Authors response to review by Shuai Yan for:

"Improved subglacial boundary conditions near Dome C, Antarctica, through rigorous integration of multi-campaign radar data and an ensemble stochastic simulation approach"

Shackleton et al., The Cryosphere Discussions.

Thank you for your review of our work, we appreciate the useful suggestions and insightful comments you have made and have incorporated these into our revised manuscript. In the following response to reviewers comments, the reviewers text is shown in *blue italics* and our response or action taken is shown in black. Text added to the revised manuscript is indicated by quotation marks.

Major comments:

(1) *My main concern is about the interpretation of local topographic redistribution of GHF. I appreciate that the authors examine the apparent coexistence of well-preserved old ice and subglacial lakes in the Dome C region, which is an interesting and important question. The manuscript suggests that topographic variation can redistribute GHF, and uses it to discuss basal melting, subglacial lakes, and old-ice preservation. However, this interpretation appears to rely on a topography-only correction, whereas topography is not the only factor that can modify GHF locally. In particular, the analysis does not consider lateral variations in thermal conductivity associated with bedrock geology. This is important because thermal refraction can substantially modify, or even reverse, the expected topographic effect, depending on the conductivity contrast between ice and bedrock (Willcocks et al., 2021, doi.org/10.1017/jog.2021.38). I strongly recommend the authors discuss this limitation.*

Added/modified the following text in response to this and comments made by the other reviewer:
"Topographic focusing of geothermal heat can redistribute heat to local ridges or valleys, and the polarity of heat refraction patterns depends on the thermal conductivity contrast between ice and the underlying rock (Wilcocks et al., 2021; Reading et al., 2022). The thermal conductivity of ice at depths beyond 750 m is estimated between 2.0 – 2.8 W m^{-1} K^{-1} (Wilcocks et al., 2021), whereas igneous Antarctic bedrock ranges 1.5 – 4.0 W m^{-1} K^{-1} in samples limited to exposed outcrops mostly near the ice margin (Wilcocks et al., 2025). The geology and corresponding thermal conductivity are uncertain beneath Dome C, so as an illustrative example of how topography could impact geothermal heat distribution we calculated an adjustment factor to account for local topographic modifications of background GHF following a simplified geostatistical approach (Colgan et al., 2021), using their equation 2 with empirically determined averaging radius of 5 km and characteristic height needed to induce 100% change in local GHF of 950 m. However, we recognise that the magnitude and polarity of such modifications could be substantially different in reality depending on the conductivity of the bed."

(2) *The authors find that approximately 80% of radar-inferred subglacial lakes are located in areas of locally elevated GHF, and use this result to suggest that topographic redistribution of geothermal heat may help explain the distribution of subglacial lakes. However, I think this interpretation needs to be stated more cautiously. A locally elevated GHF relative to the regional background does not necessarily imply that basal melting will occur. If the heat flux is still insufficient to bring the bed to the pressure-melting point, no lake would be expected. Therefore, the authors should clarify whether the magnitude of the estimated GHF enhancement is sufficient to change the basal thermal state, or whether this result should be interpreted only as a possible contributing factor.*

We have reworded this statement to the following:

"We find 80% of the radar-inferred subglacial lake sites are within a zone of locally elevated GHF (Fig. 7c), suggesting that topographic modification of geothermal heat could be a contributing factor to the spatial pattern of basal melting and lake distributions in regions where basal ice is close to the pressure melting point."

(3) *The method used for the topographic GHF correction needs more explanation. In particular, the authors should clarify how the 5 km averaging radius and the 950 m characteristic height (line 425-426) were chosen or derived. Although a reference is provided, these parameters directly affect the magnitude and spatial pattern of the correction, so readers need more information to evaluate whether they are appropriate for the Dome C region.*

The authors agree that the magnitude and spatial pattern of corrections are sensitive to these parameters. In response to this and other reviewer comments we have modified the text to highlight that these results represent an illustrative example of how subglacial topography could influence the distribution of geothermal heat, rather than presenting our findings as precise values, whereas in reality the magnitude and polarity of such modifications could be different. Since the geology beneath Dome C is unknown, we use the globally averaged parameter values presented in Colgan et al., 2021.

(4) *One strength of this paper is the incorporation of newly acquired radar data relative to previous datasets. The authors provide substantial technical detail about the radar instruments and data processing, but they do not clearly show where the new data are located relative to the previously available measurements. I recommend adding a map, or modifying Figure 1a, to distinguish the new survey lines from older datasets.*

Added a reference to Appendix Figures A6 (DTU survey) and A12 (KOPRI survey) in the relevant methodology section where the new survey lines can be distinguished from older datasets.

(5) *I recommend that the authors increase the font size in the figures, particularly some of the axis labels and in-figure annotations.*

The font sizes will be increased in the relevant figures so that the labels and annotation are clear when the final figure files are uploaded for publication.

Minor comments:

Line 15: I suggest softening the statement that subglacial topography "remains highly uncertain across Antarctica." A large volume of direct measurements (from radar sounding, etc.) of subglacial topography are available now across a large portion of Antarctica. The uncertainty is still substantial in data-sparse regions and between survey lines, but the current wording may overstate the level of uncertainty across the entire continent.

There are still large gaps in Antarctic bed measurements, especially when considering the limited locational accuracy of data collected before ca. 1994 when GPS positioning was not yet available. Despite the large volume of measurements now available there are still vast regions of the Antarctic bed without direct observations, and gaps between survey profiles even in surveyed regions are often 5 km or more, which leaves large elevation uncertainties particularly in regions with rough, undulating terrain.

Line 124 – 129: What's the impact on data quality? And what's the resolution for this system?

The data quality for the survey profile segments used in this work to trace the ice-bed interface was unaffected by these system failures, however, some segments were omitted from our analysis from the full survey track because the ice surface or bed was not traceable. The vertical resolution for this system should be ca. 1 - 2 m.

Line 337: "for each of our ensemble simulated bed" should be "for each of our ensemble simulated beds".

Changed.

Line 400: "The preservation of deep ice layers … are sensitive" should be "The preservation … is sensitive".

Changed.

Line 416: "large-sale GHF models" should be "large-scale GHF models"

Corrected the spelling.

Lines 422: "increase it in valleys" should be "increases it in valleys".

This statement has been modified already in response to a comment made by the other reviewer.

Line 436: "regional standard deviations 0.1 ± 0.0%" should be "regional standard deviations of 0.1 ± 0.0%" or "regional standard deviations (0.1 ± 0.0%)".

Added the first suggestion to the text.

Figure 1: I suggest adding an Antarctica overview map. Also, I recommend that the authors explicitly state what the histograms along the colorbars represent.

Added the following statement to the caption: “Histograms alongside colourbars show the distribution of values.”

Figure 3 caption: “Polar Sterographic projection” should be “Polar Stereographic projection”.

Changed.

Figure 7: The lake sites and core sites are difficult to see. The symbols are too small, and the green and orange colors do not stand out clearly against the background.

The lake site and core site markers will be increased in size so that they are clear when the final figure files are uploaded for publication.