EGUSphere-2024-665 – Response to referee 3

September 18, 2024

We thank the reviewer for their constructive and insightful comments that have helped us improve the manuscript. Below we provide a detailed discussion of the comments and proposed changes. We use blue colour to indicate **comments**; our **replies** are in black.

1 Major comments

I found the information provided in section 3.2 about the LEFM model inadequate – I don't think sufficient information is provided to reproduce the stress intensity factors shown in the study.

Thank you for the constructive feedback. The LEFM model demonstrates the tidal and hydrostatic stress required to induce hydrofracturing from initial flaws with a given length. We will add an appendix showing how we calculate the stress intensity factor with the weight function method.

Part of the stress field seen in figure 3 is a result of keeping the ice thickness fixed: In full-Stokes models, when you have flow across a slip/free slip boundary, the ice surface adjusts to have a very characteristic dip just downstream of the grounding line, which is a result of the speed up across this boundary (e.g., Barcilon and MacAyeal, 1993; Nowicki and Wingham, 2008). If the surface cannot adjust, residual stresses at the surface occur. Ideally, simulations would have been done with an evolving surface, but I understand that this is beyond the scope of this study. However, to account for this limitation, the difference of the deviatoric surface stress with tides and without (i.e., for a static grounding line) should be used (which I guess would be about 10 kPa less than the stresses shown, judging from the figures 3b and d).

Thanks for pointing out this limitation. In the model results in Figure 1 with revised rheological parameters, we found a background deviatoric tensile stress of approximately 30 kPa (Figure 1b,d), likely caused by the ice speed-up across the grounding line. The background stress will be extracted from the net stress in the fracture model. As the referee pointed out, our model does not fully capture the geometric complexities near the grounding line. We will include this limitation in our discussion.

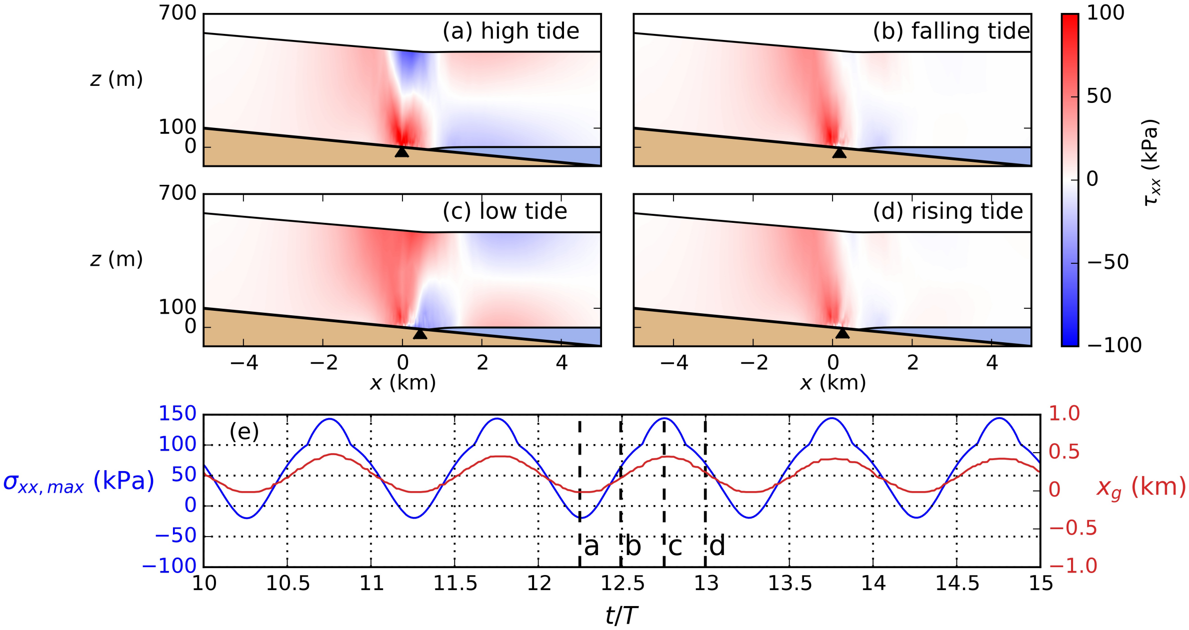

Figure 1: Tidal response of a marine ice sheet at different tidal phases, using the new set of parameters: $A_0 = 1.2 \times 10^{-25}$ Pa^{-3} s^{-1}. **(a)–(d)** Deviatoric tensile stress τ_{xx} in one tidal period. **(e)** The maximum tensile stress $\sigma_{xx,max}$ (blue) on the top boundary within the lake region ($\bar{x}_g - 0.5$ km $\leq x \leq \bar{x}_g + 0.5$ km) and the GL position x_g (red) versus time (scaled by the tidal period T) with positive values representing downstream migration. Vertical dashed lines show the time of panels (a)-(d).

The existence of a 10 m deep lake at the ice surface imposes a pressure of about 10 kPa at the ice surface, which is not necessarily negligible. How would that alter the stress considerations?

We agree with the referee that the supraglacial lake can modify the grounding-line migration, tidal stress, and hydrofracture propagation nearby. In the marine ice sheet model, the lake pressure can be accounted for by imposing an additional time-dependent lake pressure on the top of the ice sheet. During our initial model-development phase, we found that the influence of lake pressure on grounding-line dynamics is sensitive to the lake's position relative to the grounding line, since ice beneath the lake may shift from "grounded" to "floating" within one single tidal cycle. A supraglacial lake on a floating shelf can cause downward flexure [MacAyeal and Sergienko, 2013, Banwell et al., 2019, 2024], but this effect may be largely mitigated if the shelf regrounds on the bedrock during low tides. Additionally, the stress induced by the lake also depends on the specific geometry of the lake basin. While this is an intriguing topic, investigating the impact of the lake is beyond the scope of our current study. We believe future observations with higher-temporal-resolution data on lake depth and geometry near grounding lines could provide further insights into this process.

2 Minor comments

Page 4, 2nd line: “the the” → ”the”

Will Change.

Page 4, 2nd paragraph: “The subglacial cavities downstream of the grounding zone are more than 20 m wide.” I was confused by this, as BedMachine does not have 20 m resolution. What are you referring to here?

We apologise for the confusion. We are referring to the subglacial cavity being 20 m wide in the vertical. We stated this to show that the subglacial cavity under the floating shelf is large enough to allow free tidal oscillation without the formation of pinning points. Meanwhile, the water pressure can be approximated to be hydrostatic in the subglacial cavity. We will expand the sentence to include these details.

Figure 1b and caption: there is reference here to σ_1 and σ_2 but elsewhere in the text you refer to principle strain rates. Please make sure this is consistent.

We will modify the figure legend by using “principle strain rates” instead of “σ_1” and “σ_2”.

Figure 6 and corresponding text: can you comment on the zero-tidal amplitude limit? Are the results what you would expect?

Thank you for the suggestion. The zero-tidal-amplitude limit represents a static grounding line with only the background tensile stress and the lake water pressure. It shows that without tides, the lake water pressure together with background stress is insufficient to drive hydrofracturing, even if the lake basin is filled with melt water ($d_w = 10$ m). This indicates that lake drainage only occurs with tides, thus is consistent with the hypothesis from Trusel et al. [2022].

References

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Alison F Banwell, Ian C Willis, Laura A Stevens, Rebecca L Dell, and Douglas R MacAyeal. Observed meltwater-induced flexure and fracture at a doline on george vi ice shelf, antarctica. *Journal of Glaciology*, pages 1–14, 2024. doi: 10.1017/jog.2024.31.

Douglas R. MacAyeal and Olga V. Sergienko. The flexural dynamics of melting ice shelves. *Annals of Glaciology*, 54(63):1–10, 2013. doi: 10.3189/2013AoG63A256.

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