EGU2020-11779
https://doi.org/10.5194/egusphere-egu2020-11779
EGU General Assembly 2020

Optimizing the management of complex water resources systems taking into account the long-term persistence in streamflow

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The operation of multireservoir systems is a challenging decision-making problem due to (i) multiple, often conflicting, objectives (e.g. hydropower generation versus irrigated agriculture), (ii) stochastic variables (e.g. inflows, water demands, commodity prices), (iii) nonlinear relationships, (e.g. hydropower production function) and (iv) trade-offs between immediate and future consequences. Properly capturing the properties of the hydrologic processes responsible for the inflows is of paramount importance to enhance the performance of water resources systems. This becomes all the more relevant since low-frequency climate signals, which affect the hydrology in numerous regions around the globe, has increased in recent years. If traditional time series models generally fail to reproduce this regime-like behavior, so are the optimization models that are used to support multireservoir operation. Hidden Markov Model (HMM) is a class of hydrological models that can accommodate both overdispersion and serial dependence in historical time series, two essential hydrological properties that must be captured when modeling a system where the climate is switching between different states (e.g., dry, normal, wet). In terms of reservoir operation, Stochastic Dual Dynamic Programming (SDDP) is one of the few optimization techniques that can accomodate both system and hydrologic complexity. In SDDP, the hydrologic uncertainty is often captured by a multi-site periodic autoregressive (MPAR) model. However, MPAR models are unable to represent the long-term persistence of the streamflow process found in some regions, which may lead to suboptimal reservoir operating policies. We present an extension of the SDDP algorithm that can handle the long-term persistence and provide reservoir operating policies that explicitly capture regime shifts. To achieve this, the state-space vector now includes a climate variable whose transition is governed by a HMM. The Senegal River Basin (SRB), whose flow regime is characterized by multiyear dry/wet periods, is used as a case study.