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Step-wise calibration technique using SWAT model

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Abstract: It is widely recognised that hydrological models contain parameters that cannot be directly measured and must instead be estimated through calibration. A persistent challenge is the limited information available to support calibration and the resulting non-uniqueness of parameter sets (Beven, 1989). One way to address this issue is to complement catchment outflow observations with additional datasets, with previous studies showing that the informativeness of calibration data is often more important than its quantity (Zheng et al., 2023). When additional datasets are not available, however, an alternative is to extract more information from the existing data. This can be achieved using set-wise calibration approaches and data-mining techniques such as flow separation. The objective of this study is to present straightforward, stepwise subflow calibration approaches and evaluate their performance and robustness across a wide range of catchments using the Soil and Water Assessment Tool (SWAT; Arnold et al., 1998).

This study applies numerical filter techniques to separate observed hydrographs into subflow components, namely surface runoff, lateral flow and baseflow, for 71 sub-watersheds across the Iberian Peninsula. A modified version of the SWAT model was used, enabling each simulated subflow to be output explicitly and therefore calibrated separately. Three calibration strategies were tested. The first is a stepwise calibration, where each stage targets specific parameters associated with individual subflows. The second also calibrates parameter groups stepwise, but in all stages the calibration objective is the total flow rather than separated subflows. The third is the traditional one-step calibration using only total flows. For all strategies, parallel automated calibration of the 71 sub-watersheds was carried out using the SUFI-2 algorithm within the SWAT-CUP platform (Abbaspour et al., 2004).

Both stepwise calibration approaches outperformed the traditional one-step method. The stepwise strategy based on subflows provided the most consistent performance across all sub-watersheds, for both calibration and validation periods, in terms of reproducing total flow as well as individual subflows. The stepwise method using total flow performed nearly as well, and has the advantage of being less work-intensive since it does not require hydrograph separation into subflows. This makes it a valuable alternative when the internal dynamics of subflows are not of primary interest. The superior performance of the stepwise strategies is also linked to improved parameter identifiability.

These findings demonstrate that stepwise calibration using subflows can enhance the accuracy of hydrological models, particularly for representing low- and high-flow regimes. By extracting additional information from existing data, this approach makes more efficient use of limited observational records and offers a practical means to strengthen model reliability in data-scarce environments.

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