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The role of water reservoir operation in climate change impact assessments: expanding uncertainties and evolving tradeoffs

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Climate change and growing population are expected to severely affect freshwater availability by the end of 21th century. Although many river basins are likely to become more prone to periods of reduced water supply, risking considerable impacts on the society, the economy, and the environment, the operations of many water resource systems are still designed on the basis of the observed historical hydrologic variability. Yet, under changing hydro-climatic forcing, no guarantee exists that policies optimized over the past will not fail in coming years.

This work explores the impact of projected climate change and the associated uncertainty on the policy performance for different future time horizons. A perturbed physics ensemble of projected hydroclimatic conditions based on the HadCM3 General Circulation Modelis is used to simulate the whole set of Pareto optimal policies over the different futures. The changes in the overall system performance and the evolution of each single-tradeoff are analyzed to improve our understanding of the system's vulnerabilities. The study is developed on the Red–Thai Binh River system, Vietnam. The Red River Basin is the second largest basin of Vietnam, draining an area of about 169,000 km2, and comprises three main tributaries and several reservoirs, namely SonLa and HoaBinh on the Da River, ThacBa and TuyenQuang on the Lo River. These reservoirs are regulated for maximizing hydropower production, mitigating downstream flood, primarily in Hanoi, and guaranteeing irrigation water supply to the agricultural districts in the delta. We address the challenges of the policy design problem (e.g., dimensionality of the system, number of objectives involved) by adopting the evolutionary multi-objective direct policy search (EMODPS), an approximate dynamic programming method that combines direct policy search, nonlinear approximating networks and multi-objective evolutionary algorithms to design Pareto approximate operating policies for multi-purpose water reservoirs. Results show that EMODPS successfully designed alternative management strategies addressing system's tradeoffs and promoting stakeholders negotiations. The top-down climate change assessment improved our understanding of the system's vulnerabilities, with the policies performance predicted to degrade from 45% to 267% in the different objectives. In addition, the variability associated to the considered future, nonstationary, and uncertain scenarios is significantly amplified by the reservoir operation and eventually modify the system's tradeoffs, further complicating the design of adaptation strategies.