Response to Referee 2, H. Gupta

Referee Comments (Hoshin Gupta) on “Uncertainty in hydrological signatures by IK Westerberg and HK McMillan" submitted to HESS

I. Contributions of the Paper

A) Goals: (1) To contribute to awareness of signature uncertainty, including typical sources, magnitudes and methods for assessment. (2) To propose a general method for estimating signature uncertainty. (3) To demonstrate how typical uncertainty estimates translate to magnitude and distribution of signature uncertainty in two example catchments.

B) Summary: A diagnostic hydrological signature quantifies information from observed data as an index value. Uncertainties in the observed data, and subjective choices in the calculation method, propagate into the signature values and reduce their information content. However, uncertainty sources and distributions are application-specific, making a general analytic solution for signature uncertainty difficult. This paper reviews the uncertainties relevant to different signatures in rainfall and flow data, and proposes that a Monte Carlo simulation can provide a generally applicable and flexible method, by sampling equally likely possible realizations of the true data values, conditioned on the observed data (where multiple data sources are needed, grouped samples are used). Each realization is then used to calculate the signature value, and the values collated to give the signature distribution. Results are demonstrated for two catchments.

C) Findings: 1) Uncertainties are often large (±10–40% relative uncertainty) and highly variable between signatures. 2) Greater uncertainty in signatures that use highfrequency responses, small data subsets, or subsets prone to measurement errors. 3) Lower uncertainty in signatures that use spatial or temporal averages. 4) Some signatures are sensitive to particular uncertainty types such as rating-curve form.

D) Conclusions: Signatures can be designed to be robust to some uncertainty sources. Signature uncertainties of the magnitudes found have the potential to change the conclusions of hydrological and ecohydrological analyses, such as cross-catchment comparisons or inferences about dominant processes.

II. Referee Comments (Hoshin Gupta): This is a very well conceived and written paper. The organization and presentation are excellent. The subject matter is both timely and addressed in a clear and comprehensive manner. I recommend publication with no reservations.

Since I am not very well versed in the sources and nuances of observation/data uncertainty, I focused my review my attention mainly on the methodology applied. In general I concur that the Monte-Carlo approach is a suitable way to approach the problem of estimating signature uncertainty (and is more generally applicable in the context of data assimilation – i.e., estimating attributes of a dynamical systems model from data). The key sensitivity of the results will, of course, be to the choice of sampling distribution, and a certain amount of subjectivity is necessarily involved therein.

I commend the authors on another noteworthy paper (in their growing list of excellent contributions to the literature). I wonder only if they might choose to comment on (perhaps in the conclusions) in more detail on how the inevitable subjectivity involved in choice/construction of the sampling distribution might influence any interpretations, and whether (perhaps) the use of maximal entropy

forms of sampling distributions (conditional, of course, on the actual data and what is qualitatively known), might help in this regard.

Response: We thank Hoshin Gupta for his very positive and kind comments about our paper. There is certainly some subjectivity in the choice of the uncertainty estimation methods and these should be motivated by the perceptual understanding of the uncertainty sources. We agree that this is an important consideration and are currently involved in a comparison study that aims to compare and better understand the effects of assumptions and methodological choices when it comes to estimating discharge uncertainty. We mentioned this issue briefly at the end of the introduction (P4237, line 13-23) to draw attention to this at the start of the paper. However, we agree with all the reviewers that it would be good to have some further discussion at the end of the paper and will therefore introduce an extra paragraph in the discussion in section 5.2.

With regards to the choice of sampling distribution, an example is the specification of the prior parameter distributions for the rating-curve parameters that can influence the results in the estimation of rating-curve uncertainty with the MCMC Voting Point method. This occurs primarily when the rating curve is extrapolated to ungauged flow levels, in particular if there are few gaugings in the high-flow section of the rating curve so that the prior distribution plays a larger role. In effect the prior distribution is playing the role of a perceptual model that brings information to the estimation problem, as Hoshin Gupta has discussed in recent papers – we will note this in the discussion. This addresses an epistemic type of uncertainty related to lack of knowledge about the true stage-discharge relation that might be reduced by introducing new information (e.g. about the river cross-section and its characteristics) to constrain the uncertainty magnitudes. We will include some further discussion about this in the revised discussion.