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Comment on hess-2021-514

Anonymous Referee #2

Referee comment on "Pitfalls and a feasible solution for using KGE as an informal likelihood function in MCMC methods: DREAM(ZS) as an example" by Yan Liu et al., Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2021-514-RC2>, 2021

General comments:

This study suggests an approach to adapt the KGE through transformation with a Gamma distribution so that it can be better used as an informal likelihood function in calibration procedures. The study finds that the results and inference behavior when using this adapted KGE measure are very similar to the case when using the RMSE as a likelihood function. In a synthetic case study, it is also shown that the presented approach successfully re-infers the known true parameter values.

The manuscript presents an elegant and innovative approach to a solution for a very relevant problem and could therefore be of high value in many fields. The manuscript is very well written, carefully composed and logically structured, and all in all very convincing.

However, it is a bit too brief I feel in some respects and would need to be extended by some theoretical considerations among others (see comments below).

Major comments:

It is not clear to me what the "formal likelihood function" is in this case. The authors say that it is the RMSE, but it would be useful to show an equation that explicitly states which assumptions w.r.t. distribution type (I assume the normal distribution) and standard deviation this corresponds to. For example, something along the lines of: using the RMSE is equivalent to assuming independently normally distributed errors at each time step in a

formal Bayesian inference approach and assuming that the standard deviation is equal to a certain (which?) value at each time step, ideally including the full equation. As is mentioned by the authors, the RMSE is very sensitive to large flows and would not be a typical measure used in formal likelihood approaches in my opinion. There are assumptions that usually work better, such as a standard deviation that is proportional to the predicted streamflow, for example. For a comprehensive overview of the different assumptions on the standard deviation of the residual error (and associate transformations) in formal likelihood approaches, see for example McInerny et al. (2017). In my view, it would make more sense to use one of their suggested approaches as the "formal" approach in this study.

On a related note, the standard deviation of the additive error in formal likelihood approaches is an important parameter that needs to be used in prediction as well. The authors infer the posterior parameter distributions of the model parameters and then use these posteriors for prediction. This is fine if only parametric uncertainty is relevant, but by this, they completely neglect all other sources of uncertainty. The residual uncertainty (i.e., additive error) is very important since it represents the lumped effect of the input uncertainties, model structural uncertainties and observational uncertainties (present here at least in case study 3 as mentioned by the authors). The neglect of all these uncertainties is also the reason for the very narrow distribution of the performance metrics in prediction (Fig. 7 and 9). If actual streamflow predictions including error bands were shown, we would probably see that the observations are not covered at all by the error bands, which is a serious shortcoming if we are interested in reliable predictions.

Technical comments:

Line 44: It is not clear to me what you mean by "they can mimic the weight to small improvements in NSE".

Line 55: did you mean "unsatisfactory"?

Line 55-57: I find this sentence incomprehensible

Line 60: "rates" instead of "rate"

Line 65: replace "theoretically statistical" with "statistically sound", also in other instances if needed

References

McInerney, D. *et al.* (2017) 'Improving probabilistic prediction of daily streamflow by identifying Pareto optimal approaches for modeling heteroscedastic residual errors', *Water Resources Research*. American Geophysical Union ({AGU}), 53(3), pp. 2199–2239. doi: 10.1002/2016wr019168.