Geophysical Research Abstracts
Vol. 13, EGU2011-413, 2011
EGU General Assembly 2011

Using spatial flux measurements to diagnose model structural errors under data uncertainty

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Comparing (semi-)distributed model simulations to catchment outlet data is regarded as a weak test of a model's underlying assumptions and therefore reduces the possibility that the right model is identified for the right reasons. Specifically, unrealistic conceptualisations and parameterisations of spatial model units may interact so as to produce an apparently realistic outlet hydrograph. Multiple discharge measurements that characterise nested sub-catchment responses should increase confidence in assessing a model's spatial consistency, allow rejecting certain model realisations as good hypotheses of catchment behaviour and enhance our understanding of where model improvements are needed. Importantly, though, rejection criteria are conditional on the quality of the evaluation data. Hence the rejection rigour applied must be cognisant of data uncertainty through appropriate model performance metrics.

In this paper, we demonstrate a rigorous model evaluation methodology based on nested sub-catchment data. The semi-distributed conceptual Dynamic Topmodel is applied to a 48ha headwater catchment in Devon, UK, and evaluated for its temporal and spatial consistency using discharge measurements made at four nested locations. The analysis is embedded in the extended Generalised Likelihood Uncertainty Estimation (GLUE) framework, accounting explicitly for parameter and observational uncertainties. Discharge uncertainty is estimated using a fuzzification of the stage-discharge rating curve which is incorporated explicitly into model performance metrics and rejection criteria. Fuzzy logic is used here in the absence of sufficient data to estimate the full probabilistic error structure. The evaluation of spatial consistency is contrasted with a more typical evaluation using observed behaviour at the catchment outlet. We show that 'behavioural' simulations at the outlet can be composed of highly unrealistic internal fluxes and demonstrate how combining spatial information with appropriate model rejection criteria can enhance the power of model evaluation. This approach helps us quantify conceptual errors in catchment topology, which improves our model representation of catchment processes and informs our data collection through learning from model failure.