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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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I enjoyed reading this paper which in my opinion sheds new light on uncertainty estimation in hydrology and the behaviours of different methods recently proposed by the literature. I think that the manuscript is very well written and organized and therefore I certainty recommend publication on HESS.

Accordingly to my perception there are some very interesting issues that are discussed in this paper which I would like to comment in my review. What follows are just hints for the discussion and not critical comments to the paper. I hope the authors may find them useful. The above major issues are:

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.
3. The reduced amount of information delivered by coloured data (model errors for instance).
4. The value of a proper identification of disinformative data.

1 Suitability of statistical approaches for assessing the frequency behaviours of hydrological model's errors

The suitability of statistical methods for uncertainty assessment in hydrology has been long discussed. The alternative, as Beven et al. (2011) say, is the use of subjective methods like GLUE. First, let me say that I have nothing against subjective methods. Engineers and hydrologists are well used to take profit from expert knowledge in applied design and therefore I do not think that subjectivity is anathema to science (Beven et al., 2001, page 5359, line 7). But I think that subjective decisions need to be justified and their validity must be adequately substantiated, as it is done in statistics.

Actually, I have a personal belief that statistics is a set of tools to objectively profit from experience. Objectivity in statistics is supported by statistical tests that allows us to check the validity of any assumption. I agree with Beven et al. (2011) that the use of statistics for uncertainty assessment in hydrology must rely on the identification of a proper statistical model for simulation and prediction errors. If the above model does not provide a good fit, then uncertainty assessment is not reliable. Certainly hydrological errors are often non-stationary, non-Gaussian and heteroscedastic and therefore a Gaussian likelihood (Beven et al., 2001,

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page 5364) is not appropriate in many cases. As I repeatedly stated (Montanari and Brath, 2004; Montanari and Grossi, 2008) a relevant issue is to identify a reliable error model and the hydrological literature provides us with many possible solutions. For instance, I believe the meta-Gaussian model (see the above references) is a good solution which in many cases allows one to correctly fit the non-Gaussian, non-stationary and heteroscedastic behaviours of the hydrological error. Of course, goodness of fit must be checked; once statistical tests are satisfied I am convinced that statistical models provide good performances. On the other hand, I admit that identifying a proper statistical model is not always possible and I agree with Beven et al. (2011) that using an improper model leads to overconditioning. But I doubt that overconditioning may arise when proper statistical tests are used.

The reason why I am skeptical with certain ways of using GLUE is that subjectivity is sometimes not justified, namely, subjective choices are often used without inspecting their effects on uncertainty assessment. For instance, I recognise that GLUE can reproduce a heteroscedastic error, but how can we check that heteroscedasticity is correctly reproduced so that uncertainty is well assessed during floods as during droughts?

Moreover, as Beven et al. (2011) say, epistemic errors may change their behaviours from calibration to validation and it seems to me that GLUE may fail against this behaviour (as well as statistical methods). Only the recent introduction of the limits of acceptability approach (Liu et al., 2009) provides a support to assess the above goodness of fit, but still their validity in validation is questionable.

Thus, I do not fully understand the criticism of Beven et al. (2011) for statistical approaches. I agree that sometimes they may fail in providing a correct assessment, but the use of statistical tests allows us to assess their limitations. When a formally correct statistical approach is not possible I fully endorse the use of

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informal (subjective) methods (I myself used GLUE in many occasions; see Winsemius et al., 2009). Sometimes engineers and hydrologists need to provide an answer (to design) anyway and in this case the use of expert knowledge is welcome. But I believe subjectivity must be always properly justified.

2 The opportunity to treat epistemic errors with statistical approaches

I fully agree with Beven et al. (2011) that hydrological uncertainty is largely epistemic. I also agree that epistemic errors are coloured, namely, affected by regularities (correlation, time dependence, etc.). It seems to me that Beven et al. (2011) imply that epistemic errors are non-random and therefore cannot be properly treated with statistical approaches (see 5374, lines 5-10). I tend not to agree with such interpretation.

First of all, let us emphasise that random variables can be coloured, non-stationary, non-Gaussian and heteroscedastic but nevertheless can be well fitted by using statistical models. Second, epistemic errors as well can be well fitted by a statistical model, provided that the inherent regularities (colours), which are the expression of underlying deterministic processes which we do not know, are well represented by the statistical model itself. A trivial example is given by seasonal processes. These are affected by cyclical non-stationarity resulting from underlying physical processes which we cannot represent with a deterministic model. Therefore one may decide (there are plenty of examples in the literature) to preliminarily remove the seasonal components in the statistics of the investigated random variable therefore making it (weakly) stationary.

Another trivial example could be the following: let us suppose that discharge in a given river is related to observed random rainfall (in a given raingauge) by a deterministic non-linear relationship affected by a monotically increasing trend. In this case, even if rainfall is stationary, the corresponding river discharge would be

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a non-stationary random variable. If one knew the structure of the above rainfall-runoff relationship, the best way to model river discharge would be the use of the above deterministic model with random input (rainfall). On the other hand, one ignoring the above relationship may decide to simply consider river discharge as a non-stationary random variable. Then, he might decide to preliminarily transform the data by removing the trend therefore obtaining a stationary signal, that can be fitted by a stationary model. Of course additional uncertainty is introduced with this second approach, which is given by neglecting some information therefore inducing epistemic uncertainty. But what is the problem in modelling it with a statistical approach? Of course when sufficient information is available there is no doubt that a deterministic model should be used. But when a deterministic model cannot be used for lack of information or inherent randomness, I do not see any problem in using statistics. And I would welcome a different (perhaps subjective) approach if even statistics cannot be used for some reasons.

3 The reduced amount of information delivered by coloured data

I fully agree with the authors that coloured data (or coloured residuals) provide less information than independent data. This is a well known result with tremendous practical effects, which is discussed, among others, by Koutsoyiannis and Montanari (2007) and Koutsoyiannis (2010). I do not think this is a relevant problem but of course it strongly affects the amount of information delivered by hydrological observations.

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4 The value of a proper identification of disinformative data

I believe this is one of the most significant issues treated in this paper. Indeed, disinformation (unreliability of some data sets or part of them) is an issue that is frequently ignored in hydrology and I believe it is very significant and interesting to point out its potential consequences. The problem is not easy to solve. As Beven et al. (2011) correctly say (Beven et al., 2001, page 5367, lines 24-27 and page 5369, lines 19-21).

5 Conclusion

As I said, I enjoyed reading this paper, but it made me somehow wondering about the actual necessity to distinguish between different philosophies for uncertainty assessment in hydrology. Actually I am not satisfied by the outcome of the discussion on the opportunity to use statistics versus other solutions. The outcome of the discussion is often not clear. We often failed in delivering a useful recommendation about the most advisable method to use depending on user needs and data availability. Actually, our target is very clear: we need to assess uncertainty of hydrological simulations/predictions basing on the available information and our experience. I would like to be able to propose a unified theoretical framework where the distinction among different approaches is simply dictated by the problem to solve and its peculiarities (data availability, data reliability, problems in writing a formal likelihood, computational requirements etc) instead of being based on personal opinions and preferences. This is the target which I believe we should aim to.

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6 References

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