Review of "Ice motion across incised fjord landscapes" by Barndon et al.

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The article "Ice motion across incised fjord landscapes" by Barndon et al. presents an investigation of the influence of the orientation of fjord incisions on the flow of overlying ice. The manuscript highlights that unresolved features in coarse topography datasets can cause errors in the velocity field in ice-flow simulations. The authors investigate the development of Moffat eddies, spiralling flow features that form in topographic hollows. This work is of particular relevance in areas of Greenland where the ice-flow direction and the orientation of underlying fjords are not aligned.

The results of this study are novel and relevant, and the manuscript is well structured. However, the emphasis on particular aspects of the study changes throughout the manuscript. I support publication once the following comments have been addressed.

General comments

Introduction

A number of important aspects of the study could be better emphasised toward the end of the Introduction. It should be clear to the reader what the specific research gap is and how it is addressed. For example, I am missing an explicit, yet short, description of the numerical experiments performed, which metrics are used and what the specific aim of these experiments are. In particular, I suggest emphasising (1) the effect of anisotropic topography orientation on ice flow and (2) the influence of the data resolution on ice flow. It would also be helpful to briefly mention aspects that become important later in the manuscript, including the role of temperature, friction and Moffat eddies. Although implications are briefly mentioned at the end of the Introduction, I suggest strengthening these arguments. For example, what are the implications of under-resolving anisotropic topography for inverse methods? How might coarse resolution datasets influence large-scale simulations and sea-level projections?

Vorticity of Moffat eddies

The results are nicely presented and I am particularly intrigued that such simulations can resolve Moffat eddies. A natural method to quantify vortices or eddies is by calculating the curl of the velocity field, i.e.

$$\boldsymbol{\omega} = \nabla \times \mathbf{u} = \left(\frac{\partial u_z}{\partial y} - \frac{\partial u_y}{\partial z}, \frac{\partial u_x}{\partial z} - \frac{\partial u_z}{\partial x}, \frac{\partial u_y}{\partial x} - \frac{\partial u_x}{\partial y} \right). \tag{1}$$

The magnitude of this vector quantifies the spin, and the direction indicates the axis of spin. It would be valuable, though not essential, to provide some quantitative analysis of the vorticity in the different flow configurations.

Discussion and Conclusions

I suggest better aligning the Discussion and Conclusions with the Results section as a few key areas of investigation are missing, such as the Moffat eddies. Some parts could benefit from an improvement in structure and clarity, such as the paragraphs beginning on lines 205 and 242. I would also suggest placing greater emphasis on the potential impacts of the anisotropic topography and the resolution on inverse methods and ice-sheet projections. I appreciate the approach of suggesting a parameterisation of unresolved hollows in the bed topography. However, Eq. (14) does not follow directly from Glen's flow law and I suggest describing the idea in the text or providing a formal derivation. Given that there is very little mention of friction laws in the Results section, I find that there is an over-emphasis and I suggest condensing this text.

Specific comments

- A number of sentences throughout are long and/or unclear. Specifically, the sentences beginning on lines 8, 16, 23, 27, 33, 75, 127, 131, 143, 197, 201.
- The use of the future tense in a number of places is somewhat confusing, e.g. in lines 2, 41, 209, 229, 273, 278.

Line 3: I suggest rephrasing "extreme case, but are ubiquitous" as it sounds contradictory.

Line 4: Remove "likely".

Line 9: The use of the word "requires" or "required" when describing the increase in driving stress between two simulations is confusing when it is not stated what this increase is "required" for, i.e. for a target velocity magnitude. Please clarify here and throughout the manuscript.

Line 11: I suggest ending the Abstract with this sentence, as the subsequent sentence draws attention away from the main findings of this study.

Line 27: "across" -> "perpendicular to".

Line 36: "...the general pattern of fjord formation ...": I suggest rephrasing this sentence as this falsely gives the impression that the study concentrates on fjord formation.

Line 37: The Introduction distinguishes between "real" topography and "smoothed" topography, yet in the Methods section it is stated that the "real" topography is also smoothed. This caused some confusion and I suggest clarifying or rephrasing this terminology.

Line 40: The Introduction should be independent of the Abstract, so I suggest rephrasing sentences that imply prior knowledge of the experiment design, e.g. "Our simulations can therefore reveal...".

Line 51: "models" -> "model's".

Line 53: Typo in "topography".

Line 58: Please define the term "plateau ice thickness" when you first mention it.

Line 63: Please provide a sentence or two describing which details are to be found in Law et al. (2023).

Line 70: I suggest giving a brief description of the x-, y- and z-axes when the gravity vector is introduced. Which axes are parallel and perpendicular to the fjord incision?

Line 74: I don't think it is absolutely necessary to mention all of the units within the sentence, but if you do use them, then please also provide the units for the strain rate.

Line 86: The details on enthalpy are currently split by information about the surface evolution equation.

Eq. (10): Why is this defined at $z = 0$? I would remove "where $z = 0$".

Line 104: $\mathbf{u}$ is already defined above. Please also make the velocity vector in the equation bold.

Eq. (12): Please use appropriate Latex syntax for "sin"

Line 132: Please define what a Moffat eddy is at first mention.

Table 1: "base simulation" - might "reference simulation" be more suitable? I suggest moving the IDs to the first or second column. The sentence beginning "For example..." is currently missing a verb.

Fig. 5 Could you please clarify the orientation of the eddies here?

Line 221: Please clarify what is meant by "in isolation".

Line 243: Please clarify or remove the sentence beginning "These two studies non-dimensionalise...".

References

Robert Law, Poul Christoffersen, Emma MacKie, Samuel Cook, Marianne Haseloff, and Olivier Gagliardini. Complex motion of greenland ice sheet outlet glaciers with basal temperate ice. *Science Advances*, 9(6):eabq5180, 2023. doi: 10.1126/sciadv.abq5180.