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How model parameters control hydrological drought representation in three different hydrological models

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Hydrological droughts can be caused by different mechanisms such as extended periods of no/low precipitation or a deviant temperature regime which influences snow storage and melt. Water flow in the drought phase is mainly controlled by the release of stored water. In terms of modelling, an accurate reproduction of hydrological drought is complex because water storage is difficult to observe, and low discharges are prone to a relatively large observation error. Towards an accurate representation of hydrological droughts in models, the model structure is particularly important. In this way, several and partly interacting model parameters control storage and release of water during droughts.

However, no studies so far have looked into detail into the relation between model structure and hydrological drought simulations. In this study, we conducted a parameter sensitivity analysis for three different hydrological models (SAC, VIC, HBV) for two hydrological drought characteristics (drought duration and drought deficit) for 605 basins in the US covering a wide range of hydroclimatological conditions. The sensitivities of the model parameters are then related to climate and catchment characteristics (e.g. seasonality, mean winter temperature) to understand for which climate and catchment conditions, which model parameter is particularly relevant.

The sensitivity analysis revealed that within the three hydrological models, different parameters showed highest sensitivity for the drought characteristics. In SAC, for example, the soil moisture parameters showed the highest sensitivity for drought duration, while for VIC the groundwater parameters were most important. Furthermore, the results showed a clear spatial distribution, which allowed us to link the parameter sensitivity to different drought typologies. For HBV, mainly the snow parameters control the duration of cold snow season drought, while for SAC again groundwater parameters dominate for this drought typology. The relationship between parameter sensitivities and climate/catchment characteristics shows how the sensitivity changes along a gradient of different hydroclimatic conditions in the US. This study demonstrates that different models use different mechanisms to represent hydrological drought. This can have profound implications for long-term hydrological drought projections.