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Detailed responses to Reviewer 2's comments

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First, we would like to thank the Reviewer 2 who conducted a thorough review and provided relevant comments and suggestions. The modifications in the revised version of the manuscript are highlighted in blue. Below are detailed responses to all of Reviewer 2's comments.

The two reviewers suggest the use of observed discharges data to validate the results. However, it is not possible to validate the results as the reviewers suggest. The estimated discharges are obtained with a technique combining hydrologic models, interpolation and data assimilation. So, at the river sections where there is true observations, these observations are assimilated. So the real data cannot be used to validate in a strict senses the estimated discharges.

Estimated discharges at gauged sections still contain some uncertainty, primarily due to rating curve uncertainty when estimating discharges from water level measurements, especially for high discharge values. At ungauged sites, this uncertainty is greater and increases with the river distance from a gauging station. These sources of uncertainty affect the precision of return level estimates. In the manuscript, we aimed to show these impacts of uncertainty on return level estimations for both gauged and ungauged sections. To further emphasize this point in the revised version, we added Section 4.5 to analyze a gauged river section. This new analysis is twofold: first, it demonstrates the flexibility of the proposed approach to model uncertainty, and second, it shows the impact of including interpolation uncertainty in the return level estimates.

It would have been interesting to perform a cross-validation where real observations from a river section were withheld from assimilation, allowing us to compare the estimated return levels with the actual data and the estimated discharges. However, such cross-validation data were not available at the time.

That being said, the estimated discharges were already evaluated at sites with observations in Lachance-Cloutier *et al.* (2017), but the emphasis was not on annual maxima.

Summary

In this manuscript, the authors outline a seemingly novel method for estimating annual maximum streamflow at ungauged river sections using the results of hydrological modeling and a Bayesian inference method. The paper is generally clear and well-written, and the results are interesting, if somewhat limited in scope. I admit that I am not familiar enough with the methods to evaluate the details of the calculations. However, I find the strong emphasis in the paper on the uncertainty of estimates, as opposed to the estimated magnitudes themselves, somewhat puzzling. I feel that either the latter needs to be emphasized more, and validated against measurements if possible, or else the authors need to tell readers why it is of secondary importance compared to uncertainty reduction. This is the substance of the Principal concern detailed below.

Thank you for the review. We placed strong emphasis on describing uncertainty because our goal was to incorporate the uncertainty of the estimated discharges into the extreme value analysis. We believe that incorporating and utilizing this information results in more reliable extreme value estimates. This paper aims at describing a relatively simple method for including discharge uncertainties and combining multiple sources of information.

Principal concern

1. The authors emphasize the reduction in uncertainty of the annual maximum streamflow estimates at ungauged locations that results from their applied method, which propagates to estimates of extreme value distribution parameters and return levels. However, it isn't clear to me whether their method also improves their estimates of the magnitude of discharge. Isn't that equally (or more) important?

   It improves the discharge estimates by incorporating multiple sources of information: six hydrologic model configurations and the unobserved maxima from other years. The uncertainty on the true discharges is smaller than that from a single hydrological configuration due to the mild assumption of conditional independence. The method also provides an uncertainty description that would be impossible to achieve with the simpler methods discussed in Section 4.4. We added more details in Section 4.4 about this point.

2. If I understand correctly, the key results of the study are contained in Figures 2b and 5. Comparing the median values in each annmax time series, it is evident that they are systematically larger in the former series: the temporal mean appears to be roughly 1500 m3/s in Fig. 2b but $<$ 1000 m3/s in Fig. 5. Furthermore, the confidence intervals of the posterior estimates would seem to rule out even the median values from each of the 6 simulated series shown in Fig. 2b. In other words, the differences in streamflow maxima between the two series are substantial. My question is, I believe, a very natural one: can it be established that the posterior estimates are likely to be closer to the true streamflow maxima?

   Yes this is correct. We believe that the posterior etimates are closer to the true streamflow as it efficiently combines the available information.

3. While I understand that the authors developed their method to provide information on ungauged sections of the river, I don't see why their procedure omits an evaluation step wherein one or more observed streamflow time series on gauged sections of the river are compared with simulated values at the same location, such as those shown in Figs. 2 and 5.

   The estimated discharges were already evaluated at sites with observations in Lachance-Cloutier *et al.* (2017). In sections with observations, the log-discharge uncertainty is very small, and all hydrological configurations are equivalent due to data assimilation. Therefore, comparing to data is not relevant, as the data have already been used in the discharge estimations. Nevertheless, it would have been interesting to perform a cross-validation where real observations were withheld from assimilation, allowing us to compare the estimated return levels with the actual data and the estimated discharges. However, such cross-validation data were not available at the time.

Some specific questions I would like to see addressed are the following:

1. Could a map be provided, similar to Figure 9, showing the locations of stream gauges where historical measurements exist? At the top of page 6, the authors refer to "...historical observed

daily values from 1961 to 2020 over more than 80 measuring stations.” Were these data not available to them?

A map of the gauged river section is available at `https://www.cehq.gouv.qc.ca/atlas-hydroclimatique/stations-hydrometriques/index.htm`. Since we did not use the real observations directly for the reasons mentioned at the beginning of this document, we did not include this map in the manuscript. However, if the reviewers believe it is important, we would be happy to include it.

2. Would one such location be near the outlet to the Chaudière watershed, where modelled results are shown in Figures 2 and 5? If so, could the authors plot the observed annmax time series at that location, along with the simulated results, to make a comparison?

   We added Section 4.5, where we analyzed the estimated discharges for a gauged section. This provides insight into the role that interpolation uncertainty plays. However, as mentioned at the beginning of this document, we cannot compare the analysis with the true observed discharges because they have already been assimilated.

3. If there are no gauge data at the outlet, then could the authors instead choose a section (or sections) of the river for modelling where measurements are available, to compare with the corresponding simulations?

   Please see the response below.

4. If for some reason none of the above can be achieved, could the authors please answer the question: Why should we be impressed with the reduction in uncertainty demonstrated in Figs. 2 and 5 if we don’t know that the median values in the posterior estimate are likely to be improved over the priors? It seems to me that estimating these magnitudes as accurately as possible would be the best way to ensure that, as expressed by the authors in their concluding sentence, “…the developed approach meets the practical needs of engineers responsible for updating the mapping of flood zones in Southern Québec.”

   We agree. Estimating the magnitude of discharges and the corresponding return levels is paramount. We showed that the uncertainty in the estimated discharges is smaller when treating them as missing values within the model, compared to estimates derived from any individual hydrological configuration. This approach results in more robust estimates. We added comments about this point in Section 4.3.