

**Black text: S. Hoellering's comments**

**Red text: S. Markstrom's response**

### **General comments**

The authors presented an interesting idea of a methodological framework wherein parameters of the HRU based Precipitation-Runoff Modeling System (PRMS) can be identified as influential in terms of essential hydrological model based processes and statistical streamflow indices serving as objective functions. Parameter influence on model output was evaluated by parameter sensitivity index values originating from global sensitivity analysis with the Fourier Amplitude Sensitivity Test (FAST). The approach aims at reducing the number of model input parameters to focus on conceptualised processes assumed as hydrologically relevant within the watersheds of the conterminous United States.

I generally agree with the concept of referencing model response functioning in form of derived objective functions with dependent partial parameter sensitivities for region specific model parameter identification. This is one of the aspects which would be really worth publishing.

Apart from that, fundamental assumptions underlying this study are not sufficiently clarified to address the discussed issues effectively, which are certainly topical and relevant for model based catchment hydrology. The paper is technically well-structured, exhibiting findings of the presented concept concisely but it lacks the required presentation quality at too many different points. However, I found some serious shortcomings and recommend to revise a number of major and minor specific and technical points before the manuscript can be reconsidered for publication.

### **Specific comments**

1. What is the main purpose of your paper?

You mention a number of issues e.g. "parameter identification", "process identification", "calibration advise for modelers" or "identification of [model] structural inadequacies". A better focus on one or two of these issues, preferably on the first and second is advisable here.

**Yes, the other review suggested that I discuss more the relationship between parameters and processes. I think this is related to your comment here. I rewrote the introduction, with a focus on parameter and process identification.**

As uncertainty analysis is not the issue here, I furthermore suggest to remove the part starting from P16L29, which is also rather speculative.

**Yes, that paragraph has been removed.**

2. Please also name your assumptions more precisely!

The fundamental assumption of this study is, that the conceptualisation of PRMS is structurally adequate to reproduce all hydrological processes of the CONUS. It is however not adressed, whether this assumption is valid or not or if the study doesn't claim to be transferable to real world processes and consequently stays a pure virtual PRMS experiment. Conclusions on the dominant hydrological processes are only valid if it is shown that PRMS actually is a good representation of hydrological processes. Processes in the study purely originate from and are defined by the PRMS structure whereby a comparison with observational data might be helpful in this application to show potential deficiencies or justify the fundamental assumption.

**Yes, I restructured the PRMS methods section to include more about the calibration parameters and assumption and less detail about how the application was set up.**

3. P2L19/P10L20: As you similarly found out, more complex processes such as the reproduction of streamflow and its components as well as mountainous regions require more calibration parameters. The general rather small remaining subset of

sensitive parameters explaining the majority of the model output variance of processes might be predefined by the conceptual structure of PRMS and a hint to overparameterization.

Yes, I added a sentence essentially saying this.

The number of parameters required in a process is also predetermined by the model/process concept and its complexity. Maybe be a bit more specific and less general or sketchy in stating your findings i.e. in the sense of the influence a parameter exerts on a process which might not be purely predetermined by the concept of a model.

Yes. Based on the suggestion of another reviewer, I have added another table (table 1) that lists the parameters used in this study. In this table, I specify which “module type” each parameter is associated with in the source code. So, without bogging down this article with too many model structure issues, maybe this give the reader some idea of how the calibration parameters relate to the model structure.

4. P3L13: (How) do these two aspects of complexity correspond to the ones stated in the abstract and explained directly above these lines? Maybe you should be more precise here!

Yes. I added some text about using sensitivity analysis to reduce the complexity to the model user. That is my point. Obviously, SA does nothing about model structure, but the model can appear less complex to the modeler by focusing on those parameters and processes in the model that can be affected.

5. P3L32: This issue has also been partly discussed e.g. by Reusser and Zehe (2011).

Yes, added this reference.

5. P5L8: HRUs are purely derived and defined by their geographic and topographic location. Process identification and catchment classification might be hampered by this definition e.g. by mingling of processes leading to a complex interplay and location specific response behaviour which cannot be always captured by one HRU. In addition to your discussed points a redefinition of HRUs based on dominant hydrologic processes instead of the applied discretisation based on geographic position might be a conceivable outcome and a consequence of your study maybe helpful for calibration.

Yes, added to discussion section.

6. P5L20: Here a more precise explanation might be helpful. Is simulated streamflow at locations with stream gauges evaluated differently from streamflow at sites without observations?

I removed this sentence/section. The other reviewer felt this was too much detail about this aspect.

7. P7L1: Here more attention to further studies with streamflow indices could be given (see e.g. Yadav et al. (2007)). Please discuss your choice in some more details.

8. P9L25: I suggest to start this chapter with the sentence “To identify the expected count of parameters ... (P9L28)” first the theory, then a specific example.

Yes, I moved the text preceding “To identify...” down to a subsequent summary paragraph.

9. P10L23/P13L8: This view might be kind of model structure/concept specific (as stated above) and is not surprising as streamflow is a convolution of these individual processes. Isn't total HRU runoff in PRMS the pure product or sum of the other streamflow processes (surface runoff, interflow and baseflow), hence involved process parameters add up to a larger number suggesting more complexity? Maybe you can be a bit more precise in the explanations (P13L13).

Yes, this is the point. Because process that happen “earlier” in the flow cycle affect the processes that happen later, there can be unexpected sensitivity of a process to a parameter that normally is not associated with that process. I added some text about this.

P15L25: To my knowledge PRMS offers different modules for PET calculations. (How) do sensitivity results and parameter identification change by replacing one module by another? This might be subject of future studies and worth mentioning.

Yes, added to “Further study” section.

P16L3: Someone who is interested in modelling the selected catchment is probably better advised to have a look at historical meteorological observations. From these it should be obvious that snowmelt might not be of any interest here.

Yes, that’s an obvious one.

### Technical corrections

Typing errors:

The spelling and writing needs improvement and proofreading. To mention several of them:

Please be consistent in the writing and consider HESS manuscript preparation guidelines for authors e.g. Figure, Fig.

Yes, fixed Table, Fig., and Figure.

P2L15: indicate instead of indicates

Yes, fixed.

P4L3/P16L14: watersheds

Yes, fixed.

P8L15: Here poor comprehensibility can be better avoided by changing three to seven objective functions: “... 56 combinations of three objective functions and eight processes (plus totals).”

Yes, fixed.

P11L7: “...**is** surprising...”

Yes, fixed.

P15L12: “This is probably because it **is** a major component of the hydrologic cycle that is...”

Yes, fixed.

P15L21: than

Yes, fixed.

P16L7: used

Yes, fixed.

P16L11: “...**is** defined...”

Yes, fixed.

P16L14: processes

Yes, fixed.

Reference/citation errors:

Citations in the manuscript are correct while the year 2014 in complete reference is not:

Markstrom, S. L., Regan, R. S., Hay, L. E., Viger, R. J., Webb, R. M. T., Payn, R. A., and LaFontaine, J. H.: PRMS-IV, the precipitation-runoff modeling system, version 4, U.S. Geological Survey Techniques and Methods, book 6, chap. B7, 158, <http://dx.doi.org/10.3133/tm6B7>, **2015**

Yes, fixed.

Figures:

General remarks:

Resolution and quality of the presented figures and maps seem to be generally not high enough or pixelated and need substantial improvement. Unfortunately, the labeling of latitudinal and longitudinal lines are not readable at all. Please improve the legibility or remove it or incorporate it in only one figure which might be enough to show it once.

Yes, I have removed the lat/long lines from all maps. My original figure are of very much higher quality than what is shown in the draft. MS Word seems to be importing them at a lower resolution than my originals. If this continues to be a problem, perhaps I can work with someone at HESS to ensure that the figures are high resolution.

Some of the shortcomings are listed here:

Figure 1: This map lacks both sufficient quality and a valuable information content. In my opinion a different form of presentation such as histograms or kernel density estimates for selected attributes of HRUs could be beneficial.

Yes, this figure has been removed.

Figure 2: Please use consistent spelling or abbreviations for objective functions across tables and figures. Please explain the additional column "Process average" in the results section 4.1 and the meaning of the legend. The caption should also provide more information.

Yes, figure 2 has been remade with the same labels as table 2 (used to be table 1). I have also added a few sentences to explain "Process average" and how they are calculated.

Figure 3: Better use as Figure 1. It furthermore contains little information and poor legibility of region names.

Yes, this is now figure 1. I made the region labels larger.

Figure 4: "The plots A-H summarize..."

Yes, fixed.

Figure 5: Please clarify the connection to the ordered listing of Table 1.

Yes, added more to fig 4 (used to be figure 5) caption about this.

Figure 6: Please raise font sizes of titles above each map to be readable or remove them from the figure.

Yes, I removed them and remade the figures.

### References

Reusser, D. E. and Zehe, E.: Inferring model structural deficits by analyzing temporal dynamics of model performance and parameter sensitivity, *Water Resources Research*, 47, doi:10.1029/2010WR009946, 2011.

Yadav, M., Wagener, T., and Gupta, H.: Regionalization of constraints on expected watershed response behavior for improved predictions in ungauged basins, *Advances in Water Resources*, 30, 1756–1774, doi:10.1016/j.advwatres.2007.01.005, 2007.

Yes, thank you for these references. Citations to both have been added.