Representing hydropower dam operations in a physically-based distributed hydrological model

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The past decade has seen significant progress in distributed hydrological models ranging from more detailed description of hydrological processes to improved computational efficiency. Despite the fact that these models can represent the natural processes in a watershed fairly accurately, modeling their interaction with human intervention is still a scientific challenge. One such intervention is the creation of dams on the river, for various purposes, that alter its natural flow variation. Previous research has focused on the introduction of dam operation schemes in physically-based distributed hydrological models for flood control and water resources conservation, however a substantial gap still exists between research in the areas of distributed hydrological modeling and hydropower system optimization. In this research, we integrated a hydropower dam operation scheme in a Water and Energy Budget-based Distributed Hydrological Model with improved Snow physics (WEB-DHM-S). The use of a three-layered energy balance snow scheme in WEB-DHM-S allows for more accurate snowmelt runoff simulation in high elevation watersheds where hydropower dams are usually located. The hydropower dam properties in the distributed model are described by the storage-elevation curves along with their locations in the hydrological model's parameterized subgrid. The model is applied to the Ooi Watershed in Japan, which receives substantial flows in the form of snowmelt and is regulated by a series of hydropower dams. The model is calibrated for the inflows received by Akaishi Dam by varying the landuse, soil and snow related parameters and then evaluated using the observed discharge and MODerate resolution Imaging Spectroradiometer (MODIS) snow product. Downstream of Akaishi dam, three cases are considered by comparing the discharge at a control point by assuming: (a) no dam regulation, (b) conventional dam operating rules, and (c) optimized dam operation with the objective of maximizing hydropower generation. Case (b) demonstrates how the operation of a hydropower dam alters the stream in the river network in comparison to case (a). Case (c) however, demonstrates that the use of more flexible and optimized operating rules in lieu of case (b), with fixed operating rules, can lead to a higher hydropower generation, and in turn more revenue. We expect that this model is especially useful for countries like Japan, where the construction of new dams in the future is highly unlikely due to socio-environmental constraints and the focus is instead more towards increasing the generation capacity of existing dams. The expansion of this model to systems with more than one hydropower dam, connected in series or parallel, is also discussed for future consideration.

Keywords: Distributed Hydrological Modeling, Hydropower Dam Operation