies of water resources systems (WRS) are commonly evaluated using runoff scenarios as input. Such scenarios are often generated by stationary stochastic models assuming the runoff probability distribution to be conditioned on past streamflow information. However a strict stationarity assumption cannot account for the impact of climate variability on runoff. Instead, the optimisation of water resources systems requires the ability to produce runoff scenarios that are consistent with the available climatic information. We approach stochastic runoff modelling with a Markov-modulated autoregressive model with exogenous input (MARX), which belongs to the class of hidden Markov models. MARX assumes runoff parameterisation to be conditioned on a hidden climatic state following a Markov chain, whose state transition probabilities depend on the climatic information. Thus MARX allows a conditionally stationary description of runoff, as its parameters change over time according to the climatic regime. We apply MARX to model inflows of the Daule Peripa reservoir in western Ecuador, where the runoff regime is strongly influenced by the occurrence of El Niño. Sea surface temperature anomalies measured in the equatorial Pacific Ocean are used to condition runoff parameterisation. The Daule Peripa reservoir supplies a hydropower plant, a water transfer, and downstream irrigation facilities. To tackle the resulting multi-objective optimisation problem, we follow the simulation-optimisation framework by coupling a WRS simulator with a multi-objective heuristic search method, i.e. the genetic algorithm NSGA-II. To handle scenario uncertainty in the optimisation, we implement NSGA-II in a noisy environment, meaning that the candidate management policies of each generation are evaluated upon a sample of model-generated inflow scenarios. The results highlight the advantages of using a climate-sensitive inflow generator with a noisy multi-objective genetic algorithm to perform stochastic reservoir optimisation.