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Combining the generalized likelihood uncertainty estimation (GLUE) and Bayesian model averaging (BMA) to evaluate conceptual model and parameter uncertainty in groundwater modelling

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Uncertainty in groundwater models is mainly caused by a lack of knowledge to fully describe the input parameters and by simplifications of complex system configurations in simple conceptual models. Methods to deal with the uncertainty derived from the input parameters are well documented in the literature, whereas the uncertainty derived from the conceptual model has received less formal attention. Normally, once a conceptual model is successfully calibrated it is rarely questioned and, generally, it is used in order to obtain predictions of variables of interest. Nevertheless, it is known that the calibration of groundwater models is mathematically non-unique and that different conceptual models combined with different parameter sets may produce similar results. In addition to this, uncertainty estimations based on a single conceptual model are prone to statistical bias and underestimation of predictive uncertainty (Neuman, 2003).

This study proposes a methodology to account for the conceptual model and parameter uncertainty through the combination of the Generalised Likelihood Uncertainty Estimation (GLUE) methodology (Beven and Binley, 1992) and Bayesian Model Averaging (BMA) (Draper, 1995; Hoeting et al., 1999). For a suit of alternative models, parameter uncertainty is derived using the GLUE methodology. Subsequently, the predictive distributions obtained with the different conceptual models are combined fol-

lowing BMA to obtain a multi-model prediction. Hereby, the weights of the individual models are the estimated posterior model likelihoods, which represent the ability of each of the models in simulating the observed groundwater levels. The methodology is illustrated using a synthetic 3-dimensional steady-state groundwater model with spatially varying hydraulic conductivity. Results show that the proposed methodology is a flexible tool to obtain posterior model likelihoods updated in a BMA scheme. The BMA prediction results are a good compromise between all the alternative conceptual models and encompasses, in most cases, the 95% confidence intervals obtained with the models individually. This confirms that the estimation of predictive uncertainty based on one conceptual model is prone to bias and underestimation.