Fix or Flex? Hypothesis testing with a flexible approach for conceptual model development

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Whether hydrological modelling is best pursued using a fixed model structure calibrated over a wide range of catchments, or, instead, pursued using flexible model structures adapted to the specific catchments of interest, remains a controversial question in the hydrological community. On one hand, the generality of physical principles may appear to favour a single fixed model, while on the other hand, environmental diversity has often led to perceptions of "uniqueness of place". In our opinion, these questions are best explored by formulating competing hypotheses of catchment behaviour in different conditions, and carefully comparing them. This is the motivation for SUPERFLEX, a flexible approach for conceptual model development, based on generic model components, where different model structures can be systematically generated and compared. Importantly, SUPERFLEX is implemented within a robust numerical framework, which helps meaningful hypothesis-testing by protecting against spurious numerical artefacts, and making model calibration and parameter inference more efficient.

In this study, the SUPERFLEX framework was used to generate a set of alternative model structures for 4 different European and New Zealand catchments with distinct climatology and physical characteristics. The hypothesized model structures were broadly reflective of fieldwork insights available at these locations. Calibration, including parameter optimization and uncertainty assessment, suggested that the performance of the competing models differs significantly across the catchments. Experimental knowledge is then shown to be useful in interpreting the differences in model behaviour, and in lending additional evidence to the inferred mechanistic behaviour of the 4 catchments. The estimated system complexity also differed substantially, with some catchments displaying a much simpler behaviour than others. Overall, this case study illustrates the development and application of SUPERFLEX for hypothesis-testing, as a tool for improving our understanding and interpretation of both differences and similarities of catchment dynamics in diverse environmental conditions.