We thank the anonymous reviewer for their careful and constructive review, and for highlighting the value of extending the fracture toughness dataset to include firn, refrozen meltwater, and brine-saturated ice from the Brunt Ice Shelf. Below we respond point-by-point to the minor suggestions with text in green indicating the changes we have incorporated into the revised manuscript.

Figure 1: I assume the red square in panel a is the site of Halley station, but this should be mentioned in the caption. If possible, it would also be nice to indicate in panel b the path of the GPR line shown in panel c.

- We will explicitly state in the Fig. 1 caption that the red square marks Halley VI station and add the GPR transect line to panel (b) so that the location of the profile in panel (c) is visually linked to the broader map context.
- figure 1 now explicitly states the location of Halley VI and the location of the GPR transect line.

Lines 123-126: I don't think you mention what the full ice thickness is at site S2, and it would be interesting to know how it compares to the 37m core length.
- Line 150 now reads "The approximated thickness of the ice at this location is 150 m, established from freeboard calculations and density measurements."

Section 3: On first read through it took me a minute to understand the terminology you use to label samples from different core sections (e.g. line 143, "core 35"). I'd suggest either using the terminology "core section" rather than core, or adding a sentence in section 3.1 along the lines of "Each core section was numbered sequentially on retrieval, and we use this number to identify core sections in the text (e.g. core XX)".

- We agree that the terminology can be clarified. We will revise Section 3.1 to define our naming convention explicitly using "core section" where appropriate, and include a short sentence explaining that sections were numbered sequentially on retrieval and that this is used in the text and figures (e.g., "core section 35").
- Line 130 now reads "A medium-depth mechanical ice core drill (Mulvaney et al., 2002) was used to recover a continuous ice core record of 37 m, made up of 44 core sections, numbered sequentially by recovery order and we use this number to identify core sections in the 130 text (e.g. core 035)".

Figure 4: It would help readability if you define the variables here (i.e. "T and R are the thickness and radius of the sample, a is the notch length, and S is the distance between the rollers").

- We will update the Fig. 4 caption to define all geometric variables used in the equation/diagram.
- Figure 4 caption now includes "Where T refers to sample thickness, R, sample

radius, S, the separation between rollers, and a, the notch length. Dimensions used for the experiments can be found in Table 1."

Line 181: "as quickly as possible" is a little vague – it would be useful to give an indication for how quickly this is, and why speed was important.

- We will replace the phrase with a quantitative timescale.
- Line 184 now reads "Experiments were conducted in a room where temperatures fluctuated between -10 and -15 oC at the University College London cold room facilities, with experiment time taking between one to three minutes, depending on the sample."

Figure 6: The text in some of the panels has ended up quite small and hard to read. It might help to move the colorbar, or even to separate some of the panels into a different figure. In panel a, I wasn't clear whether there was a difference between the points colored deep blue and those colored in grey – are they all cases with no melt?

- We will improve the readability of Fig. 6 by increasing font sizes and reorganising the layout to two larger graphs on top of each other. We will also correct the text, which should read 'grey indicates 0% melt', not blue.
- Figure 6 has now been separated with both figures on top of one another, so both figures are larger and the labels are clearer.

Line 224 The sentence "brine infiltration reduces KIc by 14% - 34% relative to density-matched, brine-free meteoric ice" might usefully include the qualification "at the same temperature".

- We will revise the sentence around Line 224 to include "at the same temperature"
- line 226 now reads "... brine-free meteoric ice at the same temperature."

Section 5: I think it would be useful for the discussion to briefly address the effect of ice temperature and rheology on fracture propagation. Both brine infiltration and refreezing of surface meltwater are likely to increase the temperature of the ice column, and the results from Hulbe et al. (2010) suggest that areas of soft ice (such as areas of warmer ice) can reduce stress intensity at a fracture tip and reduce rift growth.

- We will add a section in Section 5 discussing how temperature-dependent rheology may alter fracture propagation and stress intensification, and we will cite Hulbe et al. (2010).

Line 246 now reads "These relatively warm conditions at the brine layer would enhance the weakening effect of the brine. However, warmer, softer ice may also relax stresses near a crack tip and reduce the stress intensity driving rift growth (Hulbe et al.,2010). Thus, as accelerated flow enhances ice shelf thinning on the BIS, the balance between refrozen melt strengthening and brine-driven weakening will increasingly dictate how rifts evolve.

Lastly, this isn't a suggestion to make any change to the paper, but your results made me think of Julian Scott's paper where they found that drilling through a melt layer within the firn triggered crevasse formation – indicating that the melt layer had higher fracture toughness and had essentially been holding that area of fir together.

- We agree it is relevant to the interpretation of refrozen melt layers as mechanically distinct horizons and will incorporate this paper as an additional citation in the discussion where we address melt-layer mechanical contrasts and their potential to influence rift initiation/arrest.

Line 265 now reads; This interpretation is consistent with field observations from Pine Island Glacier where crevasses were triggered during drilling through an exceptional firn melt layer, implying the layer acted as a mechanically strong unit that had been providing local structural support (Scott et al.,2010).

This manuscript describes a suite of experiments on samples of ice core from the Brunt Ice Shelf, examining their fracture toughness via three-point bending tests. Specifically, it examines the impact of refrozen melt and brine infiltration on the fracture toughness of natural ice. This is an interesting and worthwhile study, as previous studies have focused only on cold, dense ice, or pure laboratory-made ice, and models which incorporate calving typically assume a homogeneous value for Mode I fracture toughness. The authors show that in fact heterogeneity in the ice properties, particularly caused by melt and brine infiltration, can significantly alter the fracture toughness of the ice.

Overall it's a great paper, very easy to read and with nice results which are well presented. I have a few general comments which could be worth an additional couple of lines in the discussion to take it a bit further, but I leave it to the authors to decide if it would be over-interpreting the results to do so. All of the specific comments are very minor.

- We thank Dr Lisa Craw for their careful review and assessment of the manuscript. We appreciate the constructive suggestions on how to broaden the discussion and the minor specific edits. Below we respond point-by-point to the minor suggestions with text in green indicating the changes we have incorporated into the revised manuscript.

As you mention in the introduction that most models assume a certain fixed value for fracture toughness, it would be nice to revisit this in the discussion: do you have a recommendation for how your results could be incorporated into a model? If there must *be a fixed value for the whole shelf, would you change it based on these results? Or if it could be varied, what observable parameter could be used to do this?*

- We will add a short modelling-focused paragraph in the Discussion, suggesting the use of a GPR acquired brine map and the use of two KIC values for an ice shelf. Therefore parameterising KIc as a function of observable properties such as a brine infiltrated layer (acquired from Ground Penetrating Radar data), or known melt conditions.

- From line 233 now reads; "A practical way to represent spatially variable KIc in the case of the BIS would be to use a binary model, assigning one KIc value to unaltered meteoric ice and a lower KIc value to brine-saturated infilled ice, where the extent of the brine-saturated unit could be defined from GPR observations. "

Again, in terms of generalising your results: the Brunt Ice Shelf is quite unique in its structure. Would you expect to see the same effect on e.g. Larsen C, or is the proportion of melt to brine/ geometry of the suture zones too different?

- Although the Brunt Ice Shelf has an unusual structural setting, the material response we see should apply wherever these processes occur. The shelf-wide impact will, however, depend on how extensively melt layers and brine horizons are developed and how they are distributed across an ice shelf.
- Line 272 now reads "Although the Brunt Ice Shelf has a unique structural makeup, the material response we observe should apply to other ice shelves where these processes occur. The shelf-wide impact will, however, depend on how extensively melt layers and/or brine horizons are developed and how they are distributed within suture zones. "

The impact of temperature on fracture toughness is interesting, and strikes me as a little unintuitive: at higher temperatures, I would have assumed the ice would be more inclined to deform in a ductile way rather than fracture.

- These results are focused specifically on brittle fracture, and do not account for variations in temperature associated with ductile deformation. Additionally, the temperature dependence of KIc of ice is not clearly defined. KIc has been seen to increase, with decreasing temperature (Schulson, E.M. and Duval, P., 2009) but the scatter in the data is large and the effects is small. We will add a sentence clarifying that our results focus on brittle fracture and that these relationships are weak.
- Line 247 now incorporates "However, warmer, softer ice may also relax stresses near a crack tip and reduce the stress intensity driving rift growth (Hulbe et al.,2010).

Do we know if the ice temperatures are higher in the brine saturated/melange areas, relative to the meteoric ice blocks? Do you think it would make a difference to the results if your experimental temperatures were more constrained?

- We do not have in-situ measurements of the ice temperature in the brine saturated areas vs the meteoric blocks, so would be unable to comment on this at this time.
- No changes have been made to the paper for this comment.

Specific comments:

line 31: 'centimetre thick' sounds like they are exactly a centimetre... -> centimetre scale?

- We will change this to “centimetre-scale thickness” (or “centimetre-scale layers”) to avoid implying an exact thickness.
- Line 31 now reads; “Processes such as surface melting can introduce centimetre-scale melt layers that span hundreds of metres horizontally...”

Fig 1: I assume the bright surface at ~37m depth is the top of the infiltrating brine? It's worth labelling this just to be clear.
- We will label this feature explicitly in Fig. 1
- Figure 1 now explicitly labels the brine layer.

Fig 2: 'The spread in density from core samples is reflective of the melt within the cores': I'm not sure exactly what this means, are you referring to the lab-measured densities specifically? Or just generally the melt layers impact the density? Is the bigger spread in lab measurements because the measured sections were smaller?

- We will clarify in the text that the spread in lab measurements are due to smaller sample sizes, with some samples containing refrozen melt, which increases that samples density relative to the average core density.
- Figure 2 caption now reads; “(a) Density measurements for whole cores (black) measured in the field, and smaller samples cut from the same cores used for fracture analysis (green, orange, purple, pink) measured in the lab. The spread in density of the smaller core samples is due to some samples containing refrozen melt, which increases those samples’ density relative to the average core density. The presence of refrozen melt layers in the cores are shown by the background blue bands. Red dashed line shows temperature data recorded at specific depth intervals using TinyTag loggers. (b) Line-scanned cores for core 22 (with a top depth of 16.45 m), 35 (27.67 m), 39 (31.07 m) and 44 (35.92 m). Line scan data highlight the melt within the cores.”

Line 43: is core 35 from 35m depth? (Oh I see from figure 2 that it's ~29m. For clarity, it would help to have the depth in the text, as the core numbers are a little confusing. Same on lines 50, 59, etc)

- We will include core depths in the text.
- Line 162, and figure caption 2 now include the core depths,

Line 47: 'isotropic crystal fabrics', is this based on eyeballing the thin section under cross-polars? That's a fair enough way to do it, just worth clarifying.

- Yes this is how we established fabric, and will clarify this in the text.

Line 149 now reads; “Both sections exhibited isotropic crystal fabrics established visually.”

line 71: how was surface area of melt measured? Did you take a thin section of the fracture surface, or was it visually obvious?

- Surface melt was calculated by taking photographs of the fractured surfaces once the sample had been broken, and measuring the amount of surface area covered by refrozen melt. We will clarify this process in the text.

Line 173 now reads; “. If the sample had the presence of melt (visible by eye), the surface area of melt on the fractured surface was measured post-breaking of the sample, and a melt percentage was given for that sample.”

line 73: is this a custom-made test system, or something off-the-shelf? What is the accuracy of the load and displacement measurements?

- This is a custom made system of which we will include details of in the manuscript along with the load and displacement accuracy.

Experiments were conducted using a custom-built uniaxial servo-hydraulic deformation apparatus based on a stiff tie-bar frame incorporating a 10 kN hydraulic actuator (Eland HD series heavy-duty cylinder). Hydraulic control was achieved using a Dowty 4633 series two-stage flapper–nozzle electrohydraulic servo valve, equipped with an 80 mA, 22 Ω torque motor and a nominal flow capacity of 6 L/min at 70 bar. The valve was driven via a custom servo amplifier providing analogue (±10 V) command signals with adjustable gain and damping. Closed-loop control of the apparatus was implemented using a National Instruments PXI-based system, enabling proportional–integral–derivative (PID) control and programmable loading paths under displacement control. All analogue channels were logged synchronously at 1 kHz, ensuring sufficient temporal resolution to capture peak loads and rapid load variations during fracture.

Axial load was measured using an Applied Measurements Ltd. DDE miniature in-line load cell (10 kN capacity), operating in tension and compression with a nominal sensitivity of 2 mV/V and an accuracy better than ±0.3% of rated capacity. The load signal was conditioned using an RDP Electronics amplifier and calibrated to 1 V = 1 kN (i.e. 1 mV per N). This provides high force sensitivity relative to the low peak loads (order 10^2 N) measured during testing. All load measurements were calibrated at the experimental temperatures to account for operation in cold conditions.

Piston displacement over the full actuator stroke was monitored using a Penny & Giles SLS095 linear potentiometer, providing independent linearity of ±0.15–0.5% of full scale. This sensor was used for coarse displacement measurement and control. High-resolution displacement measurements were obtained using a 10 mm stroke linear variable differential transformer (LVDT), positioned between the loading platens and conditioned using an RDP Electronics amplifier, providing fine displacement feedback during deformation. Displacement sensors were calibrated at the operating temperatures.

All measurement signals were conditioned using custom-built signal conditioning electronics, providing gain adjustment, zeroing, and filtering prior to input to the control system and data acquisition hardware.

Figure 4: I'm a little unclear on the purpose of the rollers at the sides, since it looks like the ice is sitting on the grey bits on the inside? Or is the full weight of the ice on the rollers?

- We will revise Fig. 4 to remove the grey parts on the side, as this is misleading. The full weight of the sample is held by the rollers.

- Figure caption 4 now reads; “Experiment set up for ice fracture tests with semi-circular bend specimen. Where T refers to sample thickness, R, sample radius, S, the separation between rollers, and a, the notch length. Specimens were loaded via cylindrical rollers, with two lower support rollers and a centrally applied upper loading roller. The support rollers were free to rotate and adjust position slightly during loading, minimising frictional resistance and ensuring appropriate boundary conditions. The loading configuration was symmetric about the notch plane, and care was taken to ensure alignment of the notch with the loading direction.”

line 187: I think this should be a colon instead of semicolon

- This will be corrected in the updated manuscript.
- corrected to a semicolon

line 218: missing space before reference

- This will be corrected in the updated manuscript.
- corrected