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Integrated real-time control of water reservoirs with deterministic and probabilistic multi-timescale forecasts: Application to the Lake Como

Andrea Ficchì, Federico Staffa, Raffaele Giuseppe Cestari, Simone Formentin, and Andrea Castelletti
Politecnico di Milano, Department of Electronics, Information, and Bioengineering, Milano, Italy

Hydro-meteorological forecasts are more and more easily available with improving skill over longer timescales and with higher spatiotemporal resolutions. Their uncertainties are commonly represented by ensemble prediction systems which are now dominant at the global and continental scale, while short-term deterministic forecasts are still used, especially in some local contexts. For effective water resources management, it is critical to understand how to use the wealth of information provided by different forecast systems over multiple timescales to help meet the water demand of key competing socio-economic sectors, while reducing short-term impacts and bringing the controlled systems to desirable states in the long term. Real-time control schemes of water reservoirs like Model Predictive Control (MPC) can help meet these goals, by providing a flexible framework to use forecasts proactively and satisfy multiple competing objectives while respecting operational constraints.

In this study, we propose a new nested multi-stage stochastic MPC framework integrating the use of both deterministic and ensemble hydrological forecasts over multiple timescales from short-term (60 hours) to seasonal (7 months ahead). We demonstrate the performance of this real-time controller for the Lake Como system, located in the Italian Alps, where a large lake is regulated mainly for irrigation supply and flood control. First, seasonal ensemble forecasts are used to solve a Tree-Based MPC (TB-MPC) problem optimising the reservoir management over several months, by adopting a tree structure to summarise the ensemble information including the resolution of uncertainty in time. Second, the decisions identified so far are used to condition daily operations over a month using sub-seasonal probabilistic forecasts (up to 46 days) under the same TB-MPC approach. Third, the decisions for the first few days are then further adapted to optimize operations three days ahead using deterministic short-term forecasts with MPC. The sub-seasonal and seasonal ensemble (re-)forecasts used are those produced by the European Flood Awareness System (EFAS) from the Copernicus Emergency Management Service which uses ensemble meteorological forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF). While EFAS is uncalibrated for the study area, we apply bias-correction techniques to improve the agreement of forecasts with local observations and allow their use for resolving the water-balance within MPC. The short-term 60-h forecasts come from a locally calibrated hydrological model (TOPKAPI) using deterministic weather forecasts from the COSMO (Consortium

for Small Scale Modelling) model. The skill of all these forecasts is assessed, as well as the ensemble spread–error relationship for EFAS at different lead times. To evaluate the value of the forecasts we compare the performance of the real-time MPC controller with different benchmarks including perfect forecasts, climatology, and persistence. Finally, we investigate the link between forecast skill and value for reservoir operation, and we compare the performance of the nested MPC framework integrating multi-timescale forecasts with the MPC using single forecasts.