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Constraining Distributed Catchment Models by Incorporating Perceptual Understanding of Spatial Hydrologic Behaviour

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Distributed models offer the potential to resolve catchment systems in more detail, and therefore simulate the hydrological impacts of spatial changes in catchment forcing (e.g. landscape change). Such models tend to contain a large number of poorly defined and spatially varying model parameters which are therefore computationally expensive to calibrate. Insufficient data can result in model parameter and structural equifinality, particularly when calibration is reliant on catchment outlet discharge behaviour alone. Evaluating spatial patterns of internal hydrological behaviour has the potential to reveal simulations that, whilst consistent with measured outlet discharge, are qualitatively dissimilar to our perceptual understanding of how the system should behave. We argue that such understanding, which may be derived from stakeholder knowledge across different catchments for certain process dynamics, is a valuable source of information to help reject non-behavioural models, and therefore identify feasible model structures and parameters. The challenge, however, is to convert different sources of often qualitative and/or semi-qualitative information into robust quantitative constraints of model states and fluxes, and combine these sources of information together to reject models within an efficient calibration framework.

Here we present the development of a framework to incorporate different sources of data to efficiently calibrate distributed catchment models. For each source of information, an interval or inequality is used to define the behaviour of the catchment system. These intervals are then combined to produce a hyper-volume in state space, which is used to identify behavioural models. We apply the methodology to calibrate the Penn State Integrated Hydrological Model (PIHM) at the Wye catchment, Plynlimon, UK. Outlet discharge behaviour is successfully simulated when perceptual understanding of relative groundwater levels between lowland peat, upland peat and valley slopes within the catchment are used to identify behavioural models. The process of converting qualitative information into quantitative constraints forces us to evaluate the assumptions behind our perceptual understanding in order to derive robust constraints, and therefore fairly reject models and avoid type II errors. Likewise, consideration needs to be given to the commensurability problem when mapping perceptual understanding to constrain model states.