water

MDPI

Supplements

Objective measures

The Nash & Sutcliffe Efficiency (NSE) [38] and its logarithmic form (logNSE):

$$\mathrm{NS} = 1 - \frac{\sum_{i=1}^{n}\left(q_{obs,i} - q_{sim,i}\right)^2}{\sum_{i=1}^{n}\left(q_{obs,i} - \overline{q_{obs}}\right)^2} \tag{S1a}$$

$$\mathrm{logNSE} = 1 - \frac{\sum_{i=1}^{n}\left(\log\left(q_{obs,i}\right) - \log\left(q_{sim,i}\right)\right)^2}{\sum_{i=1}^{n}\left(\log\left(q_{obs,i}\right) - \overline{\log\left(q_{obs}\right)}\right)^2} \tag{S1b}$$

The Kling-Gupta Efficiency (KGE) [39]:

$$\mathrm{KGE} = 1 - \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2} \tag{S2a}$$

$$\alpha = \frac{\sigma_{sim}}{\sigma_{obs}} \tag{S2b}$$

$$\beta = \frac{\mu_{sim}}{\mu_{obs}} \tag{S2c}$$

r: correlation coefficient
μ: mean
σ: standard deviation

The ratio of root mean square error to standard deviation of observations (RSR) [40]:

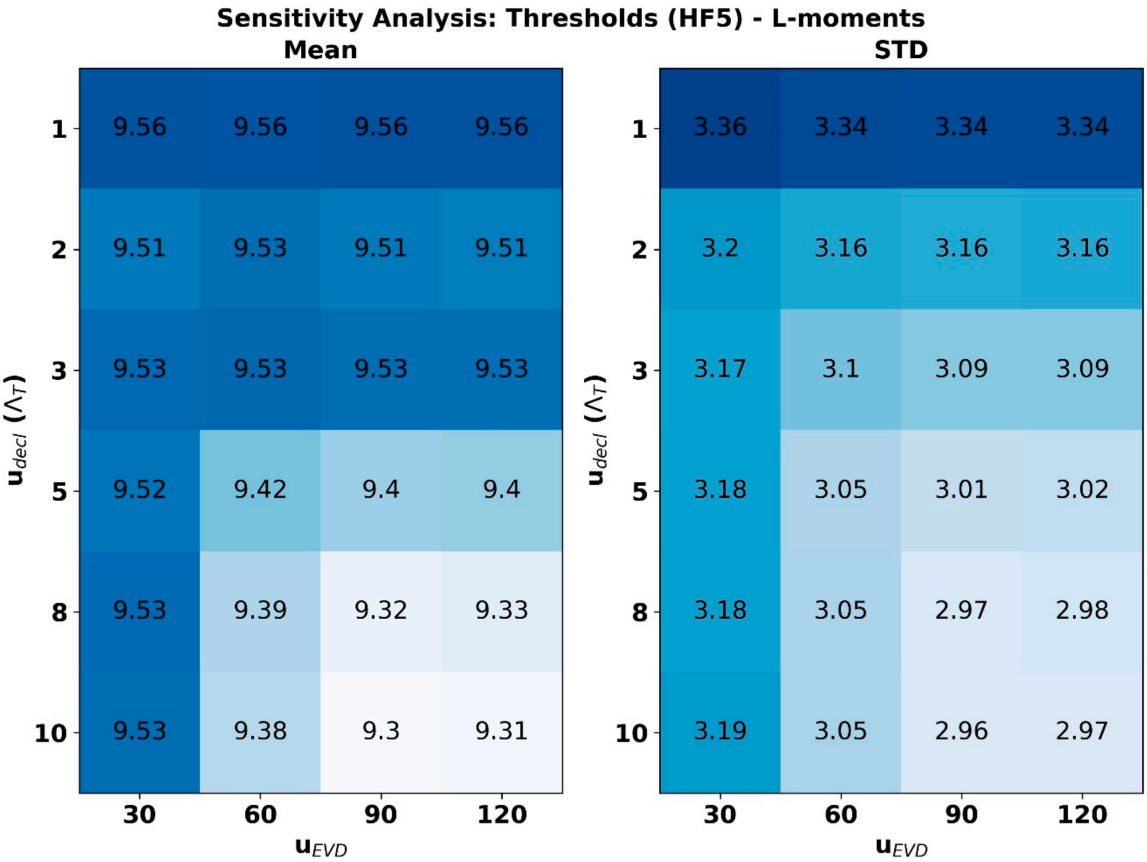
$$\mathrm{RSR} = \frac{\sqrt{\sum_{i=1}^{n}\left(q_{i,obs} - q_{i,sim}\right)^2}}{\sqrt{\sum_{i=1}^{n}\left(q_{i,obs} - \overline{q_{obs}}\right)^2}} \tag{S3}$$

Sensitivity analysis of thresholds for the Generalized Pareto Distribution (GPD)

Within the scope of the holistic approach of this study, the goal for the GPD was to find thresholds for a) the sampling (declustering) all available complete time series of discharge and for b) the GPD model fit based on the declustered samples which in combination exhibit the smallest changes between other threshold combinations. We applied a set of predefined thresholds for a and b. For the thresholds applied to derive the samples from the entire time series (a), we opted for the average number of events according to Lang et al. (1999) [44] (λ_T), with values of λ_T = [1, 2, 3, 5, 8, 10]. We then derived the second threshold from this sample choosing the n-th highest value from the resulting events (clusters), with values for n = [30, 60, 90, 120]. We consider the threshold robust, if the resulting return levels exhibit a plateau (i.e. return levels stabilize for certain combinations of thresholds for a and b). For the sensitivity analysis we then calculate the return levels (HF_x) employing the GPD model fits and normalize the results for all 98 gauges by the mean and standard deviation of the discharge (q) (Eq. S4).

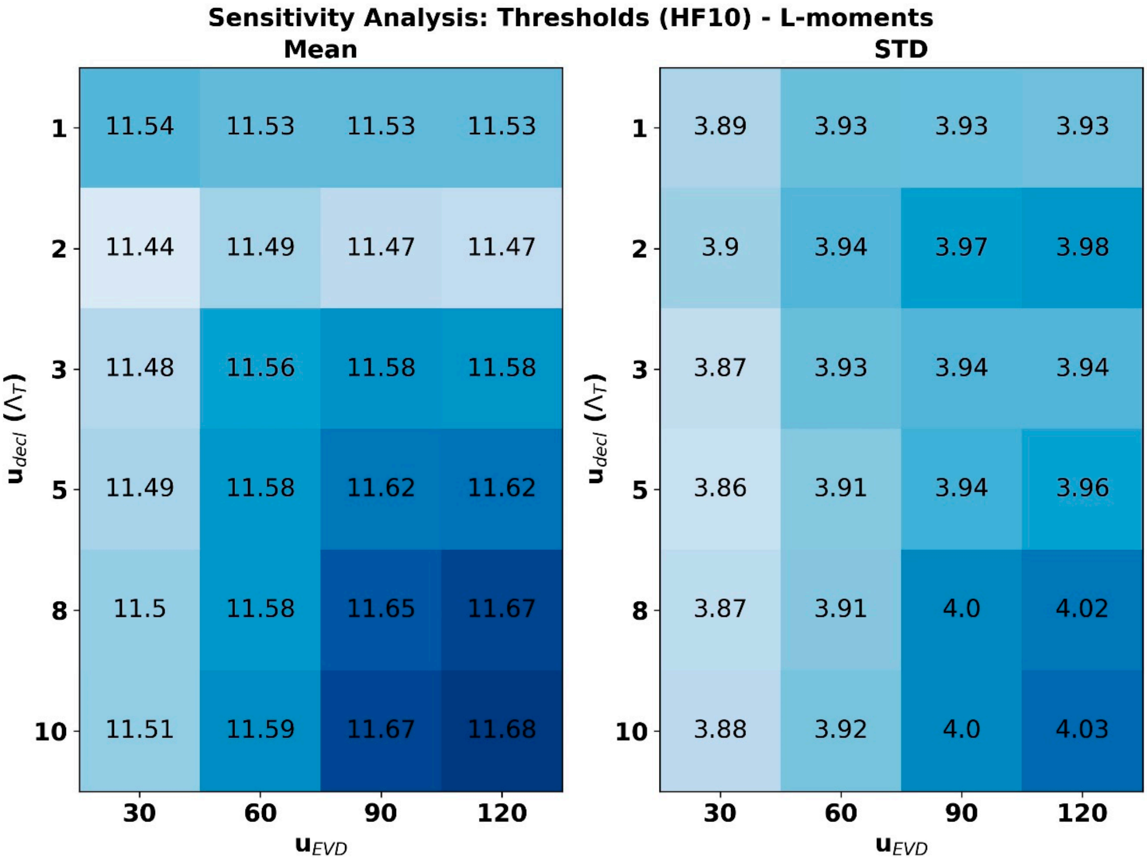
$$HF_{x,norm} = \frac{HF_x - \overline{q}}{\sigma(q)} \tag{S4}$$

We further calculate the mean and standard over all 98 normalized return levels for all combinations of thresholds employed for the GPD model fit to illustrate the stability of the results. The results from Figures 1 to 3 illustrate, that overall a stable combination of thresholds is reached for $\lambda_T = 8$ and n = 90. For the estimation of the GPD parameters (scale and shape) we employed the L-Moments approach.



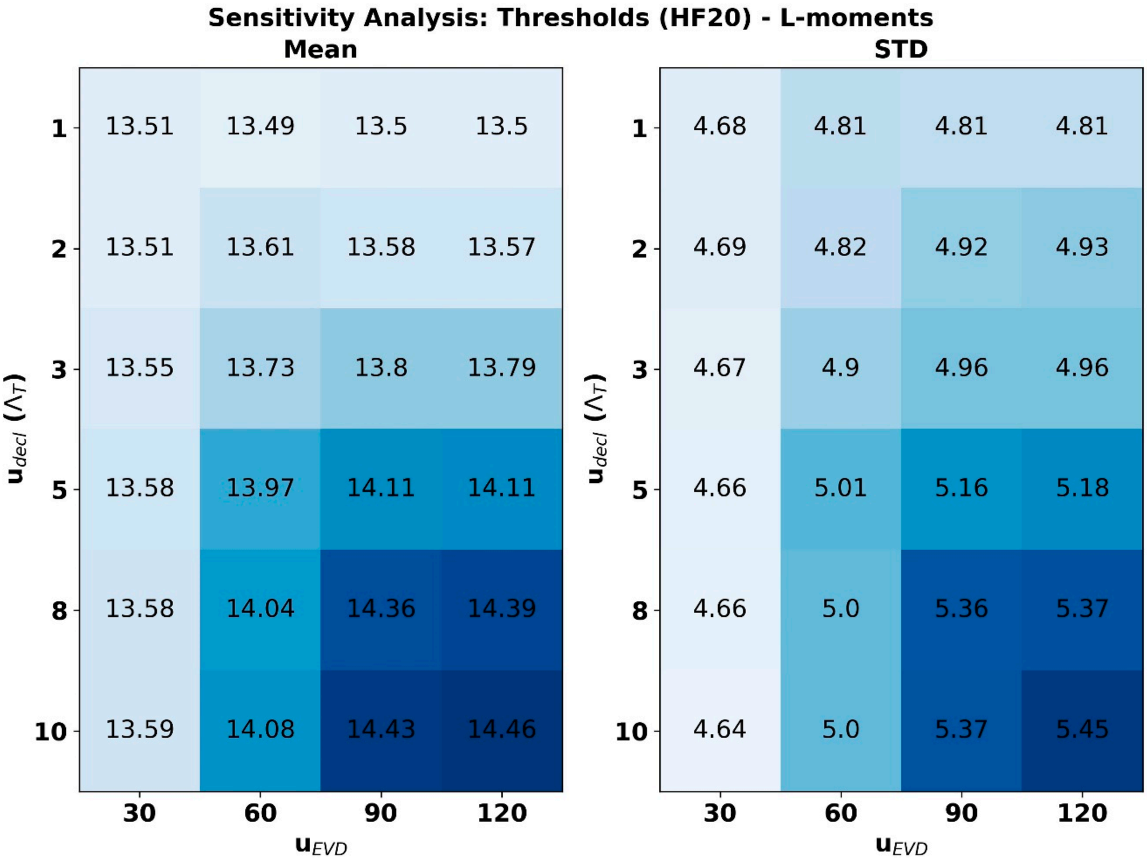
(**a**) (**b**)

Figure S1. Mean (**a**) and standard deviation (**b**) for standardized return levels of the HF5 over all 98 gauges.



(**a**) (**b**)

Figure S2. Mean (**a**) and standard deviation (**b**) for standardized return levels of the HF10 over all 98 gauges.



(**a**) (**b**)

Figure S3. Mean (**a**) and standard deviation (**b**) for standardized return levels of the HF20 over all 98 gauges.