General comments

In this study, the authors have investigated the coupled interactions between the subglacial hydrological system and the ice sheet through the basal friction coefficient – an important and challenging tuning parameter used in friction laws – and its dependence on the form of the effective pressure. They also proposed a new empirical formulation of the effective pressure. Moreover, they highlighted the importance of subglacial processes on ice-sheet dynamics and conclude the need for geophysical observations of these processes would improve models.

This paper matches the quality criteria required by The Cryosphere. I have only a few comments and recommendations to improve the quality and scientific rigour of the manuscript as well as its understanding for readers that are less familiar with the subject and the tools used.

My first general comment concerns the choice of the Budd sliding law. Knowing that the value of *m* has a major influence on ice dynamics, why hasn't the Budd sliding law with the exponent *m = 3*, which is the most commonly used value instead of m=1? Wouldn't it make it easier to compare to the Schoof sliding law?

My second general comment concerns the calculation time required for a more complex hydrological model. At what time and space scale does a more complex model (such as GlaDS) make a significant and crucial difference in glacial dynamics and does it compensate for the additionnal time of calculations used ?

My third general comment concerns the figures. If a standardisation does not allow the scales to be the same, it must be stipulated in the text for all figures concerned so that there is no misunderstanding. Also, note that this difference in scale does not allow the same analysis and comparison resolution. Also, it is better to have complete captions (variable-symbol-units) and the same than the legend (the text written next to the colorbar). It also is more readable if both limits of the scale are written.

My final general comment concerns how the types of effective pressures are expressed in the text. I think it would be better to define in an equation N_o from the beginning and not to repeat it again in the text. Why choose N_o and not choose the 'limited version' by Brondex et al, 2017 from the start? I don't quite understand how considering the two brings a lot of added value (especially by comparing figures 6c and 6d). If you decide to keep both, then set a symbol for N Brondex to avoid repetitions in the text. Finally, when we see the large difference in N values between N_o and N_G in Figure 3, it would be good to explain how a single variable can be considered with such different values.

I therefore propose some small changes in the text or the figure calls to improve clarity and understanding. The main thing is the insistence on the terms « basal » and « subglacial » which for me are important to keep throughout the text. Finally, I also propose to elaborate on more technical details with respect to the tools used and the choice of parameters.

Specific comments

L37-L117. Please to specify whether these negative effective pressures are stable, at the steady state, seasonally dependent…Please add information on the stability of this case and also whether it varies over time (depending on the seasons or the tides). It could be interesting to add a sentence mentioning that the presence of zones with negative effective pressure may be persistent and does not lead to instability.

L64. Stipulate if the model reaches the steady state after 10,000 days.

L78-L346 : If you don't add information about the ice rigidity calculation, please add a reference.

L140. As you explain that low effective pressures were associated with faster flow, give a brief explanation of this case.

L173. Use the reference Huybrechts, 1990.

Remove Budd and Jensen, 1987.

If you use the references, Johnson and Fastook, 2002 and Lebrocq et al., 2009 define the hydraulic potential = 0.

L180. Accurately calculating the effective pressure is important improve ice-sheet models. However, effective pressure parametrizations used in Brondex et al., 2017 and Kazmierczak et al., 2022 are simplified for computational purposes and numerical stability, especially when the study is either focused on grounding lines or experiments are done on a continental scale. Please, add the concept of model complexity for the subject under study.

L180 : Previous studies have investigated alternative parameterizations for the effective pressure **in the absence of a coupled ice sheet-subglacial hydrology model**.
In Kazmierczak et al., 2022., the ice-sheet model is coupled to the simple subglacial water routing from Lebrocq et al., 2009 by the subglacial water depth and by the flux.
This sentence should be modified by […]**complex subglacial hydrology model due to the** computational time.

L196 : Add a reference on the **alpine-like hydrology system**.

L220 : Since equation 1 does not include *m*, this sentence is not clear. Then perhaps add the *m* in equation 1 and mention that *m=1*.

L285-286 : Specify with which formulation of the effective pressure this conclusion is made.

L353 : Add a reference for the Paterson function.

L362 (éq. C2) : Why is Cmax (0.8) different to the value used in Brondex et al., 2017 (0.5)?

Figure 1. First time you mention Denman-**Scott** catchment. It is better to mention it in the text beforehand.

Figure 4. Could you explain how the very different effective pressures between N_G and N_O do not significantly impact the basal friction coefficient in the Schoof basal sliding law but impact significantly the basal friction coefficient in the Budd basal sliding law.

Table 1 : I never used GlaDs but as some parameters are different than in Werder et al., 2013, why? Specificity from Antarctica or this specific catchment? How did you obtain these parameters? The ice flow constant is the same for cavities and channel?

Technical corrections

Abstract

L10 Budd **friction** law

L10-14 Schoof **friction** law

Introduction

L19. Mention the dataset of Adusumilli et al., 2020 in the references. Because the data you mention are not in the paper itself.

- ➔ Adusumilli, Susheel; Fricker, Helen A.; Medley, Brooke C.; Padman, Laurie; Siegfried, Matthew R. (2020). Data from: Interannual variations in meltwater input to the Southern Ocean from Antarctic ice shelves. UC San Diego Library Digital Collections. https://doi.org/10.6075/J04Q7SHT

L20. Mention the dataset of Morlighem et al., 2020 in the references.

- ➔ Morlighem, M. (2020). MEaSUREs BedMachine Antarctica, Version 2 [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/E1QL9HFQ7A8M.

L20. Denman **Glacier**

L21. « containing 1.5 m of sea level equivalent. » → source? (rewrite Brancato et al., 2020)

L26-27. Replace « Coulomb laws » by **regularized Coulomb friction laws**.

Because in a Coulomb friction law s.s., the basal shear stress is independent of the basal sliding velocity.

L27. of the ~~of the~~ Budd

L27 & 29. On the **basal** sliding velocity

L28. **subglacial** water pressure

L29. Provide examples of the « other quantities » (i.e. rugosity of the bed…)

L29. Why unexepected?

L30. **basal** friction coefficient (2)

L31. **basal** sliding velocity

L32. **basal** friction coefficient

L38. Remove (i.e. the ice overburden pressure) or modify it by (i.e. when subglacial water pressure exceeds the ice overburden pressure)

L41. **Subglacial** water pressure

Methods.

2.1 GlaDS Setup

L58. Source for the surface velocities? MEaSUREs v2?

L59. Same comments in L20 about the Morlighem et al., 2020 source

2.2 ISSM Setup

L68. Add reference for SSA: Morland, L.: Unconfined Ice-Shelf Flow, in: Dynamics of the West Antarctica Ice Sheet, edited by: van der Veen, C. J. and Oerlemans, J., Kluwer Acad., Dordrecht, Netherlands, 99–116, 1987.
L72. Same remark in Figure 1.
L75. **basal** friction
L76. **basal** friction law
L77. Same comment in L59.

2.2.1 Solving for basal friction coefficients

L85. Why eq 2 and eq C2 are not the same? If it's a mistake, the ()^m is missing in the denominator. Is it possible to isolate the coefficients of friction in order to make them more visible?

L87. Source of the Iken's bound missing and please refer to Appendix C.

L90. **Appendix C**, Table C1

L98. For the N_o equation complete that B takes negative values below sea level and defines the variables.

Results

3.1 Subglacial hydrology

L105 and L106. Even if it's clearly written in L103, mention that the data indicated (length of the channel and the flow) come from the GlaDs modelling.

L108. If the two branches of 80 and 52 km of the Denman channel are figure 2a (iii) and (iv), mention the figure in the text.

L111 & Fig.2d(v). I know that the choice of the limits of the legend is there to allow a better reading, but I find it strange to mention 25 m of thickness whereas the legend stops at 10 m.

L112. We cannot really see on the figure that the strongest flux is toward Denman, so do not mention the figure but rather the data.

L116-117-118-119 **subglacial** water pressure

L121. Show these zones in the Fig. 2b.

3.2 Ice dynamics and inversion

L127. Schoof friction law **(éq. 2)**

L132. slow **ice** flow (maybe mention the Fig. 1b with the surface speed)

L133. Locate the Shackleton Ice Shelf in one of the figures (e.g. Figure 1).

L135. a space is missing between Fig. and 4c

L136. **basal** friction coefficient

L138. faster **ice** flow (**ice** surface speeds […]

L139. slow **ice** flow (**ice** surface speeds […]

L141. **basal** friction coefficient and please refer to (Fig. 5b).

L133-138-140. The limits given to consider an ice flow faster or slower are not the same, why?

L143. Glacier**s**

Discussion

4.2 Effective pressure and basal sliding laws

L182. : the till parametrization used in Kazmierczak et al. 2022 is from Bueler and van Pelt, 2015

L200. : The relationship between low effective pressures and low basal friction did not hold for the Budd friction law, **(Fig 3 (a), Fig 4 (e))** despite a stronger negative correlation between the friction coefficient and surface speed for the Budd friction law compared to the Schoof **friction** law **(Fig 5(a),(c**)).

L214. : when using a Weertman friction law**, which not considered the strong dependence of τ_b on the effective pressure,**

L215. : Schoof **friction** law
L216-218-221. : **Regularized** Coulomb friction laws
L229. : This study by Kazmierczak et al. (2022) examined the impact of different representations of the effective pressure – approximated in turn by height above buoyancy (van der Veen, 1987; **Huybrechts, 1990**, Winkelmann et al., 2011, **Martin et al, 2011**), reduced by the subglacial water pressure (**modified from Bueler and Brown, 2009**) or sliding related to water flux (Goeller et al., 2013) **from a simple subglacial water routing model (Lebrocq et al., 2009)**, and the effective pressure in a till (**Bueler and Van Pelt, 2015**) – on ice mass loss from Antarctica over the 21st Century.

4.3 Empirical Parametrization

L 254-255. : γ or δ ? use the same symbol
L260. : define Brondex et al., 2017 or write something like […] No on all the domain or, following the condition of Brondex et al., 2017, exclusively below sea level […] Fig. 6**a, b, c, d**
L264. : define the « saturation term »
L267. : 77~~.0~~% (use the same number of significant digits)
L279. : **basal** friction laws

L280. : **basal** friction coefficient

L285. : Schoof **friction** law

L289. : **geophysical** observations

Appendix A

L304-308-313. : pressure~~s~~ (it is correct but keep pressure or pressure**s**)

L305. : domain~~s~~

L306. : speed~~s~~

L307 + Table A1 : 500≥v<1000ma−1. The sign is not correct ?

L320-321. : (e.g. Bueler and Brown, 2009; Bueler and Van Pelt, 2015, van der wel et al., 2013, Huybrechts 1990, Kazmierczak et al., 2022 ; ~~Goeller et al., 2013~~; ~~Le Brocq et al., 2009~~; van der Veen, 1987; Winkelmann et al., 2011)

Figure A1. (a)-(b) Effective pressure~~s~~ *N* (MPa) Note that the color bar scale is not the same. It is better if both limits of the scale are written.

Appendix B

L324-332-333-334-335-336. : **basal** friction coefficient

L327. : For Rignot, 2017, the dataset I founded has to be referenced like that :

- ➔ Rignot, E., J. Mouginot, and B. Scheuchl. (2017). MEaSUREs InSAR-Based Antarctica Ice Velocity Map, Version 2 [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/D7GK8F5J8M8R. Date Accessed 04-20-2023.

And following the informations given to this link : https://nsidc.org/data/nsidc-0484/versions/2 these references has to be included :

- ➔ Mouginot, J., B. Scheuchl, and E. Rignot. 2012. Mapping of Ice Motion in Antarctica Using Synthetic-Aperture Radar Data. *Remote Sensing*. 4. **DOI: 10.3390/rs4092753.**
- ➔ Mouginot, J. et al. 2017. Comprehensive Annual Ice Sheet Velocity Mapping Using Landsat-8, Sentinel-1, and RADARSAT-2 Data.. *Remote Sensing (in press)*.

L336. : the precribed effective pressure B1? It is not clear… explain in the text (like in the Table B1. Caption) that the prescribed effective pressure is N_o.

L337. : effective pressure **calculation/representation**

Table B1. : **basal** friction - Schoof **basal** friction coefficient – Budd **basal** friction coefficient

Figure B1. Schoof **basal** friction coefficient

Appendix C

L344. : B is the bed elevation (m) **taking negative value below sea level**

L348. : same comments in L327

Figure C1. Budd **basal** friction coefficient – '.' Missing at the end of the sentence.

Figure C2. Schoof **basal** friction coefficient– '.' Missing at the end of the sentence.

Figure C3. On the figure : S**c**hoof (x2) + specify with N_o and N_G– In the caption :**Basal** friction coefficients - Schoof **basal** friction coefficient (x2) Budd **basal** friction coefficient (x2). Add the units and that the colorbar scale is not the same. It is better if both limits of the scale are written.

Figure C4. **basal** friction coefficients – prescribed → N_o?

Figure C5. It is better if both limits of the scale are written. – Caption : '.' Missing at the end of the sentence.

Table C1. Budd **basal** friction coefficient -- Schoof **basal** friction coefficient

L352. : Budd **basal** friction coefficient

L358. : **basal** friction coefficient

L361. : same comment L85

L362. : Schoof **basal** friction coefficient – Add a reference or an explanation for the Iken's bound – **basal** friction coefficient

L363. : **basal** friction coefficient

L364. : **basal** friction coefficient

Appendix D

L374-376. **ice** overburden **pressure**

Figure D1. It is better if both limits of the scale are written.

Add the units and that the colorbar scale is not the same. It is better if the caption and the legend are the same (with symbol and units) → Effective pressure (N) (MPa)/ friction coefficient for the Schoof friction law C […]/surface speed (u_s) (m a^{-1})

Figure D2. It is better if both limits of the scale are written.

Add the units and that the colorbar scale is not the same. It is better if the caption and the legend are the same (with symbol and units)

Appendix E

L380. : define ρ, g and H in the p_i equation

L381. : **subglacial** water pressure

L394. : to avoid a confusion with the power law exponent, maybe chose another letter than *m*.

L395. : **subglacial** water pressure (x2) – ~~allowed~~ water pressure **allowed**

Figures

Figure 1.

- (a) Bed elevation **(unit missing)** from Bechmachine v2
    - Detail : it's « Bed elevation » in the caption and « Bed topography » on the figure. Use the same formulation.
- (Morlighem et al., 2020) same comment as L20.
- (Rignot 2017) same comment as L327. → And modify by « Rignot **et al.**, 2017 »
- It misses a '.' At the end of the caption.

Figure 2.

- modify overburden pressure by **ice** overburden pressure.
- On L114, you mention « the nothern branch » of the Denman glacier, but in the caption you mention in Fig2a (iii) a western branch and in (iv) an eastern branch. I'm

confused. Please, is it possible to have a clarification/harmonisation between the figure and the text and also to say which one is longer compared to what is written on L108.

Figure 3.

Place the figure in the subsection 3.2.

(a) Effective pressure (MPa) calculated by GlaDS, N_G, […]

(b) ~~prescribed~~ effective pressure (MPa) […]

Figure 4.

Caption : **surface** velocity/ Schoof **friction** law (2)/ Budd **friction** law (2)

Figure 5.

Fig. 5b S**c**hoof

It is better if both limits of the scale are written.

Fig. 5d for r^2 = write the same number of significant digits.

In the caption : The red line is the linear line of best fit, and the slope of this line is reported **(r^2)**.

Figure 6.

a-b-c-d for the colorbar, maybe write « N_G/Pi » - « N_E/Pi » - « N_o/Pi » « N_B/Pi »? and explain it completely in the caption. Use the same wording in the legend as in the caption.

(f) The difference between the proposed empirical parameterization of effective pressure (N_E) and the GlaDS effective pressure (N_G) as a fraction of ice overburden pressure.

As figure f is explained before firgure e in the text, I would switch them.

Table 1.

Channel ~~C~~**c**onductivity

Ice density kg.m^{-3}

Sheet ~~W~~**w**idth ~~B~~**b**elow ~~C~~**c**hannel

Table 2.

In the caption, use the same formulation than in the fig. 3 caption : […] to **the ice** overbruden pressure […] **formula**