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Coordination and adaptation: how advances in multi-objective control can reduce food-energy-water conflicts in multi-reservoir systems

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Multi-reservoir systems require adaptive control policies capable of managing evolving hydroclimatic variability and human demands across a wide range of time scales. However, traditional operating rules are static, ignoring the potential for coordinated information sharing to reduce conflicts between multi-sectoral river basin demands. In this study, we show how recent advances in multi-objective control enable the design of coordinated operating policies that continuously adapt as a function of evolving hydrologic inputs, diminishing tradeoffs between flood protection and hydropower production or water supply. We illustrate these benefits in the Red River basin of Vietnam, where four major reservoirs serve to protect the capital of Hanoi from flooding, while also supplying farmers with irrigable water supply and the surrounding region with electric power. Operating policies recently proposed by the Vietnamese government seek to improve coordination and adaptivity in the Red River using a conditional if/then/else rule system that triggers alternative control actions based on current storage and recent hydrology. However, these simple, discontinuous rules fail to protect Hanoi to even the 100-yr flood, when the Vietnamese desire protection at the 500-yr level. Utilizing Evolutionary Multi-Objective Direct Policy Search (EMODPS), we are able to design policies that, using the same information, are able to not only provide protection to the 500-yr flood, but with lower supply deficits and greater hydropower production, fully dominating the proposed control rules. Policy diagnostics using time-varying sensitivity analysis illustrate how our proposed operations make better use of coordinated system information to reduce food-energy-water conflicts in the basin. These findings accentuate the need to transition from static rule curves to dynamic operating policies in order to manage evolving hydroclimatic variability and socioeconomic change.