

The Cryosphere Discuss., referee comment RC2  
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## **Comment on tc-2021-63**

Anonymous Referee #2

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Referee comment on "Upstream flow effects revealed in the EastGRIP ice core using Monte Carlo inversion of a two-dimensional ice-flow model" by Tamara Annina Gerber et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-63-RC2>, 2021

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The following is a review of "Upstream flow effects in the EastGRIP ice core using a Monte Carlo inversion of a two-dimensional ice-flow model" By T.A. Gerber, et al.

This manuscript describes a study of the upstream ice flow of the Northeast Greenland Ice Stream (NEGIS). The authors make use of the EastGRIP ice core and a 2-d ice flow model to invert for model parameters and boundary conditions, including accumulation rates, basal melt, and basal sliding along prescribed flow lines. They also investigate the sensitivity of modeled kink height. The team varies their inversion method in order to constrain uncertainties in their results, including the use of three different flow lines spanning the ice stream and the use of a Monte Carlo method to navigate the parameter space for the minimization of the misfit between the modeled and observed isochrones derived from radio echo sounding. This inversion allows them to trace the source location and to quantify source accumulation rates for specific identified flowline isochrones, constrained in the region between the EastGRIP area and ~350km upstream. The authors present a robust match between the model and ice core layer thicknesses, and their conclusions are in agreement with characteristics of NEGIS ice flow reported by previous studies. Results inform future studies for analysis of ice cores in the region as well as more complex ice flow modeling efforts.

The described study represents a novel use of observations and models to infer uncertain information about the past climate and flow conditions in Greenland's largest ice stream. The discussion and conclusions are interesting, and the figures are highly informative. The information presented here will be of interest to both the paleo/ice core community as well as to the ice sheet modeling community. A major advantage of this study is that the

authors determine uncertainties using a Monte Carlo approach in order to better constrain their model parameters and the sensitivity of the model results to those parameters. In this way, they are able to compare the consequences of perturbations in each of their parameters, and illustrate that their conclusions are robust. The authors also allocate adequate space in the manuscript to describe study limitations, which is commendable. I find that this study is well-suited for the Cryosphere, and I recommend publication with suggested revisions.

Specifically, I find that the methods section is difficult for non-experts to follow, and in particular I find that the current version of the manuscript lacks a description of the authors' logic behind the overall analysis and modeling strategy. This could probably be solved by some rework of each of the method sections to be organized in a logical way as to clearly lead the reader through the authors' reasoning. For example, the addition of a summary paragraph with an introduction of the method steps at the beginning of section 2 and a few sentences at the beginning of each section indicating the purpose of the described methods step would really help ground the reader for each part of the study. Overall, I find that the data and methods section is the most difficult to comprehend, since it seems to lack logical flow. Either adding some more context to lead the reader, or adding something like a flow chart for reference to show the methods graphically, would improve the manuscript greatly. Many of my questions and suggestions stem from vagueness within and my confusion about the written description of the methods.

Below, I list some more specific comments and questions for the authors:

Line 30: Please specify "snow" or "source" deposition

Line 32: "where"-> "so" or "therefore" or something similar

Line 38: Can you define here what you mean by "non-climatic" within the text? As is, the sentence is confusing since you describe variability in climatic variables as "non-climatic". I think you are technically referring to non "local" climate effects.

Line 40: "parameter" sounds like something from a model instead of the physical characteristic of the ice. Maybe "measurement" or "properties" or something similar?

Line 57: "upstream effects... quantities". It is not clear to me what this sentence means. It would be more impactful if you clearly spelled out and expanded upon for the reader how your results can inform future studies.

Line 60: As mentioned above, a brief upper-level description of your methods strategy would help bring all the below sections together for the reader. In addition, every section in part 2 might also benefit from an introductory sentence or two to describe the motivation for the methods described in the given section and to give context to how it follows from the previously described method steps. Or, even something like a methods flow chart with inputs and outputs as well as the order of your method steps could help convey the information I feel is missing in this section.

Line 72: I suggest that the information in paragraph 3 of this section (line 3) introducing the radar data be placed before paragraph 2 here, to add context to the flightline discussion.

Lines 83 and 86: References to paper in preparation are not appropriate.

Lines 94-96: I think you are saying here that the Mojtabavi et al. (2020) paper is motivating and informing this work, and for this study you extend the analysis through the depth reached by 2019 (which is from 49.ka b2k). But it took me many times reading these sentences to understand that relationship. Please try to rephrase so that the relationship between the past work and what is done in this study is clear to the reader (especially readers who might not be experts in ice core analysis).

Line 104: "termination of the Greenland Stadial (GS) 2"

Line 118: As for the other sections, some summary sentences motivating why you need to do this step and the context of how it informs the following steps would be highly appreciated. The way it is written now, that knowledge is assumed and the transition from the previous section to this section is very abrupt.

Line 127: Which Matlab program is used?

Lines 129: "subsequent" -> "subsequently"

Lines 128-130: I am not sure what this sentence means. Please try to rephrase it so that it more clearly describes the method used.

Line 156: "propagation" and also their evolution (i.e. thickness)?

Line 164: Use of "B" for base is confusing because it was previously used in eq. 2 as radar bandwidth.

Line 172: Please define w within the text, e.g. "vertical velocities (w)"

Line 175: Please define S and B in the text (e.g. "surface (S) and bedrock (B) are:")

Line 183: I suggest adding -> age of the isochrones "above the bed, respectively".

Line 199: Please define what is mean by the "slope" of the accumulation

Line 202: Please quantify or more clearly describe what is considered a "good" approximation

Line 203: This methods section is the most difficult to understand. It would improve the manuscript if it were expanded and reworked to be clearer (and reproducible by future studies).

Line 204: How are your parameters initialized?

Line 205: Please specify here how the eight are selected (e.g. reference to Table 3, equally spaced for computational efficiency, etc)

Eq. 18: The use of  $S$  is confusing because it was used to mean surface in earlier equations. Also, please define in the text (i.e. "The misfit ( $S$ )").

Line 208: Please define in this context what is meant by uncertainty. Is it the standard deviation or a defined uniform error spread? How is it determined?

Line 209: Please quantify "a large number"

Line 214: " $m_{curr}$  is perturbed" -> Please specify how the parameters themselves are perturbed. For example, are they all perturbed independently from each other?

Line 218: What is meant by a "burn-in phase"? Please specify in the text.

Line 219: Please specify in the text how the thresholds (or maximum deviations) are determined?

Figure 3 (caption), Line 5: "(a,e,j)" -> "(a,e,i)" ?

Figure 3 (caption): The particle trajectories should probably be described earlier in the caption when panels a,e, and i are first described. At this point, please distinguish that they are illustrated by the solid lines and that the IRHs are represented by broken lines of the same color to indicate age of deposition.

Figure 5: Please add a label for the y axis (i.e. number of model scenarios/samples/runs or something more appropriate).

Table 4: Could uncertainties also be included in this table?

Figure 6: It appears that the colored lines for panel f are colored with the same scheme as the lines in Fig. 3 and Fig. 4. This is a very nice feature and connection between the figures, and I don't remember this being strongly noted in the text. I may have missed it, but if it was not, please make sure to point out to the reader that you made this effort, since it is a definitely a helpful tool. For example, in Fig. 3 and Fig. 4 captions you could reference Fig. 6f as to where one could see where the lines fall within the core. It would also be helpful if this nice connection was pointed out clearly in the text. In addition, for Fig. 6, maybe you could highlight in the panel f somehow the 8 chosen isochrones or connect them with their layer number as noted in Table 3.

Line 298: Please reference a figure (i.e. Fig. 3c,g,k). Also, add directionality to this statement for clarity. i.e. "increasing accumulation along the flow line with distance upstream" or something similar

Line 300: It would be helpful to directly specify what exactly the climatic reasons are for this.

Lines 301-302: This sentence is awkward and could be rephrased to be clearer as to lead the reader more directly. Please also reference the figures and panels that support your argument.

Line 333: Please be clearer about what is meant by "out-of-plane effects" and why this means that the core is not affected.



Line 429: our model allowed "us" to invert for

Line 436: As for line 298 comment above please be specific about directionality of the increase in accumulation.