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Hydrology and Earth System Sciences Discussions

Interactive comment on "An educational model for ensemble streamflow simulation and uncertainty analysis" *by* A. AghaKouchak et al.

A. AghaKouchak et al.

amir.a@uci.edu

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The authors thank the anonymous reviewer for his/her thoughtful comments and suggestions which led to substantial improvements in the revised version. In the following, the issues raised by the reviewer are addressed point-by-point in the order they are asked. Reviewer comments are shown in italic; authors' reply is shown in regular text. For convenience and better tracking of changes, a copy of the manuscript with the changes highlighted is included.

RC: Anonymous Referee 4

RC: Received and published: 26 August 2012

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Interactive Discussion

Discussion Paper

RC: General comments The paper describes the HBV-Ensemble modelling toolbox and how it has been used in teaching. The use of hands-on tools like this toolbox is valuable for teaching students about rainfall-runoff modelling and how it can be used to simulate hydrological processes. A valuable contribution of the toolbox is that it addresses the uncertainties inherent in the modelling of natural hydrological systems. However, the quality of the paper can be improved from a number of aspects (see below) and I recommend a major revision of the text before it is published.

1) A more in-depth literature review on how similar modelling tools have been used in teaching and what has been found regarding their effectiveness in improving student learning is needed. This would also be important for reference in the discussion of the results.

We agree that a more detailed literature review would improve the paper, and we have added references to several recent and novel developments in hydrology education. We point out that there are several other papers in this special issue (Hydrology education in a changing world) that provide literature review (e.g., [1], [2], [3], [4], [5]). We have tried to minimize the overlap with other papers in this special issue.

2) The aim of the study could be more clearly stated, also against previous studies.

This objective of this study is to introduce HBV-Ensemble which is a recently developed educational software for teaching ensemble simulation and uncertainty analysis. More information is added to Paragraph 6 in Section Introduction.

3) The abstract only describes the toolbox not the paper/study as a whole. The conclusions part is now written like an abstract, I would suggest using this part as the basis for the new abstract and deleting or substantially shortening the conclusions section.

Following the reviewer's suggestion, the abstract has been revised. Section Conclusions includes a very brief summary of the work and, in our opinion, should not be shortened.

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4) Instead of having the Conclusions section it would be more interesting to include a Discussion section that discussed the results and gives an outlook to the future about how teaching using the toolbox can be developed, and how the toolbox itself can be further developed. The experiences from this study in light of what others have found in previous studies also needs to be discussed. More discussion on modelling uncertainty in the teaching is needed given that this is a main focus of the paper.

These issues are addressed below in response to Specific Comments. In brief, the Section 3 is changed to Student Feedback and Discussion. A discussion on how this tool can be further developed is included (see last Paragraph in Section Student Feedback and Discussion). Other studies related to uncertainty analysis such as Wagener et al., 2004, Beven 2009 and Seiger and Vis 2012 are acknowledged in the manuscript.

5) The term "model" is used instead of "modelling toolbox" in several places throughout he paper. Since the hydrological model used is HBV, it would be better to consistently refer to HBV-Ensembles as a "modelling toolbox" to avoid confusion.

We agree. The term model, when referring to HBV-Ensemble, has been changed to modeling toolbox or educational toolbox.

Specific comments

1) Page 7298, line 18. Not only hydrological extremes, but also water balance is important, especially for this type of model application.

Water balance is added.

2) Page 7299, line 5. "Student centred methods" sounds vague, can you give an example?

A discussion on student-centered methods is beyond the scope of this work. We have provided a reference for interested readers (Ngambeki et al., 2012)

3) Page 7299, line 25 change "batch simulations" to "Monte Carlo simulations for

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uncertainty analysis". Since the HBV-light enables uncertainty estimation using Monte Carlo methods and is used for this in teaching hydrology (see e.g. Seibert and Vis, 2012 in this special issue), it would be relevant to describe this further – especially considering the discussion on page 7300, line 10-13. It could also be made clear how the uncertainty estimation using HBV-Ensembles differs from the one in HBV-light and other toolboxes used in education such as RRMT (also implemented in Matlab, Wagener et al., 2004)

"batch" is replaced with "Monte Carlo" We have acknowledged Seibert and Vis, 2012. The main difference is that HBV-Ensemble provides an ensemble of streamflow simulations. The Monte Carlo-based uncertainty estimation part is similar in the two models. It should be noted that HBV-Light [2] also includes a Genetic Algorithm and Powell optimization (GAP) module for uncertainty estimation. This feature is not available in HBV-Ensemble. Wagener et al., 2004 is acknowledged.

4) The background section on uncertainty estimation in hydrological modelling and the references in this section could be revised, e.g. referring to books like Beven, 2009, and review studies on the topic. It would be good with a few sentences about the different uncertainty estimation methods there are (statistical, non-statistical, etc) as an overview and background to the method chosen here.

In the revised version, the discussion is extended and the readers are pointed to Beven 2009 for more details on different methods of uncertainty estimation.

5) Page 7302, paragraph 1. This section could be deleted as this is covered in the introduction and background and no references are given for the statements.

The paragraph is deleted.

6) Page 7303, Line 8-16. This needs to be revised as much information is repeated within the paragraph and with previous paragraphs. "all simulations that satisfy the objective function will be accepted as one realization in the ensemble output" this is

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not clear, how are all the simulations one realisation?

The repeated part was eliminated from the revised version. Thank you.

Also, the above sentence is revised as: "Each accepted simulation will then be a member in the final ensemble. Alternatively, one can select the best simulations (e.g., top 100) that lead to a root mean square error below an acceptable threshold."

7) Page 7303, line 5. How are the samples drawn – from a uniform distribution?

We have used built-in MATLAB function to draw samples uniformly between the upper and lower bounds of parameters.

8) Page 7303, line 12. The correlation coefficient is mentioned as well in another part of the paper.

Correlation coefficient is added to point 5.

9) Page 7303. The difference to GLUE is not clear and point 5 is repeated

We are using GLUE for parameter estimation (see Point 5 in Section 2). The repeated point is eliminated.

10) Page 7304, Line 10-12. Could be change to "The grey lines show the uncertainty limits for all the acceptable parameter value sets, the simulation from the best-estimate parameter-value set is also shown."

We have revised the sentence based on the reviewer's suggestion.

11) Pages 7305-7306. Discuss how uncertainty in the modelling was handled in the teaching and perceived by the students. Discuss how the modelling toolbox and the teaching using it can be further developed in the future.

Students were asked to change model parameters and initial values and report their observations by preparing figures similar to Figure 4 in [7]. Two of the questions in Figure 5 were related to uncertainty, sensitivity, and ensemble simulations, and stu-

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dents' response provides some information on how it was perceived by the students. We have added a brief discussion on how the manuscript can be developed further in future (see the last paragraph in Section Student Feedback and Discussion).

12) Fig. 2. It would be good to plot the rainfall and temperature data in a subplot to show students how the runoff relates to the input. Simulated should be "best-estimate simulated".

Following the reviewer suggestion, precipitation and temperate data are added to Figure 2.

Technical corrections A detailed review of the text with respect to language is needed and repeated text could be deleted in several places.

The revised version has been edited.

References Beven, K. J. 2009. Environmental Modelling: An Uncertainty Future? Routledge, London T. Wagener, H. S. Wheater, H. V. Gupta, 2004. Rainfall-runoff modeling in gauged and ungauged catchments. Imperial College Press, London.

Both Beven 2009 and Wagener et al., 2004 are acknowledged.

References

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 7297, 2012.