A parametric Budyko method for representing actual reservoir operations

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Abstract: Reservoirs exert a significant influence on the flow regimes of global rivers (Vorosmarty et al., 2010), serving as a critical means to meet various human demands such as flood control, irrigation, industrial, domestic water supply, and hydropower generation (Yassin et al., 2019). Therefore, better representations of reservoir operations are essential for accurately modelling the reservoirs' impact on streamflow in hydrological and land-surface models simulations (Liu et al., 2023).

Previous studies are often region-specific, with models either complex and parameter-intensive or unable to accurately reproduce observed flows. There is a lack of universal and simple methods for simulating actual reservoir outflow at the continental or larger scale.

In this study, a parametric Budyko reservoir operation method based on the supply-demand framework was developed to approximate the actual reservoir operation. The method, which relates monthly reservoir inflow, storage, demand, and outflow, was tested for 95 irrigation reservoirs located in the Western contiguous United States from 1991 to 2018. The reservoir operation period was divided into two seasons, irrigation and non-irrigation seasons. The demand during the irrigation season was determined by the downstream irrigation water requirement, which was calculated using the CROPWAT method (Smith, 1992) based on 0.5-degree grids irrigation areas and meteorological data (Hanasaki et al., 2006). For non-irrigation season, the demand was the maximum outflow recorded for the same month in previous years (e.g., a specific demand value for all Octobers).

The results from the case studies show that the proposed reservoir method leads to an improved simulation performance (Nash-Sutcliffe Efficiency value, NSE) for both irrigation and non-irrigation seasons compared to existing inflow-outflow reservoir operation approaches. Appropriate demand data and its utilization strategy are critical in achieving accurate reservoir outflow simulation. The satisfactory accuracy and low complexity of the method make it possible for further integration into hydrological or land-surface models.

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