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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.

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The authors would like to thank Dr. McMillan for her constructive comments and suggestions which led to substantial improvements in the revised version of the manuscript. In the following, the issues raised by the reviewer are addressed point-by-point in the order they are asked. Dr. McMillan's 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: H. McMillan (Referee)

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RC: Received and published: 14 July 2012

RC: This paper describes a hydrological modelling GUI which has been designed as a teaching tool. The GUI is built in Matlab and runs a version of HBV as the hydrological model. The main differentiating point between this and previous teaching software is the ability to create and run an ensemble of models. The ensemble is created by random sampling of parameter sets, with parameter values between lower and upper bounds selected by the user. The software then uses the model ensemble to create confidence bounds around the simulated streamflow. The paper is clearly written and addresses an important question; namely how to introduce students to the uncertainty inherent in parameter choice for hydrological models, and the effects of this uncertainty on the modelled flow. However there are several points where I feel the paper and modelling tool could be improved.

RC: 1. The modelling concept is very similar to the GLUE procedure as introduced by Keith Beven. The authors should make this clear, and perhaps comment on the GLUE demonstration software already made available by Keith through the Lancaster University web site. One difference is that HBV-Ensemble does not weight the ensemble members by their NS score: the authors could comment on why they chose not to do this.

The reviewer is right. In fact, in Section 2, we have already mentioned that the parameter estimation is based on the Generalized Likelihood Uncertainty Estimation (GLUE; [1]). Per reviewer's suggestion, we have added the following to Section 2: ". . .- see GLUE demonstration software available through the Lancaster University for more information" It should be noted that the purpose of this model is to provide a simple and easy to use toolbox for educational purposes. For this reason, we have simplified the HBV model and ensemble streamflow simulation.

RC: 2. In Section 2.1, the list describing the procedure has bullet 4 repeated and seems to miss a description of how all ensemble members are run and the confidence

bounds are created. It also states that the 'model gives the best set of parameters using GLUE' – but GLUE does not give a best set of parameters.

The repeated bullet is eliminated. Regarding simulations, as mentioned in the paper ([2] section 2), after sampling the parameters (e.g., 1000 sets), the model will run all parameter combinations. Then, the model, accepts simulations (ensemble members) and parameter sets that satisfy a certain objective function (e.g., Nash-Sutcliffe coefficient above 0.7). 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. Here, the best set of parameters is defined as the set of parameters that lead to the best objective function (e.g., highest Nash-Sutcliffe coefficient, lowest root mean square error). More information is added to this section of the manuscript to make everything clear.

RC: 3. A helpful addition to the software would be an ability to view the 'dotty plots' which are commonly associated with this type of analysis, i.e. scatter plots of each parameter value against the performance measure. This would be a good way to introduce the students to sensitivity analysis and see whether the parameter bounds chosen were reasonable.

We agree with the reviewer's comment. Work is in progress to include dotty plots. This will be added to the package in the next version.

RC: 4. The software is said to produce the 'Simulated Runoff'. Is this the ensemble median? Or a deterministic run. It is not clear.

The model does not calculate the ensemble median. The outputs include one deterministic run based on the best set of parameters (as described above), and all accepted members of the ensemble streamflow simulation procedure mentioned in Section 2. Of course, an interested user can easily calculate the ensemble median.

RC: 5. There is some confusion in the paper about applications of the software which

do or don't use the ensemble feature. In the Section 3. Application, there are several comments which suggest that a deterministic model is being used, e.g. students 'changing the parameters' and 'comparing output hydrographs'. The authors should make clear whether their software also provides for deterministic simulations, and which applications relate to the deterministic vs ensemble version.

We do not believe that 'changing the parameters' and 'comparing output hydrographs' indicate that the model is necessarily deterministic. As discussed above and in the manuscript (Section 2), the model presents an ensemble of streamflows in addition to streamflow based on the best set of parameters.

RC: 6. It would be nice to see some applications which specifically use the ensemble feature of the model, since that is the focus of the paper. For example, how does changing the performance measure used and the behavioural threshold change the spread of the ensemble? Is the spread different in different parts of the hydrograph (rise, peak, falling limb, recession period)? Which parameter bounds have most effect on the ensemble spread? The last question would become much clearer if the dotty plots suggested above were presented.

RC: 7. A further useful extension would be to provide some performance measures for the simulation ensemble. These could be simple (e.g. % of time the measured flow is within the ensemble bounds) or more complex such as skill score or rank histogram.

Response to Comments 6 and 7: We would like to stress that the purpose of this paper is to introduce HBV-Ensemble and its capabilities for hydrology education. This education toolbox is designed such that it can be used in undergraduate courses. Topics such as the effects of the performance measures and behavioral threshold on the spread of the ensemble are beyond the scope of undergraduate hydrology. On the other hand, at this point, the model does not include features with which one can quantitatively describe the effects on parameter bounds on ensemble spread, and/or differences in the spread. While one can do extra processing and use ensemble

members for such analysis, this paper focuses on what can be done with this particular toolbox.

References

[1] Beven K.J., Binley A.M., 1992, The future role of distributed models: model calibration and predictive uncertainty, Hydrological Processes, 6, 279-298.

[2] AghaKouchak A., Nakhjiri N., Habib E., 2012, An Educational Model for Ensemble Streamflow Simulation and Uncertainty Analysis, Hydrology and Earth System Sciences Discussions, 9, 7297-7315, doi:10.5194/hessd-9-7297-2012, 2012.

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