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Independent determination of the maximum root zone storage (S_{uMax}) in conceptual models

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The maximum root zone storage in the unsaturated zone is an important parameter in most conceptual hydrological models, although it is known by different terms such as S_{uMax} (SUPERFLEX), W'_{mm} (Xinanjiang/VIC), FC (HBV), and S_{rmax} (Topmodel), $x1$ (GR4J). S_{uMax} is not only used for partitioning precipitation into runoff and infiltration under different soil moisture conditions, but it is also a key variable determining actual transpiration. Since S_{uMax} at the scale of conceptual models cannot be directly observed, it is normally determined by calibration. In this study, we propose an approach to estimate it directly from the observed hydrograph. The approach makes use of the Ripple diagram (which is traditionally applied in reservoir storage design) to estimate the root zone depth required for ecosystem to overcome the driest period in the time series. The assumption is that ecosystem adjust the root depth in a way that they can survive in a critical dry period. We applied the SUPERFLEX model with the Xinanjiang/VIC conceptualization for the unsaturated reservoir to represent the spatial variable rooting depth. The minimum storage requirement derived from Ripple diagram was subsequently compared to the average maximum root zone storage in the basin obtained from model calibration. The storage equals $S_{uMax}/(1+\beta)$ in agreement with the beta function spatial distribution over the basin. Eleven catchments in the Upper Ping River Basin in Northern Thailand have been selected as a case study to test our hypothesis. The results suggest that the $S_{uMax}/(1+\beta)$ indeed represents the average root zone storage, which is strongly determined by an extreme dry period in the time series (approximately once in 10 years). Extreme dry year conditions determine how deep the roots extend into the soil, which can be interpreted as an approximation of the storage capacity of the unsaturated reservoir in conceptual hydrological models. This further suggests that the $S_{uMax}/(1+\beta)$ can be directly inferred from data, thereby considerably reducing the feasible parameter space.