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Discussions

Interactive comment on "Parameter-state ensemble data assimilation using Approximate Bayesian Computing for short-term hydrological prediction" *by* Bruce Davison et al.

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Responses to RC1

Thank you for the positive "overall recommendation." In answer to your major and minor concerns:

Major Concerns

1) I had to go back to the methods sections several times to interpret what methods were covered by "P-SEDA" and how the method was applied. Algorithm 1 is extremely helpful, but I would suggest a second algorithm or a flow chart that is specific to the

P-SEDA method applied, and perhaps specific to the 3-day moving window application presented in the manuscript. The manuscript should be more explicit about how P-SEDA is different from Algorithm 1.

Author Response: A second algorithm is added in section 2.7 to illustrate how the P-SEDA method is applied and how this is different than Algorithm 1.

Pseudo-code of the implementation of the ABC algorithm in this paper
Require: A positive integer ($M = 10,000$) and an integer between 1 and M ($k_M = 10$).
for $i = 1$ to $10,000$ **do**
generate parameter set i from all possible parameter sets using LHS;
generate streamflow i using the model (MESH)
end for
return The parameter sets with the lowest 10 RMSE values between observed and simulated streamflow values from the $10,000$ model runs. (This is the filter.)

2) I cannot tell from the description in the methods section if the filters are applied sequentially or if they always draw from the same set of 10,000 simulations. This is stated more clearly in the conclusions. Because the majority of particle filters are applied sequentially, it should be clear early on that this is not the case in this paper.

Author Response: The following sentence will be added at the end of section 2.1 to clearly state up front that the filters are always drawn from the same set of parameters. "Unlike the majority of particle filters, which are applied sequentially, the P-SEDA approach always draws from the same set of M simulations."

3) I would not expect three days of streamflow to be enough to determine reasonable streamflow parameters. The parameters that produce good baseflow are rarely the same parameters that produce good flood peaks. Please provide more justification for testing this method

Author Response: This is an excellent point. The relatively small size of the basin

(1,324 km^2) provides some justification for smaller time periods to be used as filters. The 3-day filter would likely be completely unsuitable for basins that are much larger. In addition, the results of the parameter and preceding streamflow filter illustrate that obtaining reasonable results during rainfall events require more than the 3-day filter of streamflow alone. The reviewer's point that parameters that produce good baseflow are rarely the same parameters that produce good flood peaks provides justification for an application of the P-SEDA method that includes parameter sets that produce good baseflow as well as parameter sets that produce good flood peaks, or more likely parameter sets that produce simulations that capture the transition between low and high flows.

The final sentence of the third paragraph in section 4.2 will be changed to include "... rain during dry conditions, baseflow conditions, flood peaks, transitions between low and high flows, or whatever else..."

In addition, the following paragraph after the third paragraph in section 4.2 will also be added: "The relatively small size of the basin (1,324 km^2) provides some justification for the relatively small time period of three days to be used as a filter. The 3-day filter would likely be completely unsuitable for basins that are much larger. However, the results of the parameter and preceding streamflow filter illustrate that obtaining reasonable results during rainfall events requires more than the 3-day filter of preceding streamflow alone. One possible solution to this problem is to have a longer filter period, but other options also exist, as described in the following paragraphs."

Finally, a short paragraph will be added at the end of section 4.2. "All such possible methods to improve the P-SEDA approach require further examination that is beyond the scope of this paper."

Minor concerns

1) Tables 4 5, lines 10-25, p. 13, and Figure 8, Conclusions: terminology suddenly changes. "Projection methods" were never defined; previously the four P-SEDA meth-

ods were all referred to as "filters". It is unclear which is the "3-day filter" and which are projections. I assume they correspond to the previously defined filters as follows, but I am not certain: a. 3-day filter = minimized uncertainty filter b. 3-day projection = preceding streamflow filter c. bulk projection = bulk calibration filter d. 3-day projection with constrained parameters = parameter and preceding streamflow filter.

Author Response: We appreciate the reviewer pointing this out and will change tables 4, 5, lines 10-25, p.13 and Figure 8 to correspond to the previous definitions.

2) Line 21, p. 6: Instead of saying "ensemble data assimilation filters", say "P-SEDA" filters. Otherwise, it is not clear that P-SEDA encompasses all 4 filter approaches.

Author Response: We agree and will make the change in text as suggested.

3) Lines 30-31, p. 13: I assume that you do not use the bulk calibration filter here because it performed poorly, but it is probably worth stating that.

Author Response: Yes. This is correct. The following sentence will be added to the end of the first paragraph in section 3.6. "The bulk calibration filter is not considered due to its poor performance."

4) Line 32, p. 17: The reason you chose to focus on 2014 should be stated in methods.

Author Response: The last two paragraphs of section 4.3 will be moved to the end of section 2.8 in the methods.

5) How do the authors propose to implement the parameter and preceding streamflow filter? Operationally, one would not extract parameters for all days during a year's precipitation events before setting the parameter range for this filter. Would it be based on the previous year's filter or would the parameter prior distribution be updated based on the days leading up to the current date? How would that impact the result? This is touched on in the conclusions, and it is probably beyond the scope of this study, but it would be helpful if this limitation were mentioned in the methods section.

Author Response: Yes. The implementation of this filter in an operational setting would be a problem. It was mainly included to show that a small subset of the 10,000 LHS runs could be used more effectively than the full 10,000 parameter sets. The application of the approach operationally would have to use a different method to determine a more effective set of parameters. As per the reviewer's suggestion, the following sentence will be added at the end of section 2.7.4: "It is worth noting here that this filter would be difficult or impossible to implement operationally for this basin in the same way it is implemented in this study, particularly in the spring and early summer. It is included in this study to highlight some of the limitations of the other filters."

6) Line 8, p. 19: Shouldn't it be the minimized uncertainty filter that shows the model is capable of simulating streamflow for any 3-day period.

Author Response: Yes. This will be corrected in the text.

Typos, grammar, etc.

1) Line 23, p. 9: "eror" -> "error"

Author response: This will be corrected.

2) Line 25, p. 13: I'm pretty sure you mean 4c to 4e and 7.

Author response: This will be corrected.

3) Lines 20-21, p. 15: "...including the state of basin storage in the assessment of equifinality clearly shows that the parameter-state sets are not equal." I'm not sure what is meant by "assessment of equifinality." Also, please refer either to a figure, a table or a citation that supports this.

Author response: Thank you for pointing this out. This sentence is not clear and the paragraph will be adjusted as follows:

"The issue of widely-varying simulated basin storage (Figure 4c) also highlights the issue of equifinality, which is defined here as the idea that many different model simu-

lations can produce acceptable results (Beven, 1993). The model is able to find many parameter-state sets that fit the streamflow for short periods of time. If only streamflow observations are available, the selected simulations are equifinal. However, including the state of basin storage clearly shows that the parameter-state sets are not equal. If soil moisture observations are also available and used, then these simulations are not equifinal and the selected simulations can be further constrained."

The following sentence in the original manuscript will begin as a new paragraph.

4) Figure 1: Color of lakes and rivers in legend should match their color in Fig. 1c.

Author Response: The figure will be changed accordingly.

5) Figure 2: The toolbar at the top should be removed.

Author Response: The figure will be changed accordingly.

6) Figure 5: Plot storage on the same scale in a and b. I'm guessing the solid black line is precipitation and the dots are storage simulated by the best 10 parameter sets. A legend would help.

Author response: The figure will be changed accordingly.

7) Table 4: "assessement" -> "assessment"

Author response: This will be corrected.

Beven, Keith. "Prophecy, reality and uncertainty in distributed hydrological modelling." Advances in water resources 16.1 (1993): 41-51.

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