Response to "RC1: 'Comment on egusphere-2025-4771', Sam Herreid, 13 Jan 2026"

Dear Dr. Herreid,

Thank you for reviewing our manuscript and for your thoughtful and valuable feedback, which have helped us improve the manuscript's quality and scope.

In response to your major comments, we have revised our discussion of IBE and removed the figure panels demonstrating the correlation as well as the reconstructed surface displacements without IBE. We have also added an IBE correction based solely on GEM, which may be useful for the broader glaciological community. In addition, we revised our terminology and the Discussion section based on the comments from both reviewers.

Our detailed responses to all comments are provided below in blue font.

Review for **Intra-annual grounding line migration and retreat: insights from high resolution satellite and in-situ observations over Milne Glacier in the Canadian High Arctic**

The article "Intra-annual grounding line migration and retreat: insights from high resolution satellite and in-situ observations over Milne Glacier in the Canadian High Arctic" by Antropova et al. presents a well organized narrative of both methodologies and and local results exploring the intra-annual changes of the flexure zone of a marine termination glacier in the Canadian High Arctic. Ground and airborne data are combined with a dense time series of SAR images to unpack what is happening not just at a high resolution throughout a year but also looking along three longitudinal transects that exhibit variability that the authors do a nice job of unpacking and quantifying. Finally, they put this work into a wider context by looking at the bed topography for where future pinning points might be and how they might affect subglacial melt.

Below are my main comments followed by in line minor comments.

The authors spend some time exploring the importance of including the inverse barometer effect (IBE), but I think this as been well established by Padman et al., 2003, Padman et al, 2008 and e.g. Chen et al., 2023. While quantifying and partitioning the relative terms is very useful, I'm not sure if IBE needs to be demonstrated as important against a simulation excluding it.

We agree that IBE is well documented already and have reduced the IBE discussion accordingly. We retained only three panels showing the correlation between "SSH" (i.e., IBE included) and "DInSAR displacement" (Fig. 4 d-f) and moved "DTide" (i.e., without IBE) vs. "DInSAR displacement" panels (Fig. 4 a-c) to the Appendix. We also removed panels related to reconstructed ice surface height based on simulated tides only from Fig. 6 in the initial version of the manuscript. We revised the text accordingly, removing the discussion of IBE from the Abstract and reducing it in the Results and Discussion sections.

The authors use GEM to fill data gaps in the pressure record, this is somewhat of a footnote. I'm not sure if there are other studies that do this, but since the authors have a dense timeseries of supporting data it could be a useful result for the community to use only GEM data and see if the 15 x 15 km grid 9 km away can reproduce the same tidal model.

Model-based IBE corrections have been discussed previously in the literature, for example through the use of ECMWF atmospheric reanalyses (ERA5) by Chen et al. (2023) and Rignot et al. (2024); however, we are not aware of any direct examples using GEM. In response to this suggestion, we added a figure demonstrating a solely GEM-based IBE correction in the Appendix (Fig. 1AR middle panels) to facilitate comparison with the predominantly in situ-based IBE corrections and to make our analysis more useful to the glaciological community. Given that, in general, the in-situ-based IBE corrections tend to yield higher correlations (Fig. 1AR) and, in our view, add value to this case-based study we use our primary analysis based on in situ observations for analysis.

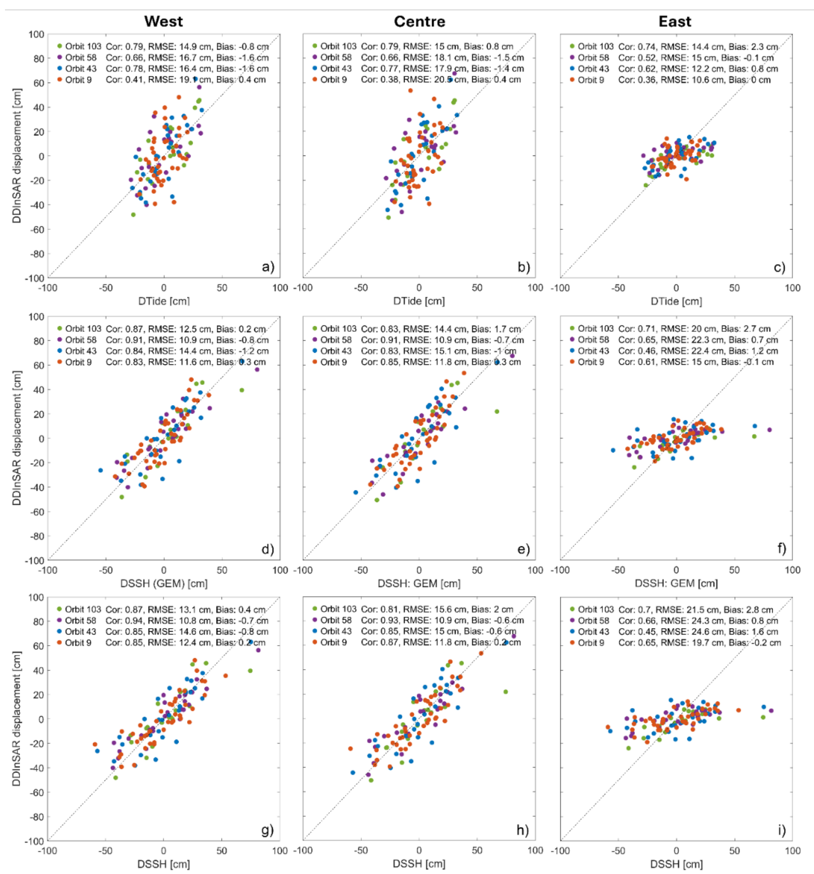

Figure 1AR: Correlation results calculated for the three transects. Upper panels (moved to the Appendix): DInSAR displacement and T_TIDE-simulated tides. Middle panels (added to the Appendix): DInSAR displacement and T_TIDE-simulated tides + GEM-based IBE. Lower panels (retained in the main text): DInSAR displacement and T_TIDE-simulated tides + in situ–based IBE.

There seems to be some inconsistencies throughout with regard to FZ and GZ, both in the terms used and what was calculated and how. I would ask the authors to read through this carefully and make sure terms are consistent throughout and clearly derived if used later in the paper.

We revised L52-54 and the caption of Fig. 1 to explain how the FZ and GZ terms are defined and calculated. As per request from the second reviewer, we adopted "tidal flexure zone" (equivalent to "flexure zone") and "grounding zone" terms and updated them consistently throughout the manuscript.

We note that there are terminology discrepancies in the literature stemming from differences between oceanographic usage and that of the DInSAR community, particularly for terms such as "grounding zone," "grounding line," and "hinge line." Numerous studies (e.g., Rignot, 1996; Rignot, 1998; Fricker & Padman, 2006; Fricker et al., 2009; Sykes et al., 2009; Hogg et al., 2016; Dawson & Bamber, 2017; Freer et al., 2023) define the "grounding zone" as a feature spanning from the hinge line, i.e., the inland limit of tidal flexure, past the grounding line to the line of hydrostatic equilibrium.

In contrast, more recent DInSAR-focused studies (e.g., Mohajerani et al., 2021; Chen et al., 2023; Ciracì et al., 2023) tend to refer to the DInSAR-derived landward limit of tidal ice flexure as the "grounding line" (rather than the hinge line), and to the region over which this landward limit migrates with the tides as the "grounding zone." In addition, the size of this zone is commonly reported using the term "grounding zone width," even though it is measured along the glacier flow direction.

In this manuscript, we adopt the following terminology to remain consistent with recent literature and to address the reviewers' comments:

Hinge line: the DInSAR-derived inland limit of tidal flexure.
Tidal-flexure zone or flexure zone, initially referred to as the "ice flexure zone": the zone of ice flexure due to tides, spanning from the hinge line to the line of hydrostatic equilibrium. The width of the flexure zone (initially referred to as the "FZ span") is measured along the three red transects (Fig. 1).
Grounding zone: the region over which the hinge line migrates between its most landward and most seaward positions in response to tides. The width of the grounding zone (initially referred to as the "GZ span") is measured along the three red transects (Fig. 1). The following text from the manuscript describes how it was calculated:
"The Milne Glacier grounding-zone width for the entire period of observations (2023 - 2024) was calculated as the difference between the maximum and minimum distances from point A to the most seaward and landward DInSAR-derived hinge lines, respectively, along the three transects (e.g., $|A\ B_{Wmax}| - |A\ B_{Wmin}|$ for the western transect)."

We also note that the terms "hinge line" and "grounding line" can be used interchangeably when discussing DInSAR-derived short-term migration or retreat processes, as hinge-line and grounding-line migrations are directly correlated (Rignot, 1996; Hogg et al., 2016), as clarified in the Introduction.

There is a use of stable and unstable which I found to be imperfect terms for an intra-annual time series. In Section 4.2 the authors relax this language and talk in terms of season. I think the stable/unstable delineation might be more easy to follow and possibly more accurate to label in terms of seasons. A possible title could be "Seasonal grounding line migration (I'm not sure if there is a long enough time series here to identify permanent retreat?). Also in the title is "high resolution" high temporal resolution? I think this is really the key factor that make the study unique.

Thank you for the suggestions. We adopted the terms "steady" and "unsteady" periods to describe the analyzed velocity regimes and to address comments from both reviewers.
We would like to avoid the use of "seasonal" grounding line migration because we do not have data spanning multiple seasons to reliably identify seasonal regimes. Additionally, our division of periods is based primarily on changes in velocity and SAR data availability rather than on seasons (e.g., the summer season is not represented, and the fall and winter seasons overlap).
In the title, "high resolution" refers to both spatial and temporal resolutions. We would like to retain the title in its initial short form, but we have added a clarifying sentence to the abstract:

"We explore changes in this zone, spanning from the inland limit of tidal flexure (known as the hinge line), across the actual grounding line, to the hydrostatic equilibrium line, where the ice tongue becomes freely floating, at high-spatiotemporal resolution."

The paper is largely a collection of substories, one of which is the notch which I had the hardest time following. Maybe there's a figure that could help the reader along.

We added Fig. 2AR to the Appendix, which demonstrates examples of differential interferograms with and without the new eastern notch and pinning points.

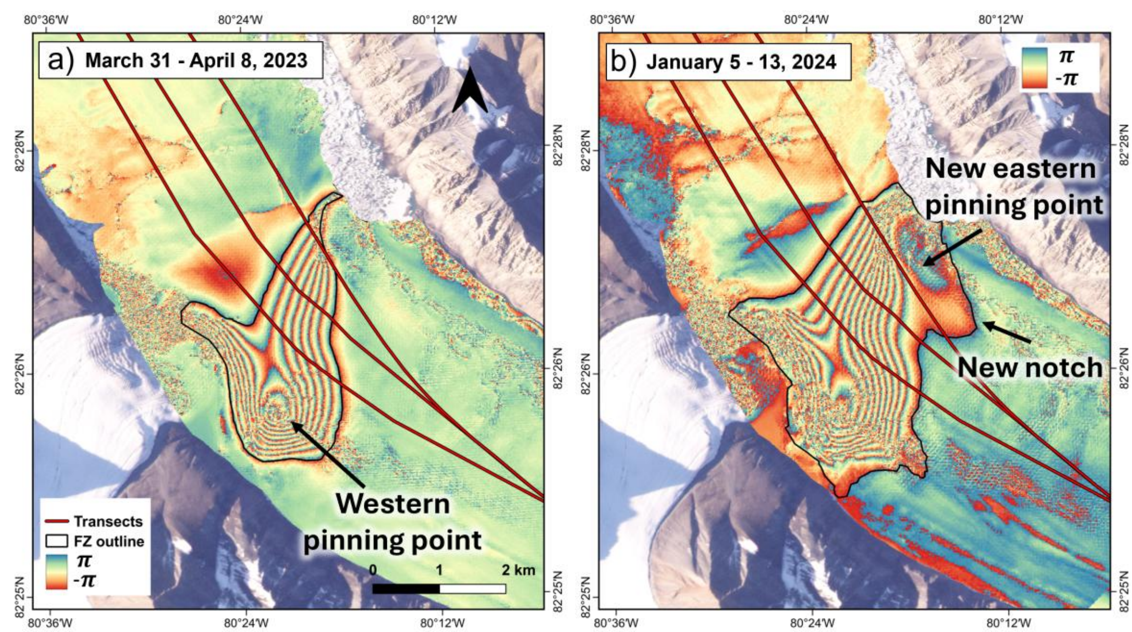

Figure 2AR: DInSAR result examples for: a) flexure zone without the new eastern notch, b) flexure zone with the eastern notch formed around a pinning point.

We also modified the caption of Fig. 3 to better clarify the connection between the new pinning point and the notch:

"A pronounced retreat associated with the formation of a new notch around a pinning point on the eastern margin was discovered after hinge line delineations in 2023 by Antropova et al. (2024)."

Finally, as an intra-annual study, I think a nice addition to the discussion section could be a recommendation to future researchers, who might be limited to a more sparse dataset, on how they might be confident or cautious comparing data from different instances in the seasonal cycle.

We revised Section 4.2 of Discussion with respect to SAR-line-of sight errors due to velocity contributions and due to ice stretching and compression caused by bending (as per request from the second reviewer). We added our recommendations regarding the reliability of DInSAR results, considering the quantified errors associated with the seasonal cycle and SAR viewing geometry.

L14-15: The language isn't quite correct here, either something like "Knowledge of changes at the boundary…is critical for…" or "Changes…the grounding line control glacier stability…"

Thank you. We have revised the sentence as follows:
"Observing and quantifying changes in the boundary where marine- terminating glaciers transition from grounded to floating, known as the grounding line, is critical for advancing our understanding of glacier stability"

L15: Is there a more succinct way to build directly off of the grounding line established in the first sentence to flexure zone rather than seemingly developing a new term and then at the end of the sentence connecting it back to grounding line? Within a system with a flexure zone, isn't there not an "actual grounding line" location but rather a moving will occupy throughout an observed tidal maximum and minimum?

We revised the text as follows:

"The actual grounding line is difficult to observe directly; however, it is revealed through changes at the ice surface as the ice flexes in response to tides, forming a tidal flexure zone. We explore changes in this zone, spanning from the inland limit of tidal flexure (known as the hinge line), across the actual grounding line, to the hydrostatic equilibrium line, where the ice tongue becomes freely floating, at high-spatiotemporal resolution."

We note that flexure zone is the zone where ice experiences flexure with tides, and the grounding zone, where the DInSAR-derived hinge line moves with tides (in line with the DInSAR nomenclature).

L20-L21: measured or modeled tides? Was atmospheric pressure implicit or explicit?

Tides were simulated using the T_TIDE algorithm based on our 10-month in-situ pressure records in 2016-2017 (Antropova et al., 2024). The atmospheric pressure was implicit (i.e., it becomes "unexplained variation" not accounted for by the tidal constituents) in the simulated tides, but then it was added through the inverse barometric effect (IBE) correction to get sea surface height (SSH).

L22: 0.81, 0.94 m?

These numbers represent Pearson's correlation coefficients; therefore, they are dimensionless.

L22-25: Is the vertical displacement a key result of your project? I would think the key point to get across is sensitivity in z to determine a meaningful x,y. The following sentence is unnecessary detail for the an abstract in how it's presented here. As it reads, here it should just be +/- error bounds for 0.81 and 0.94, but I would argue that these numbers aren't so fundamental to the study and the sentence of interest here is z accuracy as it relates to x,y accuracy.

We revised the manuscript text, including this sentence, and added information on the accuracy of the z component (i.e., the SAR line-of-sight) relative to the more meaningful x and y (i.e., horizontal) components. The highest combined SAR line-of-sight error from velocity variability and ice bending (i.e., additional analysis performed in response to the second reviewer's comment), calculated for orbit 09 (i.e., the highest incidence angle, descending pass) during the unsteady period, reaches ~3.3 cm, including 2.3 cm from velocity variability and 1 cm from bending. This corresponds to ~1.2 fringes in RCM C-band SAR (one fringe is ~2.8 cm displacement). Assuming a typical dense fringe pattern, where one fringe corresponds to ~200 m along the glacier, this error translates to an uncertainty of ±240 m in the delineated bounds of the flexure zone.

L25: Maybe you mean the downstream edge of the GZ, presumably there is a gradient somewhere in the upper boundary of the GZ.

This statement is based on Fig. 11 and its discussion:

"The grounded ice moved downstream at about 100 m yr^{-1} and then accelerated to 200 m yr^{-1} at ~3 km up-glacier of the FZ, reaching a velocity of 270 m yr^{-1} in the FZ and then up to 320 m yr^{-1} down-glacier of it during summer months. Hence, Milne Glacier FZ zone was associated with ~2.7-fold increase of glacier velocity compared against its upglacier grounded part shown in Fig. 11."

We prefer to use only the terms grounding line and flexure zone in the Abstract to avoid reader confusion arising from the terminology discrepancies mentioned above.

L25: How should a reader interpret this result, is this abnormal? A change? Did this seasonal cycle drive the retreat in the following sentence?

We replaced this sentence with information about line-of-sight errors and the corresponding horizontal errors due to velocity in the DInSAR-derived bounds (see the L22–25 comment above).

L25: new meaning previously unreported or newly developed within some amount of time?

Corrected to "newly developed" as this grounding line retreat was observed from our DInSAR images within our 2023-2024 period of observations.

L26: Why grounding line here and not GZ?

We believe that both GZ and grounding line would be appropriate in this context; however, we prefer to use only the terms 'grounding line' and flexure zone already introduced in the Abstract to avoid reader confusion arising from the terminology discrepancies mentioned above and to save space in the Abstract.

L27: "...shows how bed features can alter the grounding…"

The sentence was revised as follows:
"We discovered a newly developed ~2.4 km grounding-line retreat associated with water intrusion behind a pinning point at the eastern margin of the glacier. Pinning points alter the grounding-line short-term migration and its long-term retreat."

L31: Add citation(s)

Two citations: "Black & Joughin, 2022; Kochtitzky & Copland, 2022" were added.

L31: Establish this connection: Rising atmospheric and ocean temperatures can cause marine-terminating glaciers to speed up, which then leads to …

The sentence was revised as follows:

"Rising atmospheric and oceanic temperatures can cause these glaciers to accelerate, leading to increased sea level rise and discharge of icebergs or ice islands into adjacent waters."

L32: Check formatting of IOCC ref. Is it 2021 or 2023?

The "IPCC (2021)" citation was replaced with original research articles from peer-reviewed journals, as requested by the second reviewer: "(Morlighem et al., 2019; Wood et al., 2021; Carnahan et al., 2022; Holmes et al., 2025)."

L33, try to establish the location for the reader, something like, "In the Arctic, …"

We modified the first sentence of the corresponding paragraph to emphasize that we are narrowing its focus to Arctic-related research, which is more relevant to our area of interest:

"Marine-terminating glaciers, which drain ice masses from land to the ocean, have experienced dramatic changes in recent decades due to warming climate, particularly in the Arctic, where temperatures are rising faster than the global average (Black & Joughin, 2022; Kochtitzky & Copland, 2022; Rantanen et al., 2022)."

L33: What was the change? Faster and smaller?

We revised the sentence to clarify the documented changes:

"Increased ice discharge and ice mass losses associated with pronounced Arctic glacier volume decrease, retreat, and deterioration were recently documented by Millan et al. (2017, 2023) and Van Wychen et al. (2020)."

L38-39: Suggest: …exhibit dynamic behaviour at two key scales, ysub-day variability from tides and [insert some time scale, e.g. years to decadal] changes as a response to climate and glacier dynamics.

Thank you, but we prefer to retain the original text, as distinguishing between timescales in this context is uncertain due to tidal variations spanning sub-daily/daily cycles (e.g., semi-diurnal and diurnal) to longer-term cycles (e.g., spring-neap-spring ~14 - 15 days, perigean-apogean ~27 days, seasonal equinox events, lunar nodal ~18.6 years) and sea-level rise. Similarly, defining an appropriate timescale for grounding line retreat due to long-term glacier changes is problematic, as it varies greatly with environmental and glacier-specific factors, which interact and can result in a rapid and pronounced grounding line retreat, as documented in this study.

L41: maybe effective rather than efficient

Thank you - we have modified it to "effective," as it is more appropriate in this context.

L45: Yes, Fricker at al, uses grounding zone for flexure zone, Freer et al, in their Fig. 1 do differentiate their points, F, H as the flexure zone proxy but also F_max and F_min, the limits of the GL. I would encourage the authors to affirm the language flexure zone for what DInSAR measures, the ice grounding zone for the true max and min of tidal migration of the GL (ice used here to differentiate from an oceanographers definition of the grounding zone which I believe is slightly different from a glaciologist's perspective), finally the grounding line referred to not a fixed location but moving both diurnally with tide and over years with glacier-wide and climate changes. I think the authors are mostly holding to this, but it's not perfectly concrete. (your L48 and 50-54 are very good and clear). I think you could just define FZ and GZ, I'm not sure what span adds.

Our study assumes that a single DInSAR image can be used to delineate the "tidal flexure zone" that occurs between three or four SAR data acquisitions. This zone spans from the inland limit of the fringe pattern (i.e., hinge line) to its seaward limit (i.e., hydrostatic equilibrium line), whereas multiple DInSAR image patterns can be used to monitor the landward and seaward bounds of hinge line migration referred to as "grounding zone" in the most recent glaciological studies (e.g., Mohajerani et al., 2021; Chen et al., 2023; Ciracì et al., 2023) and in our study. Given the availability of frequent DInSAR images from different orbits with different acquisition times in our study, we were able to quantify a reliable DInSAR-derived grounding zone width, which serves as an adequate proxy for the true "Fmax-to-Fmin" distance, occurring between maximum and minimum tides modulated by atmospheric pressure. We hope that this explanation, together with our response to the terminology question above, fully clarifies our use of terminology in the manuscript.

L47: This "however" is a little misplaced I think, make sure there is clear conceptual contrast.

We replace it with “Nevertheless” to emphasize the coexistence of definitions.

L49, 58, Chen et al., 2023 is missing in References

Thank you, we added the citation to the list.

L59 GZ spans for consistency.

We prefer to retain “grounding zones” here, as in this context we discuss melt across the entire grounding zone.

L61: I think the objective is to understand the controls and responses of a system that happens to be deteriorating. We hope these observations will work in a phase of glacier growth also.

Thank you, we revised the sentence to refine our objectives:
To improve these models, a detailed investigation of the controls and responses of a glacier system that drive grounding line migration over short-term cycles, as well as its advance or retreat over long term, is required, along with an assessment of how these processes can be reliably monitored through satellite-based observations.

L65: Generally would say model results or inputs not model datasets

Thank you; this has been revised as follows:
“Our study explores intra-annual changes in the Milne Glacier flexure zone based on a combination of RCM DInSAR-derived results, in situ and simulated datasets, and a numerical weather prediction model output.”

L64,66 if using FZ “span”, use throughout

FZ (changed to “flexure zone”) refers to the entire zone of ice flexure delineated based on the DInSAR fringe pattern from one DInSAR image/result here. “Span” was changed to “width” in the current version of the manuscript.

L70: what does marked mean? Could just say acceleration and no acceleration for a and b. Is it acceleration and deceleration that makes an unstable regime?

We revised these sentences to clarify the details as follows:

“a) a steady period, when the in situ-measured Milne Glacier velocity did not change appreciably during winter and the DInSAR assumption of invariant velocities was met; and
b) an unsteady period, when velocity changes were evident, the glacier decelerated after a velocity peak in summer, and the DInSAR assumption of invariant velocities was violated.”

Please note that “steady/unsteady period” terminology was adopted instead of “stable/unstable regime”.

L71: In 64-66 you establish intra-annual as a short term, is this still the same short term? Or do you mean 1d or 4d changes?

We removed "short-term" and revised the first objective to avoid giving the impression of establishing full equivalence between the intra-annual and short-term timescales, and to provide further details about the time scale:

"Delineate the Milne Glacier FZ using RCM image acquisitions from four different orbits, with a 4-day repeat interval within each orbit and about 1-day interval between orbits, spanning February 17, 2023, to September 17, 2024."

We note that, although changes in flexure zone occur in response to SSH (i.e., tides plus IBE), our definition of a "short-term" period is limited to DInSAR observations generally with a 4-day repeat interval within each orbit and about 1-day interval between orbits; for example, in January of 2024, the coverage was: orbit 103: Jan. 5, 9, 13; orbit 43: Jan. 9, 13, 17; orbit 58: Jan. 10, 14, 18; orbit 09: Jan. 11, 15, 19. The RCM acquisition timeline throughout 2023-2024 is shown in Fig. 2a.

L93-95: Does Van Wychen et al, provide a mechanism for these velocity changes? Obviously velocity context is useful, but will the speed up slow down cycle come back into the story here?

Thank you, we added a clarifying transitional sentence to show the connection between changes in velocity and grounding line retreat and discuss mechanisms for these velocity changes:

"Van Wychen et al. (2020) suggested that this cyclical behaviour may result from prominent bedrock features that modulate velocity where the glacier front rests below sea level. In contrast, Antropova et al. (2024) noted that the post-2016 acceleration was preceded by the highest grounding line retreat rate along the glacier's centerline between 2011 and 2018, suggesting the presence of feedback mechanisms between grounding line retreat and glacier acceleration upstream of this zone."

We are working on a follow-up paper, which confirms glacier thinning above the grounding zone. We are testing the hypothesis that dynamic thinning, associated with a velocity increase in this zone and likely triggered by grounding line retreat, is involved. However, we consider this outside of the scope of this current paper.

L96-98: There isn't a citation here, is this your result? Add citation or move to results.

These results are from Antropova et al. (2024). Since this work is already cited in the previous and following sentences, we prefer not to add another citation here.

L123: automated or manually delineated?

"manually" was added.

L129: It's possible resampling the DEM to a lower resolution can help maintain coherence with the crevasse pattern in the interferograms, just a suggestion for the future.

Thank you. The ArcticDEM resampling could be considered in the future, but based on our experience with 30 m ASTER and GLO-30 Copernicus DEMs, these areas were also affected by noise, when these lower-resolution DEMs were used.

L134: It's not clear which dataset actually defined the three transect lines. I think figure 1 could benefit from an inset with the surface and bed airborne and in situ radar transects and the IceBridge flightlines.

We added the radar lines to Fig. 1 and the following text: "(Fig. 10 in the Results section)" to direct readers to the figure presenting surface and bed airborne and in situ radar transects.

L138-L138, Isn't the distance from Bw1 to Bw2 a change over time, your migration term not the GZ?

Yes, we used the distance from B_{W1} to B_{W2} as a simplified example based on only two DInSAR images to illustrate the concept behind the term. However, the DInSAR-derived grounding-zone width reported in this study was calculated using all DInSAR images over the entire observation period.

We revised the sentence as follows to better explain this idea:
"- grounding-zone width (i.e., the distance along the glacier between the most landward and most seaward hinge-line delineations based on all DInSAR images over the entire observation period, for example, represented by the distance between B_{W1} and B_{W2} in Fig. 1, derived from two DInSAR images based on SAR data acquisitions in March-April 2024 and September 2024);"

L141: Was the unwrapped phase calibrated to the surrounding bedrock? What is a phase discontinuity? A phase jump? How was this corrected?

We calibrated the unwrapped phase with respect to the mean value of the grounded ice surface as follows: for orbits 43, 58, and 103, the grounded ice surface means were negligible; therefore, correction for the incidence angle alone was sufficient (i.e., dividing the derived displacement by the cosine of the incidence angle). For orbit 09, an additional calibration relative to the grounded ice surface mean was applied.

Yes, this sentence refers to phase jumps, also referred to as discontinuous shifts in the measured phase. These were corrected using a MATLAB script that identified and removed phase jumps exceeding 2 cm along the three transects. This threshold was chosen to be slightly more conservative than half of the RCM C-band wavelength (i.e., 5.5 cm / 2).

We revised the sentence to better clarify these processing steps as follows:

"The final calibration of the SAR line-of-sight displacement was conducted along the three transects (Fig. 1) using an automated script. Values were divided by the cosine of the incidence angle, additionally calibrated to the mean value of the grounded ice surface for orbit 9, and then corrected for phase jumps exceeding 2 cm (i.e., more conservative than half of the RCM C-band wavelength)."

L148: change and to are. In this study are…

We revised the text to incorporate this change and improve readability:
"Flexure zone variables explored in this study **are** computed along the western, central, and eastern transects (subscript W, C, and E) shown in red (through points A, B and C). **These variables include**: 1) distance to hinge lines (A to BW1, A to BC1, A to BE1 for FZ 1 (blue polygon) and A to BW2, A to BC2, A to BE2 for FZ 2 (orange polygon), 2) -width of the two flexure zones (BW1 to CW1, BC1 to CC1, BE1 to CE1 and BW2 to CW2, BC2 to CC2, BE2 to CE2), 3) Grounding zone width (BW1 to BW2, BC1 to BC2, BE1 to BE2), and 4) surface displacement height of the floating ice

L174: The notch isn't perfectly clear to the reader at this point in the article.

We added the following information in the "Methods: 2.2.2 Analysis of tides" section:

To explore the origin of the newly developed notch along the eastern margin, we tested the hypothesis that it appears in DInSAR images associated with SAR acquisitions during periods of high SSH, suggesting that seawater intrudes farther inland and results in ice ungrounding around a pinning point.
We also added a new figure demonstrating DInSAR results with/without the notch, as stated above, to the Appendix

L180: It looks like the unstable period is the white block between sable-blue and unstable-red. And why isn't all of the flat velocity before the beginning of the first blue block considered stable? It seems to me these are environmental classifications that are actually instrumental classifications, where data was available and where there was coherence. I would encourage the authors to say something like "winter observation block" and late-summer/fall observation block" otherwise this is very confusing for the reader. Layer L191 admits this.

Yes, this breakdown was based on SAR data availability and glacier velocity, as clarified in the text (previously L191).
We revised the caption of Fig. 2 to better explain this:

"**The cold winter period of SAR observations** associated with a steady glacier regime, highlighted in blue, corresponds to relatively steady and low velocity values of 0.4 m d^{-1}. **The relatively warm fall period of SAR observations** associated with an unsteady regime, highlighted in orange, corresponds to velocity values decreasing from 0.6 m d^{-1} to 0.4 m d^{-1}."

L195: It is technically "not stable" because there is change in velocity, but I wouldn't call a predictable seasonal slowdown as "unstable"

We adopted "steady/unsteady" terminology in the current version of the manuscript.

L227: A height range converted to a spatial extent using ArcticDEM?

L227 refers to the DInSAR-derived grounding zone located between the most landward and most seaward hinge-line positions. Its width was calculated as the distance between points with XY coordinates at the intersections with the three red transects: first, the distance from point A to the most seaward hinge-line position was measured; next, the distance from point A to the most landward position was measured; finally, the difference between these two distances was computed to characterize the grounding zone width.

We revised the sentence to better clarify this:
"The Milne Glacier GZ width for the entire period of observations (2023 - 2024) was calculated as the difference between the maximum and minimum distances from point A to the most seaward and landward DInSAR-derived hinge lines, respectively along the three transects (e.g., $|A\ B_{Wmax}| - |A\ B_{Wmin}|$ for the western transect)."

L246: Don't you have bed geometry and ice thickness (L220), why not explore this rather than leave as speculative "likely due to a distinctive bed geometry and ice thickness"

This sentence was removed from this section, as the corresponding clarifications are provided in the Discussion section.

L283: Can this or a plot like this include the pinning point(s)? It would be cool to see how the Eastern transect changes

We have added this figure to the Appendix (as noted above) to better illustrate the DInSAR results with and without the notch. This figure demonstrates that the primary changes at the ice surface occur farther east of the eastern transect.

As shown in Figure 3b, the changes observed from orbit 43 at the ice surface along the eastern transect are not pronounced. The hinge line migrates only approximately 400 m landward (from km 39.4 to km 39 along the IceBridge transect). Therefore, we retain the current version of the figure, as adding vertical lines to indicate the most landward hinge-line positions, with and without the notch, would not substantially improve its clarity.

We also refer to Figure 8b to highlight the bed rises, suggesting that the glacier remains grounded near these features and farther east (between km 39.5 and 40.5, labeled as the "pinning point region"), when high tide allows water to intrude farther inland.

L294: Maybe I missed it, what is the reference height SSH is based on?

SSH is derived from T_TIDE-simulated tides referenced to mean sea level and subsequently corrected for the inverse barometer effect (IBE), assuming that a 1 hPa increase (decrease) in atmospheric pressure results in a 1 cm drop (rise) in sea level (Wunsch & Stammer, 1997; Padman et al., 2003). In the T_TIDE MATLAB package (Pawlowicz et al., 2002), mean sea level is determined as the mean level of the input data series, recorded by our pressure sensor. Then

T_TIDE computes amplitudes and Greenwich phase lags based on the deviation from this mean. Therefore, our simulated tides were reconstructed relative to this in situ mean baseline (considered as mean sea level) recorded by our pressure sensor.

L303: Table 3, It's essentially a new fringe or two that you're saying is a persistent feature and thus not error. From this table it seems possibly within error but if it's spatially consistent this is maybe a better argument. Why no middle value along with SD and max min, and the first column says averaged across all observations, but really divided between sets of notch and no notch?

Yes, the surface changes are minimal (shown in Appendix); however, they are spatially consistent and persistent across different orbits, as shown in Figure 3.
The purpose of this table was to clarify the origin of the newly developed notch in the eastern margin, specifically to test our assumption that the notch (i.e., ungrounding around the pinning point) occurs during high SSH (tides+IBE). For this reason, we examined two categories of DInSAR images: with and without the notch. The occurrence of the notch during periods of higher SSH maxima (0.21 m vs. 0.13 m for observations with and without the notch, respectively) supports our interpretation that it caused by seawater intrusion.

We revised the sentence to better explain this:

"Our hypothesis that the newly observed notch formed during periods of high SSH, leading to seawater intrusion and ice ungrounding around the eastern pinning point, was evaluated using statistical characteristics of SSH (i.e., sea surface heights at the time of SAR data acquisitions rather than their displacement values of DSSH) along the eastern transect. The calculated characteristics for the DInSAR results were divided into two groups 1) cases without the notch, and 2) cases when the notch was observed (Table 3)."

L318-319: Is the loss of correlation a suggestion to future scientists that acceleration/decelation lowers the confidence of DDInSAR measurements? Is there also something we're learning about this particular glacier? It's read like a result for the particular glacier but I think the key result is methodological.

Thank you, we added the following clarifying sentence to better explain the associated methodological issues:

"This example demonstrates that pronounced changes in velocity violate the DInSAR assumption of invariant velocities between SAR acquisitions; therefore, the DInSAR results should be interpreted with respect to errors arising from variable velocity."

L380-384: I'm not sure if I recall the authors giving their method to derive GZ from the data.

The following sentence (also discussed above) clarifies this:

"The Milne Glacier GZ width for the entire period of observations (2023 - 2024) was calculated as the difference between the maximum and minimum distances from point A to the most seaward and landward DInSAR-derived hinge lines, respectively along the three transects (e.g., $|A\ B_{W_{max}}| - |A\ B_{W_{min}}|$ for the western transect)."

L385: East and West is reversed

Thank you. We have revised the figure references to direct readers to the appropriate panels corresponding to the West and East sections.

L386: Did you calculate this flux or is it just assumed based on a roughly parallel bed profile to cross-sectional ice surface?

This text has been revised to provide additional information:

"The widest grounding zone along the western transect of the glacier was associated with the highest velocity of 166.4 m yr^{-1}, averaged over a year and across the observed grounding zone width (Fig. 11 c), and the thickest ice (mean value of 225.6 m, Fig. 10 d). This section discharged approximately 37 540 m^3 yr^{-1} of ice along a 1 m-wide flow line. The narrower and thinner grounding zones along the eastern and central transects, with mean thicknesses of 210.0 m and 200.5 m (Fig. 10 b, c) were associated with slower average velocities of 144.6 m yr^{-1} and 159.8 m yr^{-1} (Fig. 11 a, b), discharged approximately 30 366 m^3 yr^{-1} and 32 040 m^3 yr^{-1}, respectively.

L393-401: I think the role of IBE is well established in Padman et al., 2003 (cited but missing in references), also Padman et al., 2008, and as you cite Chen et al., 2023. Is/was there an assumption that the tidal effect would be different for marine terminating glaciers in the Canadian Arctica?

Thank you. As discussed above, we reduced our discussion of the IBE. While we acknowledge the fact that the IBE has been well explained in the literature with respect to SSH and is expected to be more pronounced where tidal ranges are small, our aim was to demonstrate that IBE plays a critical role in DInSAR-derived surface elevation changes for glacier tongues flowing into fjords with small tidal amplitudes, such as Milne Fiord.
DInSAR-related studies include IBE corrections, however, most of them focus on ice shelves and glacier tongues in Antarctica or Greenland, where the modeled tidal range is larger (approximately ±1 m) than in our study; consequently, the relative contribution of IBE is smaller in these cases. For instance, Rignot et al. (2024) demonstrated for Thwaites Glacier that the modeled tidal range (–80.8 cm to 96.5 cm) changed by only about 6% after including IBE (–93.5 cm to 95.1 cm). Similarly, Chen et al. reported a tidal range (IBE included) of approximately –90 to 112 cm and showed that applying the IBE correction improved the model fit (reducing the root-mean-square error from 0.932 to 0.780). Wild et al., 2025 reported modeled tides of ±0.4 m and the IBE, of ±0.15 m at Priestley Glacier.
In contrast, for Milne Fiord, the simulated tidal range spanned from –20 cm to 21 cm over the observation period. After correcting for IBE, the range increased 2.3-fold, spanning from –44 cm to 50 cm, which substantially improved the correlation between the SSH and DInSAR derived surface displacements shown in Fig. 4 of the original version of the manuscript.

L410-412: The grounding line migration of 800m wasn't explained or reported earlier. This should be a result and I'm not sure I know how the grounding line analysis was done.

In the Introduction we stated: “We also assume that the relative movements (e.g., short-term migration and long-term retreat) of the DDInSAR-derived ‘hinge line’ and the actual ‘grounding line’ are equivalent, as their positions are strongly correlated (Rignot, 1996).” Therefore, our grounding line analysis with respect to its migration was based on the DInSAR-derived hinge line positions.

We moved L410-412 to the Results section and provided additional details (800 m was based on observations from orbit 09 only):

“The hinge line, and thus the grounding line, shifted upglacier by 1 km compared to the most landward position observed during March 27-April 4, 2023 (Fig. 3 d) reported by Antropova et al., (2024), and exhibited a shift of approximately 690 m between the most landward hinge-line positions derived from all orbits in this study along the eastern transect due to the newly detected notch. This shift was even more pronounced farther east, where the notch advanced landward by 2.5 km compared to the last reported position and by 2.4 km (measured parallel to the eastern profile) during the period covered by this study.”

The sentence in the Discussion part was revised as follows:
“Milne Glacier’s topography within its grounding zone controlled the grounding-zone width over the period of observations: the newly detected notch, associated with a pinning point, caused a 30% increase in the GZ width along the eastern transect.

L420: Do you mean for future predictions of pinning points? Because for a general understanding of active pinning points we don’t need detailed information of bed geometry, just good DDInSAR.

Yes, thank you, we revised the sentence to better communicate this idea:
“Therefore, detailed information on bed geometry upglacier of the grounding zone is essential for improving predictions of grounding-line retreat, particularly where potential pinning points may form due to water intrusions and ice ungrounding around bed rises.”

Citation: https://doi.org/10.5194/egusphere-2025-4771-RC1

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