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An integrated modelling framework for regulated river systems in Land Surface Hydrological Models

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Many of the large river systems around the world are highly regulated with numerous physical flow control and storage structures as well as a range of water abstraction rules and regulations. Most existing Land Surface Models (LSM) do not represent the modifications to the hydrological regimes introduced by water management (reservoirs, irrigation diversions, etc.). The interactions between natural hydrological processes and changes in water and energy fluxes and storage due to human interventions are important to the understanding of how these systems may respond to climate change amongst other drivers for change as well as to the assessment of their feedbacks to the climate system at regional and global scales.
This study presents an integrated modelling approach to include human interventions within natural hydrological systems using a fully coupled modelling platform. The Bow River Basin in Alberta (26,200 km2), one of the most managed Canadian rivers, is used to demonstrate the approach. We have dynamically linked the MESH modelling system, which embeds the Canadian Land Surface Scheme (CLASS), with the MODSIM-DSS water management modelling tool. MESH models the natural hydrology while MODSIM optimizes the reservoir operation of 4 simulated reservoirs to satisfy demands within the study basin.
MESH was calibrated for the catchments upstream the reservoirs and gave good performance (NSE = 0.81) while BIAS was only 2.3% at the catchment outlet. Without coupling with MODSIM (i.e. no regulation), simulated hydrographs at the catchment outlet were in complete disagreement with observations (NSE = 0.28). The coupled model simulated the optimization introduced by the operation of the multi-reservoir system in the Bow river basin and shows excellent agreement between observed and simulated hourly flows (NSE = 0.98). Irrigation demands are fully satisfied during summer, however, there are some shortages in winter demand from industries, which can be rectified by revising rule curves.
Therefore, this system promises a good approach to the representation of human interventions in land surface models at the watershed level. This will allow improved global understanding of water fluxes from irrigation or large storage reservoirs and prediction of the large regulated river systems for climate impact studies.