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The value of oxygen-isotope data and multiple discharge records in calibrating a fully-distributed, physically-based rainfall-runoff model (CRUM3) to improve predictive capability

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Fully-distributed, physically-based rainfall-runoff models attempt to capture some of the complexity of the runoff processes that operate within a catchment, and have been used to address a variety of issues including water quality and the effect of climate change on flood frequency. Two key issues are prevalent, however, which call into question the predictive capability of such models. The first is the issue of parameter equifinality which can be responsible for large amounts of uncertainty. The second is whether such models make the right predictions for the right reasons – are the processes operating within a catchment correctly represented, or do the predictive abilities of these models result only from the calibration process? The use of additional data sources, such as environmental tracers, has been shown to help address both of these issues, by allowing for multi-criteria model calibration to be undertaken, and by permitting a greater understanding of the processes operating in a catchment and hence a more thorough evaluation of how well catchment processes are represented in a model. Using discharge and oxygen-18 data sets, the ability of the fully-distributed, physically-based CRUM3 model to represent the runoff processes in three sub-catchments in Cumbria, NW England has been evaluated. These catchments (Morland, Dacre and Pow) are part of the of the River Eden demonstration test catchment project. The oxygen-18 data set was firstly used to derive transit-time distributions and mean residence times of water for each of the catchments to gain an integrated overview of the types of processes that were operating. A generalised likelihood uncertainty estimation procedure was then used to calibrate the CRUM3 model for each catchment based on a single discharge data set from each catchment. Transit-time distributions and mean residence times of water obtained from the model using the top 100 behavioural parameter sets for each catchment were then compared to those derived from the oxygen-18 data to see how well the model captured catchment dynamics. The value of incorporating the oxygen-18 data set, as well as discharge data sets from multiple as opposed to single gauging stations in each catchment, in the calibration process to improve the predictive capability of the model was then investigated. This was achieved by assessing by how much the identifiability of the model parameters and the ability of the model to represent the runoff processes operating in each catchment improved with the inclusion of the additional data sets with respect to the likely costs that would be incurred in obtaining the data sets themselves.