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Hydrology and Earth System Sciences
Discussions

Interactive comment on "A Multi-Objective Ensemble Approach to Hydrological Modelling in the UK: An Application to Historic Drought Reconstruction" *by* K. A. Smith et al.

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Here the authors address two unique research questions. First, the authors define a multi-objective approach to calibrating a hydrologic model to consider low flows, high flows, and water balance. Second, they use this approach to reconstruct flows for rivers throughout the UK beginning in the 1891, made possible by recovered meteorologic datasets.

The paper is well-written, of strong interests for HESS readers and a novel piece of research. I have some concerns about a general lack of reference to the hydrologic calibration literature, particularly with relation to prior multi-objective approaches. The

authors' application is certainly novel and they made choices to weight their multiple objectives a priori, which is a realistic approach when repeating this for many watersheds. However, there are more advanced multi-objective schemes that should be mentioned for context (and potentially for follow-up research). Because of this weighting approach, there must be some discussion of how the objectives are related to one another and how these weightings affect results.

Overall, I recommend this article for publication pending the major revisions to provide a better literature context and to better explain the objective weighting scheme's effects.

Major Comments 1. I have a concern that there is a wide body of calibration/optimization literature not being referenced in this paper. Many approaches have been used for hydrologic model parameter calibration, and although the paper mentions some, there are gaps that could put this work in context. I suggest to at least mention PEST, which is a single objective optimization scheme, but almost ubiquitous in the U.S. hydrologic community. Wallner (2012) "Evaluation of different calibration strategies for large scale continuous hydrological modelling" provides a good overview of these calibration strategies.

2. Although the words "multi-objective optimization" aren't often written together in the text, this approach appears to be an a priori multi-objective optimization. By using the sum of each objective's rank as your objective, you have defined weightings a priori to merge multiple objectives into a single objective function. Please include at least one or two sentences explaining this and mentioning the difference between this and a posteriori multi-objective optimization (below).

I mention this because you state that "multi-objective optimization methods have been advancing since the turn of the century", but this area has a pretty rich literature that goes back well into the 1990s. Additionally, most optimization researchers think of a posteriori (not a priori) when they think of multi-objective optimization. A posteriori approaches try to find a set of non-dominated Pareto optimal solutions and then select

the best compromise afterwards. You might include references to other multi-objective papers that take this approach like:

“Multiobjective Automatic Parameter Calibration of a Hydrological Model” (Jung et al, 2017) “Comparing multi-objective optimization techniques to calibrate a conceptual hydrological model using in situ runoff and daily GRACE data” (Mostafaie et al. 2018) “Automatic calibration of HEC-HMS using single-objective and multi-objective PSO algorithms” (Kamali et al. 2013) “Multi-objective calibration of a distributed hydrological model (WetSpa) using a genetic algorithm” (Shafi and de Smedt 2009)

Or consider some of their references for older publications.

3. Because of the a priori weighting (Comment #2), please provide information about how the multiple objectives are related to one another. Are some highly correlated? Negatively correlated? If, for instance, the rankings from the 4 high/water balance objectives operate as one and the 2 low flow indices operate as one, is there a concern that you are overweighting towards high flows?

4. Line 245-250: I find it surprising that there is a single very poor fit among nearly perfect fits, for example in Cornwall. As you are mentioning the reasons for poor fits in this paragraph, it is important to mention there does not appear to be a spatial pattern. Presumably, the same abstractions and groundwater issues affect the 0-10% threshold poor fit as its > 90% good fit neighbors. Are there any other feasible explanations?

Minor Comments

Line 45 – Suggest 1 or 2 more references to fill out the discussion of low flow climate projections for the UK.

Line 70 – You may want to mention some proxy-based reconstructions; for example Jones et al (1984) “Riverflow reconstruction from tree rings in southern Britain” or the Old World Drought Atlas (Cook et al 2015) “Old World megadroughts and pluvials during the Common Era” which covers the UK.

Line 193 – Please define LHS500. This is the first time it is included in the text (only in the abstract).

Table 2 – If possible, please try to fit the ranges on a single line of this table.

Lines 273 – You do a great job of describing a low UncW and low ContR as biased and under-sensitive - this is a helpful translation for readers. As a reader, I would also like a description of the converse. What does high UncW and high ContR mean?

Line 344 - Can you provide a description of which objective function(s) is driving the best fit parameter set in the Avon to consistently overestimate low flows?

Line 372 – Please add the words “we consider” before “SSI values. . .”. The thresholds of -1 and -1.5 are largely arbitrary and more of a convention than a true definition.

Figure 9 – Please mention that you are plotting the mid-point of each event in the caption. It is currently only in the text (Line 417).

Figure 9 – For the Crimple watershed, there are 3 unique drought events for the Modeled data shown in the period 1975-1979. But Figure 8 shows only 2 crosses of the -1 threshold. Please confirm what is going on here.

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