

# Review of the article entitled “Surging of a Hudson Strait Scale Ice Stream: Subglacial hydrology matters but the process details don’t” by M. Drew and L. Tarasov

## 1 General comments

This study investigates the implications of introducing different subglacial hydrology model formulation for the surge dynamics of an Hudson Strait like ice stream. The manuscript first introduces the different approaches that are used for the subglacial hydrology modelling before providing a verification of these implementations. The authors then present a framework for long term simulations of an Hudson Strait like experimental design that allows to perform a large ensemble of simulations on long time scales. The results of the ensemble is then presented both to emphasise the parameter sensitivity of the different hydrology model and the differences that arise between the different approaches.

I found this study to be overall well presented and clear on an interesting and topic that as not been studied in details before. In an effort to give a clear description of their approach and models, the authors end up with a quite lengthy paper but I expect that it can not really be avoided here, I only noted a few places where some paragraphs may be omitted which would make room for more critical information.

As a general note, I am under the impression that some of the conclusion of the study and particularly the one relative to the unimportance of “process details” is overstated. I agree that the results shown here on the Hudson Strait surges frequencies seems to be unchanged by the different hydrology modelling approach used here but it feels to me that it is a bit thin to have such a strong conclusion.

Regarding the hydrology processes themselves, I am unsure if the efficient drainage is applied to the linked cavity system only or two both the mass transporting hydrology setups. I also am not sure why this part of the model is not compared to the GlaDS model, to me the shift between efficient and inefficient drainage is one of the crucial point of a subglacial hydrology model and I would be very interested to see how the approaches used here compare to GlaDS with a higher recharge scenario (like A5 from SHMIP).

The presentation of the ensemble results and the sieve treatment made this part easy to read and interpret and that was a very interesting read, I noted a few places where referencing could be improved. I would also like to suggest a few changes to the figures that are listed in the minor comments bellow and would improve readability.

## 2 Specific comments

Bellow are some comments on specific sections of the manuscript.

Introduction. The reference to Hank et al. here is a bit problematic as it is not clear to me what we are talking about, perhaps a succinct description of the method developed in the Hank paper should be introduced here.

Section 2. I find the description of the inefficient drainage systems to be well presented here but I am less convinced by the description for the efficient drainage system, I am not sure for example if the efficient drainage applies to both poro-elastic and linked cavity systems or to only one of those.

Section 3. The sub-sectioning of this part could be improved, perhaps the very short introduction can be replaced by the current sub-section 3.2 which would serve the purpose of introduction here. I would also suggest to have a specific section for the hydrology model verification which in my opinion is an important part of the study. The assumption of the hydrology model are also quite important in the description of the model and should in my opinion appear in the section 3 rather than in the supplementary. In order to shorten the main manuscript, section 3.1.1 could be moved to the supplementary materials. Regarding the subsection on model validation, I am unsure of the necessity of the introductory paragraph I would however like to see a comparison of the model to GlADS with a higher input scenario to assess the changes that are due to this part of the model.

Section 4. Part of this section might be reduced, I feel that the parameters for which only a few lines are given with no strong argumentation could only appear in a table with a reference cited to justify the range. I am not sure of the temperature description that is given in equation 18. Following the equation given there and the map of LISq the temperature at the northern end of the domain would not be  $T_{north}$  but  $T_{north} + 5000T_{grad}$  also, the elevation dependant term is summed with the others but the lapse rate is positive which would give higher temperature at higher elevation.

Discussion. As for the title I feel that the discussion here is a bit too strong in term of wording. I agree that the details of hydrology approaches presented here do not impact greatly the frequency of surges but they may be important for other applications (as shown

in figure 13 for example). It feels also necessary here to underline the shortcomings of the present study and their potential implications on the conclusion.

Here are more technical comments given with their line number.

- Line 7: Is “BraHms” here an acronym, if yes it should be spelled.
- Line 8: I am not sure what “systems” are referred to here.
- Line 19: I would not say that the role of subglacial hydrology at time scales larger than a season is clear, so perhaps this sentence can be rephrased.
- Line 21: The sentence ending on this line is not the clearest and could be reworded.
- Line 32: Studies by Fürst et al. (2015); Shannon et al. (2013) might be relevant here and could be added.
- Line 43: “begin to rapidly slide” “to is missing.
- Line 48: References for the hydrology formulations should be added.
- Line 52: A reference is missing for GSM.
- Line 64: I expect that “HS” stands for Hudson Strait but it has not been introduced before.
- Line 70: It should be “or” in place of “and”.
- Line 78: I am not sure why porous media is used here where poro-elastic is used everywhere else.
- Line 79: Flowers (2015) should be added here.
- Line 91: Smith et al. (2021) could be added here.
- Line 94: I find this formulation unclear.
- Line 116: I feel that the formulation here could be shortened giving only the new equations are the exponents of equation 1.
- Line 121:  $P_{water}$  is already defined above.
- Line 133: I feel that the formulation here could be shortened giving only the new equations are the exponents of equation 1.
- Line 133:  $k$  is referred to here but  $K$  is in the equation.

- Line 135:  $N_{eff}$  is usually referred to as effective pressure, is there a reason for it being pressure closure here?
- Line 141:  $N_{eff}$  was defined above already.
- Line 146: There is a missing reference here.
- Table 1: The acronyms of the table should be described in the caption.
- Line 174: Numbering is missing for those equations and it should be  $h_{cav}$  in place of  $h$ .
- Equation 9:  $\phi_{eng}$  and  $m_t$  are not described.
- Line 182:  $drain$  and  $s_{melt}$  could be added on this line for description.
- Line 183: A comma is missing in the reference.
- Line 198: “v2” is missing for BraHms.
- Line 245: The sentence starting on this line should be rephrased.
- Line 258: Figure 1 shows the convergence for all parameters not only  $N_{eff}$  so I am not sure here what  $\Lambda$  stands for.
- Line 307: “Bay/Strait” is capitalised here but not bellow.
- Line 307: “HEINO” here needs a reference.
- Table 2: This table is missing from my version of the manuscript.
- Equation 20: There is no description of the parameters of this equation.
- Line 350:  $k_{min}$  value should be fixed.
- Line 350: Is there a reason to have upper case and lower case “k” for conductivities.
- Figure 5: Colours on this figure should be changed for more colourblind friendly versions.
- Figure 5: I am not sure which Flow speed is referred to on the x axis.
- Equation 21: Operator log and arctan should not be slanted fonts.
- Equation 21: is there a reason for the renaming of  $h_c$  to  $h\_crit\_dpe$  here?
- Line 358: I have not seen  $T_{bp}$  used anywhere else.

- Equation 22: I have not seen  $K_f$  defined anywhere.
- Equation 22:  $T_{froz}$  here and in the text have different font.
- Line 371: “e.g.” should be before the reference.
- Line 372: I am not sure that the precision on the referencing are needed here.
- Line 385: I am not sure of the meaning of “communiton”.
- Line 390: See my comment above on the clarification for the Hank paper.
- Line 397: I am not sure of the point of the sentence starting on this line.
- Line 402: I think that the reference to fig. 6 here is misplaced.
- Figure 6a: Label is missing on the y axis.
- Line 452: Shouldn’t reference here be to figure 8 rather than 12.
- Line 457: Shouldn’t reference here be to figure 8 rather than 12.
- Figure 8: The horizontal line is not described in the caption.
- Figure 9: Line colours should be given in the caption, the legend should be moved for clarity and upper case letter used as in the caption.
- Line 476: Reference to figure 9 should be added here.
- Line 489: Reference to figure 9 should be added here.
- Line 497: I am not sure what “tbl. 3” references to is it in the referenced study?
- Line 504: “on of HSIS” either “on” or “of” should be removed.
- Figure 10: The colours between PE and NH should be changed for colourblind friendliness.
- Figure 10: On this type of figures perhaps a line would be clearer than the histogram to compare the different models.
- Figure 10: “Run Density” of panel a is missing ticks and labels.
- Line 527: “Fig 12” should be referenced here.
- Figure 11: The colours between PE and NH should be changed for colourblind friendliness.

- Figure 11: Upper panel y-axis of panel a is missing a label.
- Line 535: A reference to figure 13 should be added here.
- Figure 12: The horizontal line is not described in the caption.
- Figure 12: I wonder why the delineation between sensitive and insensitive is not presented as in Figure 8.
- Figure 13: The font on this figure is a bit small.
- Line 551: The paragraph starting on this line could be clearer.
- Line 554: The number of the referenced figure is missing.
- Figure A1 and A3: Same colour issue as before, and the grey region is not described in the caption, ticks and labels on the left panel are missing.
- Figure A2 and A4: Same issues as figure 11.
- Figure C1: The colours should be changed for colourblind friendliness.
- Line 634: The number of the equation referenced here is missing.

## References

- Flowers, G. E. (2015). Modelling water flow under glaciers and ice sheets. *Proc. R. Soc. A*, 471(2176):1–41.
- Fürst, J. J., Goelzer, H., and Huybrechts, P. (2015). Ice-dynamic projections of the Greenland ice sheet in response to atmospheric and oceanic warming. *Cryosphere*, 9(3):1039–1062.
- Shannon, S. R., Payne, A. J., Bartholomew, I. D., van den Broeke, M. R., Edwards, T. L., Fettweis, X., Gagliardini, O., Gillet-Chaulet, F., Goelzer, H., Hoffman, M. J., Huybrechts, P., Mair, D. W. F., Nienow, P. W., Perego, M., Price, S. F., Smeets, C. J. P. P., Sole, A. J., van de Wal, R. S. W., and Zwinger, T. (2013). Enhanced basal lubrication and the contribution of the greenland ice sheet to future sea-level rise. *Proceedings of the National Academy of Sciences*, 110(35):14156–14161.
- Smith, A. M., Anker, P. G. D., Nicholls, K. W., Makinson, K., Murray, T., Rios-Costas, S., Brisbourne, A. M., Hodgson, D. A., Schlegel, R., Anandakrishnan, S., and et al. (2021). Ice stream subglacial access for ice-sheet history and fast ice flow: the beamish project on rutford ice stream, west antarctica and initial results on basal conditions. *Annals of Glaciology*, 62(85-86):203–211.