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Hydrology and Earth System Sciences Discussions

Interactive comment on "On the colour and spin of epistemic error (and what we might do about it)" *by* K. Beven et al.

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Response to the Referees

We thank both Alberto Montanari and Andras Bardossy for their comments. Both referees provide responses to our discussion of the issues raised rather than suggesting that the paper be modified. We have however made some modifications as noted below.

Alberto Montanari discusses 4 points.

1. the suitability of statistical approaches for assessing the frequency behaviours of hydrological model's errors. 2. The opportunity to treat epistemic errors with statistical

approaches.

These questions are partly a question of philosophy and partly a question of good practice. We would absolutely agree that good practice in the application of statistical methods requires that the assumptions of a statistical model of the residuals are checked for validity. This should be, but is often not, a part of every study using formal statistical likelihood methods.

But even if the assumptions appear to be met, we would suggest that there might still be a possibility that a formal statistical likelihood will overestimate the information in a series of residuals and consequently over-condition model parameter distributions. This is in part because of the effect of epistemic errors leading to nonstationarity in the residual characteristics (e.g. changing rating curves, non-random errors in the inputs), but also from the physics of the system – for example a Gaussian error on the inputs will produce a structured error on the model outputs that has changing autocorrelation structure.

Without accurate a priori knowledge of the nature of the epistemic errors and residual characteristic (which is in practice never available) any probability model resulting in a statistical likelihood is itself a subjective judgment (even if the residual model appears valid) of the modeler and may be in error. It is somewhat unfortunate that this is not recognized in contrasting (as in Alberto's comments) the statistical approaches with "subjective" approaches (we need another word that carries less baggage for approaches with alternative interpretations). As suggested above, the authors believe it is not possible to be objective in the application of statistical methods especially when there are epistemic errors involved. Overconfidence will result if it an objective analysis is believed to be achievable. We have modified the text by introducing a discussion of terminology in the introduction to stress this point.

Alberto is correct that there have been applications of informal likelihoods without any testing of whether they satisfy some objective requirements (even if those requirements

might be different from a formal statistical approach – he notes the advantage of the limits of acceptability approach in this respect). In his view the possibility of such tests is a major advantage of the formal statistical approach. We note in the original manuscript that the non-stationarity of epistemic errors reduces the effective information content and undermines this theoretical advantage (as is evident from the normal expectation of poorer performance in validation than in calibration). We have added text to stress that such tests should be part of good practice.

3. The reduced amount of information delivered by coloured data (model errors for instance).

The comment somewhat misses our point. Our point is that the type of colour induced by epistemic uncertainty is nonstationary and therefore cannot be easily represented by a statistical model. This point already seems to be made rather clearly in the original text.

4. The value of a proper identification of disinformative data.

We agree this is difficult – the approach we have taken is subject to the accuracy with which the master recession curve can represent what might have happened following any particular event and this might particularly affect the analysis of small events.

Alberto also raises a 5th point in his conclusions: the need for a common framework for uncertainty assessment. In one important sense GLUE already provides this (both frequentist and Bayesian statistical approaches can be considered as special cases of GLUE when the strong assumptions of a formal likelihood are justified).

From Andras Bardossy we extract the following comments

1. Some of this kind of removal of data might also lead to false models, for example in the case of systematic errors in the input. . .. The correct treatment of these data would require an appropriate estimation of the bias (in the form of a temporally highly correlated term).

It is indeed easy to show that consistent errors in the inputs will have an effect on posterior parameter distributions. It is much more difficult to identify that effect when there is no prior knowledge of what that (nonstationary) bias might be. So the only prior checks that can be made are for some form of hydrological consistency. If the data appear hydrologically consistent to a hydrologist, then they should contain information even if the consequent inference is biased by unrevealed epistemic errors. If the data appear hydrologically inconsistent then (unless the reason for the inconsistency is known and can be allowed for) they should not be treated as informative. Using them in model identification will certainly lead to much greater bias. Thus we are at least taking a step in the right direction.

2. Our experience shows that models can be well identified on a very small subset of observations which contain unusual periods with partly highly dynamical precipitation changes and some longer dry periods. A positive approach of choosing the informative data is also possible.

We would agree and this is certainly not inconsistent with what is being suggested. It does raise an interesting issue, however. In what way is it possible to differentiate unusual periods of consistent informative data from unusual periods of inconsistent disinformative data!!

We have considered all these points in preparing the revised version of the manuscript.

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