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Trade-off Assessment of Simplified Routing Models for Short-Term Hydropower Reservoir Optimization

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Short-term reservoir optimization, also referred to as model predictive control, integrates model-based forecasts and optimization algorithms to meet multiple management objectives such as water supply, navigation, hydro-electricity generation, environmental obligations and flood protection. It is a valuable decision support tool to handle water-stress conditions or flooding events, and supports decision makers to minimize their impact. If the reservoir management includes downstream control, for example for mitigation flood damages in inundation areas downstream of the operated dam, the flow routing between the dam and the downstream inundation area is of major importance.

The unsteady open channel flow in river reaches can be described by the one-dimensional Saint-Venant equations. However, owing to the mathematical complexity of those equations, some simplifications may be required to speed up the computation within the optimization procedure. Another strategy to limit the model runtime is a schematization on a course computational grid. In particular the last measure can introduce significant numerical diffusion into the solution. This is a major drawback, in particular if the reservoir release has steep gradients which we often find in hydropower reservoirs.

In this work, four different routing models are assessed concerning their implementation in the predictive control of the Três Marias Reservoir located at the Upper River São Francisco in Brazil: i) a fully dynamic model using the software package SOBEK; ii) a semi-distributed rainfall-runoff model with Muskingum-Cunge routing for the flow reaches of interest, the MGB-IPH (Modelo Hidrológico de Grandes Bacias - Instituto de Pesquisas Hidráulicas); iii) a reservoir routing approach; and iv) a diffusive wave model. The last two models are implemented in the RTC-Tool toolbox.

The overall model accuracy between the simplified models in RTC-Tools (iii, iv) and the more sophisticated SOBEK model (i) are comparable, and a lower performance was assessed for the MGB model (ii). Whereas the SOBEK model is able to propagate sharp discharge gradient downstream, the diffusive wave model is damping these gradients significantly due to the course spatial schematization. In the reservoir routing model, which is also schematized on a course grid, we counteract this drawback by modeling parts of the river reach by advection. This results in an excellent ratio between model accuracy / robustness and computational effort making it the approach of choice from the predictive control perspective.