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Analysing spatio-temporal dynamics of processes and parameters in a hydrological model to understand catchment similarities among different landscapes

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The hydrological behaviour of catchments differs due to varying relevance of processes in space and time. These differences are related to landscape and climate conditions but also to seasonal variations of driving factors such as precipitation or temperature. Due to that, catchments are characterised by typical temporal patterns of dominant processes.

Universally applicable hydrological models aim to represent these typical characteristics of contrasting catchments making use of site-specific model parameter values as well as emphasising the hydrological processes that are of major relevance. With respect to hydrological modelling, patterns of temporal dynamics in dominant modelled processes and their corresponding parameters are a fingerprint of how a model represents the hydrological system. In this study, it is demonstrated how fingerprints from catchment data and model results can be jointly used to understand the reasons for hydrological similarity and dissimilarity among different catchments.

At first, catchment metrics are used to characterise contrasting catchments representing different landscape conditions (lowland, upland and alpine) in a data-based approach. Simulations are carried out by applying a complex hydrological model to calculate the temporal variability of dominant processes and parameters using a temporally resolved sensitivity analysis (TEDPAS). Temporal dynamics of dominant processes and model parameters are related to catchment metrics to analyse how catchment metrics explain temporal variations in process dominance in the model.

In each catchment, three to four typical phases during the year are identified that show strong differences in the dominant processes. These phases can be related to selected catchment metrics and explain the similarity between the catchments. All catchments show a typical hierarchical process appearance following the concept of the vertical water redistribution. Following a landscape gradient, high flow phases are dominated by different hydrological components that represent surface or fast-reacting subsurface flow. By contrast, the applied model shows groundwater dominances in low flow phases in all catchments. The largest differences both in catchment metrics and in temporal patterns of process and parameters are identified for the alpine catchment, whilst similarities are found between the other catchments.

Our study shows that the hydrological model is able to represent the different processes according to the hydrological conditions in the study catchments. It is demonstrated how similarities in catchment behaviour are represented in a hydrological model. The joined analysis of catchment metrics and temporal dynamics of dominant processes and parameters explains the degree of similarity among catchments from different landscapes.