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Discussions

Interactive comment on "Exploring the impact of forcing error characteristics on physically based snow simulations within a global sensitivity analysis framework" *by* M. S. Raleigh et al.

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Note: reviewer comments are in italics and the authors' responses and manuscript revisions are in normal face.

Comment: *This study applied Sobol' global sensitivity analysis for testing model sensitivity to coexisting errors in all forcings. Sensitivity analysis can reveal which forcing error characteristics matter most for hydrologic modelling. As there are fewer detailed studies focusing on forcing uncertainty, this work provides insights on the topic and provide a method that could be extended to more complex physically based models*

such as land surface models and climate models. It is a very interesting work, and the paper is clear and well structured. I think the paper should be considered for publication on HESS. Here, I have only some concerns about the Sobol' SA method used in this paper.

Response: We thank you for your time in reviewing the paper.

Comment: *(1) This study is too computational expensive. 1520000 Monte Carlo samples used here is too much, making that it will be inpractical to be extended to other complex models. As I know, Sobol' method will cost a lot to estimate the interaction, such as second-order effect. But it can be less expensive to get the first-order effect and total effect. Did the study consider the SA results from fewer samples? In fact, I suggest either RS-HDMR or response surface based Sobol' can be used here to get similar results.*

Response: Computational expense is an important consideration of any SA study. We should note that while we evaluated the model over 1.8 million simulations, this was somewhat excessive because convergence was reached before all simulations were completed. Additionally, this number includes multiple error scenarios (5) and multiple sites (4), so it seems higher than in reality. Figure 1 (this document, below) shows the time history of the total sensitivity indices (as a function of sample size) for Scenario NB (other scenarios exhibited similar levels of convergence). Examining this figure, it is evident that the same conclusions for the study (at least qualitatively) could have been drawn with fewer simulations. A dynamic system of calculating sensitivity indices as model completes simulations would optimize the analysis by stopping the process once convergence has been reached, but such a system was not implemented here. Such approaches might be needed when extended the error analysis framework to more complex model, such as land surface models. While we do not expect that this framework (and number of simulations) can be extended to all modeling endeavors, we note in our discussion the availability of more efficient sensitivity analysis methods and the need for improved efficiency.

Manuscript Revisions: We now provide more context for the computational expenses at the end of the discussion section: "Finally, while the Sobol' method is often considered the "baseline" method in global sensitivity analysis, we note that it comes at a relatively high computation cost (1 840 000 simulations across four sites and five error scenarios) and may be prohibitive for many modeling applications (e.g., for models of higher complexity and dimensionality). For context, the typical time required for a single simulation was 1.4 seconds, resulting in a total computational expense of 720 hours (30 days) across all scenarios. Examination of the convergence rates indicated that most sensitivity indices stabilized after one-third of the simulations completed, and hence the same results could have been found using significantly fewer simulations (no figures shown). Ongoing research is developing new sensitivity analysis methods that compare well to Sobol' but with reduced computational demands (e.g., FAST, Cukier, 1973; method of Morris, 1991; DELSA, Rakovec et al., 2014), and is comparing how different methods classify sensitive factors differently (Pappenberger et al., 2008; Tang et al., 2007). We expect that detailed sensitivity analyses that concurrently consider uncertainty in forcings, parameters, and structure in a hydrologic model will be more feasible in the future with better computing resources and advances in sensitivity analysis methods." Note that we have now include a fifth scenario to address concerns raised by another reviewer about precipitation uncertainty, and this brings the total number of simulations to 1 840 000.

Comment: *(2) This study used the total effect to quantify the sensitivity of different error type, different error distributions and error magnitudes. As the sum of total effect of each factor will be above 1, in order to quantify the contribution of each factor, I suggest to use the index STi/sum(ST), which is the total effect of one factor divided by the sum of total effect of all the factors.*

Response: While we thank the reviewer for this logical suggestion, we declined to make this change because we do not find a strong precedent for this practice in the sensitivity analysis literature. We prefer to report the total sensitivity indices according

to common practice.

Manuscript Revisions: No changes made regarding this point.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 13745, 2014.

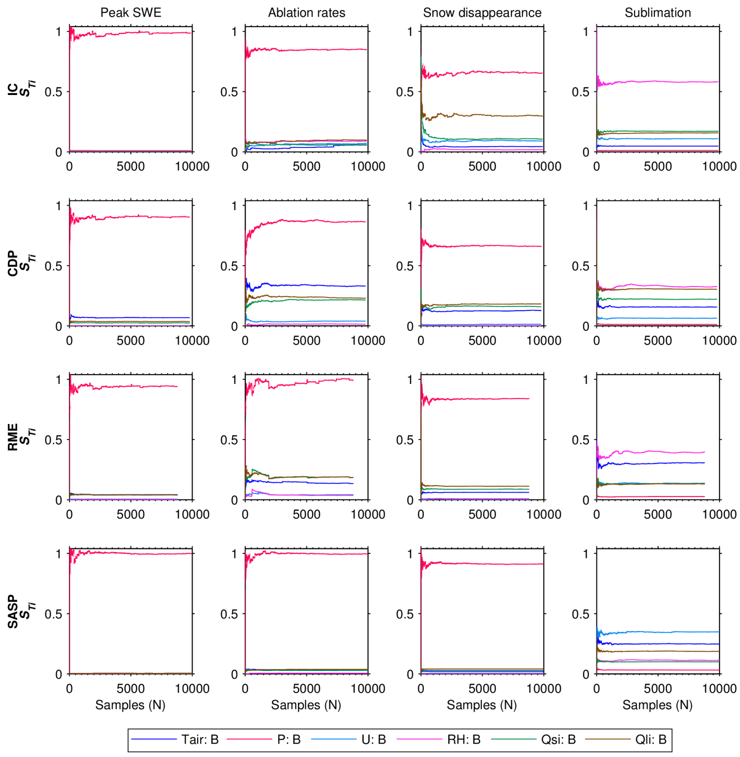

Fig. 1. Convergence history of total-order sensitivity indices in scenario NB for the four model outputs at the four sites, as a function of sample size.