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Testing GR4H model parameter transferability for extreme events in Cyprus: evaluation of a cluster analysis approach

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The Mediterranean island of Cyprus has been recognized as a hot spot for climate change, bringing a reduction of average annual rainfall and an increase of extreme events. These changes will affect both the water resources and the occurrence of floods events over the island. This study focuses on hydrologic extremes. Its objectives are i) to develop a robust method for rainfall-runoff model calibration of single extreme events; ii) to evaluate the spatial and temporal transferability of model parameters based on a watershed clustering on environmental variables. Two extreme events that occurred in January 1989 and November 1994 are analyzed over 22 watersheds located in the Troodos Mountains, the main mountain range of Cyprus. Model runs are performed with GR4H, starting with a two-month spin-up period followed by a single month simulation. Model outputs are evaluated on hourly streamflow using four indices, Nash-Sutcliffe Efficiency (NSE), Kling-Gupta Efficiency (KGE), Percentage Bias (PB), and Mean Absolute Error (MAE). Model calibration is performed with a double optimization procedure based on the random generation of parameter sets (10000 in the first step, 1000 in the second step) within decreasing parameter ranges. The cluster analysis is carried out by the k-means algorithm. The environmental variables are slope, geology, land use, distance from faults, and time of concentration. Based on the best average silhouette coefficient, three clusters are recognized. Within clusters, 90% of the transferred parameter sets leads to NSEs larger than 0.5. However, the cluster with watersheds occupied by large areas of highly fractured rock masses show a poor transferability (average NSE below zero). Model validation (calibration-validation over two events in the same watershed) returns NSE values larger than 0.5 for 70% of the calibrated model parameter sets. Poor results are related to large differences in the calibrated values of the routing store and unit hydrograph parameters in the two events of 1989 and 1994, which were characterized by very different antecedent soil moisture conditions. Results indicate that both initial conditions and the fracturing of geologic formations can have a direct effect on hydrologic processes related to extreme events. Since low performances occur for both validation and spatial transferability, it means that both the GR4H model structure and the watershed clustering can be improved.