We greatly appreciate the insightful feedback of Reviewer 2. We agree that our analysis does not support ice anisotropy as the cause of (elastic) shear zone weakening and have removed this claim accordingly, for the reasons you outlined. The discussion has been revised to reflect this. We also incorporated additional sensitivity tests on bed stiffness and improved the methods section. We hope the updated roadmap and new Section A2 address your concerns effectively.

RV2-1:

This is a really interesting paper doing some innovative things about investigating the spatial variations in effective Young's modulus near the grounding line that is deeply needed for updating our knowledge about the in situ rheology of ice and tidal processes in the grounding zone. It's a good site to pick for this analysis to sidestep the firn problem and the grounding line migration. It is excellent technical work at the difficult intersection of models and observations.

Thank you for your positive feedback and for recognizing the significance of our work. We deeply appreciate your acknowledgment of the challenges involved in bridging models and observations in the flexure zone.

RV2-2:

Overall the figures are rich and detailed and could generally be accompanied by a bit more narrative explication. I really appreciate figure 4d, I've rarely seen the tidal corrections overlaid like that and it's but helpful and interesting to look at the relative magnitudes and phases. I think figure 9 i-l tells a good story and is helpful to understanding the method.

We incorporated additional narrative explanations where needed to enhance clarity and guide the reader through the key insights presented in the figures.

RV2-3:

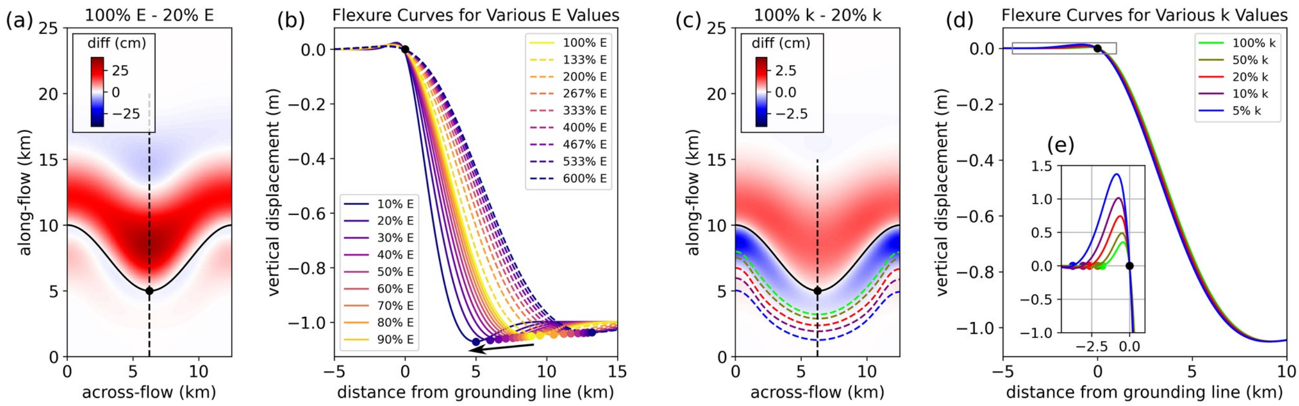
Overall, I think the narrative and "thesis" of the paper, and the sequence of what exactly was done, could be made clearer to the reader. Providing a roadmap in the methods section might help. I was surprised when certain aspects of the methods came up, for instance the radar thickness data. For this paper, I would also not assume the reader is at all familiar with alpha maps and elect not to force them to read the preceding paper. A standalone explanation is needed and they can be referred to the previous paper for details.

We reorganized the manuscript for better clarity and flow. We now provide a more detailed, standalone explanation of alpha maps at the beginning of Section 3. Regarding the radar ice thickness data, we decided not to place too much emphasis on these measurements, as they were acquired in November 2013 and are relatively outdated compared to the other datasets used in the study.

RV2-4:

I also think that some of the modeling choices could be fleshed out in greater detail, particularly the value for the Young's modulus of ice, and the assumption of an elastic bed with the spring constant used in the work. I know Sayag and Worster (2013) have a value for the spring constant in there and I'm curious how it compares. Sketching some uncertainty bounds around these parameters would strengthen the argument that the signal in the flexure can be distinguished enough from the noise to attribute it to the Young's modulus of the ice.

Thank you for this insightful comment, and we appreciate the reviewer bringing it up. We performed additional experiments using our idealized model setup to better understand the sensitivity of ice-shelf flexure to variations in bed stiffness. The results from this experiment indicate that up to 2-3% of the 10% change in flexure might be influenced by the bed stiffness. These sensitivity experiments have been added to the Appendix.



A direct quantitative comparison with Sayag and Worster (2013) is challenging, as their model experiments use stiff-fixed and soft-free grounding line boundary conditions, while our fulcrum is soft-fixed. The main takeaway from Sayag and Worster's work is that the discrepancy between laboratory-derived Young's modulus and in situ-derived Young's modulus could be explained in their model by altering the boundary condition from stiff-fixed to soft-free, which then allows the grounding line to migrate inland during high tide. However, we circumvent this effect by choosing the Priestley Glacier study site, where tidal grounding line migration is minimal due to the steep bed slopes present.

We clarified these modeling choices and incorporate a discussion of the sensitivity of the flexure signal to variations in bed stiffness, as well as consider uncertainty bounds around the parameters used, to strengthen the argument that the signal in the flexure can indeed be attributed to variations in the Young's modulus of the ice.

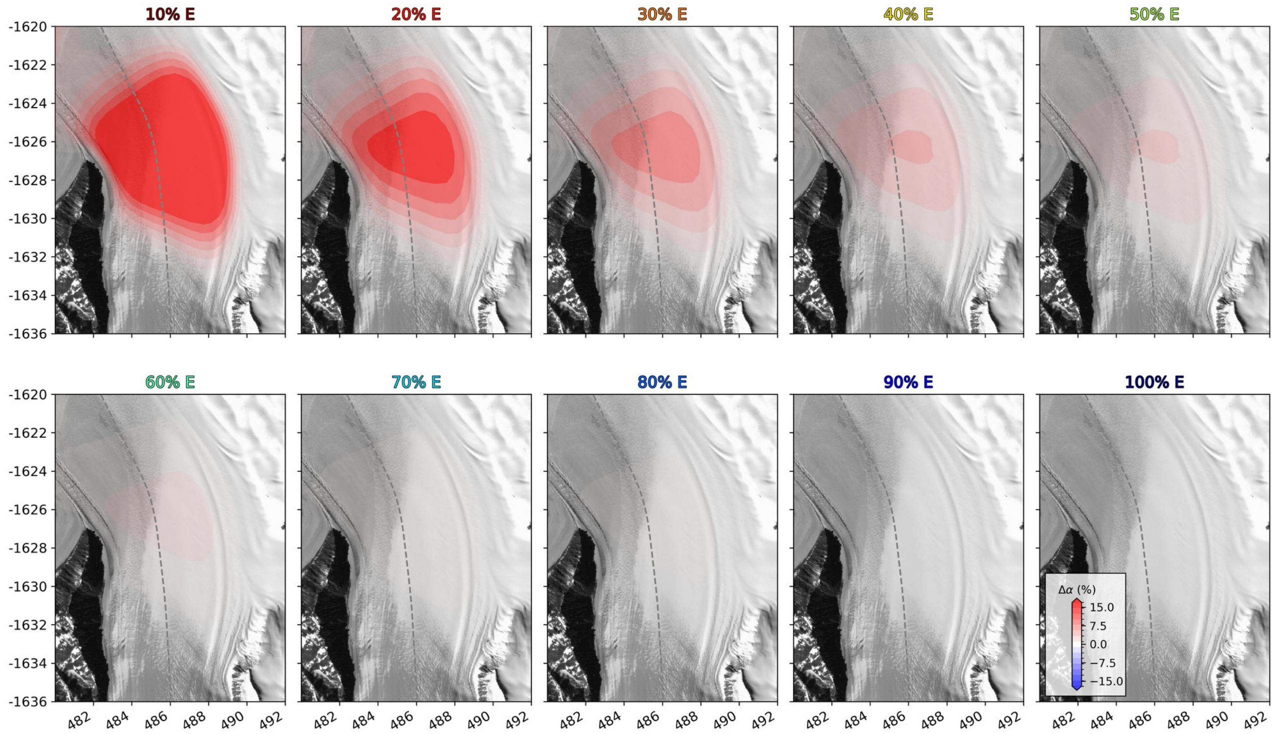
RV2-5:

I also think the connection to fabric is somewhat tenuous and might be rebuilt somewhat around the surprising idea that we just don't know very well what affects Young's modulus in situ. It may be worth touching some of the older and newer literature around laboratory experiments on the stiffness of ice. I might restructure the discussion to include a general discussion of the main takeaways in the results before getting into the weeds of viscoelasticity that hasn't been brought up yet (though I understand the need for the justification of the elastic model, which I am fine with). There are some things I found interesting that didn't get returned to- the shape of the bulge in figure 1e for instance. Overall this makes a clear contribution to the field and will be made even better with a clearer and more self-contained explanation of the methods.

We agree with both reviewers that our analysis does not provide evidence that ice anisotropy is the cause of the observed softening in the shear zones. We clarified this in the revised manuscript and focus more on the uncertainty around in situ Young's modulus.

We also incorporated relevant literature on ice stiffness and restructure the discussion to highlight key results before addressing viscoelasticity.

The shape of the buldge depends on the amount of shear-zone weakening. We added the buldge of the best heterogeneous model (20% E) to a new Figure. For the sake of completeness, here are the other buldges. The buldge disappears for Young's modulus



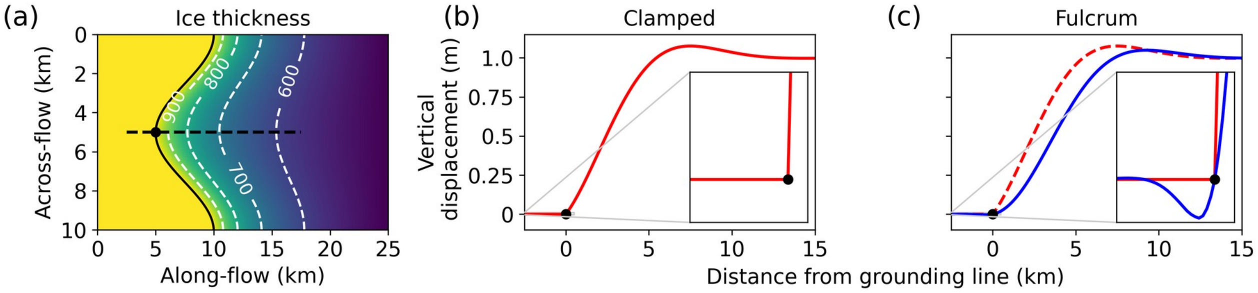
>60%.

131: Why 1.6? There's a range found in other studies (mostly not referenced here).

1.6 GPa is the value of the Young's modulus that was derived by Wild et al., 2017 and further employed in Wild et al., 2018 from the McMurdo Ice Shelf. We think it's a better reference value for a homogeneous case than 1.0 GPa as derived from the more complicated Darwin Glacier in Wild et al., 2019, because the reduced value might be a similar signal of shear zone weakening at Darwin Glacier (which would be an interesting follow-up study, to proof that a similar flexure pattern can be produced with E=1.6 GPa and weakening Darwin Glacier's shear zones)

146: I'm curious about what only means here, was there consideration given to changing the boundary conditions?

"Only" refers to model experiments by Still et al. (2022), where they suggested that either the sidewall boundary condition or the assumption of a uniform Young's modulus could be incorrect. Their GNSS observations indicated that a heterogeneous Young's modulus or partial contact with the sidewall improved model fit. We also tested changes to the grounding line boundary condition. Although our model simulations are in planar view (so partial ungrounding on sidewalls isn't supported), we experimented with clamped versus fulcrum boundary conditions. We found that a fulcrum more realistically produces the s-shaped flexural signature, while the clamped condition results in an "onion-like" structure.



160: what does "adjustments for the input data used for predictions" mean?

It means that tide-model output has to be 'adjusted' to agree with DInSAR measurements. We added a roadmap of the method at the beginning of Sect. 3

185: this is a bit confusing and could use a more extended discussion in plain language, connecting back to the method at large.

This step is essential for aligning our model predictions with the DInSAR observations. If we use the tide model output without adjustment, the mismatch with DInSAR can be as large as ±15 cm, or several fringes, making direct comparison meaningless. To address this, we calibrate the tide model to match observed displacements in freely floating ice, ensuring consistency between model input and satellite data. We hope this adjustment is now clearly outlined in the roadmap and revised Methods section.

200: From this description I don't know what an alpha map is, and certainly couldn't reproduce it from this paper. Even though referencing another paper, a recapitulation here would help, especially as it seems important to the methods of this paper in discerning what we're comparing.

We reworded Sect. 3.1.2 "Derivation of an alpha-map from DInSAR measurements".

215: what does "processed the data" mean?

It means how we converted the raw data from the TRIMBLE receivers into coordinates.

221: sources for k = 5 MPa? My impression is this is very uncertain and probably varies by a lot.

The value of k = 5 MPa comes from Walker et al. (2013), which was based on observations of 1 cm uplift reported by Heinert and Riedel (2007) on the Ekström Ice Shelf. We appreciate the reviewer's note on the uncertainty of this value, and we hope that our sensitivity experiments (RV2-4) and the section in the appendix (A2) help address this concern.

226: first mention of effective Young's modulus? What are you defining it as in this paper?

We use the term "effective" Young's modulus to acknowledge that, in natural, real-world conditions, ice behaves differently from theoretical or laboratory-based conditions due to factors like ice fabric, temperature variations, and impurities. Added this sentence to the revised manuscript.

245: what was the magnitude of these corrections?

A +1 hPa anomaly of atmospheric pressure translates to an instantaneous −1 cm contribution to the tidal forcing, as shown by Padman et al. (2003). Added this sentence to the revised manuscript.

258: I could use another sentence or two on what thickness update means here.

The thickness update refers to the difference in ice thickness between the Control Model, which uses the BedMachine dataset, and the Local Model, where we perform our own inversion of the ice-shelf freeboard to estimate the ice thickness. Added a short statement.

269: I think this is the first mention of radar thickness data, how do you use it?

We use the radar ice thickness transect primarily to compare it with the BedMachine dataset and our 'thickness update' from the inversion of freeboard. However, we do not focus heavily on this comparison as the IceBridge radar thickness data is from 2013, which is relatively outdated. The IceBridge flight path, however, follows a flowline and is therefore where we define our profile through alpha-maps and model solutions presented in later Figures.

288: it's not abundantly clear to me what least squares adjustment means here.

As also noted by RV1, the approach involves adjusting the tide model output at t1,t2,t3 as little as possible to match the DInSAR observations on the freely-floating part of the ice shelf. The challenge is that DInSAR represents a double-differential tide from three individual time points:

$(t1-t2)-(t2-t3)$.

The least squares adjustment finds the smallest offsets $\Delta x, \Delta y, \Delta z$ to correct the model output at t1,t2,t3 while best matching the observed tide. This is done by minimizing the following expression:

$\min\sum[((x+t1)-(y+t2))-((y+t2)-(z+t3))-\text{observed value}]$,

where x,y,z represent the adjustments to the model outputs at times t1,t2,t3, respectively. This is essentially done for all 31 DInSAR measurements at once by solving the combination matrix.

341: why might they over then underestimate? If you discuss later, you can point the reader there. Also, we may want to be careful about prescribing the exact location of the grounding line from interferograms. The extent of upstream flexure is likely past the grounding line because ice is thick.

At ~16 km downstream of the grounding line, the lateral grounding line on the Nansen Ice Shelf may be incorrect due to noise in the interferograms, which prevented precise delineation. This coincides with the true right shear zone, which runs parallel to the

Nansen's grounding line. For our model, we interpolated between visible fringes, so this might be an artifact.

Your second point is interesting. We agree that individual interferograms often capture a hinge line rather than the true grounding line, as shown in previous studies. However, at Priestley Glacier, we compared a grounding line derived from an alpha map (based on 31 interferograms across tidal cycles) with a TerraSAR-X-derived grounding line and found a good match. Alpha maps average out spurious displacement due to beam flexure (Rack et al., 2017), making them less susceptible to such biases.

356: how these statements follow from one another is unclear to me.

Thank you for pointing this out. Up to this point, we have compared model solutions along a single transect (the IceBridge flight path). Here, we extend the model-observation comparison to the entire grounding zone. To avoid confusion, we outlined this region of interest (ROI), which is also used for Fig. 10, in the corresponding figure panels 9f/g/h.

Minor comments:

75: sentence fragment

Reworded

288: "millimeters"

Reworded