

**Review of the manuscript « Comparing the impacts of single and multi-objective optimization on the parameter estimation and the performance of a land surface model » by Xu et al.**

General comment:

The paper proposed by Xu et al investigates several issues related to sensitivity analysis (SA) and optimization using the Land Surface Model CLM. The final objective is to study the effect of using a single or several variables during the optimization process on parameter estimation and the overall performance of CLM applied on an ICOS site located in Russia. Before performing optimization, sensitivity analysis is performed using 4 approaches to identify the parameters that mostly impact the simulated variables. Optimization is then performed in a single or multi-objective mode using the PEM-SMC algorithm that was specifically adapted to reduce the computational burden and make such an optimization possible.

I believe that the paper proposed is interesting. Considering the information provided in the introduction on the increasing trend to use multi-objective optimization, I feel like the outcomes of the paper are not very significant. This paper still provides a good illustration of why multi-objective optimization should be preferred to improve the robustness and the prediction capabilities of LSM. Overall, I found that the methodological aspects and explanations on the choices made could have been more developed. Although CLM is a LSM widely used in the community, basic aspects on the equations and parameters behind should be presented somewhere. Without this information, it is hardly possible to clearly understand the sensitivity analysis results and the parameter optimization. The paper also lacks schemes that would greatly help in understanding the methods used. I think this paper should be improved significantly before being considered for publication in HESS. I would like the following comments to be considered or answered if possible:

Major comments:

- As mentioned above, the paper is not self-consistent as no information on CLM - equations and parametrization – are provided. In my opinion, the paper should be reshaped to include a part dedicated to the presentation of CLM. Furthermore, the name used in the paper – CoLM – should be changed throughout the paper and turned into CLM to avoid confusion.
- I don't get why 3 qualitative sensitivity analysis approaches are used prior to the Sobol's analysis. From Figure 1, it seems that MOAT alone could be sufficient to identify the most sensitive parameters to be used in the following. In my opinion, the need of multiple qualitative approaches, their potential complementarity and what kind of different information they can bring in should be detailed and explained more clearly. The use of 3 methods rather than one makes it more difficult for the reader to understand the overall method.
- If the use of the 3 approaches is relevant, the description of each approach should be improved to better explain its own interest for sensitivity analysis. The sizes of the different samples seem to be set arbitrarily. Maybe justifications – that are not only related to the computation burden – should be given as it can impact the performance of the sensitivity analysis.
- The description of the overall approach – presented from L189 to L212 – should be improved. As it stands in this version, sensitivity analysis and optimization are mixed together which is rather hard to catch. I think a scheme is highly needed here. And I also think that the authors

should more clearly stand that the target variables are NRMSEs computed with LEE/NEE/both.

- There are also some discrepancies between what is presented L189 to 212 and what is presented afterwards. It is stated L205 that 10 parameters are selected for SA when less parameter are kept in the application example. It is said that the optimization is guided by Sobol's analysis. Does that mean that some parameters are removed after Sobol's indices are computed?
- The technical aspects of part 2.3 are very hard to follow. Once again, I fell like a scheme could help understanding what is proposed and done.
- It's not clear how many particles/set of parameters are kept during the optimization process. I think this should be clearly specified somewhere. The way the values for non-sensitive parameters are set should also be clearly explained.
- After the SA results are presented, I think the physical meaning of the sensitive parameters should be explained. In my opinion, SA brings insights on how a model works. This aspect is rather poorly developed in the paper. This could greatly help for the analysis of the results, especially to understand the different values obtained after single/multiple optimization.
- After the optimization, some optimized parameters – P36 and P3 - reach one of the bounds of its variation interval. In my opinion, this is a bit troublesome and this question the way the bounds of the intervals were chosen.

Specific comment:

- In the abstract and conclusion, the impact of efficiency is sometimes in % and sometimes in raw values. I think it's more convenient and easier to use % everywhere.
- L52: what's the difference between LSM and soil-vegetation-atmosphere coupled models?
- L135: please specify the signification of delta here?
- L187: extensive dataset (104 or 105 or more): I guess it  $10^4$  and  $10^5$ ?
- Fig 3: change the values on the x-coordinates. Not easy to read.