Review of "Ground penetrating radar on Rutor temperate glacier supported by ice-thickness modeling algorithms for bedrock detection"

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1 General

The authors demonstrate a model-driven technique for picking points in radargrams corresponding to the glacier bed. They first ran three different models based on surface features, later used to guide the manual picking of Ground-Penetrating Radar (GPR) radargrams of 2012 and 2022. They then estimated the ice thickness in regions without GPR measurements by running the GlaTE model constrained by the GPR measurements.

The manuscript is well-written, and the subject of the work, the difficulty of retrieving the glacier bed, is a hot topic in glaciology, which deserves all the attention of the community. It is one of the most important sources of uncertainty for estimates of the future contribution to sea level rise. Dynamical glacier models are based on reconstructions of bed topography, which are themselves based on *in situ* measurements such as GPR and boreholes. The latter are reliable data, but they are not practical for surveying large areas. In this sense, GPR measurements are the foundation for glaciological studies. For this reason, the manuscript "Ground penetrating radar on Rutor temperate glacier supported by ice-thickness modeling algorithms for bedrock detection" from Vergnano et al. is very important.

However, it is important not to turn the logic around. Since GPR measurements are an important source of *in situ* information, reversing the process and leaking the modeling data into the GPR measurements can be delusive. This is the most important comment I have for this work, and I would like to see it discussed further in the manuscript.

2 Major comments

As mentioned previously, my main concern is related to the leakage of modeling data into measurement data. When inversion modeling is performed, it is crucial to have reliable data to constrain the model and evaluate its quality (see, for example, [Shahateet et al., 2023], where they show the impact of using different thickness maps for ice-discharge calculation and [Shahateet et al., 2024] where they show the importance of reliable thickness measurements). If the measurements are biased toward a specific model, it can highly impact everything that comes after, such as the inversion of the bed and the dynamical models that will use the inversion map.

The methodology is valuable, but the main point is to what extent you can use the picking drove by modeling estimations without data leakage. By analyzing Figure 5 and the appendix, I think you introduced too much bias. Some of the picks are not seen in the radargrams, only through the models.

I think that instead of having the model to then do the picks, the best approach would be to do several different picks and compare them to the models you have. In this case, you have less data leakage and more reliable measurements. In case where you have no reliable pick, leaving it without value is better than filling with model information, since in the future you do the inversion modeling of the ice thickness to cover all the domain. In this way, all the measurements you have are trustful and can be used broadly.

In this case, since you use models to support the picking of GPR measurements, you need independent data to validate your method. For this reason, it is desirable to use your method in another glacier with borehole measurements. In this way, you can have an independent validation method. I know it is easy to say and hard to do, but I think it is something important to keep in mind.

In chapter 5.1 (comparison of the three ice-thickness modeling algorithms), you stated that the GlaTE and GlabTop2 had similar results, proving the consistency between the different algorithms. First, you do not provide an overall analysis of their agreement, except by the total volume. To say that, you at least need to show an overall metric to conclude that. Second, it is no surprise that they agree well, since they use the same perfect plasticity method. In my opinion, their agreement is not a proof of the consistency of the method.

L287-288 is a warning that something may not be right. Why is the thickness overestimated near the outline of the glaciers? This is the region where you have reliable information from the GPRs, which shows that the measurements do not agree well with the models. Furthermore, L316 stated that 20% of the GPR data was used. Does it mean that 80% of the other points were taken from the models? In this case, it is no surprise that the total mass calculation of your method agrees well with the other models.

3 Minor comments

- The description of the homogenization of the different data sources is confusing and hard to follow with so many different years. Consider clarification and reduction of information.
- Why do you use the GlaTE as your final model? You never gave a complete reason for that. See my comment on L170-L175.
- In the Methods chapter, the figures are not presented in order. Furthermore, Figure 2 is not mentioned in the text except in the first enumeration of the Methods chapter. In the text, you mentioned Figure 1, and the next Figure to be mentioned is Figure 5. In general, I think it is important to improve the way you make references to the figures.
- Where do the other inputs from the OGGM model come from? You did not describe all the inputs.
- You don't need the enumeration from L245-253. This information is contained in the legend of the figures. Also, it is better to start talking about the figures before showing them out of the blue.
- You cite a personal communication twice. If you do not have a regular citation for that, rephrase it. For example, changing the word "considered" in L129 to "...showed to be..." avoids the need for a citation of a personal communication.
- For the OGGM model, you assumed that the glacier was in equilibrium to infer the ice volume flux (q), which according to the section of the study site is wrong. You can easily use a geodetic mass balance (the one you mentioned) to account for this mass change.
- Several times, you should change to "Rutor Glacier", with capital "G".

4 Specific comments

- L42: The acronym EM is not defined, and it is the first and only time that you use it. So, it is not needed.
- L52: Change "paragraph" to "section".
- L96: Change "multiisciplinary" to "multidisciplinary".
- L118: I think mentioning the v.sample tool in this overview of the methodology is not necessary and can distract from the main point.

- L123: The information in this line is not needed.
- L151: The sentence "according to the following steps," made me get lost. It looks like you are going to explain the steps, but you start to talk about the software. Only in the next page you are actually explaining the steps. Consider passing the sentence to the end of the paragraph: "The raw data were processed using the commercial... open source software (Huber and Hans, 2018), according to the following steps:".
- L170-L175: I think this paragraph is not necessary. It seems to me that you try to give a reason to use them because of their popularity. I would try to address this question with a more objective reasoning.
- L177: "Ice dynamics" instead of "ice flux mechanics".
- L183: Change "writers" to "authors".
- L188-L190: How do you avoid the glacier flow line computation? Furthermore, in L190 you say that h_f is the mean ice thickness along the central glacier flow line. So do you actually not avoid it?
- L190: You say what is f, but no further explanation is given. What value did you use? It highly impacts the final result, since it accounts for lateral drag. I presume that in an alpine glacier, this value is important to discuss.
- L198-199: You can exclude this line and pass only "Further details are provided in the appendix of Frey et al. (2014)" and a good reference of the code (see my next comment).
- L199: several times you wrote the URL link as reference. I think it is not the right way of referencing a webpage.
- L202: "Clarke et al., 2013" should be "Clarke et al. (2013)" and "(Clarke et al., 2013)" is duplicated.
- L223: Same as L199.
- L228: "is" should be removed.
- L238: Same as L199.
- L239: The data is not well cited. It is (NASA JPL, 2020). Also, the reference is wrong in L465.
- L240: Better "(based on DEM differencing)".
- L280: Same as L239.
- 311: How the bias can not be considered significant? You said that the interpretation of GPR measurements below 50 m was difficult and only 20% of the GPR data was clearly identified (presumably in shallow regions, considering the previous statement). It means that in 80% of the time you used ice thickness from the models, or at least driven by it (it is not clear to me when it is driven and when you simply used the same thickness), especially in the regions where it accounts more to the total volume (deep regions). For me, this bias is the major concern regarding the methodology used, and need to be addressed in more details.
- L337: "from" is duplicated in "... from starting from..."
- L339: Change "miimizing" to "minimizing".
- L357-360: It is a conclusion.
- L365: 17.5 m "on average".

4.1 Figures

- Figure 1: In the legend, change "areas" to "categories". Furthermore, remove the parentheses from "(Crameri, 2021)".
- Figure 2: The legend is confusing. Why not numbered from 1 to 5? Also, it is better to number at the end also (e.g.: end-1).
- Figure 4: Same comment as in Figure 1 regarding "(Crameri, 2021)".
- Figure 5: The legends of GlaTE and OGGM are indistinguishable. It would be clearer if you used different colors for the different models.
- Figure 6: Same as in Figure 4.
- All the Appendix Figures: Same as in Figure 5.
- Is Figure A2 the same as Figure 5. If so, no need to show it again.

References

[Shahateet et al., 2024] Shahateet, K., Fürst, J. J., Navarro, F., Seehaus, T., Farinotti, D., and Braun, M. (2024). A reconstruction of the ice thickness of the antarctic peninsula ice sheet north of 70°s. EGUsphere, 2024:1–29.

[Shahateet et al., 2023] Shahateet, K., Navarro, F., Seehaus, T., Fürst, J. J., and Braun, M. (2023). Estimating ice discharge of the antarctic peninsula using different ice-thickness datasets. Annals of Glaciology.