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Evaluating the structure of hydrological models using hydrodynamics, tracers and landscape organisation

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Measurements of hydrological state variables and environmental tracers can be used to identify the dominant processes driving the hydrological cycle at various scales. This process knowledge can be readily conceptualized in simple hydrological models to simulate stream flow response. However, incorporating tracer-based data into such models can in turn provide information about the geographical sources of runoff and their temporal dynamics that can be used to test hypotheses of hydrological function implicit in models. This provides a potentially rich alternative source of data for evaluating and rejecting models.

Here, we present results from an evolving modeling study in nested sub-catchments of a relatively large (750 km2) heterogeneous river basin in NE Scotland. Empirically-based insights into differences in hydrological response were derived from extensive, integrated hydrometric and tracer studies framed within a process-based GIS analysis of contrasting landscape characteristics investigations. Non-linearities in runoff response, recession curve gradients, geochemical source area tracers and isotopic time domain tracers were utilized as soft data controls to develop and evaluate appropriate model structures in a rejectionist framework. Starting from very simple linear storage models, inadequacies leading to model structure rejection were explored by routing geographical source and time domain tracers through the models as well as evaluating the modeled system state using the soft data controls. The landscape evolution history of the study catchment facilitated comparison of areas with contrasting characteristics ranging from mountainous headwaters and intensively farmed lowland headwaters, which were integrated by the hydrological response at the catchment outlet. Such better-constrained model structure provided a more robust means for predicting hydrological responses of a large heterogeneous catchment to climate change.