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Hydrology and Earth System Sciences
Discussions

# *Interactive comment on* "Simultaneously Determining Global Sensitivities of Model Parameters and Model Structure" *by* Juliane Mai et al.

**Anonymous Referee #2**

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The manuscript focuses on Sensitivity Analysis (SA) of hydrological models. It introduces a more general version of the well-known Sobol method, designed to operate on groups of parameters instead of on individual parameters.

Overall I enjoyed reading the manuscript - its on a topical area and the methods described are sound. I appreciate this work on mathematical model analysis, and the idea of grouped parameter sensitivity is novel at least in hydrology as far as I know. With multi-model/flexible frameworks such as RAVEN and others, analysis of their sensitivity would benefit from such "grouped" analysis.

I have the following concerns with the current manuscript form:



1. The algorithms are not explained in a sufficiently clear way. For example, for the description of Sobol method on lines 300-307, and the description of the xSSA method on lines 324-330, are in my opinion not sufficient for a paper presenting a mathematical method.

Yes, I could probably translate the description there into a procedure / pseudocode, but: first I would not be quite sure if I got it right, and second I (respectfully) suggest the onus is on the authors to provide such an un-ambigous description. Appendix B is helpful to a degree, but seems to use a different notation to the main text (where are the matrices A and B and Cm?).

2. Terms such "uncertainty, "sensitivity", "influence", "importance" are being used in a pretty loose, seemingly interchangeable way. For example, the paragraph on lines 31-40, which starts with "uncertainty" and then immediately switches to "sensitivity". Then line 104 mentions "sensitive/influential/important" parameters. Are these referring to the same characteristic? Similar confusing usage then carries through later in the manuscript.

I suggest the terminology should be much tighter to avoid confusion. Given the mathematically demanding topic, I would suggest giving clear definitions of the various concepts (with links to existing literature where appropriate), and avoiding the alternation of these terms in the remainder of the presentation. There are useful and interesting ideas on lines 100-115, but these are already using the terms above in a way I found unnecessarily confusing because its not clear which terms are used synonymeously and which are not.

The current literature review is heavily focused on sensitivity analysis - which is appropriate given the topic. But if the connection to uncertainty is to be made, I would say the literature review of the latter is currently rudimentary at best.

3. The aims and key contributions of the study seem to drift over the course of the manuscript/presentation. For example the Introduction is focused on sensitivity analy-

sis (and to some extent uncertainty) - but in the Conclusions the contribution #1 is listed as formulating model ensembles as weighted sums of process options, with Sensitivity Analysis then being contribution #2.

I think the coherence between the introduction / aims and contributions could be improved, so that there is a clearer set of aims, appropriate background given on each aim, and then a clear set of conclusions that match those aims.

A clearer vision of the contributions could also help improve the structure of the manuscript, by putting the important contributions much earlier. This would avoid the multiple forward references to the proposed method and its properties before its actual description is given - e.g., see lines 235-237, which are not really that meaningful before seeing how the xSSA method operates. The new XSS method in Section 2.2.2 comes after several quite detailed sections on models and case studies - and it was not immediately apparent that this is the main advance being presented.

4. Some lack of clarity in how important new concepts are defined

Eg, is the sensitivity to groups of parameters taken as sensitivity to processes? Or is that something different? Please check wording across manuscript.

Line 115-122 - I suggest this summary of findings would work better in Abstract + Conclusions. It would also help being clearer in the wording on the comparisons that are being made. Is "conventional" approach the SSA or the Baroni method?

Line 278, where it is pointed out that a traditional single-parameter SA analysis could produce groupped-sensitivity analysis by aggregating results for individual parameters? In a paper advocating the new "groupped-SA" method - should such comparison receive priority to show the advantages of the new method. The hypothetical scenario where sensitivity is underestimated (line 279) - is this common in practice? As this goes to the motivation for the new method, I think it could receive more attention.

Line 352 "limitations of existing Baroni method" - as this comparison is important in



this paper - would seem preferable to describe the Baroni method in appropriate detail before discussing its limitations.

Line 535: "it can be deduced that the potential melt, the quickflow options BASE_VIC and BASE_TOPMODEL, and the evaporation options are most influential upon modeled streamflow". Here the lack of clarity on what is meant by "influential" can cause confusion to a reader. Especially sensitivity to a specific option for a process (eg, BASE_VIC for quickflow) - normally sensitivity is to a range of possible values for a decision - here it is to a single specific value? I don't quite follow this.

Section 3.3 - nice sections. Would be improved by providing clearer definitions of sensitivity, influential processes, uncertainty, etc (see earlier comment). Current usage is unnecessarily loose and confusing here.

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Many these comments focus on presentation , but given the technically demanding nature of the work, a more targetted presentation would make it easier to digest by an interested reader.

Other comments

1. Line 4: "apply" or "develop"?

2. Line 24 - what is "they" referring to? Also what does "non-unique" refer to here? Is this with regard to many models co-existing in the literature? Or non-uniqueness in their inversion when estimating parameters? I think some clarity would be useful here

3. Line 27 - are these decisions always subjective? Surely there exist studies where model decisions are developed according to sensible strategies?

4. "Sensitivity to model structural uncertainty" - I think studies such as McMillan et al 2010, Clark et al 2010 and other have investigated this?

5. "recent" - with references back to 2008 is this still recent?

6. Baroni method - seems an important method in the context of this work. I think it would be helpful to provide the gist of that method at least in an Appendix, in the way that is is applied here.

It is also a little unclear from the abstract that a comparison to this method is made. Eg line 13 "alternative" - if this is Baroni's method - should this be "existing" method? To avoid a confusion the reference algorithm should be clearly described.

7. line 49 - "did not change when moving between model structures" - is this for different hydrological models? or models from across multiple disciplines?

8. line 50 - what are "hyper-parameters"?

9. line 52 - not entirely clear what "form" refers to here. I found the entire sentence a bit confusing when trying to understand exactly what its trying to say

10. line 53 - "the method introduced ..." - is an incomplete sentence?

11. line 55 - "individual" - maybe clarify that the previous study assessed ONLY combined sensitivities? This is not clear from the current wording. And I thought that combined sensitivities are an advance rather than individual sensitivities? So why is that a limitation of the previous work?

12. line 62 - "sensitivité of a model" - is this for model simulations? or model parameters? or both? See comment about making sure the key concepts are clearly defined

13. line 78-79 - "it is therefore ..." - i think these ideas on the utility of SA should be introduced earlier in the presentation, to provide a stronger motivation and a practical context for the work.

14. line 88 - this property "structure can vary continuously" / "weighted average". I found this aspect quite interesting in the work. The statement below that xSSA "is made uniquely possible" to RAVEN - do you mean it can only be used by RAVEN? This seems strange as multi-model ensembles where each model has a weight are



fairly common (e.g., see the "model averaging" literature).

15. line 96 - "uniquely"?

16. line 105 Metric B - very interesting concept. but without some elaboration seems potentially ill-defined. Eg, how do you determinne if a parameter appearing in different model structures is "the same parameter"?

17. line 120: "conventional approach" - is this the Baroni method? If so best to name it. Also it was referred to as "alternative" in the Abstract

18. Section 2 - consider splitting into several sections and place in order of relevance to the contributions of the paper

19. line 145 - see earlier comment - how do you know it the "same" parameter? It seems a relevant discussion point

20. line 169 / eqn 16 - how do you "decide" in a modelling context what is a shared parameter? say is x3 in eq 16 the same as x3 as in eqn 13? Is this considered determined purely by the choice made by the modeler regarding the parameters to calibrate?

21. line 235 - 236 - I think these are discussion points - would work better in Discussion rather than forward references here - at this point of the paper the new method is not described yet!

22. Line 312 - would help clarify here that this is approach is new and introduced in this work. And as mentioned earlier - I think it would benefit from being given more prominence in the paper.

23. line 318 - "depicts"?

24. line 409 - "hereafter called Baroni method" - already said this earlier on line 48 - but still referring to this method by multiple names

25. Appendix A - an extra 1-2 sentences that refer to where in the main text are these weights used would be helpful here

26. Appendix B - I am confused why this seems duplicated in the Intro and the Appendix. If this is new - would seem better somewhere in the Theory and then Discussed, where it can be discussed in appropriate detail.

Figures

1. Figure 2 - the bleue font in panel B is quite hard to read

2. Figure 5 (and others to various extents) - could be more generous with fontsize, as many labels etc are virtually illegible

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