Review of "Quantifying the Buttressing Contribution of Sea Ice to Crane Glacier" by Parsons et al., 2024.

This article deals with the interesting and important topic of how the presence of mélange can affect viscous stresses within ocean-terminating glaciers. The authors focus on the calving and acceleration of Crane Glacier following the removal of landfast sea ice from the Larsen-B Embayment in early 2022. They use a numerical model to calculate a local "buttressing number" representing the amount of buttressing provided to Crane Glacier by proglacial mélange prior to its removal, and changes in viscous stress within the glacier following its removal. They find the removal of mélange caused perturbations in stress of order 10kPa and suggest that this caused the retreat and acceleration of Crane Glacier from 2022 onwards.

This study is well motivated, scientifically sound and makes a robust and important contribution to an interesting discussion that has been the subject of recent literature. The article is well written and should be published in The Cryosphere as it will be valued by a broad range of cryospheric scientists. However, this is subject to some revisions - particularly regarding the use of the words "sea ice", the placement of the research in the context of other recent literature, and the general quality of the figures.

The following review gives some general comments on the article before listing a set of additional, specific comments that are not covered there.

General comments:

In a number of places throughout the article, the authors use the term "sea ice" where I think they mean "ice mélange" (including in the title of the article). This distinction is both important to how the reader should interpret the results of the article, and how to place the work within the context of contemporary literature (see below). Though sea ice is an important component of mélange, it is a quite different material with different properties and conclusions regarding the ability of mélange to bear stress shouldn't necessarily be applied to pure sea ice (even when it's thick). This should not be too difficult to fix throughout the article and will improve it significantly.

The use of the term "sea ice" also slightly muddies the waters regarding previous work on this area. In general, though the authors do a nice job of summarising previous work on landfast sea ice in the Larsen-B Embayment, the assessment of how previous modelling work relates to this study should be improved. For example, there are a number of references to this being the first example of using a numerical model to calculate the effect that landfast sea ice has on englacial stress, but Surawy-Stepney et al., 2024 (who used a modelling set-up which explicitly neglected the presence of mélange) calculate an upper limit for this in their figure 4d. Looking at that figure, the numbers they come up with are the same order of magnitude as those presented here (10s of kPa). In which case, the biggest differences between the two studies seem to be that SS24 consider the idealised case of pure landfast sea ice, while this study considers the realistic case of proglacial mélange, and in the interpretation of the resulting stress changes as 'big' or 'small'. The reader could be left with the impression that this article disagrees fundamentally with previous modelling efforts, whereas in reality there seems to be no contradiction (e.g. not one arising from the different methods of initialising the rate factor prior-to or post removal of proglacial ice, as suggested in the introduction).

The figures are nicely placed throughout the article and cover all the necessary bases, but they are a little bit difficult to read in general. Making the text quite a bit bigger in the figures would go a long way to fixing the issue.

Specific comments:

Line 76: Could the authors elaborate on how the DEM strips were co-registered?

Line 116: Out of curiosity, could the authors elaborate on these boundary conditions a bit? The use of a boundary condition on speed seems sensible given the domain doesn't reach the edges of the fjord or the margin of the landfast sea ice. Is it the case that stress boundary conditions would be more desirable given that it's the stress across the domain that we're ultimately interested in and we don't know the mélange rheology? Is the speed used to define the boundary conditions the same as that used in the inverse problem? Does it matter that this data is probably noisy?

Line 128: The use of "prior" makes the reader think of prior distributions in the Bayesian sense which I don't think would be right unless the regularisation terms have a particular form (and these values are the mean of the prior distribution). If so, it might be better to say "initial guesses for A and C" or something to avoid confusion.

Line 130: Tikhonov regularisation is a class of regularisation methods, which one in particular was used?

Section 3.3: It would be great to see (perhaps just as a supplementary figure) maps of: 1) ice speed used in the inverse problem, 2) the rate factor found at convergence, and 3) the solution misfit. This would help the reader gauge the success of the inverse problem (which I'm sure is very good) particularly regarding transition across the calving front. E.g. I would be interested to see whether the ice speed data is any noisier in the proglacial mélange than on the ice shelf.

Line 148: It might be worth making it clear that these are vertically-averaged stresses to avoid any confusion.

Section 4.1: Given that this is the first attempt to quantify buttressing using the buttressing number, it would be nice to see some more discussion of the sources of uncertainty associated with the numbers computed. Even if exact quantification is difficult, how large might these uncertainties be expected to be? The authors' exploration of solutions to the inverse problem with different mélange thickness, and how the model compensates by changing the rate factor to produce similar stress fields, is nice. However, there are likely to be many sources of uncertainty and it's not clear to me how many of these are covered by the thickness sensitivity experiments.

Figure 4: A key showing how the lengths of the lines corresponds to vertically-averaged stress would be great.

Discussion/section 4.2: It would be nice to see some discussion about how these numbers compare with those computed in Surawy-Stepney et al., (2024) – particularly their figure 4. To me they seem fairly similar, perhaps their stiff-but-thin sea ice has a similar load-bearing capacity to your weak-but-thick mélange?

Section 5.2: For those who find it a bit difficult to contextualise numbers such as "stress of 60kPa" or "change in stress of 19.2kPa" it might be helpful to have a reference stress to consider. For example, I imagine basal stresses calculated during the inverse problem are on the order 100kPa? This section might be a nice place to put a sentence with this comparison.

Lines 290 onward: The conclusion suggests that inverting for the rate factor again might allow for the inclusion of sea ice of unknown thickness/rheology in numerical models. It is worth noting that it is possible to get away with this in diagnostic simulations such as that presented here, and when considering mélange. However, though the stress distribution found using this kind of method during the inverse problem might be roughly correct, transient simulations will require a better treatment of sea ice/mélange rheology, which differs from that of meteoric ice by more than just its viscosity!

Editorial comments:

Line 22: Gudmundsson reference should be at the end.

Equation 6: That should be $2\tau_{yy} + \tau_{xx}$

Line 203: “lead” should be “led”.

Figure 2: Should the last line of the caption read “solid black line” rather than “dashed yellow line”?

References:

Surawy-Stepney, T., Hogg, A. E., Cornford, S. L., Wallis, B. J., Davison, B. J., Selley, H. L., Slater, R. A. W., Lie, E. K., Jakob, L., Ridout, A., Gourmelen, N., Freer, B. I. D., Wilson, S. F., and Shepherd, A.: The effect of landfast sea ice buttressing on ice dynamic speedup in the Larsen B embayment, Antarctica, The Cryosphere, 18, 977–993, https://doi.org/10.5194/tc-18-977-2024, 2024.