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LETTER TO THE EDITOR

Comment on "Equifinality of formal (DREAM) and informal (GLUE) Bayesian approaches in hydrologic modeling?" by Jasper A. Vrugt, Cajo J. F. ter Braak, Hoshin V. Gupta and Bruce A. Robinson

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This comment is intended to follow directly on from the published version of the paper by Vrugt et al. (2008). While I acted as a reviewer for Vrugt et al. (2008), a nagging doubt about some of the results led to some later discussion of the results, which revealed just why the formal Bayesian method appears to give generally better results than GLUE in their application. In particular, following the revision by Vrugt et al. of their manuscript during the review process, I queried the results from the validation period with Vrugt (e.g. Fig. 5, time periods 185–220). The GLUE results are based only on weighted simulations from the set of behavioural models. This reveals that none of those models (or perhaps not enough to influence the upper prediction bound) can reproduce the observed discharges during that period, probably (since the set of behavioural models does well elsewhere) because of a problem with an underestimation of inputs to the catchments. This is not evident, however, in the Bayes results, which fit the observations with low uncertainty.

This is odd because, in calibration, the Bayes methodology incorporates the identification of multipliers for every rainstorm event. Since these are not known for the validation period, a distribution of multipliers must be used for every event. In Vrugt et al. (2008), it is assumed that the 95% confidence limits in the multipliers are (approximately) from 0.7 to 1.3. Even the upper value would not be sufficient, however, to compensate for the apparent underestimation by the GLUE behavioural models in the period 185–220 in Fig. 5. So, either the Bayes methodology is identifying a quite different posterior parameter distribution giving much, much better simulations to GLUE (Fig. 3 does show that the posterior marginal distribution for the $C_{\max}$ parameter is slightly different) or something else is different.

It turns out, from my discussions with Vrugt, that the latter is the case. The formal Bayes estimates are based on an autoregressive error model. This has been implemented so as to produce predictions of the error at time t, conditional on the error at time $t-1$, while taking account of uncertainty in the model parameters and rainfall multipliers. The problem is that, in both calibration and validation, the Bayes estimates are produced assuming that the observed value is known at time $t-1$ in predicting the error at time t. This information is not, however, supplied to the GLUE simulations. The formal Bayes method is, therefore, effectively using one-step ahead forecasting, but it is being compared with GLUE applied in simulation (i.e. not assuming that the observation at time $t-1$ is known).

Thus, this paper is not comparing *like with like*. Two proper comparisons could be made: either both Bayes and GLUE applied to one-step ahead forecasting (GLUE could be applied in this way), or both Bayes and GLUE applied in simulation (Bayes could be implemented with an autocorrelated error model in this way). This was pointed out to Vrugt after the paper by Vrugt et al. (2008) had been accepted, with the suggestion that either or both of the proper comparisons be included before the paper was published.

I do have other issues with the application of the formal Bayes methodology to do with the overestimation of the information content of the residuals in calibration and the compensation for model structural deficiencies by the 57 calibrated rainfall multipliers and consequent highly

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(unrealistically?) constrained posterior parameter distributions. These issues have been discussed more generally elsewhere (see Beven 2006, 2008; Beven et al. 2008). Here, they are undoubtedly less important than the assumption that the observed discharges are known in validation in applying the formal Bayes! The conclusion that a one-step ahead forecasting model beats a simulation model in predicting discharges is hardly a surprise. The greater surprise is that the authors even considered making such an inappropriate comparison.

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