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Stress test modelling to assess catchment drought resistance and recovery

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Dry spells and heat waves control the frequency and duration of streamflow drought events. Groundwater storage and release in catchments can modulate their timing and severities in terms of deficit volume and persistence. To better understand the role of recharge and groundwater storage for catchment sensitivity to droughts we investigate the effect of recharge scenarios on streamflow drought characteristics and baseflow for 50 mesoscale catchments with different hydrogeological characteristics in southwestern Germany. In model experiments, we simulate daily recharge on a 1 km resolution with the water balance model TRAIN reflecting the most dominant soil-vegetation processes. Then we calibrate long-term reference simulations, fitting the outflow of different conceptual groundwater box models with varying model structure to hydrograph-separated baseflow. After calibration, we define probabilistic stress tests as scenarios of reduced pre-drought recharge. The tolerance of catchments to different drought intensities is analyzed based on the concepts of resistance, resilience, and recovery to drought situations. Results suggest that catchments with higher resistance and resilience are less sensitive to recharge stress, but recovery is often much slower. However, by comparing the events of e.g. 2003 and 2018 specifically, we show that the sensitivity is also a function of the intensity and duration of the stress test simulation, the drought event characteristics, and the storage memory of catchments. Additionally, the performance ranking of all groundwater models in each catchment allows to link the variability in model structure to catchment properties (e.g. geology). The analysis shows that catchments with short-term or long-term storage memory react differently under different stress tests. Stress test simulations may help to answer planning-relevant questions such as which preconditions make a drought intensification or prolongation more likely and how long does it take for the system to recover to the reference condition. Catchment-specific stress tests with historical worst-case pre-conditions before extreme drought events may thus be a way forward to constrain relevant timescales of drought management and drought early warning.