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Picturing and modelling catchments by representative hillslopes

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Hydrological modelling studies often start with a qualitative sketch of the hydrological processes of a catchment. These so-called perceptual models are often pictured as hillslopes and are generalizations displaying only the dominant and relevant processes of a catchment or hillslope. The problem with these models is that they are prone to become too much predetermined by the designer's background and experience. Moreover it is difficult to know if that picture is correct and contains enough complexity to represent the system under study. Nevertheless, because of their qualitative form, perceptual models are easy to understand and can be an excellent tool for multidisciplinary exchange between researchers with different backgrounds, helping to identify the dominant structures and processes in a catchment.
In our study we explore whether a perceptual model built upon an intensive field campaign may serve as a blueprint for setting up representative hillslopes in a hydrological model to reproduce the functioning of two distinctly different catchments. We use a physically-based 2D hillslope model which has proven capable to be driven by measured soil-hydrological parameters. A key asset of our approach is that the model structure itself remains a picture of the perceptual model, which is benchmarked against a) geo-physical images of the subsurface and b) observed dynamics of discharge, distributed state variables and fluxes (soil moisture, matric potential and sap flow).

Within this approach we are able to set up two behavioral model structures which allow the simulation of the most important hydrological fluxes and state variables in good accordance with available observations within the 19.4 km^2 large Colpach catchment and the 4.5 km^2 large Wollefsbach catchment in Luxembourg without the necessity of calibration. This corroborates, contrary to the widespread opinion, that a) lower mesoscale catchments may be modelled by representative hillslopes and b) physically-based models can be parametrized based on comprehensive field data and a good perceptual model. Our results particularly indicate that the main challenge in understanding and modelling the seasonal water balance of a catchment is a proper representation of the phenological cycle of vegetation, not exclusively the structure of the subsurface and spatial variability of soil hydraulic parameters.