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Comparing model predictive control and stochastic dynamic programming for water resources systems management

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Hydroeconomic optimization can be used to guide rational decision making in complex water resources systems. Simplification of the physical system is inevitable in the development of a representative model of any real world system. Different hydroeconomic optimization methods, capable of handling different levels of complexity, are described in the literature.

This study compares stochastic dynamic programming (SDP) and an implementation of model predictive control (MPC) to optimize the operation of a complex river basin in the North China Plain under uncertain future water availability. Applications of SDP are limited to a few state variables due to the curse of dimensionality. Thus, SDP requires a high level of aggregation and a highly simplified system model. As a result, the SDP model uses a single aggregated surface water reservoir with upstream and downstream water use sites, representing agricultural, industrial and domestic water users. MPC-based approaches do not have such strict limitations. Therefore, the system model can therefore resolve all 5 major reservoirs, the 7 river branches and the resulting 12 different water use sites explicitly. In addition, the South-to-North Water Transfer Project, which cuts through the basin, can be represented realistically.

The physical system is in both cases described as a linear program that minimizes the total costs for the system. The MPC model uses the flow path method, where all sources and sinks are connected by individual flow paths. It thus determines the amount of water in each flow path in each of the monthly time steps, and contains several hundred thousand decision variables. While the input data (historic runoff, water demands, curtailment costs, etc.) is identical to the SDP model, the higher spatial resolution of the MPC model can provide more detailed insights. With a single aggregated reservoir, the SDP model is able to utilize the entire aggregated reservoir storage capacity to mitigate economic losses during droughts. In contrast, the MPC model reveals that some reservoirs are over-dimensioned and cannot be fully utilized given real-world connectivity of flow paths. While the SDP model can quantify the upstream-downstream trade-offs, the MPC model can additionally reveal varying water scarcity across the basin, along with detailed trade-offs between the users. As a result of accounting for these differences, the minimum total costs evaluated by the MPC model are 20% higher than in the SDP model in this basin. These results clearly illustrate the impact of simplification and aggregation in regional-scale water resources system optimization models.