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Reply on RC1

Thibault Lemaitre-Basset et al.

Author comment on "Unraveling the contribution of potential evaporation formulation to uncertainty under climate change" by Thibault Lemaitre-Basset et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-361-AC1, 2021

Responses to comments of Referee 1:

We would like to thank the referee for the useful comments and his/her interest for our study. We will include all the specific comments mentioned by the referee, clarify the vocabulary, and correct figures directly in the manuscript.

Comments 1:

Table.2: It is great that the code provides the details of how each PE formulation is calculated. However, it would be good to add a little more detail to Table 2 as some of these methods do not have a unique formulation. For example, which Morton estimate of ET is being used? Is the Penman-Monteith reference crop (FAO56) or a different version of Penman-Monteith? Which version of Penman is being used? The formula for each method would make this clearer and or an indication of whether the formulation is open water, potential evaporation or reference crop. In addition, Hamon should include sunshine hours as a variable

Section 2.2: The seven formulations in Table 2 include estimates of potential evaporation (unlimited water availability) over land or water, reference crop (well-watered short grass) and open water evaporation. Therefore, these formulations are not expected to produce results of a similar magnitude – it would be good to indicate which formulations estimate the different types of evaporation and which produce higher to lower values (I would expect open water evaporation > potential evaporation > reference crop). While I agree that all of these seven formulations can be used to represent future atmospheric demand for climate change impact assessments, it is important to be clear about what they actually estimate and how these differences may influence the later uncertainty estimates.

Figure.2a: Much of the difference in PE between the seven formulations is likely due to them representing different evaporation variables. As mentioned previously re the seven formulations in Table 2 they include potential evaporation (unlimited water availability) from a surface, reference crop (well-watered short grass) and open water evaporation. Furthermore, most of them are estimates of evaporation from a point, whereas Morton is likely to be an estimate for a large area, which we would expect to be lower than a point estimate. If these seven formulations are kept in the analysis, then it is important to be

clear that the variability is not just different formulations of a single type of evaporation metric (potential evaporation), but variability between different evaporation concepts.

Answer to Comments 1:

The referee would like more details on the potential evaporation formulations we used. We agree that not all the formulations used were developed for the same purpose; however, we would like to emphasize that they are regularly used in a similar way in hydrological modelling. Therefore, we will add some clarifications regarding the type of formulation and the related environment.

Regarding the Hamon formulation, we chose the equation with theoretical sunshine hours, since observed sunshine hours are not directly produced by climate models. Furthermore, other Hamon formulations using theoretical or observed sunshine durations exist. However, again, the sunshine duration variable is not available in climatic projections and we cannot use such formulation straightforwardly. Thus, it would have been necessary to use an empirical relationship to calculate the daily observed sunshine hours from solar radiation data. Oudin et al. (2005) and Almorox et al. (2015) have already used Hamon equation with theoretical sunshine hours and the later reference will be added in Table 2.

Comments 2:

Figure.5 bottom row – signal-to-noise ratio: The method used in this manuscript to calculate the signal-to-noise ratio is not clear, despite the reference to Hawkins & Sutton (2012). Table 1 does not list any pre-industrial control simulations, so it is unclear what has been used in this analysis to define the natural climatic variability against which the RCP scenarios would be compared to see if the signal-to-noise ratio is > 1. In addition, it is not clear which RCP scenario is being shown in Figure 5 (bottom row) or whether the signal-to-ratio is average across the three RCP scenarios considered. The different RCPs will have different signal-to-ratios as they have very different signals, yet only one map is shown for all RCPs. It would not make sense to combine different RCPs into a single signal-to-ratio metric as they have very different signals – they should be considered one RCP at a time. More details about how the signal-to-ratio is calculated is required to understand what is being shown here and why the results are the way they are. I see that later at line 211 it appears that the different RCPs have been combined in the signal-to-ratio metric, which is not informative

Section 4.2: The authors note that the uncertainty due the PE formulation in this study is lower than in other studies (Line 237). They suggest this may be due to other studies only considering a single RCP, which is a reasonable suggestion. I recommend only considering a single RCP at a time, rather than combining the RCPs into the one analysis as combining the RCPs will likely inflate the uncertainty in the GCM/RCM/RCP components of the analysis. However, another suggestion may be that the other studies may have bias corrected the GCM/RCM output prior to assessing the uncertainty contributions. Bias correcting the GCM/RCM projections would remove any bias between GCM/RCMs and place each GCM/RCM on a common baseline from which the difference in GCM/RCM/RCP signal would emerge. Whereas, in this study it is not clear that any bias correction of the GCM/RCM projections has occurred, so there will be increased variability in the GCM/RCM projections due this uncorrected bias.

Answer to Comments 2:

One of the most important comments refers to the experimental approach used to conduct the uncertainty analysis. The referee suggests analysing the uncertainty on potential evaporation considering a single RCP at a time, rather than combining the three RCPs. We have considered all three RCPs all together for the QUALYPSO analysis in the study, as we consider them as the primary source of uncertainty when considering the impact of climate change, following (Evin et al., 2019), among others. However, we agree that considering only one scenario could be interesting to compare our results with other studies only considering a single RCP. Separating RCPs would certainly result in different time of emergence and signal-to-noise ratio outputs.

Performing such a test could be useful especially for the long-term projections, where the weight of the RCP factor is higher than at the short term. To conduct these experiments, it would be necessary to select GCM/RCM couples available for each scenario our data of climate projections to have same GCM/RCM couples for each RCP considering in the uncertainty analysis with QUALYPSO. However, only six GCM/RCM couples are common to the three scenarios, so it will drastically reduce the number of GCMs and RCMs accounted for in the uncertainty estimation.

To follow the reviewer's recommendations, we will analyse the new partition of the total variance for each factor (GCM/RCM/PE formulations) through conducting one uncertainty analysis on a single RCP, namely RCP 8.5. Using only this RCP to compute the uncertainty will provide new insights on the signal/noise ratio and its interpretation. RCP 8.5 has the strongest change signal of the three RCPs, and all the GCM/RCM couples used are available for this scenario. This will help us to clarify the contribution of PE formulation to the total uncertainty.

We will add more details on the method used to calculate the uncertainty and the signal-to-noise ratio to improve justifications and the understanding of the method (also suggested by the second referee). The reference period defined in the article, namely 1976-2005, is used in the signal/noise analysis as the reference; we do not consider a pre-industrial period. Finally, we will make clearer that our data are not bias corrected, and the consequences on our conclusions will be discussed to improve the comprehensiveness of the results and the discussion part. Sources of uncertainty also exist in bias correction methods for the climate variables, and the interdependence of the climate variables must be preserved to calculate potential evaporation, which is not always warranted by statistical bias correction methods. The bias correction methods could be an interesting source of uncertainty to explore in further studies, but this point is beyond the scope of this study.

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