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Implementation and sensitivity analysis of the Dam-Reservoir OPeration model (DROP v1.0) over Spain

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1 Supplementary study - Reservoir model calibration over Spain

To better underline the importance of the sensitivity analysis, a calibration scheme was run over the reservoir model parameters for Spain reservoirs. Model parameter sampling and C_{2M} performance index optimization scheme are here performed using the differential evolution stochastic method, available in open-source Scipy Python library (SciPy, 2022). An initial population of parameters values is generated following Latin Hypercube sampling in order to scatter the sample points as uniformly as possible over the parameter space and maximize its coverage (here the same bounds as for the sensitivity analysis, see Table 2 in Sadki et al. (2022)). A population size of 50 is chosen to ensure convergence of the calibration scheme. The algorithm seeks to minimize a cost function defined in this study as the difference between 1 and C_{2M}. The tolerance threshold is set to 0.01, as given by default by the function. Regional parameters (same parameter values for all reservoirs) for the case study were set within this step and a comparison to default values from Hanasaki et al. (2006), Biemans et al. (2011) and Shin et al. (2019) (R_{new} simulation, where ($c_{threshold}$, b)=($1/\alpha$,1)) is hereby represented. The optimisation was carried out on reservoir outflows, independently on irrigation and non-irrigation reservoirs as the parameters involved are different depending on the main purpose (see section 3.4 in Sadki et al. (2022)).

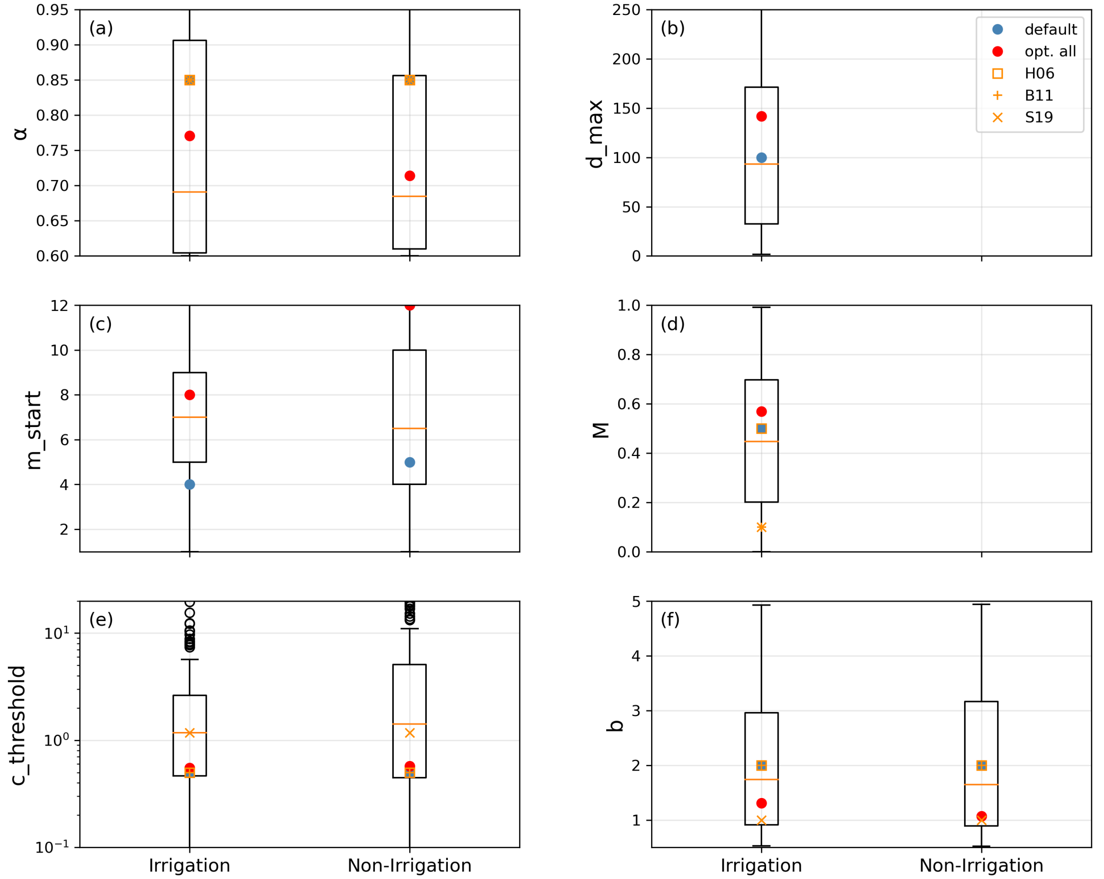

Figure S1. Parameter values before and after C_{2M} optimization: In blue is represented as 'default' the set of parameter values used in the default parameterization of the given reservoir scheme. In orange are shown the default values used in (Hanasaki et al., 2006), (Biemans et al., 2011) and (Shin et al., 2019) (R_{new} simulation) papers, labeled respectively as 'H06', 'B11' and 'S19'. The red marked 'opt. all' values represent the optimal parameters values when calibrating over all Spain reservoirs outflows. The boxplots in black represent the spread of optimal parameter values for each reservoir when optimized individually.

Fig. S1 shows the distribution of parameter values before and after calibration, for irrigation and non-irrigation reservoirs separately, since the number of parameters involved is not same in both categories of reservoirs (6 and 4 parameters respectively). First, the parameter values used in the reservoir model default configuration (see Table 2) are shown in blue. In orange are shown default values used by Hanasaki et al. (2006), Biemans et al. (2011) and Shin et al. (2019) (R_{new} simulation) studies. The remaining values represent two distinct optimisations: the points in red represent the configuration of parameters to best simulate the whole of Spain's reservoirs. These represent the regional model configuration to be set for Spain. If we optimized each reservoir separately, the boxplots in black illustrate the spread and the range of the parameters' values. Regarding the results of the calibration over the entire country: the default global values of α and M given by the previous papers are not appropriate for Spain; indeed, for α, the optimal regional value ranges between 0.71 and 0.77 when considering all reservoirs. The calibration per reservoir even shows that half of the reservoirs simulate best flow seasonal variation with an α below 0.69. This may be related to the high anthropogenic pressure on water resources combined with the semi-arid climate, which would make reaching 85% of storage an unrealistic target for this particular region. Concerning the parameter M, specific to irrigation reservoirs, the default values set by H06 and B11 are within the range of M optimal values, but the optimal setting for the country's reservoirs is relatively higher (0.57). The optimal value of $c_{threshold}$ in both types of reservoirs is ~ 0.56 which is close to default values set in older versions. $c_{threshold}$ is the most influential parameter, the dispersion observed on the optimums of this parameter when running a reservoir-by-reservoir calibration shows that setting a global or regional value limits the performance of the model. This is shown in Fig. S2 where distribution of the reservoir model performance index (C_{2M}) is displayed for both types of reservoirs.

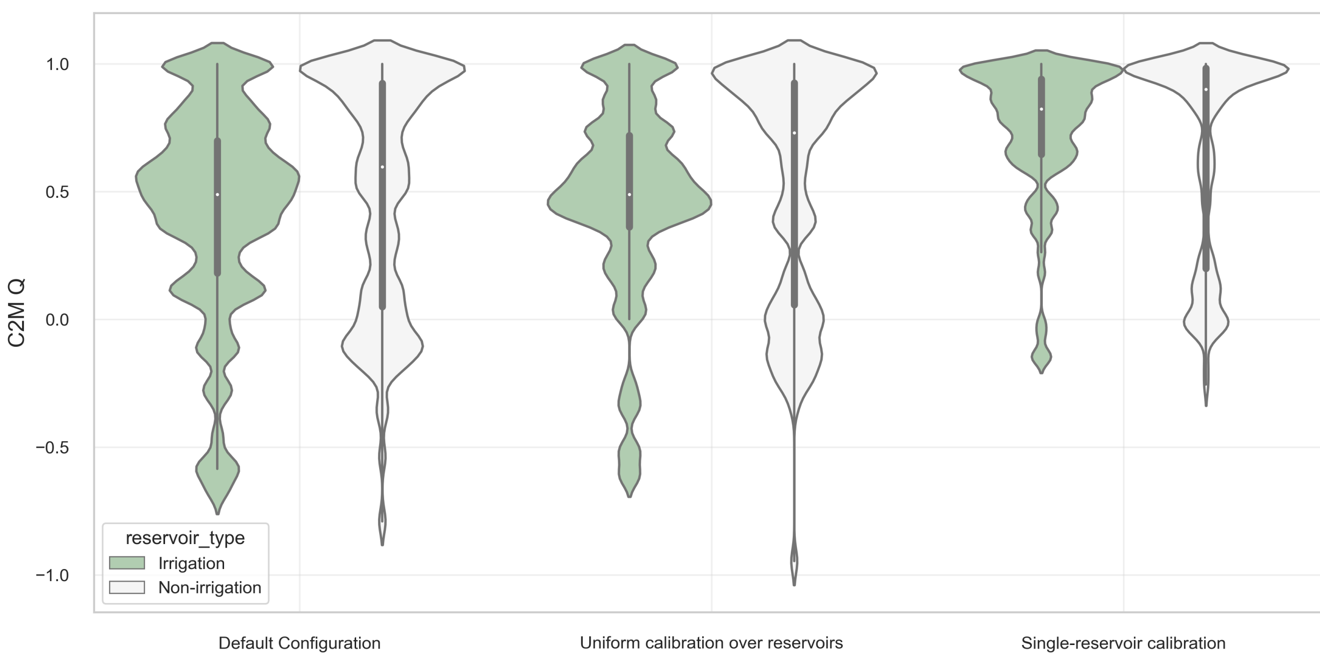

Figure S2. Distribution of the reservoir model performance index C_{2M} over outflows before and after calibration in irrigation (green) and non-irrigation reservoirs (light grey). The default configuration stands for the default setting of the model, the two others are respectively the model calibration performed uniformly on all reservoirs and on each reservoir individually.

The individual reservoir calibration, on the other hand, shows a wide dispersion of the optimal parameter values, especially for α and $c_{threshold}$ (Fig. S1). This is linked to the reservoir characteristics, but also to Pareto fronts that may occur, such as for $c_{threshold}$, interacting with several other parameters, as the 2nd Sobol indices revealed in Figure (10). By taking into account the individual characteristics of each reservoir in the calibration, the performance of the model is considerably improved

(Fig. S2). Overall, confronting Spain's optimal parameter ranges with the global default values shows the interest of having a regionalization which implicitly integrates the impact of the specific climate, land use and demographic pressure of a study area in the management of its dams and water resources. The dispersion of the optimums from the per reservoir calibration and the significant performance gained show the importance of having specific values for each reservoir. To this purpose, observations from recent and future satellite missions, especially in ungauged basins. In particular the forthcoming SWOT which will provide water level observations and river flow estimates, as well as reservoir water surface areas, heights and volume variations, seems very promising.

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