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Incorporating teleconnection information into reservoir operating policies using Stochastic Dynamic Programming and a Hidden Markov Model

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Water reservoir systems are often affected by recurring large-scale ocean-atmospheric anomalies, known as teleconnections, that cause prolonged periods of climatological drought. Accurate forecasts of these events—at lead times in the order of weeks and months—may enable reservoir operators to take more effective release decisions to improve the performance of their systems. In practice this might mean a more reliable water supply system, a more profitable hydropower plant or a more sustainable environmental release policy. To this end, climate indices, which represent the oscillation of the ocean-atmospheric system, might be gainfully employed within reservoir operating models that adapt the reservoir operation as a function of the climate condition.

This study develops a Stochastic Dynamic Programming (SDP) approach that can incorporate climate indices using a Hidden Markov Model. The model simulates the climatic regime as a hidden state following a Markov chain, with the state transitions driven by variation in climatic indices, such as the Southern Oscillation Index. Time series analysis of recorded streamflow data reveals the parameters of separate autoregressive models that describe the inflow to the reservoir under three representative climate states ("normal", "wet", "dry"). These models then define inflow transition probabilities for use in a classic SDP approach. The key advantage of the Hidden Markov Model is that it allows conditioning the operating policy not only on the reservoir storage and the antecedent inflow, but also on the climate condition, thus potentially allowing adaptability to a broader range of climate conditions. In practice, the reservoir operator would effect a water release tailored to a specific climate state based on available teleconnection data and forecasts.

The approach is demonstrated on the operation of a realistic, stylised water reservoir with carry-over capacity in South-East Australia. Here teleconnections relating to both the El Niño Southern Oscillation and the Indian Ocean Dipole influence local hydro-meteorological processes; statistically significant lag correlations have already been established. Simulation of the derived operating policies, which are benchmarked against standard policies conditioned on the reservoir storage and the antecedent inflow, demonstrates the potential of the proposed approach. Future research will further develop the model for sensitivity analysis and regional studies examining the economic value of incorporating long range forecasts into reservoir operation.