

The Cryosphere Discuss., referee comment RC1  
<https://doi.org/10.5194/tc-2022-103-RC1>, 2022  
© Author(s) 2022. This work is distributed under  
the Creative Commons Attribution 4.0 License.

## **Comment on tc-2022-103**

Anonymous Referee #1

---

Referee comment on "Compensating errors in inversions for subglacial bed roughness: same steady state, different dynamic response" by Constantijn J. Berends et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2022-103-RC1>, 2022

---

The manuscript "Compensating errors in inversions for subglacial bed roughness: same steady state, different dynamic response" by C. J. Berends et al. investigates the impact of uncertainties in various ice sheet parameters and fields on inferred basal friction on two idealized configurations. The paper is well written and provides a comprehensive analysis of how uncertainties in ice viscosity, surface mass balance, basal mass balance, topography or sliding parameters affect inferred basal conditions. The results show that viscosity and topography have a strong impact on the inferred parameter and also impact the response of the simulation to future changes.

While the results are interesting, various aspects of this question have been investigated by different groups in the past, which is not discussed in the paper. Therefore, this manuscript should better cite the literature and provide context for this study. Additionally, and as explained in the introduction, unknown parameters are either inferred using variational data assimilation or adjusted during long transient simulations in the ice sheet modeling community. These two methods are completely different, and there are sometimes confusions in the manuscript, for example using terms like steady-state when the data assimilation method does not make any hypothesis about a possible steady-state (see major and technical comments below). Finally, this manuscript describes an improvement in the inversion procedure but no comparison with the previous method is provided; it would be interesting to see how this improvement impacts the results.

Major comments:

There are some confusions or inaccuracies at times about the two inversion methods. This is especially the case when referring to inversions overall and discussing the question of steady-state: while the steady-state assumption is used for the inversion based on transient simulations, this is not needed for "snapshot" inversions based on variation data assimilation. The geometry and velocity observations are used in the stress balance equation only, and the ice sheet does not need, nor is assumed, to be in steady-state. The combination of the given velocity and geometry will prescribe whether the ice sheet is in steady-state or evolves over time. Such terms are mostly used in the abstract and introduction and should be clarified to remove any possible ambiguity.

The results proposed show the impact of errors in various ice sheet fields on the inferred basal friction values in a relatively comprehensive way, but does not put this work in the context of previous studies. Previous work on inferring several fields (Arthern et al., 2015; Gudmundsson and Raymond, 2008), impact of rheology (Seroussi et al., 2013), or role of errors in observations (Habermann et al., 2012) has been done in the past and should be referenced and discussed to better describe the improvements and new results proposed here.

There is limited discussion on the choices made to perturb the different fields (viscosity, surface mass balance, etc.) and I would be curious to understand how these choices were made. Also, how do these changes compare to each other between the different fields (are these large or small bias) and how do they compare to our knowledge of the different fields and the current uncertainty for each of them? Such information would help better inform the results, and in particular the uncertainty in future evolution (Fig.9).

Finally, there is an improvement described for the inversion technique, but this impact of this improvement on the inferred bed roughness and misfit with observed field is not shown. It would be interesting to add an experiment to compare the results with and without this improvement (e.g., using the non-steady-state case).

Technical comments:

p.1 l.22: "retreat" -> "mass loss"

p.1 l.26: the ABUMIP experiments are not only idealized cases but also extreme experiments remove all the ice shelves around Antarctica. These results are therefore showing an extreme case, and are difficult to compare with experiments using more nuanced forcing. It would be good to nuance this paragraph.

p.2 l.30: maybe not just basal sliding and roughness but basal conditions overall.

p.2 l.34: this paper demonstrated the role of the basal sliding law used, but did not really conclude on the bed roughness itself.

p.2 l.53: as explained here, this second method is performed using observations at a given time, and the model is not run forward in time as part of the inversion procedure. The geometry is therefore "given" but not really "kept fixed" as there is no notion of time.

p.2 l.54: it would be important to mention how this method works: a cost function, measuring the distance between some observed fields and their modeled equivalent, is defined and this cost function is minimized during the inversion procedure.

p.3 l.65: you need to make a distinction between the two methods here: what is described only works for the first inversion technique, in the second one, there is no impact of the ice sheet geometry as part of the inversion and therefore no "steady-state" ice sheet. This should be rephrased to either distinguish the two methods or to make the description generic enough to cover both methods. (same with "thinning the ice" on l. 66)

p.3 l.78: remove "still"

p.3 l.82: remove "of" (of as a result)

p.3 l.75-83: this is an accurate description of what is done in the paper, maybe the abstract is a bit too generic, which can lead to confusions about the two overall methods to infer properties (variational data assimilation and adjustment during a long transient run).

p.4 l.101: add some references in this paragraph (sliding laws, etc.)

p.5 l.135: explain what the "I" variables are. Also, why use the entire flowlines and not a region of influence with a given region of influence around the various points/regions?

p.5 Eq.6-7: It's not clear if/how these variables defined for a single point are extended to the entire domain. Are the I variables defined and used locally or globally?

p.6 l.155: Can you detail these artefacts and the impact of the scaling values used?

p.6 l.160:  $\tau$  was used for the basal shear stress so it might better to use a different letter for the time scale.

p.6 l.171: How do these terms compare to the regularization terms used in other methods?

p.7 l.191: target geometry and velocity

p.9 l.217: "a deep oceanic trough" -> "a deep ocean" (there is no trough on the ocean part on Figure 3)

p.9 l.221: What value is used for A?

Sections 3.1 and 3.2: How do you grow these two configurations to a steady-state and how long does it take to grow them? What is the resolution of the model?

p.10 l.232: What is the impact of using a different initial value for  $\phi$ ? 5 degrees is the most common value in this set-up so it might be good to make sure this initial value does not influence the results of the inversion!

p.10 Fig.5: It would be good to change the colorbars for the surface elevation and surface velocity differences and better see the errors. In caption, change "ice-sheet geometry" to "ice-sheet surface elevation". Finally, the colorbars for Fig. 4 and 5 are the same, but the velocity is very different for the two simulations, so it would make sense to adjust the values and really focus on the velocity modeled for each experiment.

p.11 Fig.5: In caption, change "ice-sheet geometry" to "ice-sheet surface elevation" and "three unperturbed" to "two unperturbed". Same as Fig. 4 for the colorbars of the surface elevation and surface velocity differences.

p.11 l.251: Mention this is for experiment 1.

p.11 l.259: How about the role of local errors due to noise in observations? For example a random noise of 5 or 10% in the velocity, thickness, etc.? How long is the model run to reach the steady-state? And how do you know that this steady-state is reached?

p.12 Fig.6: again I would focus the colorbar for the surface elevation difference given the relatively small range of errors. Caption: "steady-state geometry" -> "steady-state geometry and velocity". Add "from left to right" before the list of parameters studies (viscosity, surface mass balance, ...)

p.13 l.284: How do you define that these are acceptable? How do they compare to observational errors?

p.13 l.292: Over what part of the domain do you perturb the basal mass balance (grounded, floating, both)?

p.13 l.294: "introduced errors" -> "errors introduced"

p.13 l.299: "except for the inversions with perturbed basal melt rate" (or rephrase to make that more clear)

p.13 l.299: missing word after "these"

p.14 l.313: For which experiment?

p.14 l.315: I am not sure to interpret that correctly: is the inversion or the run providing the data for the inversion run only to 10% of the steady-state? The second case would better represent reality, though as the ice sheet is never in steady-state, neither case is ideal.

p.14 l.318: These errors are actually not so large compared to some of the runs with perturbed fields and the errors are located only upstream of the grounding line.

p.15 l.326: remove "steady-state" (last case is not steady-state)

p.15 l.328: indicate where along the y axis is this grounding line shown?

p.15 Fig.9: It would be good to add the percentage of mass loss on the right of panel A.

p.16 l.338: remove "negligibly"

p.16 l.340: Change tense in paragraph (We investigated instead of We have investigated, etc.)

p.16 l.340: How does that compare to the previous approach? It would be good to show one case with the previous and new approach to see the impact of the changes (maybe the non steady-state MISIP+).

p.16 l.346: this is not really new

p.16 l.356: How do the different changes applied in the different fields compare to our knowledge (lack of knowledge) in these fields? What are the implications for comparing these uncertainties?

p.16 l.361: "not clear": what did you try?

p.17 l.363-369: need more references and justifications