Response to the review of "Ephemeral grounding on the Pine Island Ice Shelf, West Antarctica, from 2014 to 2023," submitted to The Cryosphere.

Editor:

We sincerely thank Editor and Reviewers for the thoughtful review and constructive feedback on the figures. In response, we have improved the visualization of all figures to enhance clarity and presentation.

We recognize that the Appendix section had a weak connection to the main narrative. To maintain a clear and focused presentation centered on our most robust results, we decided to remove this section.

In this document, we provide a detailed, point-by-point response to all comments. The reviewer's comments are shown in black, and our responses are shown in blue, with proposed new text in bold. Some sentences were underlined to emphasize key content closely related to the comments.

Dear authors,

Many thanks for the update manuscript. As you can see in their reports, that referees still have identified some outstanding issues. Most of these are about the figures, but some also about the results and interpretation. I invite you to submit a revised manuscript, which I will review.

Referee 2 provided a list of comments on the figures. Please implement all the suggested changes and add explanation where requested by R2. Likewise, implement all the suggestions made by R1 concerning figures. If you decide to keep both the right and left ICESat-2 beams in figure 9, please motivate your choice in the rebuttal. Please also show the areas along the transect that Sentinel-1 detects grounding, if data is available there.

Response 1: We have removed Figures 9c and 9e from the original Figure 9, as suggested by R1. In the revised Figure 9c, we added the ephemeral grounding sites on each track to show the locations detected by ICESat-2.

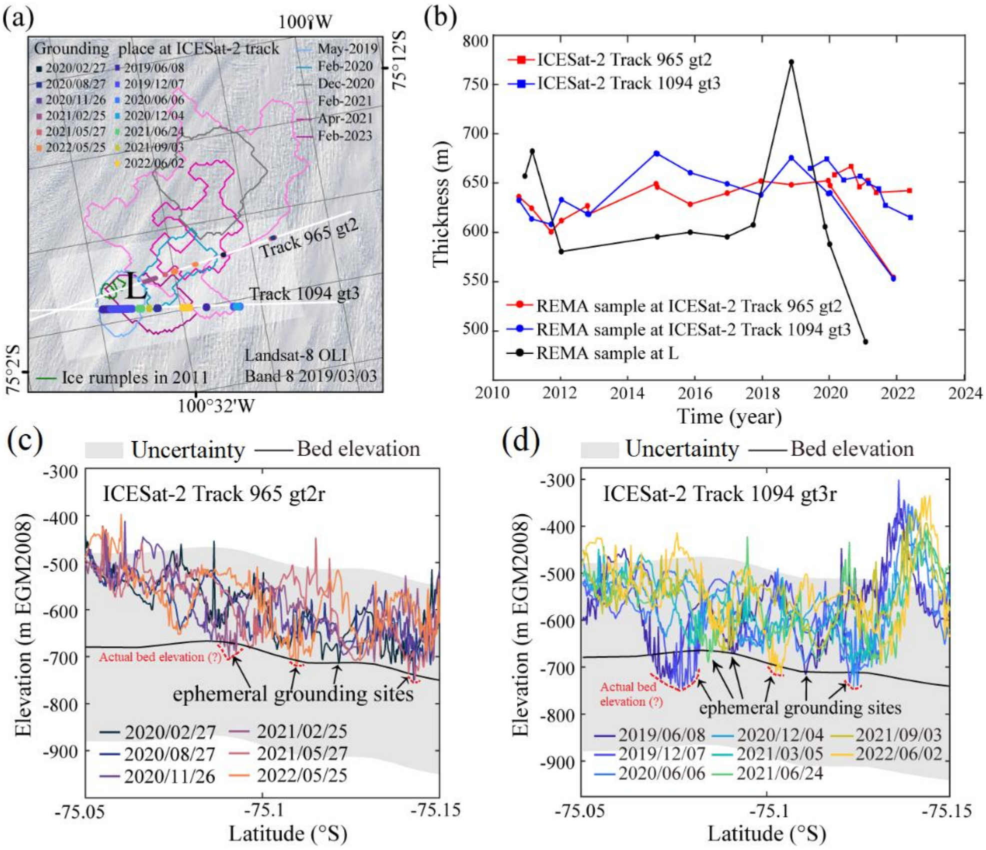

Figure 9. Time series of mean ice-equivalent freeboard thickness and ice shelf bottom elevation profiles along ICESat-2 tracks 965 and 1094. (a) ICESat-2 tracks 965 and 1094 that used for ice-equivalent freeboard thickness change analysis and grounding lines near the ice rumple L from April 2011 to February 2021. Background is from Landsat-8 OLI optical image on 3 March 2019. (b) Time series of mean ice-equivalent freeboard thickness (2010–2022). Mean ice-equivalent freeboard thickness from ICESat-2 was calculated along tracks 965 and 1094 between 75.15°S and 75.05°S, representing the average of measurements from both the strong and weak ICESat-2 beams. REMA thickness values were sampled at the same locations as the ICESat-2 tracks. (c) Ice shelf bottom elevation profiles along ICESat-2 track 965 gt2r between February 2020 and May 2022. (d) Ice shelf bottom elevation profiles along ICESat-2 track 1094 gt3r between June 2019 and June 2022. Bed elevations are from the BedMachine v3 dataset (Morlighem et al., 2020; Morlighem, 2022), converted from EIGEN-6C4 to the EGM2008 geoid to match the vertical datum of REMA strips. The estimated vertical uncertainty is ±200 m (shown as a grey transparent box). The potential actual bed elevation is marked by a red dashed line.

Regarding the first comment of R1, I agree that this sentence is unclear: "Ephemeral grounding region, characterized by double-differential vertical displacements close to zero, shows significant correlation with oceanic tidal variations (Figures 6-7 and Movie S1)." Specifically, it is unclear what is correlated with the ocean tidal variations, since 'Ephemeral ground region' is not a quantity that can be correlated to something else.

Response 2: Thank you and R1 for pointing this out. Based on our results, we found out that there is no relationship between the area of grounding region and tidal variation. Thus, the sentence on lines 215–217 has been revised to: **"Figures 6-7 and Movie S1 show the two-dimensional double-differential vertical displacement changes and time series of double-differential tidal height differences."**

On line 235-237, add the correlation value. Related to the point above, please p-values for whenever you give correlation values.

Response 3: Revised. We have revised the content in Section 3.1 paragraph 2:

"……Figure 7 identifies 80 ephemeral grounding events between September 2016 and October 2021, including 43 during spring tides (red points) and 37 during neap tides (blue points). As shown in Figures 6a and 7a, positive vertical-displacement anomalies generally coincide with negative tidal-height differences, and vice versa, indicating a strong inverse linear relationship between these variables ($r = -0.80$, $p = 2.41 \times 10^{-19} < 0.05$, $R^2 = 0.65$). In contrast, Figure 7b shows no significant relationship between tidal-height difference and area of grounding region ($r = -0.02$, $p = 0.887 > 0.05$, $R^2 = 0.00026$). During spring tides, only three grounding events exceeded an area of 100 km², while all other events remained below this threshold. No significant linear relationship is observed between tidal-height difference and area of grounding region during spring tides ($r = -0.11$, $p = 0.484 > 0.05$, $R^2 = 0.012$). Similarly, during neap tides, area of grounding region ranges from 0 to 90 km² and show no significant dependence on tidal-height difference ($r = 0.07$, $p = 0.694 > 0.05$, $R^2 = 0.004$)……"

Include references to Joughin, 2021 where appropriate.

Response 4: We have added the reference to Joughin et al. (2021) in Section 3.3, last sentence:

"……Together, these observations support Joughin et al. (2021) in suggesting that ephemeral grounding events facilitate rift propagation and thereby indirectly influence the calving process of the ice shelf."

We also included it in the Discussion (paragraph 4):

“……Our findings support Joughin et al. (2021) in suggesting that ephemeral grounding is linked to ice-shelf rift propagation……”

R1 is correct that the lack of melt observations after 2020 doesn’t limit the ability to observe grounding events, since this is based on satellite observations. Please adjust.

Response 5: We have removed this sentence.

Furthermore, I agree that the discussion of the melt rates can be strengthened by adding a more thorough and transparent analysis, and a discussion of other processes that can explain the discrepancies between the melt rates and elevation changes.

Response 6: We agree that the discussion of melt rates could be strengthened with a more thorough and transparent analysis, including consideration of other processes that might explain the discrepancies between melt rates and elevation changes. However, to maintain a clear and focused presentation centred on our most robust results, we have decided to remove this section.

Line 339: “The melt rate may influence the ice thickness near to the grounding line upstream than the ice rumples K and L”: Is there a word missing before ‘than’ - more/less than, for example? This sentence is unclear to me, please rephrase.

Response 7: We apologize for the lack of clarity. We meant to say that the melt rate may influence ice thickness near the grounding line along the main trunk. Since we have removed the content related to melt rate, this part may no longer be visible in the revised manuscript.

Fig A: add the locations of the PIG-S and PIG-N station in the Landsat image.

Response 8: Since we have removed the content related to melt rate, this part may no longer be visible in the revised manuscript.

In the caption, make clear over which area the ‘Time series of mean ice-equivalent freeboard thickness’ are calculated.
Response 9: Revised. The description has been added to the caption of Figure 9b.

Figure 9b. Time series of mean ice-equivalent freeboard thickness (2010–2022). Mean ice-equivalent freeboard thickness from ICESat-2 was calculated along tracks 965 and 1094 between 75.15°S and 75.05°S, representing the average of measurements from both the strong and weak ICESat-2 beams. REMA thickness values were sampled at the same locations as the ICESat-2 tracks.

In all the figures containing ICESat-2 and REMA data, make sure that the figure legend is correct (there is no ICESat-2 data before 2018).

Response 10: Revised. See Response 1.

In the abstract, add a short explanation of what ‘ephemeral grounding’ is, for non-experts.

Response 11: Revised. We have added a brief explanation of ephemeral grounding in the first sentence of the abstract.

“Ephemeral grounding refers to the intermittent contact between an ice shelf and elevated seafloor features……”

Response to the review of "Ephemeral grounding on the Pine Island Ice Shelf, West Antarctica, from 2014 to 2023," submitted to The Cryosphere.

Reviewer #1:

We sincerely thank Reviewer 1 for the thoughtful review and constructive feedback on the figures. In response, we have improved the visualization of all figures to enhance clarity and presentation.

We recognize that the Appendix section had a weak connection to the main narrative. To maintain a clear and focused presentation centered on our most robust results, we decided to remove this section.

In this document, we provide a detailed, point-by-point response to all comments. The reviewer's comments are shown in black, and our responses are shown in blue, with proposed new text in **bold**. Some sentences were underlined to emphasize key content closely related to the comments.

Summary

The authors have gone to great lengths to respond to the comments made previously, and the manuscript is much improved as a result. The authors have now justified most of their claims, and the presentation of their work is much clearer.

There remain many grammatical errors across the manuscript that need to be corrected.

We appreciate you bringing these errors to our attention, and the necessary corrections have been made.

General comments on the results and discussion

The authors contradict themselves in lines 215-217 ('Ephemeral grounding region, characterised by double-differential vertical displacements close to zero, shows significant correlation with oceanic tidal variations') and lines 235-237 ('Figure 7b reveals no clear correlation between tidal height and grounding region area').

Response 1: Thank you for pointing this out. The sentence on lines 215–217 has been revised to: **"Figures 6-7 and Movie S1 show the two-dimensional double-differential vertical displacement changes and time series of double-differential tidal height differences."**

- From 7b it looks like there is little correlation. Perhaps worth doing a simple correlation between the two to test this.

Response 2: We performed a simple correlation analysis and found a weak inverse linear relationship. Accordingly, we have revised the content describing Figure 7.

Section 3.1 paragraphs 2 and 3:

"Figure 7 identifies 80 ephemeral grounding events between September 2016 and October 2021, including 43 during spring tides (red points) and 37 during neap tides (blue points). As shown in Figures 6a and 7a, positive vertical-displacement anomalies generally coincide with negative tidal-height differences, and vice versa, indicating a strong inverse linear relationship between these variables ($r = -0.80$, $p = 2.41 \times 10^{-31} < 0.05$, $R^2 = 0.65$). In contrast, Figure 7b shows no significant relationship between tidal-height difference and grounding-region area ($r = -0.02$, $p = 0.887 > 0.05$, $R^2 = 0.00026$). During spring tides, only three grounding events exceeded an area of 100 km², while all other events remained below this threshold. No significant linear relationship is observed between tidal-height difference and

grounding-region area during spring tides (r = −0.11, p = 0.484 > 0.05, R^2 = 0.012). Similarly, during neap tides, grounding areas range from 0 to 90 km² and show no significant dependence on tidal-height difference (r = 0.07, p = 0.694 > 0.05, R^2 = 0.004).

Figures 7c and 7d further show no significant relationship between tidal height and area of grounding, indicating that area variability is not solely governed by tidal forcing. Notably, area of grounding region increased from December 2016 to February 2019 and decreased thereafter. When combined with Figure 6a, where near-zero double-differential vertical-displacement signals suggest the upstream advection of thicker ice, these observations indicate that ice-dynamical processes likely play a substantial role in driving ephemeral grounding."

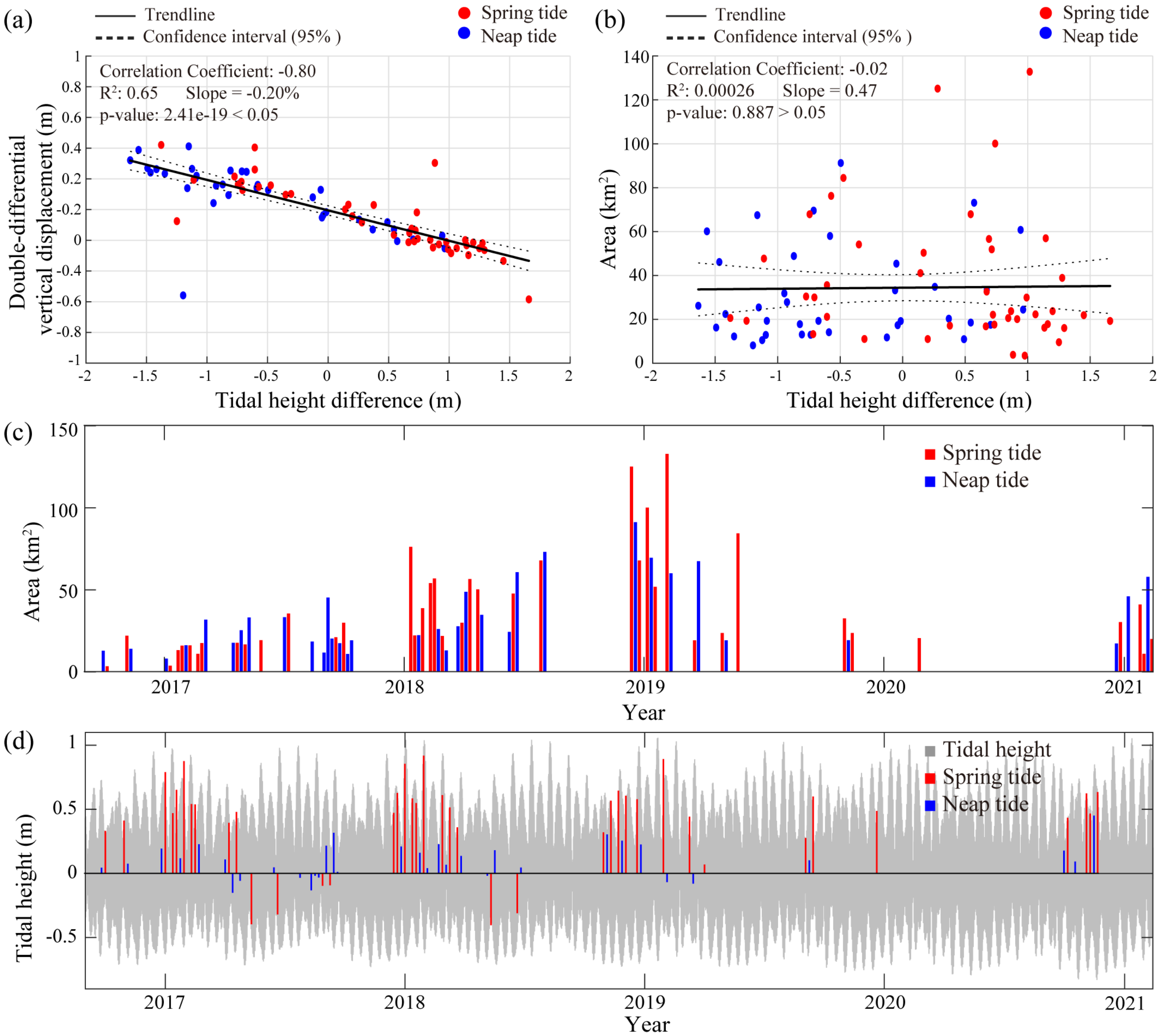

Figure 7. Comparison of tidal height differences with double-differential vertical displacement, comparison of tidal height differences and area of grounding region, including time series of area and tidal height variations. (a) Scatter plot of tidal height difference versus double-differential vertical displacement, showing a strong negative linear correlation between the two variables (r = –0.80, p = 2.41×10^{-19} < 0.05, R^2 = 0.65). (b) Scatter plot of tidal height versus area of zero vertical displacement region, indicating weak relationship between the two datasets (r = –0.02, p = 0.887 > 0.05, R^2 = 0.00026). (c) Time series of changes in ice rumple area. (d) Time series of tidal height changes, where 0 represents

mean sea level. In all panels, blue vertical lines or points indicate ephemeral grounding events during the neap tide period, while red vertical lines or points represent those during the spring tide period.

- Can you colour the points in 7b to match the spring and neap tides in Figure 7d, which might make the difference in the 2 categories clearer

Response 3: Revised. See Response 2.

- Can you explain the groundings during negative tide heights?

Response 4: In Figure 7d, time series of tidal height changes are shown, <u>where 0 represents mean sea level. Negative tidal heights indicate that the water level is below the mean sea level.</u> During these periods, the ice shelf can contact with the bed, leading to ephemeral grounding. Grounding at negative tide heights occurs because the lower water level reduces buoyancy, allowing the ice bottom to touch the seafloor.

It is hard to interpret the elevation change at L in Figure 8. Perhaps simply showing a time series of elevation in the vicinity of L would be easier to interpret, especially as the authors don't make use of the high-frequency elevation variations visible in this figure. I suggest this time series could even be overlaid on Figure 9b.

Response 5: We have removed the elevation label and included the ice thickness changes at L in Figure 9b, as suggested.

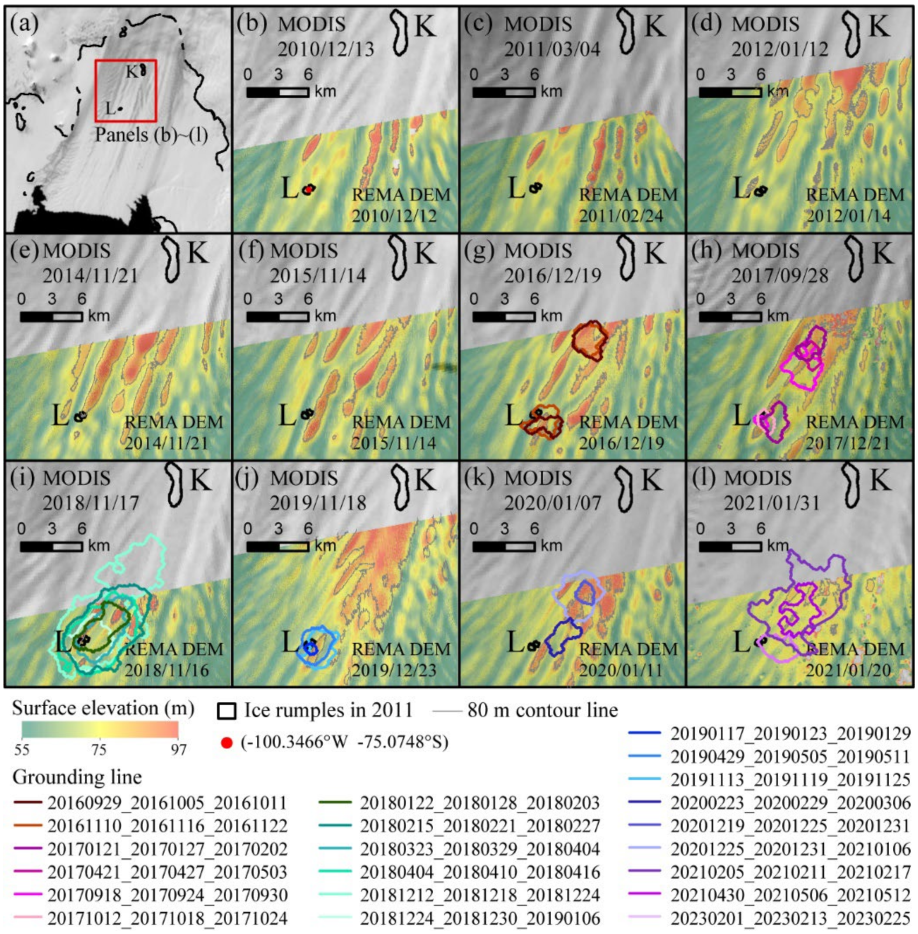

Figure 8. Changes in surface ridges at PIIS near ice rumple L. (a) Overview map showing the subregion outlined by the red frame, corresponding to panels (b) to (l). (b)–(l) Surface ridges and their elevation changes from 2010 to 2021, derived from corrected REMA strips. The two black circles indicate the positions of ice rumples. Grounding lines are delineated based on the zero-contour of the double-differential vertical displacement. Grey lines are the 80m contour line. The red point in panel (b) marks the location where the thickness time series near Rumple L was extracted in Figure 9b.

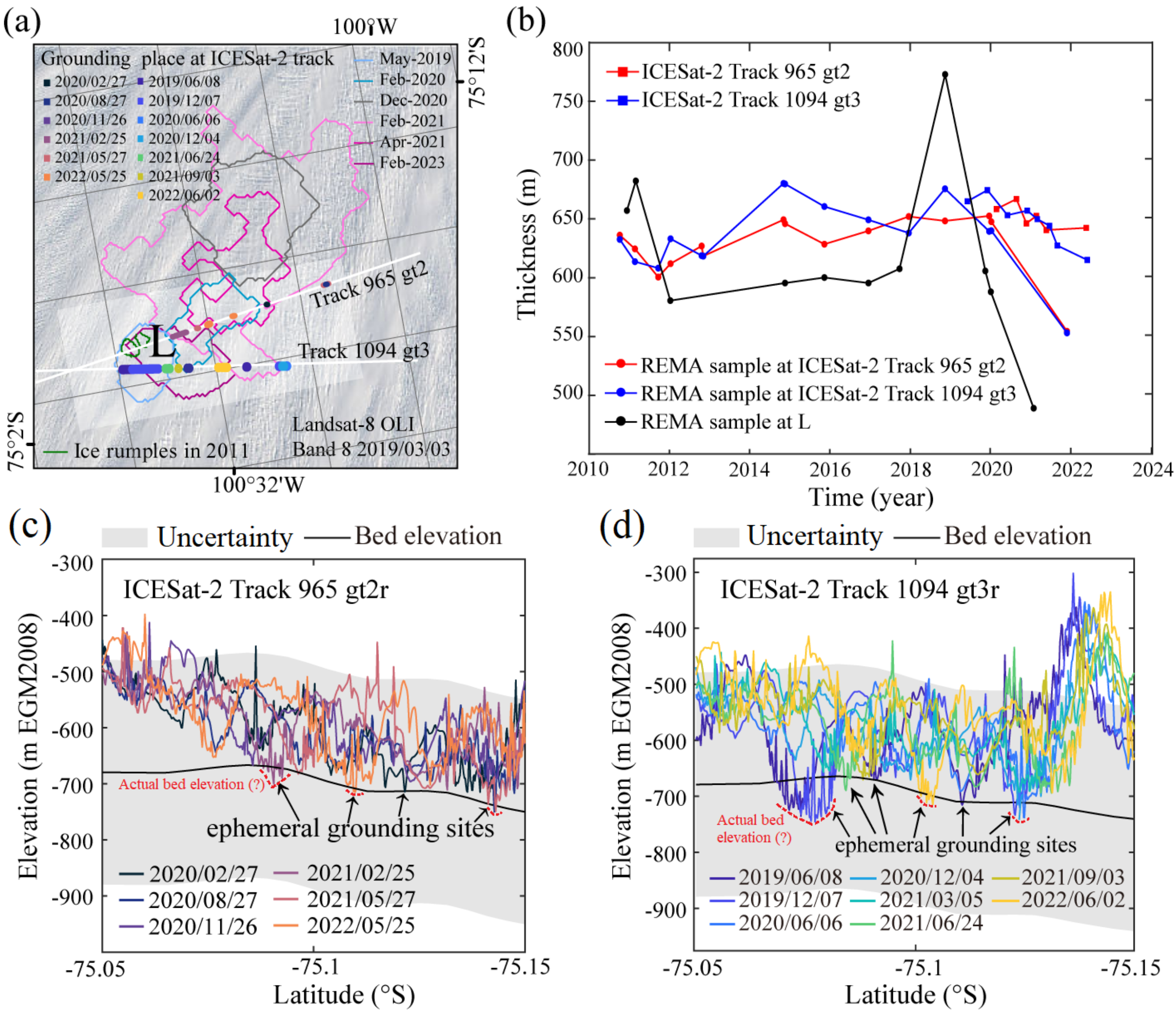

Figure 9. Time series of mean ice-equivalent freeboard thickness and ice shelf bottom elevation profiles along ICESat-2 tracks 965 and 1094. (a) ICESat-2 tracks 965 and 1094 that used for ice-equivalent freeboard thickness change analysis and grounding lines near the ice rumple L from April 2011 to February 2021. Background is from Landsat-8 OLI optical image on 3 March 2019. (b) Time series of mean ice-equivalent freeboard thickness (2010–2022), representing the average of measurements from both the strong and weak ICESat-2 beams. Mean ice-equivalent thickness from ICESat-2 was calculated along tracks 965 and 1094 between 75.15°S and 75.05°S. REMA thickness values were sampled at the same locations as the ICESat-2 tracks. (c) Ice shelf bottom elevation profiles along ICESat-2 track 965 gt2r between February 2020 and May 2022. (d) Ice shelf bottom elevation profiles along ICESat-2 track 1094 gt3r between June 2019 and June 2022. Bed elevations are from the BedMachine v3 dataset (Morlighem et al., 2020; Morlighem, 2022), converted from EIGEN-6C4 to the EGM2008 geoid to match the vertical datum of REMA strips. The estimated vertical uncertainty is ±200 m (shown as a grey transparent box). The potential actual bed elevation is marked by a red dashed line.

The authors fail to reference Joughin et al. 2021 at multiple points throughout the manuscript. This paper also showed rifts propagating from the ephemeral grounding point in the centre of PIG.

Response 5: Thank you for pointing this out. We have added the reference to Joughin et al. (2021) in Section 3.3, last sentence:

"…Together, these observations support Joughin et al. (2021) in suggesting that ephemeral grounding events facilitate rift propagation and thereby indirectly influence the calving process of the ice shelf."

We also included it in the Discussion (paragraph 4):

"…Our findings support Joughin et al. (2021) in suggesting that ephemeral grounding is linked to ice-shelf rift propagation…"

The authors discussion regarding ice shelf basal melt rates remains unsatisfactory. Firstly, the lack of melt observations after 2020 doesn't limit the ability to observe grounding events (lines 342-345). The melt data presented shows a decrease in melt rates on the order of 10m/yr in 2015. If the ice is in hydrostatic equilibrium, this would be seen as a ~1m change in the surface elevation. Whereas the IceSat-2 observations presented suggest up to a 70m change in thickness and the elevation data shows a ~20m change. It is clear from these approximate numbers that there must be another process involved in the ephemeral grounding here.

Response 6: Thank you for pointing this out. We have deleted the sentences in lines 342-345.

Further, the authors don't discuss the potential role of the thick column of ice that was advected downstream in the ephemeral grounding. They do mention this in their introduction (lines 135-137).

Response 7: Thank you for pointing this out. We have revised the sentence to: **"Ephemeral grounding could be driven by tidal cycles, ice shelf thinning or thickening, sea-level rise, sea-level fall, <u>and the downstream advection of thicker ice column</u>—depending on prior grounding conditions (Schmeltz et al., 2001; Rignot, 2002; Matsuoka et al., 2015).".**

The authors discuss melt rates and ocean mooring data within the context of ice shelf thinning in Appendix A. In its current form, it is unclear what this section contributes to the main narrative. While a rigorous analysis could potentially reveal a meaningful link between ocean conditions, basal melt rates and ephemeral grounding, the present version lacks sufficient clarity and detail. I recommend either substantially refining this section with a more thorough and transparent analysis or removing it altogether. In particular:

Response 8: Thank you for pointing this out. <u>We have deleted the content relate to the basal melting to maintain a clear and focused presentation centered on our most robust results.</u>

- What depths in the ocean mooring profile have the authors used to construct the time series?

Response 9: The depth we used to construct the time series is at 648 m to 657 m at the PIG-N and at 665 m to 690 m at the PIG-S to show the temperature changes near where the top of the mCDW is (~600m). Since we have removed the content related to basal melting, this change may not be visible in the revised manuscript.

- The authors claim that the decrease in melt in 2015 corresponds with decreased temperatures in the mooring (lines 394-396). To me, it looks like the cooling occurs after the peak in reduced melting.

Response 10: Thank you for pointing this out. We have plotted the time series of basal melting, ocean temperature, and ice thickness together for comparison (Figure R1). As you noted, changes in ocean temperature do not align with variations in basal melting. Thus, we delete the related content.

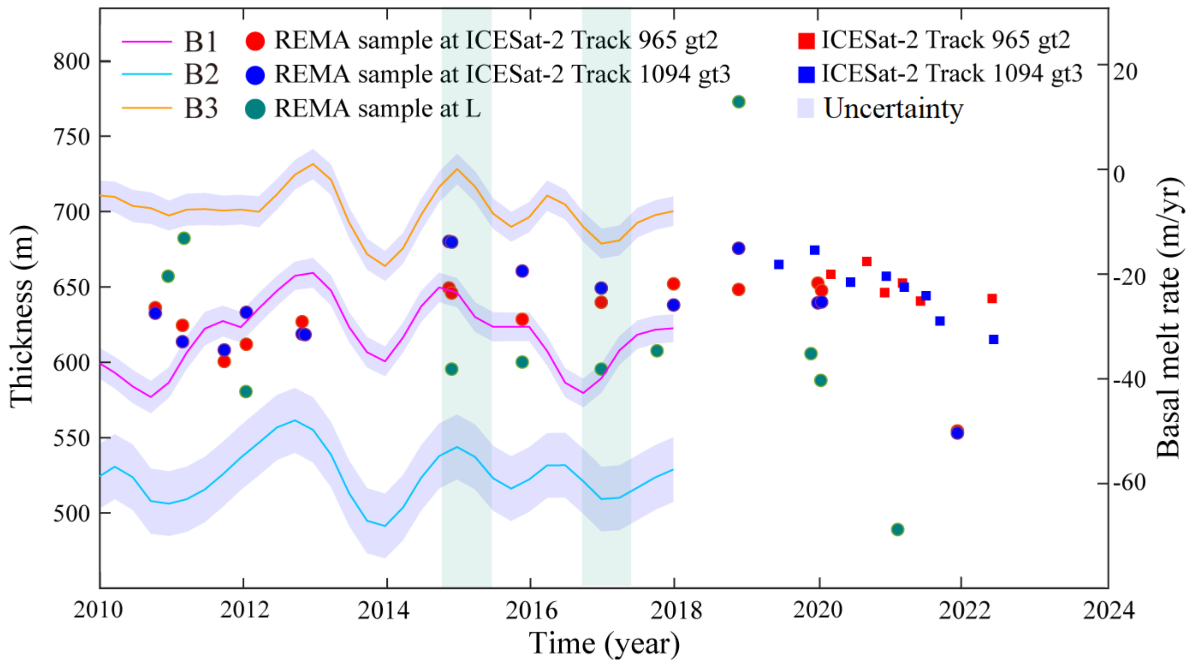

Figure R1. Time series of basal melting, ocean temperature, and ice thickness.

- Joughin et al., 2021 showed that there was a 12% acceleration of the ice shelf between 2017 and 2020. It is likely this has contributed to some of the observed thinning through divergence.

Response 11: We agree ice-shelf acceleration between 2017 and 2020 likely contributed to some of the observed thinning through divergence. However, the processes driving ice-shelf thinning are complex. To maintain a clear narrative, we have chosen to focus on the robust results—such as thinning, thickening, and rift propagation—while a detailed analysis of the causes of thinning is beyond the scope of this study.

Specific Comments

Comments related to grammar or word choice:

Line 1 abstract: 'The evolution of ephemeral grounding in ice shelf can…' should read 'The evolution of ephemeral grounding of an ice shelf can…'

Lines 23-24: 'Despite the grounding line retreat, the Pine Island Ice Shelf (PIIS) was observed to maintain intermittent contact with the bathymetric high when thick ice column being advected from…' should read 'Despite the grounding line retreat, the Pine Island Ice Shelf (PIIS) was observed to maintain intermittent contact with the bathymetric high when a thick ice column was advected from….'

Line 136: 'The grounding of ice shelf' should read 'The grounding of an ice shelf…'

Line 137: remove 'as an obstacle against ice flow' and replace with 'by'

Line 205: 'Our results reveal recurring of ephemeral grounding…' should read 'our results reveal recurring ephemeral grounding…'

Response 12: All comments related to grammar or word choice have been revised as suggested.

Lines 8-9: Please provide a citation.

Response 13: Revised to **"A prominent example of these dynamics can be seen in the Amundsen Sea sector of West Antarctica, which accounts for over 31% of the continent's total ice loss <u>(Smith et al.,</u>**

2020). Within this sector, the Pine Island Glacier (PIG) basin alone contributed approximately 3.0 mm to global sea-level rise between 1979 and 2017 (Rignot et al., 2019).”

Reference:

Smith, B., Fricker, H. A., Gardner, A. S., Medley, B., Nilsson, J., Paolo, F. S., et al.: Pervasive ice sheet mass loss reflects competing ocean and atmosphere processes, Science, 368, 1239–1242, https://doi.org/10.1126/science.aaz5845, 2020.

Line 323: ‘These signals disappeared during the 2020-2021 thinning period but reappeared in December 2020’. This doesn’t make sense. Please check the dates.

Response 14： This sentence has been revised to: **“These signals disappeared between March and December 2020, during the ice shelf thinning period from 2020 to 2021.”**

Lines 330-331: ‘Notably, we find the rift that…’ Joughin et al., (2021) suggested this. Should be cited.

Response 15： This sentence has been revised to: “**Notably, we find the rift that caused the 2020 calving event appeared after pass through the ephemeral grounding region. Our findings support Joughin et al. (2021) in suggesting that ephemeral grounding is linked to ice-shelf rift propagation…….**”.

Line 337: De Rydt et al., (2014) results don’t seem particularly relevant to anything discussed in the following paragraph.

Response 16： Removed.

Line 338: Warm waters at the bottom of the ocean here should be referred to as Circumpolar Deep Water.

Response 17： Thank you for pointing this out. Since we have removed the content related to basal melting, this change may not be visible in the revised manuscript.

Lines 358-360: ‘Observed large-scale surface and basal structures… basal melt modulated by ocean temperature variability’. This sentence is confused and certainly doesn’t belong in the conclusion.

Response 18： Removed.

Figure 7 : - Colour the points in b depending on the spring or neap tide

Response 19： Revised. See Response 2.

Figure 8:

- Here, the reader is interested in elevation change over time. Showing the elevation anomaly from some reference might make the author’s point clearer. Furthermore, a simple time series might be easier to interpret.

Response 20： Revised. See Response 5.

Figure 9:

- I don’t think we learn anything extra from having the across transect profiles from both the right and left ICESat-2 beams

Response 21： Revised. We have removed the original Figures 9c and 9e, which contained results from the weak beams (see Response 5).

- A single colour ramp that spans c-f would help the reader compare observations on different tracks

Response 22： We decided to retain the color ramp to highlight the ephemeral grounding locations along the ICESat-2 tracks in Figure 9a. Since the two ICESat-2 tracks correspond to different dates, using different colors helps to make this distinction clearer.

- Could the areas along the transect that Sentinel-1 detects grounding be shown?

Response 23： Yes. We plotted the grounding regions in Figure 9c as dots that cover the ICESat-2 tracks, using the same colors as the lines in Figure 9d.

Response to the review of "Ephemeral grounding on the Pine Island Ice Shelf, West Antarctica, from 2014 to 2023," submitted to The Cryosphere.

Reviewer #2:

We sincerely thank Reviewer 2 for the thoughtful review and constructive feedback on the figures. In response, we have improved the visualization of all figures to enhance clarity and presentation.

In this document, we provide a detailed, point-by-point response to all comments. The reviewer's comments are shown in black, and our responses are shown in blue, with proposed new text in **bold**.

Thanks for providing substantial revisions on the manuscript and I think the overall quality has improved a lot. Please find my comments below.

Line 292: It should be 27 November 2018 according to Figure 10g.

Response 1: After rechecking the date of the Landsat-8 image, we confirm that the image used is from 11 December 2018. The date originally labeled in Figure 10g was incorrect. We have now corrected it.

In Figure 7, why does the number of ephemeral grounding events marked by blue and red vertical lines in 7d not match the number of red vertical lines representing the ice rumple area in 7c? The area of grounding zone should exceed zero if there is a grounding event.

Response 2: We originally applied the MATLAB function **graythresh** to determine the threshold for identifying the grounding-line region. However, this function only operates on positive values, causing incorrect extraction for double-differential vertical displacement maps containing negative values. Thus, we correct the script and produced correct result.

Previously, the automatically detected grounding areas were smaller than those identified manually from the 2D double-differential displacement maps (i.e., the white "spots"). In the revised approach, we first extract the ephemeral grounding regions using the Otsu method, then compare the results with the 2D displacement maps and remove noise or ambiguous detections. Using this method, we identify 80 ephemeral grounding events during the observation period. We have also revised the relevant figure and ensured the number of vertical lines in Figures 7c and 7d is consistent.

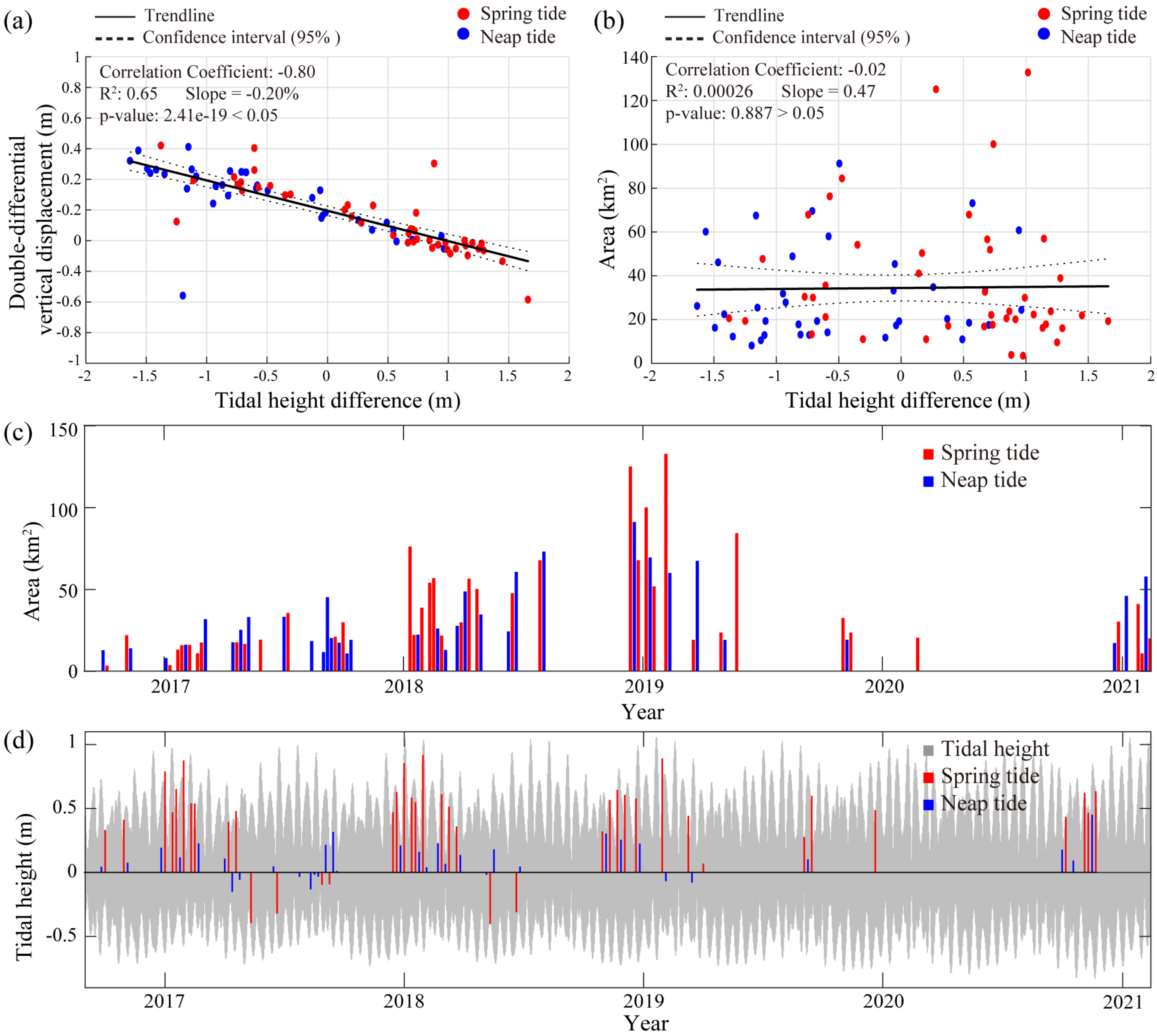

Figure 7. Comparison of tidal height differences with double-differential vertical displacement, comparison of tidal height differences and area of grounding region, including time series of area and tidal height variations. (a) Scatter plot of tidal height difference versus double-differential vertical displacement, showing a strong negative linear correlation between the two variables ($r = -0.80$, $p = 2.41\times10^{-19} < 0.05$, $R^2 = 0.65$). (b) Scatter plot of tidal height versus area of zero vertical displacement region, indicating weak relationship between the two datasets ($r = -0.02$, $p = 0.887 > 0.05$, $R^2 = 0.00026$). (c) Time series of changes in ice rumple area. (d) Time series of tidal height changes, where 0 represents mean sea level. In all panels, blue vertical lines or points indicate ephemeral grounding events during the neap tide period, while red vertical lines or points represent those during the spring tide period.

In Figure 8, please remove the labels 'Surface elevation xxx' from the plots and put them somewhere else, currently they overlap the surface features and make the figures rather messy.

Response 3: Revised. We moved the surface-change results to Figure 9b and replaced elevation with thickness.

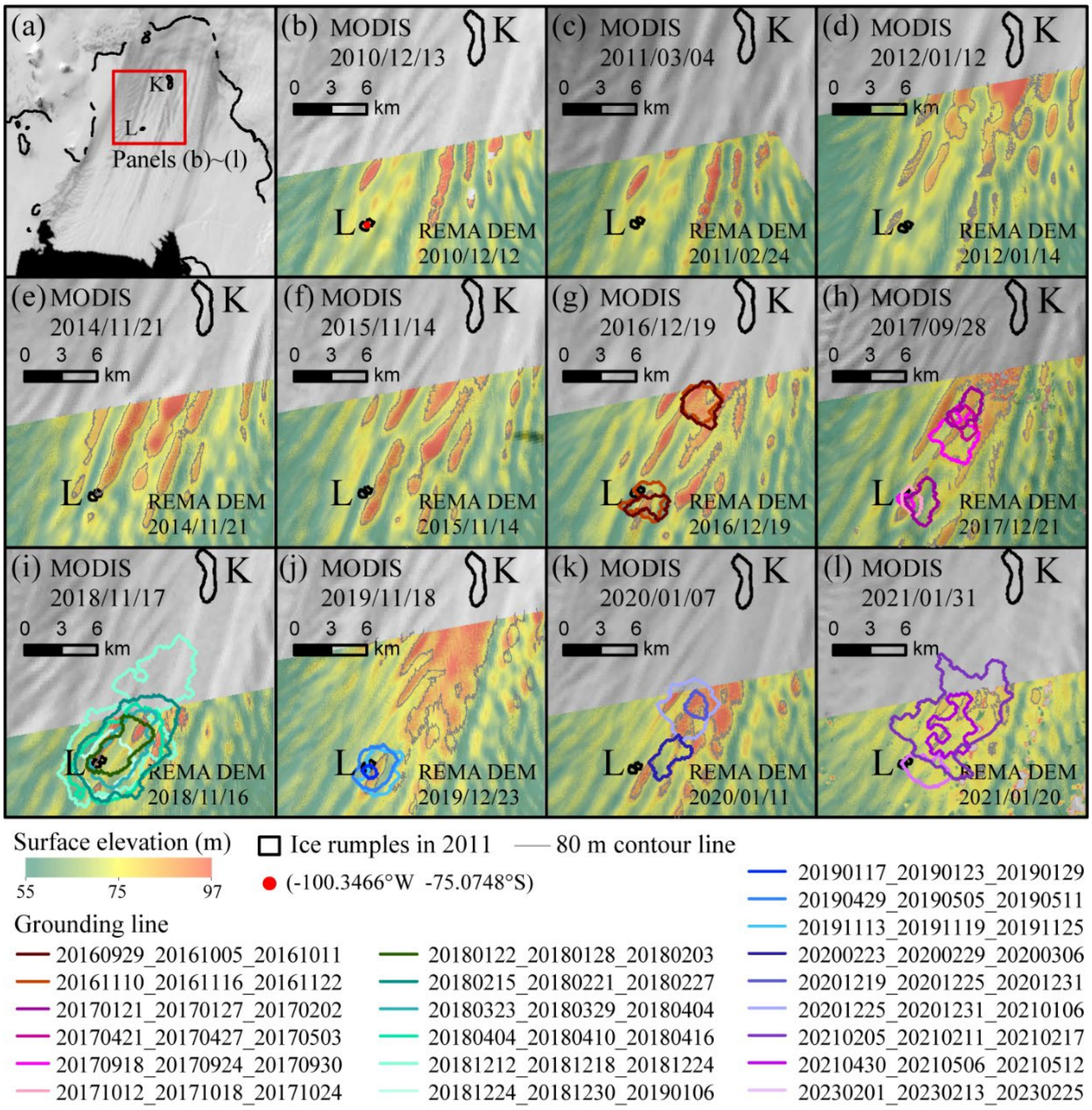

Figure 8. Changes in surface ridges at PIIS near ice rumple L. (a) Overview map showing the subregion outlined by the red frame, corresponding to panels (b) to (l). (b)–(l) Surface ridges and their elevation changes from 2010 to 2021, derived from corrected REMA strips. The two black circles indicate the positions of ice rumples. Grounding lines are delineated based on the zero-contour of the double-differential vertical displacement. Grey lines are the 80m contour line. The red point in panel (b) marks the location where the thickness time series near Rumple L was extracted in Figure 9b.

In Figure 9b, it is impossible to quickly distinguish ice thickness measured from these two different ICESat-2 tracks due to color choices. Please change to a different color scheme, and I suggest making line plots for each different ground track measurement. Does 'REMA DEM gt2l' mean the REMA DEM sampled at gt2l ground locations?

Response 4: Yes, "REMA DEM gt2l" refers to REMA DEM values sampled at the gt2l ground locations. We have revised both the description and the labels. We also updated the color scheme and changed the dot plot to a line plot with markers, averaging values from both tracks (e.g., Track 965 represents the mean of gt2l and gt2r; Track 1094 represents the mean of gt3l and gt3r). This modification improves clarity.

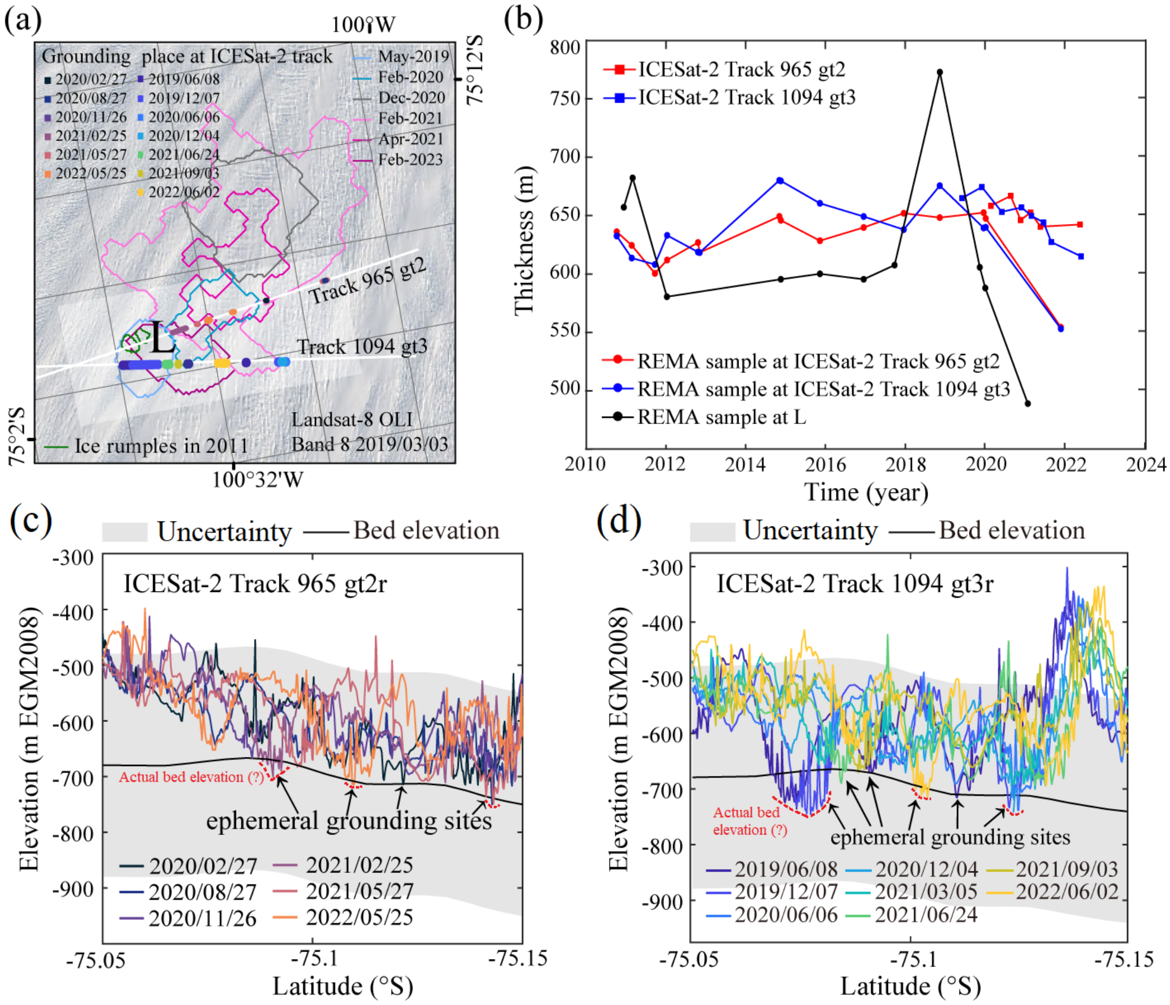

Figure 9. Time series of mean ice-equivalent freeboard thickness and ice shelf bottom elevation profiles along ICESat-2 tracks 965 and 1094. (a) ICESat-2 tracks 965 and 1094 that used for ice-equivalent freeboard thickness change analysis and grounding lines near the ice rumple L from April 2011 to February 2021. Background is from Landdsat-8 OLI optic image on 3 March 2019. (b) Time series of mean ice-equivalent freeboard thickness (2010–2022). Mean ice-equivalent freeboard thickness from ICESat-2 was calculated along tracks 965 and 1094 between 75.15°S and 75.05°S, representing the average of measurements from both the strong and weak ICESat-2 beams. REMA thickness values were sampled at the same locations as the ICESat-2 tracks. (c) Ice shelf bottom elevation profiles along ICESat-2 track 965 gt2r between February 2020 and May 2022. (d) Ice shelf bottom elevation profiles along ICESat-2 track 1094 gt3r between June 2019 and June 2022. Bed elevations are from the BedMachine v3 dataset (Morlighem et al., 2020; Morlighem, 2022), converted from EIGEN-6C4 to the EGM2008 geoid to match the vertical datum of REMA strips. The estimated vertical uncertainty is ±200 m (shown as a grey transparent box). The potential actual bed elevation is marked by a red dashed line.

Figure 10:

• Please explain how you tracked the rift propagation history – I would like to know how you managed to put R1 and R2 arrows in Figures 10b,c,d, because there aren't any visible surface features in those locations from the images.

Response 5: We manually identified the rift. We have revised the figure to highlight the rift more clearly.

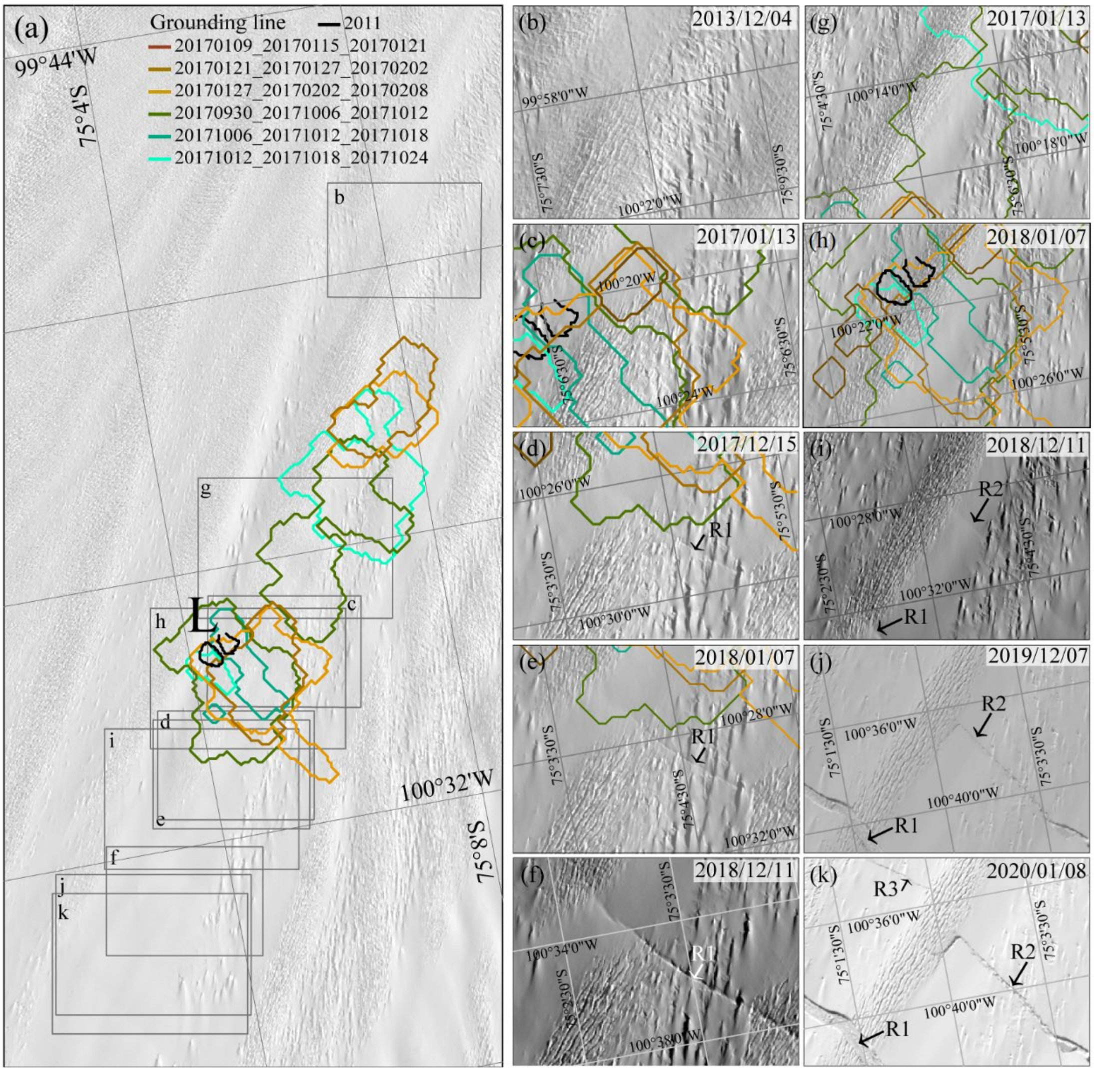

Figure 10. Rift propagation history from 2013 to 2019. (a) Overview map showing the positions of panels (b) to (k). The background image is a Landsat-8 panchromatic image from 4 December 2013. (b)-(k) show the propagation history of the rifts R1, R2, and R3 (black or white arrow), which led to the 2020 calving event. The black circles indicate the positions of ice rumple L. Grounding lines are delineated based on the near-zero value of the double-differential vertical displacement.

• In the figures, if an image does not have any rift formed, consider removing the labels. Also it should be 'not appeared', not 'no appeared'

Response 6: Revised. See Response 5.

• In Figures 10a, 10e and 10g, it's difficult to identify the rifts from these plots. Please make a high-resolution zoom-in map to show the rift patterns in detail

Response 7: Revised. See Response 5.