RC1: Steven Markstrom

Thank you very much for your thorough review and insightful comments on our manuscript titled "Equifinality Contaminates the Sensitivity Analysis of Process-Based Snow Models." We appreciate your positive feedback on the organization and writing of our article, and we are grateful for your suggestions to improve our manuscript. Below, we address your general comments and minor suggestions in detail. Please find our response in **Blue** color.

General Comments

Comment: The word "equifinality" is in the title and it is an important concept to this article, but because this term has such a history in the literature, I think that a better description of what is specifically meant by equifinality is required. For example, is "parameter insensitivity" and "equifinality" the same within the context of this article?

Response: Thanks for the comment. Basically, we meant that the same parameters (e.g., the 12 parameters in Table 1) get different sensitivity rankings depending on the performance metrics used. To further clarify, no insensitivity concept was intended. We will add the following clarification to the revised manuscript.

"Equifinality is a well-known concept in hydrological modeling that describes the situation where different combinations of model parameters can lead to similar model outputs (Beven, 2006). This phenomenon complicates the process of model calibration and sensitivity analysis because it can obscure the true relationships between parameters and model behavior. In the context of our study, equifinality refers to the ability of different parameter sets to yield similar performance metrics, which can mask the sensitivity of individual parameters. It is crucial to distinguish equifinality from parameter insensitivity, the latter being a condition where changes in parameters do not significantly affect model outputs. By clearly defining and addressing equifinality, we aim to enhance the reliability of sensitivity analyses in process-based snow models."

Comment: Likewise, there needs to be more in the discussion about equifinality in the results section. For example, in the paragraph at lines 304 through 314, there is some discussion of "differences in model sensitivity" to different parameters and the identification that the model seems to be more sensitive to "water balance" parameters than "energy balance" parameters. What does this imply about model structure when some parameters exhibit equifinality and others don't? How could this information be used when modeling with SUMMA?

Response: These are valid and very constructive questions. It is believed that the higher sensitivity of certain process-based snow modelling parameters (e.g., water balance parameters and parametrizations) provide an information about how effective these parameters can be in the model calibration and/or an improvement to their physical descriptions can lead to higher accuracy of snow depth predictions. We will modify the discussion section to elaborate on the relations between parameters sensitivity and the model structure.

We would also like to note that, based on another reviewer's comment, we will make an important change to our discussion section by separating the "Performance Metrics" (i.e., RMSLE, KGE, NSE) from the "Signature Metric" (i.e., Mean). This change will subsequently impact the title and contribution of this study. Accordingly, less emphasis on equifinality in describing the model structure is expected; instead, the discussion will focus on the difference and application of these metrics (i.e., performance and signature metrics) on the model calibrations and behavior.

Comment: There is not mention of discretization and distribution of parameters and the simulated snowpack throughout space. Were the parameters varied spatially during the sensitivity analysis? Presumably the model simulates spatially varying snowpack (i.e., the snowpack is deeper in some locations than others) how did the objective function calculations account for this variability? Do the quality of the performance measures and their sensitivities vary according to how the depth of the pack vary across space? Maybe all of this is beyond the scope of the article, but some mention of how spatial variability is delt with is required.

Response: This is a good suggestion. We will revise the relevant part to the following in the revised manuscript.

"An important aspect not addressed in our current sensitivity analysis is the spatial variability of snowpack characteristics and parameter distributions. In this study, parameter sensitivity was analyzed using spatially averaged snow depth outputs in sheltered sites, which may not fully capture the spatial heterogeneity of snow processes. Future studies should incorporate spatially distributed parameters to better understand how spatial variability affects model sensitivity and performance. Acknowledging and addressing spatial variability will be critical in advancing the understanding of snow processes and improving model predictions."

Specific comments:

Ln. 221 This should reference figure 3 (not figure 4)
Response: This will be corrected in the revised manuscript.

Ln. 264 This should reference figure 4, (not figure 5)
Response: This will be corrected in the revised manuscript.

Ln. 286 This should reference figure 5 (not figure 6)
Response: This will be corrected in the revised manuscript.

Ln. 277 "of" instead of "as"
Response: This will be corrected in the revised manuscript.

Fig 4. Y axis label should be "Mean snow depth (m)".
Response: This will be corrected in ht erevised manuscript.

Thank you once again for your valuable feedback. We believe these revisions have significantly improved the clarity and robustness of our study. Please do not hesitate to contact us if you have any further questions or suggestions.

References:

Beven, K.: A manifesto for the equifinality thesis, J. Hydrol., 320, 18–36, https://doi.org/10.1016/j.jhydrol.2005.07.007, 2006.

Sincerely,
Tek Kshetri, Amir Khatibi, Yiwen Mok, Shahabul Alam, Hongli Liu, and Martyn P. Clark