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Hydrology and Earth System Sciences Discussions

Interactive comment on "A novel approach to parameter uncertainty analysis of hydrological models using neural networks" *by* D. L. Shrestha et al.

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In this paper the authors use Artificial Neural Networks (ANN) to help perform Monte Carlo analysis, and predict the ranges of the model output in terms of 5 and 95% quantiles of the prediction uncertainty bounds. The approach is illustrated using discharge data from the Brue Catchment in the UK using the HBV conceptual watershed model. This model has 9 parameters and has been extensively used and discussed in the literature.

Comments:

1. P1678 – 1679: L24 – 4: The authors highlight the GLUE concept of Beven and

coworkers as widely used approach that utilizes Monte Carlo simulations to estimate parameter uncertainty. Other approaches that deserve to be highlighted in this context include Markov Chain Monte Carlo (MCMC) simulation approaches that use iterative sampling to estimate nonlinear parameter uncertainty intervals. Examples of this include the Random Walk Metropolis (RWM), Delayed Rejection Adaptive Metropolis (DRAM: Haario et al. 2006), SCEM-UA (Vrugt et al. 2003), and DREAM (Vrugt et al. 2008) methods that have found application in the field of hydrology. Given the increasing interest in Bayesian sampling, and uncertainty quantification these methods are increasingly likely to be used to estimate parameter and model prediction uncertainty.

2. P1679: 5 – 7: If replaced with MCMC then comparison of statistics of multiple sample paths in parallel would provide a more formal solution to assessing how many model evaluations are required to assess convergence and obtain stable statistics of model output and parameters.

3. P1679: 19 – 22: Dekker and Bouten used ANN approaches to analyze the mismatch between model predictions and observations through a hierarchical analysis approach. This method was able to correct the response functions of a Jarvis type of forest transpiration model, and provide important insights into model structural error. This work deserves to be highlighted within the present context.

4. P1687 – 1688: The authors consider 74,467 different MC runs to define parameter uncertainty with the HBV model. This is a significant number of model runs considering that only 9 different parameters are tuned. Adaptive MCMC simulation with multiple chains in parallel such as utilized in SCEM-UA or DREAM would have generated these results much more efficiently, and would have also produced a calibrated model. My experience suggests that about 25,000 HBV model evaluations are required at most to derive the optimum of the HBV model, and a sample set defining parameter uncertainty. This approach is much more efficient than the MC method considered herein, and provides a statistically exact estimate of the model prediction bounds.

5. P1687 – 1688: L24 – 17: The authors use the Coefficient of Variation to determine how many samples are sufficient to obtain reliable and stable MC statistics. Why did the author select this criterion, and how would the MC results look if another metric was used to characterize the distance between model predictions and observations? Nowadays many hydrologic studies utilize multiple performance functions to measure the quality of a model. In principle, the ME and SDE statistics can be computed with any objective function.

6. P1688 – 1689: Histograms of parameters: MCMC simulation with adaptive proposal updating could have created these results much more efficiently. Also, this approach has a more formal way of testing convergence by comparing the evolution of different sampling paths. This is somewhat similar to the statistics utilized herein, but then applied to a multi-chain method using the R-statistic of Gelman and Rubin (1992). See previous comment related to the introduction.

7. ANN emulating prediction uncertainty bounds: Does this ANN model consider uncertainty in its predictions? That would be appropriate within the current context. Bayesian calibration could in principle be used to derive the posterior distribution of the weights and biases of the network. Also, how does the performance of the ANN depend on the selection of the complexity of the network? Some insights into this might be helpful and appreciated by the readers.

8. P1692, Figure 7: The scatter plots demonstrate considerable autocorrelation between the residuals. This suggests either error in the input data or structural inadequacies in the model or a combination of both. The analysis presented in this paper would be more completely if it includes explicit recognition of model and/or rainfall (forcing) error.

9. P1692. Figure 9: Model prediction uncertainty caused by parameter uncertainty is rather large. Obviously the approach utilized herein to distinguish between behavioral and non-behavioral parameter combinations is not formally Bayesian. This needs to

be highlighted.

10. P1692: What is the computational time required to run / implement the proposed approach, and how does this compare to using standard MC runs with the HBV model? My experience with the HBV model suggests that this model can be calibrated within just a few minutes, including proper assessment of parameter uncertainty. So, there is no need to adopt the approach presented herein for the current problem.

11. How would the ANN model perform during extrapolation? The way the authors have used the ANN in the present context is essentially for interpolation. However, in many practical situations involving computationally demanding forward models it is conceivable that prediction limits are required for yet unobserved events whose magnitude and conditions are quite different than any observed during the calibration period. The ANN model will exhibit severe difficulties producing reliable prediction limits.

12. The impact of the presented work would be greatly improved if the authors provide a software package that others can download and use in their own research. Would it be possible to make available such a package? If not available, I wonder whether the approach developed herein will actually find practical implementation.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 1677, 2009.