Response to reviewer #1 for 'Short and long-term grounding zone dynamics of Amery Ice Shelf, East Antarctica' - EGUSPHERE-2025-849

Yikai Zhu, on behalf of the authors,

We would like to thank Reviewer #1 for their detailed and constructive feedback on our manuscript. We greatly appreciate the time and effort taken to read the manuscript and provide insightful suggestions. These comments have been very helpful in improving the quality and clarity of our work. Below, we provide a point-by-point response to each of the reviewer's comments. Reviewer comments are reproduced in the **Comment** column, with our **Response** listed alongside. The **Line** column refers to the position of the relevant text in the original submission, and the **New line** column indicates where changes were made in the revised version. All modified text is highlighted in blue to clearly indicate revisions made in response to reviewer feedback.

ID	Comment	Line	Response	New line
1.1	In particular, the identification of linear, threshold, and asymmetric migration modes largely replicates the classification framework introduced by Freer et al. (2023), and the reported correlations between GZ width and glaciological parameters (e.g., bed slope, ice velocity) parallel earlier insights from Chen et al. (2023).		We appreciate the comment and gratefully acknowledge the classification framework introduced by Freer et al. (2023), which provided a useful reference for analyzing short-term grounding line migration patterns. Similarly, the insights from Chen et al. (2023) were valuable when examining potential controlling factors. The inclusion of ice velocity as a parameter in our analysis represents a new addition in this study.	
1.2	This work provides a high-quality observational foundation and demonstrates the utility of DROT for grounding line science.		We sincerely thank the reviewer for the positive comment.	
1.3	Consider elaborating on the specific advantages of the DROT method in this context and providing a brief rationale for its selection over other grounding line detection techniques. This would help clarify the methodological motivation at an early stage in the manuscript.		**Done.** In response, we have revised the introduction to briefly explain the rationale for selecting the DROT method in this study. Specifically, we now highlight that DROT enables high-frequency, spatially continuous measurements under all-weather conditions, and offers advantages over other techniques: it is less affected by cloud cover and track spacing limitations compared to RTLA, and remains effective in fast-flowing and low-coherence areas where DDInSAR technique is often limited. We believe this revision helps clarify the methodological motivation at an early stage in the manuscript. Line 41: "In this study, we adopt the DROT method due to its ability to provide spatially continuous, high-frequency measurements under all weather conditions. Compared to RTLA, it is less affected by cloud cover and track spacing limitations, while unlike DDInSAR, it remains effective in fast-flowing or decorrelated regions where interferometric coherence is often lost."	41-44

1.4	It would be helpful to clarify the basis on which the GL migration along profile 4 is interpreted as permanent. Specifically, how does Figure 2d/Figure 1c support the conclusion that the observed inland migration exceeds short-term tidal variability?	220-222	**Done.** We have revised the text in this section to clarify our criteria for identifying long-term GL migration. Specifically, we compared the historical GL location from MAGv2 dataset with the seaward limit (Fmax) of the DORT-derived GL positions in 2021. If the historical GL is located more than 4 km farther seaward than our most seaward DROT observation, we interpret this as an indication of long-term retreat beyond short-term tidal variability. In profile 4, the MAGv2 GL is located over 5 km farther seaward than the DROT-derived Fmax, which supports our interpretation of a sustained inland migration in this region. Line 221: "To determine whether this inland migration represents a long-term change beyond short-term tidal variability, we compare our DROT-derived seaward GL position (Fmax) with the historical GL location from the MAGv2 dataset. If the reference GL lies more than 4 km seaward of seaward-most DROT-derived measurement, we interpret this as evidence of long-term retreat. In profile 4, the MAGv2 GL is located over 5 km farther seaward than the seaward DROT-derived GL, satisfying this criterion."	221-225
1.5	In the phase legend of Figure 3a, it is recommended to use 180° instead of 3.14.	Fig. 3a	**Done.**	Fig. 3a
1.6	For Figures 3b–c, it is recommended to display the grounding lines derived from both methods simultaneously within the same panels, if feasible. This would enable a more direct and intuitive visual comparison between the results.	Fig. 3b-d	**Done.**	Fig. 3b-d
1.7	Comparison with Other Grounding Line Measurements: It is recommended that the authors consider incorporating a comparison with the dataset available at https://nsidc.org/data/nsidc-0778/versions/1. This product, part of the MEaSUREs program, provides a continent-wide map of short-term grounding line migration zones derived from InSAR during 2018–2020. Given its closer temporal proximity to the 2021		**Done.** We have incorporated a comparative analysis between our 2021 DROT-derived GZ and the MEaSUREs Antarctic GZ Version 1. This comparison provides an opportunity to assess the consistency of GZ mapping results from different techniques (DROT vs. DDInSAR) acquired within a relatively short temporal window. We now present this comparison in Section 3.2 and Figure S2, including both boundary-level analysis and spatial overlap metrics (e.g., Intersection of Union, precision, and recall). This addition helps contextualize the performance of DROT and highlights the effects of methodological and tidal difference on GZ delineation. Line 262: "The MEaSUREs Antarctic GZ Version 1 (MAGZv1) dataset provides a comprehensive map of short-term GL migration zones across the Antarctic Ice Sheet using the DDInSAR technique (Rignot et al., 2023). We compared DROT-derived GZ results with the	262-294; Fig. S2

	DROT results presented in this study, it would serve as a valuable reference for contextual validation and potentially enhance the robustness of the comparative analysis.		subset of MAGZv1 dataset over the AmIS, which is based on Sentinel-1 data acquired in 2018, to assess their spatial consistency. We first computed the Intersection over Union (IoU), defined as the area of intersection divided by the area of union (Figure S2a), to evaluate the overall spatial agreement between the two GZ products. The comparison yielded an IoU of 0.44, indicating a moderate level of spatial overlap. Notably, the recall reached 0.84, suggesting that the DROT-derived GZ successfully captures the majority of the area defined by MAGZv1. However, the precision was relatively lower at 0.48, implying that over half of the area identified by DROT as GZ lies outside the extent of MAGZv1. This asymmetry reflects a broader delineation of the GZ by the DROT method, potentially capturing additional zones not included in the earlier dataset. We further evaluated the spatial offsets along the landward and seaward GZ boundaries (Figure S2b-c). For the landward boundary, the DROT-derived GZ was positioned on average 459±697 m landward relative to the MAGZv1 boundary. For the seaward boundary, the offset was -255±666 m, indicating that the DROT extend farther seaward into the floating ice shelf (Figure S2c.i and c.ii). These patterns suggest that the our DROT-derived GZ results tends to resolve a broader GZ, with boundaries shifted in opposite directions compared to MAGZv1. We attribute the differences observed between the DROT-derived GZ and the MAGZv1 product to a combination of methodological, temporal, and tidal factors. First, the two techniques are based on fundamentally different approaches. While MAGZv1 employs the DDInSAR method to detect vertical tidal flexure through interferometric phase change, the DROT technique measures displacement from SAR amplitude imagery, enabling GZ detection even in areas with low coherence. However, DROT has a slightly lower measurement sensitivity (a fraction of a range pixel) compared to the sub-wavelength sensitivity of DDInSAR (Joughin et al., 2016). Consequently, the DROT technique tends to position the GL slightly further seaward than DDInSAR technique, consistent with our direct comparison over three representative regions, which shows a mean absolute offset of 0.35-0.42 km with standard deviations ranging from 0.14 to 0.26 km (Table 1). In addition, the two products are derived from different acquisition periods: MAGZv1 for the AmIS is based on Sentinel-1 data acquired in 2018, whereas the DROT-derived GZ uses imagery from 2021. This temporal offset means that some of the differences may reflect real GL migration over the three-year interval, though rates of change in the AmIS region are generally modest compared to dynamic West Antarctic outlets (Park et al., 2013). Lastly, both methods are sensitive to tidal conditions at the time of acquisition, but the MAGZv1 dataset does not provide metadata on tidal amplitude for each SAR acquisition. This limits our ability to directly quantify the contribution of tidal state mismatches to the observed discrepancies. In the	

			absence of precise tidal alignment, apparent offsets in GL position may partly reflect differences in tide-induced flexure captured at different stage of the tidal cycle. Taken together, these differences underscore the importance of method-specific sensitivities, acquisitions timing, and tidal phase alignment when comparing GL or GZ products derived from distinct remote sensing techniques.”	
1.8	The manuscript states a typical offset of 1.5 km between DROT- and DDInSAR-derived grounding lines. Could the authors clarify whether this value represents an average across specific regions? Additionally, the observed differences in this study appear smaller—what factors might account for this discrepancy, and how spatially consistent are these deviations across the Amery Ice Shelf?	304	**Done.** We appreciate the reviewer’s attention to the reported DROT–DDInSAR grounding line offset. We apologise as the previously stated value of ~1.5 km was a preliminary number. This reviewer comment prompted us to update this by performing a detailed comparison over three representative regions (b–d). The results show that the mean absolute offset between the DROT- and DDInSAR-derived grounding lines ranges from 0.35 to 0.42 km, with standard deviations of 0.14 to 0.26 km (Table 1). These values indicate that the discrepancies are smaller than our initial assessment and are spatially consistent across the AmIS within the areas of available DDInSAR measurements. We have updated the manuscript with this clarification. Line 282: “Consequently, the DROT technique tends to position the GL slightly further seaward than DDInSAR technique, consistent with our direct comparison over three representative regions, which shows a mean absolute offset of 0.35-0.42 km with standard deviations ranging from 0.14 to 0.26 km (Table 1).”	282-284
1.9	The interpretation of a positive correlation between grounding line migration distance and the absolute double-differential tide range would benefit from further clarification. Does a lower absolute double-differential tide range necessarily imply smaller ice surface deformation? For instance, if the first and second SAR acquisitions occur at high tides and the third and fourth at low tides, substantial ice deformation may occur, yet the computed absolute double-differential tide range could remain small.	355-359	**Done.** To clarify, the absolute double-differential tidal range used in this study represents the absolute difference in ocean tide height changes between two ROT pairs. Each ROT result is derived from a SAR image pair and reflects tidal-driven ice motion at that time. While the absolute double-differential tidal range is a useful indicator of variation in tidal forcing between epochs, we acknowledge that a small double-differential tidal range does not necessarily imply low total deformation – for example, if both ROT pairs are acquired during similar tidal amplitudes (e.g., both from low-to-high tide), significant ice motion may still occur. We have added this clarification in the revised manuscript. Line 347: “Here, the double-differential tide range refers to the absolute difference in ocean tide height change between two ROT pairs used in DROT processing. Each ROT result is computed from a SAR image pair and reflects the ice deformation induced by tidal forcing during that interval. The double-differential range therefore approximates the variation in tidal amplitude between two measurement periods. While this metric does not fully capture the cumulative tidal forcing or ice deformation. For instance, if both ROT pairs are acquired during similar tidal stages (e.g., both from low to high tide), the double-differential range may appear small, even though substantial ice deformation occurs within each pair. Despite this limitation, we observe a	347-355

			general trend that greater double-differential ranges are associated with broader GL migration, suggesting that short-term variability in tidal forcing plays a significant role in modulating the observed GL positions.	
1.10	Figure 2e in Chen et al. (2023) similarly demonstrates that the grounding line position of the Lambert and Mellor Glaciers oscillates between two discrete states over timescales of several months. Also, given that the temporal sampling in the present study is sparser than that of Chen et al., it is possible that some short-term transitions or episodic changes may not have been fully captured.	375-377	**Done.** We also agree that the lower temporal sampling in our dataset may limit the detection of short-term or transitional GL migration events. This limitation has been explicitly stated, and we now interpret the observed bistability as potentially influenced by both physical processes and observational resolution. Line 373: "This apparent switching behaviour between discrete GL positions is consistent with previous findings (Chen et al., 2023), which documented similar bistable GL states at Lambert and Mellor Glaciers over multi-month timescales. Due to the lower temporal sampling in our study compared to Chen et al., some short-term or transitional events may not have been fully captured. As a result, the discrete nature of the observed GL states may partly reflect our sampling interval. Nevertheless, the persistence of these states across successive observations suggests a degree of stability in the GL position under specific tidal or stress conditions."	373-378
1.11	The synchronized grounding line migration observed for the two glaciers suggests a common driving mechanism. Could this be attributed to tidal forcing, or do the authors propose that subglacial hydrological processes—such as simultaneous subglacial lake drainage or basal melting—could exert a temporally comparable influence on both glaciers? Further discussion on the plausibility of shared controls would enhance the interpretation.	Fig. 5b	**Done**. We agree that the synchronized migration observed in profiles 14 and 15 suggests the potential influence of a shared control mechanism. In the manuscript, we examined the relationship between the GL migration and tidal forcing but found no clear correlation between the most retreated GL positions and the highest tidal amplitudes observed during the study period. This suggests that tides alone do not explain the observed behaviour. We also discussed the possible role of subglacial hydrological processes, such as the drainage of active subglacial lakes and associated basal melting, in influencing GL migration independent of tides. We also highlight that the observed downstream shifts occurred simultaneously in both profiles, which may reflect temporally aligned subglacial water fluxes. However, due to the lack of synchronous time-series observations of subglacial lake drainage and basal melting in this region, we are currently unable to confirm this mechanism and thus discuss it only as a plausible contributing factor.	380-419
1.12	Is this the reason behind the classification of this island as part of the grounding zone in Figure 1c?	455-456	**Yes.**	457-458

1.13	It would be helpful to specify how the along-profile length over which the slopes are calculated was defined. What criteria were used to determine the extent of the landward and seaward segments used in the slope analysis?	570-571	**Done**. In our study, the slopes of the bed, surface, and ice thickness were calculated along the profile tracks by fitting the elevation data over the region between the landward and seaward bounds of the grounding zone (GZ), as shown by the black dashed lines in Figure 6e–h. These bounds correspond to the inland and seaward limits of short-term tidal migration of the grounding line, which were identified manually from the DROT results. Therefore, the length over which the slopes were computed varies between profiles, depending on the width of the GZ. Line 572:"The slopes used in panels (b-d) were calculated by linearly fitting the respective data over the domain bounded by the black dashed lines in panels (e-h), which represent the landward and seaward limits of the tidally-induced short-term GL migration."	572-574