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On the effects of adaptive reservoir operating rules in hydrological physically-based models

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Recent years have seen a significant increase of the human influence on the natural systems both at the global and local scale. Accurately modeling the human component and its interaction with the natural environment is key to characterize the real system dynamics and anticipate future potential changes to the hydrological regimes. Modern distributed, physically-based hydrological models are able to describe hydrological processes with high level of detail and high spatiotemporal resolution. Yet, they lack in sophistication for the behavior component and human decisions are usually described by very simplistic rules, which might underperform in reproducing the catchment dynamics. In the case of water reservoir operators, these simplistic rules usually consist of target-level rule curves, which represent the average historical level trajectory. Whilst these rules can reasonably reproduce the average seasonal water volume shifts due to the reservoirs' operation, they cannot properly represent peculiar conditions, which influence the actual reservoirs' operation, e.g., variations in energy price or water demand, dry or wet meteorological conditions. Moreover, target-level rule curves are not suitable to explore the water system response to climate and socio economic changing contexts, because they assume a business-as-usual operation.

In this work, we quantitatively assess how the inclusion of adaptive reservoirs' operating rules into physically-based hydrological models contribute to the proper representation of the hydrological regime at the catchment scale. In particular, we contrast target-level rule curves and detailed optimization-based behavioral models. We, first, perform the comparison on past observational records, showing that target-level rule curves underperform in representing the hydrological regime over multiple time scales (e.g., weekly, seasonal, inter-annual). Then, we compare how future hydrological changes are affected by the two modeling approaches by considering different future scenarios comprising climate change projections of precipitation and temperature and projections of electricity prices. We perform this comparative assessment on the real-world water system of Lake Como catchment in the Italian Alps, which is characterized by the massive presence of artificial hydropower reservoirs heavily altering the natural hydrological regime. The results show how different behavioral model approaches affect the system representation in terms of hydropower performance, reservoirs dynamics and hydrological regime under different future scenarios.