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Optimizing low flow predictions in river systems: a multi-objective, multi-gauge calibration approach for process-based hydrological models

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Understanding the variations of streamflow is critical for studying the ecology of river systems. Low flow periods can pose significant pressures to river ecosystems, including flow intermittence, drying, increasing water temperature or pollutant concentration. Process-based spatially distributed hydrological models, can be used to simulate streamflow along river networks and provide valuable insights to study river ecology. However, until now, the use of these models to simulate streamflow at a high resolution, with a focus on low flow periods, has been limited. Therefore, traditional calibration techniques need to be adapted and refined to effectively address the challenges of sustainable river system management.

In this study, we present a new approach to calibrate a process-based spatially distributed hydrological model (JAMS/J2000) to optimize the simulation of low flows in river systems. This approach combines traditional efficiency criteria (KGE, NSE, pBias, RMSE, etc.) with hydrological signatures specific to low flows (KGE(sqrt(Q)), 10th quantile, base flow index, etc.) to optimize the model at multiple gauging stations. In order to select the optimized parameter set, simulated ensembles of different parameter sets were generated using Latin Hypercube sampling and an objective function developed that combines the efficiency criteria at each gauging station. This allowed us to evaluate the performance of multiple potential parameter sets and select the one that optimizes the simulation of low flows in the river system.

This calibration method was applied in 6 mesoscale catchments in different European countries (Croatia, Spain, Finland, France, Hungary, Czech Republic), which cover different ecoregions in Europe. The study was conducted as part of the Horizon 2020 DRYvER project (Datry et al. 2021). Our results show that the integration of hydrological signatures in the objective function has a strong impact on the calibration procedure and improves model performance during low flow periods.

Datry et al. (2021) Securing Biodiversity, Functional Integrity, and Ecosystem Services in Drying River Networks (DRYvER). Research Ideas and Outcomes. https://doi.org/10.3897/rio.7.e77750