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How simple can a distributed hydrological model be?

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It is well known that lumped conceptual models can often reproduce catchment streamflow response with about a 'handful' of model parameters. But what is the appropriate complexity of a distributed hydrological model, in order to reproduce the distinct streamflow response of heterogeneous internal subcatchments? Is the number of identifiable parameters proportional to the number of stream gauges? Into how many pieces should the catchment be broken-up? And which model structures are best suited to represent the behavior of particular landscape units?

We investigated these questions in a case study based on the Attert basin in Luxembourg, where 10 sub-catchments with clean and mixed geologies and land use manifested different rainfall-runoff behavior. The hydrological response of individual subcatchments was well represented using a range of lumped models with 4-8 parameters. We then attempted to simulate the 10 streamflow time series simultaneously, using a distributed model. Existing distributed models are often perceived to be over-parameterized. In order to avoid this problem, model development followed an iterative hypothesis-testing process. We developed, calibrated and compared alternative model variants, differing in the landscape classification approach, and in the structure of components intended to represent individual landscape elements. Decisions such as how to break-up the catchment, and which structure to assign to distinct landscape elements were found to significantly influence the model's predictive performance. In the present case, we determined that a geology-based landscape classification provided the best characterization of the observed differences in streamflow responses. In addition, we found that the individual geological units could be represented by remarkably simple model structures. The overall complexity of the distributed model was of about two 'handfuls' (10) of model parameters.