

Comments submitted by Reviewer-2 on 29/07/2026

Review for: “Brief Communication: Comparing ICESat-2 Altimetry and COSMO-SkyMed Synthetic Aperture Radar Interferometry Grounding Zone Products over Antarctica”

This manuscript compares published grounding zone (GZ) observations derived from COSMO-SkyMed differential SAR interferometry (CSK DInSAR; Ross et al., 2025) and ICESat-2 repeat-track laser altimetry (Li et al., 2022) across 73 Antarctic glaciers. The authors evaluate offsets between ICESat-2-derived Point F, I_b and H grounding line (GL) proxies and the CSK DInSAR GL product, and make comparisons between East Antarctica, West Antarctica, and the Antarctic Peninsula.

I support the motivation for a systematic comparison of altimetry- and DInSAR-derived GZ proxies, and the study has the potential to provide a useful assessment of the strengths and limitations of combining these observation types. However, I have several major concerns regarding the methodology and interpretations presented here, which undermine the conclusions of the paper. I suggest that substantial reanalysis and reframing is required to address the major and specific comments outlined below. In its current form, I do not consider the reported conclusions to be sufficiently robust for publication.

We thank the Reviewer for their careful evaluation of our manuscript and constructive comments, which have helped us improve the manuscript.

Major Comments:

1. Treatment of DInSAR GL as the ‘true’ and ‘instantaneous’ grounding line

The authors treat the CSK DInSAR GL as the “true” GL, Point G, which is misleading. As has been established in the literature (including the review by Friedl et al. (2020)), DInSAR identifies the inland and seaward limit of detectable vertical tidal flexure in the GZ, corresponding to Points F and H. These are effectively the same proxies derived using ICESat-2. Comparing GZ proxies derived from two measurement techniques is itself a valid exercise, but it should be made clear that it is not validating ICESat-2 GZ points against a “true” GL measured using CSK DInSAR.

The statement “*DInSAR remains the gold standard for pinpointing the instantaneous grounding line*” is also inaccurate. As discussed in previous studies (including Ross et al. (2025) from which this dataset is taken), each CSK-derived GL is determined from a differential interferogram constructed from four separate SAR images acquired at different times and tidal states. In this dataset, each differential interferogram is formed from a pair of interferograms generated from 1-day repeats, with the two interferograms separated by 16 to 64 days. Therefore, the resulting GL cannot be described as “instantaneous”.

I recommend revising this terminology throughout the manuscript and ensuring that the physical interpretation of the DInSAR-derived features remains consistent with the established literature.

We used the DInSAR-derived grounding line as an independent spatial reference to compare with the ICESat-2-derived grounding zone proxies, rather than implying that the DInSAR product represents absolute ground truth. We therefore corrected the conclusion and revised the terminology and relevant sections of the manuscript to ensure this interpretation is applied consistently throughout.

We have changed the word “instantaneous” throughout the manuscript. The sentence "DInSAR remains the gold standard for pinpointing the instantaneous grounding line" has been deleted, and the revised manuscript no longer describes the DInSAR-derived grounding line as instantaneous or as a gold standard. Section 2.1 now states: "Each DInSAR-derived grounding line is delineated manually at the most landward interferometric fringe of a double-difference interferogram formed from two 1-day repeat-pass CSK interferograms separated by a multiple of the 16-day repeat cycle (16 to 64 days for all but 13 of the 3950 lines; Milillo and Ross, 2026), that is, from four acquisitions at different tidal states (Ross et al., 2025a). It therefore approximates the landward limit of detectable flexure (Point F) integrated over the acquisition interval, not the position of Point G at a single time." We no longer describe the DInSAR-derived grounding line as Point G or as a reference for validation, and the Introduction now describes the study as an intercomparison. We have kept the name "DInSAR-derived grounding line" because it is the name used for this product in the literature (Rignot et al., 2011; Ross et al., 2025a), and Section 2.1 defines it as the landward limit of detectable tidal flexure.

2. Temporal mismatch between datasets

The comparison uses GLs derived from non-contemporaneous datasets: March 2019 to September 2020 for ICESat-2, and 2020-2021 for CSK (exact dates not specified). The authors justify this on the basis that GL positions are expected to have migrated relatively slowly over this period. However, this assumption may not hold for some rapidly changing. Because ICESat-2 observations overlap with the CSK acquisition period, the authors could reduce this limitation by reproducing the approach of Li et al. (2022) using the overlapping ICESat-2 ATL06 data.

More importantly, the analysis does not account for tidal sampling. The inland flexure limit (Point F) has been shown in both DInSAR and ICESat-2 studies to migrate over tidal timescales, in some locations by up to 15 km (Freer et al., 2023; Milillo et al., 2017, 2019, 2022; Rignot et al., 2024; Chen et al., 2023...). An ICESat-2 observation acquired at one combination of tidal states could therefore differ substantially from a DInSAR-derived position sampled a different combination of tidal states, even if both methods are accurate.

This is a critical limitation because the reported offsets may reflect real tidally-driven migration rather than a discrepancy between measurement techniques. The authors should engage more fully with literature on this process and quantify differences in acquisition timing, absolute tidal height, and differential tidal forcing of each GL measurement being compared. They should then test whether their observed offsets vary systematically with these differences.

I note that the authors acknowledge this issue in the conclusions, but do not address it in the analysis. In my view, such a limitation that is likely to have a non-trivial influence on the main result cannot be treated only as a caveat.

We agree that differences in acquisition timing and tidal state can influence the observed position of grounding-zone features and therefore may contribute to the spatial separation between the ICESat-2 and DInSAR-derived observations. We have mentioned this in the manuscript as well.

However, a proxy-wise temporal and tidal-state comparison is not possible using the ICESat-2 grounding zone and the corresponding DInSAR-derived grounding line. The distributed grounding zone dataset from Li et al. (2022) provides the F, I_b , and H data proxies together with beam, beam pair, repeat-cycle number, tidal range, and track, but does not explicitly report the acquisition date and time alongside each grounding-zone proxy. Rather than assigning temporal or tidal differences based on assumptions, we therefore use the tidal-range information provided with each ICESat-2 point and, for the CSK DInSAR-derived grounding line associated with each point, retrieve the corresponding interferometric acquisition dates and modeled tidal conditions. This allows us to directly evaluate whether differences in tidal sampling between the ICESat-2 and CSK observations are associated with the observed F-GL offsets. For the CSK interferograms, we additionally account for the inverse-barometer contribution from atmospheric pressure when evaluating the environmental signal affecting the interferometric observations.

Furthermore, the objective of this study is to characterize the spatial relationship between two independently derived grounding zone/ grounding line datasets, rather than to generate a new contemporaneous ICESat-2 grounding zone product. Reprocessing ATL06 data to reproduce the Li et al. (2022) methodology for each CSK acquisition would constitute a separate analysis beyond the scope of the present cross-dataset comparison.

Nevertheless, the temporal coverage of the datasets provides substantial overlap. Approximately 78% of the glacier investigations have CSK DInSAR-derived grounding-line observations falling within the temporal coverage of the ICESat-2 grounding zone dataset. Thus, the comparison is not based exclusively on temporally non-overlapping datasets, although the individual observations cannot be temporally matched because acquisition dates are not provided with the distributed ICESat-2 grounding zone proxies. We calculated the statistics separately for the 57 glaciers and ice streams with overlapping grounding-line observations and ICESat-2 data acquisition periods and the remaining 16 glaciers and ice streams without temporal overlap. The results are given in Tables R1 and R2.

The spatial distribution of grounding-zone proxies differed between the 57 glaciers and ice streams with overlapping ICESat-2 and DInSAR-derived grounding-line observations and the remaining 16 glaciers without temporal overlap. In the 57 overlapping glaciers (Table R1), F proxies are predominantly located downstream of the grounding line across all regions, accounting for 66-73% of observations, while I_b proxies showed a more balanced distribution, with downstream proportions ranging from 48% in East Antarctica to 68% in West Antarctica. H proxies are overwhelmingly downstream in all three regions (96- 98%). Across Antarctica, the mean signed distances are 183 ± 327 m for F, 36 ± 902 m for I_b , and 4663 ± 2744 m for H, indicating that F and I_b observations are, on average, relatively close to the grounding line, whereas H observations are located substantially farther downstream. For the remaining 16 glaciers (Table R2), F and I_b proxies are also predominantly downstream at the continental scale, representing 63% and 61% of observations, respectively. All H proxies in this group are downstream, with a mean distance of 2310 ± 1503 m. The regional differences are evident, particularly for F proxies in West Antarctica, where all 14 observations are downstream, and all I_b proxies in East Antarctica, where the downstream proportion is 56%. Overall, the two groups exhibit broadly similar downstream-

dominated distributions for F and I_b proxies and a consistently downstream distribution for H proxies. However, the smaller sample size and regional imbalance of the 16-glacier group require cautious interpretation of statistics.

Table R1. Statistics for the 57 glaciers with temporal overlap between the CSK DInSAR-derived grounding lines and ICESat-2 grounding-zone proxies

Proxy	N	Mean $\pm$ SD (m)	Min (m)	Max (m)	Median (m)	IQR (m)	Upstream (N)	Downstream (N)
East Antarctica: Total 22 glaciers and ice streams								
F	587	182 $\pm$ 330	-926	995	114	388	171 (29 %)	416 (71 %)
I _b	1574	-156 $\pm$ 1005	-4856	3809	-4	558	815 (52 %)	759 (48 %)
H	599	4629 $\pm$ 2539	-4970	9974	4877	3356	24 (4%)	575 (96 %)
West Antarctica: Total 14 glaciers and ice streams								
F	366	224 $\pm$ 333	-800	970	151	472	98 (27 %)	268 (73 %)
I _b	1322	277 $\pm$ 783	-3362	4983	105	518	420 (32 %)	902 (68 %)
H	303	5661 $\pm$ 3107	-5363	9991	6383	5034	11 (4 %)	292 (96 %)
Antarctica Peninsula: Total 21 glaciers and ice streams								
F	235	120 $\pm$ 296	-851	971	60	270	80 (34 %)	155 (66 %)
I _b	670	-21 $\pm$ 757	-4774	4026	14	219	308 (46 %)	362 (54 %)
H	198	3190 $\pm$ 1947	-9495	8233	3110	2226	4 (2 %)	194 (98 %)
Antarctica: Total 57 glaciers and ice streams								
F	1188	183 $\pm$ 327	-926	995	112	405	349 (29 %)	839 (71 %)
I _b	3566	36 $\pm$ 902	-4856	4983	25	401	1543 (43 %)	2023 (57 %)
H	1100	4663 $\pm$ 2744	-9495	9991	4682	3896	39 (4 %)	1061 (96 %)

Table R2. Statistics for the 16 glaciers without temporal overlap between the CSK DInSAR-derived grounding lines and ICESat-2 grounding-zone proxies

Proxy	N	Mean $\pm$ SD (m)	Min (m)	Max (m)	Median (m)	IQR (m)	Upstream (N)	Downstream (N)
East Antarctica: Total 3 glaciers and ice streams								
F	12	-17 $\pm$ 365	-574	620	-16	284	7 (58 %)	5 (42 %)
I _b	126	107 $\pm$ 935	-2340	2932	86	719	56 (44 %)	70 (56 %)
H	5	1720 $\pm$ 683	606	2576	2030	720	0 (0%)	5 (100 %)
West Antarctica: Total 5 glaciers and ice streams								
F	14	411 $\pm$ 243	11	828	513	399	0 (0 %)	14 (100 %)
I _b	247	68 $\pm$ 697	-2016	4108	64	428	94 (38 %)	153 (62 %)
H	10	2819 $\pm$ 1780	175	5627	2445	2658	0 (0 %)	10 (100 %)
Antarctica Peninsula: Total 8 glaciers and ice streams								
F	39	-11 $\pm$ 287	-706	533	32	459	17 (44 %)	22 (56 %)
I _b	165	80 $\pm$ 1155	-4849	3984	102	491	62 (38 %)	103 (62 %)
H	32	2248 $\pm$ 1457	153	7577	2109	1531	0 (0 %)	32 (100 %)
Antarctica: Total 16 glaciers and ice streams								
F	65	81 $\pm$ 342	-706	828	76	323	24 (37 %)	41 (63 %)
I _b	538	81 $\pm$ 916	-4849	4108	88	491	212 (39 %)	326 (61 %)
H	47	2310 $\pm$ 1503	153	7577	2053	1534	0 (0 %)	47 (100 %)

We have therefore revised the manuscript to explicitly acknowledge temporal and tidal sampling as potential contributors to the observed spatial separations and to avoid interpreting these separations solely as differences between the two measurement techniques. We have also clarified that our results represent

a cross-dataset spatial comparison rather than a contemporaneous validation of ICESat-2 grounding zone data proxies.

Section 2.3 now also cites observations of tidal migration of the landward limit of flexure with DInSAR and ICESat-2 (Milillo et al., 2017, 2019; Freer et al., 2023), which in places exceeds the F offsets reported here.

For potential influence of tidal sampling on the position of F proxy, we agree that differences in tidal state between the ICESat-2 and DInSAR observations could contribute to the observed F-GL separation. Three possible explanations for the predominantly downstream offsets of the ICESat-2 proxies relative to the CSK DInSAR-derived grounding lines are considered: (1) difference in the measurement techniques and spatial representation of the grounding-zone position in the two datasets; (2) tidal migration of the grounding zone between observations acquired under different tidal conditions; and (3) difference in the tidal conditions sampled by the CSK acquisitions used to generate the interferometric products, which may affect the detectable flexure fringes and the resulting grounding-line delineation. We conducted two complementary analyses to investigate the tidal-related explanations using the tidal metrics available in our datasets. These analyses assess whether the observed F offsets vary systematically with the examined tidal metrics; they do not directly measure grounding-zone migration or test the DInSAR detection limit.

First, to investigate the relationship between the CSK tidal forcing and the signed F offsets, we examined the absolute CSK double-difference tide, which characterizes the tidal difference between the two SAR acquisitions contributing to an interferogram. We divided this variable into three bins: 0-10 cm, 10-20 cm, and > 20 cm, and calculated the median and interquartile range (IQR) of the signed F offsets for each bin. The median signed F offsets are 190 m (IQR = 494 m, $n = 476$), 177 m (IQR = 456 m, $n = 230$), and 43 m (IQR = 318 m, $n = 547$), respectively (Table R3). Contrary to the expectation that larger differential tidal forcing would be associated with larger downstream F offsets, the median signed offset decreased with increasing absolute CSK double-difference tide. The corresponding within-bin Spearman correlation coefficients are -0.05, 0.17, and 0.05, respectively, indicating weak and inconsistent associations within the individual bins. These results do not support a systematic increase in downstream F offsets with increasing absolute CSK double-difference tide. They therefore weaken the hypothesis that the magnitude of the tide difference between the CSK acquisitions systematically explains the downstream offsets, although they do not exclude tidal effects on individual observations.

Second, we compared the CSK tidal range with the ICESat-2 tidal range to examine whether the relative tidal ranges sampled by the two datasets are associated with differences in the signed F offsets. Of the 1253 F proxies, 961 are included in this comparison because tidal-range values are unavailable for the remaining 292 proxies. The 961 observations are divided into two groups: (1) CSK tidal range less than or equal to the ICESat-2 tidal range and (2) CSK tidal range greater than the ICESat-2 tidal range. The second group represents cases in which the CSK tidal range is larger than the corresponding ICESat-2 tidal range.

For observations where the CSK tidal range is less than or equal to the ICESat-2 tidal range ($n = 827$), the median signed F offset is 117 m (IQR = 400 m, $Q1 = -9$ m, $Q3 = 391$ m) (Table R4). In contrast, where the CSK tidal range exceeded the ICESat-2 tidal range ($n = 134$), the median signed F offset is 73

m (IQR = 476 m, Q1 = -79 m, Q3 = 397 m) (Table R4). This means that the group in which CSK sampled a larger tidal range had a smaller, rather than larger, median signed F offset. These results do not support the expectation that larger CSK tidal ranges relative to the ICESat-2 tidal ranges are systematically associated with larger downstream F offsets. However, this comparison examines relative tidal ranges rather than the instantaneous tidal states at the respective acquisition times and therefore cannot directly establish whether tidal migration occurred between the observations.

The two tidal-range quantities also have methodological differences that should be considered when interpreting this comparison. The ICESat-2 tidal-range estimates in the grounding-zone proxy dataset of Li et al. (2022) are derived from elevation anomalies at the H proxy and are described in relation to the CATS2008 tidal model. We have not identified documentation in Li et al. (2022) confirming that inverse-barometer effects are applied to the CATS2008 predictions used to derive these estimates. In contrast, our CSK tidal-range estimates are derived from CATS2008 predictions corrected for inverse-barometer effects. Consequently, the two quantities may not represent perfectly equivalent measures of tidal variability. We therefore interpret this comparison as an assessment of the relative tidal ranges available from the two datasets, rather than as a direct comparison of instantaneous tidal states.

Taken together, the two analyses weaken the specific hypotheses that larger absolute CSK double-difference tides or larger CSK tidal ranges relative to the ICESat-2 tidal ranges systematically produce larger downstream F offsets. Nevertheless, these findings do not demonstrate that tidal migration is negligible or exclude a tidal contribution to individual offsets. A direct observation-specific assessment of tidal migration would require the acquisition times and corresponding tidal states of the ICESat-2 and DInSAR observations. The published ICESat-2 grounding-zone proxy dataset does not provide explicit acquisition timestamps, preventing us from reconstructing and directly comparing the instantaneous tidal states at the two observation times.

Finally, differences in the measurement techniques and spatial sampling remain plausible contributors to the observed downstream offsets of the ICESat-2 F proxies relative to the CSK DInSAR-derived grounding lines. The potential contribution of tidal migration also remains unresolved at the individual-observation level. We have revised the manuscript to clarify the definitions of the tidal variables, report the quantitative results, explain the sample size of the tidal-range comparison, and distinguish the tidal relationships weakened by our analyses from the mechanisms that cannot be ruled out with the available data.

Table R3. Statistics of signed F offsets grouped by absolute CSK double-difference tide

Absolute CSK double-difference tide (cm)	N	Median of signed F offset (m)	Q1 (m)	Q3 (m)	IQR (m)	Spearman ρ
0-10	476	190	4	498	494	-0.05
10-20	230	177	4	460	456	0.17
>20	547	43	-46	272	318	0.05

Table R4. Statistics of signed F offsets grouped by the relative CSK and ICESat-2 tidal ranges

Relative tidal-range group	N	Median of signed F offset (m)	Q1 (m)	Q3 (m)	IQR (m)
CSK range $\leq$ ICESat-2 range	827	117	-9	391	400
CSK range $>$ ICESat-2 range	134	73	-79	397	476

3. Offset distance calculation method

The methods described in Section 2.3 for filtering observations and calculating distances between GL proxies require further explanation. If I have interpreted this correctly, the authors have calculated the distance between each ICESat2 GL points and the nearest part of the DInSAR GL. Several aspects of this require clarification:

- (a) The Ross et al. (2025) DInSAR GL product contains multiple GLs derived from different combinations of CSK acquisitions. Which GL is used to calculate the offset from each ICESat-2 GL point? Is it the closest in acquisition time, the closest in distance, or some mean position? This choice should be clearly described and justified.**
- (b) Does the offset measurement account for ice-flow direction or the orientation of the ICESat-2 track from which the different GZ proxies were derived? I would think that in locations with more sinuous grounding lines or towards the edges of the main glacier trunk, simply measuring the distance between an ICESat-2 GL point and the nearest section of the DInSAR GL would be misleading.**

The authors should describe and, where possible, quantify the uncertainties associated with both the filtering procedure and distance-calculation method. Sensitivity tests are needed to establish whether the main results are affected by these methodological choices.

(a) For each ICESat-2 grounding-zone proxy, we calculated the offset to the spatially nearest DInSAR-derived grounding line from the Ross et al. (2025) dataset. The selection is therefore based on minimum spatial distance, rather than acquisition time or an averaged grounding-line position. We have clarified this procedure in the revised manuscript.

(b) In the original analysis, the offset for each ICESat-2 grounding zone proxy is calculated as the minimum spatial distance to the spatially nearest DInSAR-derived grounding line. We agree that this metric does not explicitly account for glacier-flow direction or the orientation of the ICESat-2 track and may be sensitive to grounding-line curvature, particularly in sinuous grounding zones or near the margins of glacier trunks.

To assess the sensitivity of our results to the distance metric, we additionally calculated the offset along the local glacier-flow direction. We have included Table A2 in Appendix A (Table R5 in this response letter) on page no.17 and analyzed it in section 3.2 on page no. 12-13 in the revised manuscript. For the

valid grounding zone proxy-grounding line pairs identified using the closest-distance criterion, we additionally calculated distances along the local ice-flow direction. Applying flow-aligned distances reduced the number of matched proxies by 22.6% for F (1253 to 969), 8.7% for I_b (4104 to 3743), and 61.3 % for H (1147 to 444), while the mean signed offset remained broadly consistent at 167 ± 395 m, 74 ± 1180 m, and 4657 ± 3413 m, respectively. The regional analysis shows that the flow-aligned subset includes H proxies from all three Antarctic regions. Of the 444 retained H proxies, 244 (54.9%) are from East Antarctica, 75 (16.9%) from West Antarctica, and 125 (28.2%) from the Antarctic Peninsula. The retained H proxies are predominantly downstream of the grounding lines in all three regions (90% in East Antarctica, 96% in West Antarctica, and 98% in the Antarctic Peninsula).

Table R5: Cross-comparison of F, I_b , and H ICESat-2-derived grounding zone proxy data with DInSAR-derived Grounding lines for flow direction calculation.

Proxy	Distance Type	N	Mean ± SD (m)	Min (m)	Max (m)	CV	Median (m)	IQR (m)	Upstream (N)	Down Stream (N)
East Antarctica: Total 25 glaciers and ice streams										
F	Signed	416	149 ± 405	-988	993		102	491	146 (35%)	270 (65%)
	Absolute		330±278	1	993	0.8	246	458		
I _b	Signed	1472	-136 ± 1442	-4962	4979		-2	936	749 (51%)	723 (49%)
	Absolute		929 ± 1111	0.1	4979	1.2	461	1312		
H	Signed	244	4881 ± 3807	-5712	9968		5108	5037	24 (10%)	220 (90%)
	Absolute		5539 ± 2765	29	9968	0.5	5187	4544		
West Antarctica: Total 19 glaciers and ice streams										
F	Signed	318	215 ± 389	-940	991		143	580	99 (31%)	219 (69%)
	Absolute		334 ± 293	0.5	991	0.9	240	516		
I _b	Signed	1490	278 ± 1023	-4565	4981		111	637	505 (34%)	985 (66%)
	Absolute		641 ± 845	0.2	4981	1.3	286	726		
H	Signed	75	4325 ± 3027	-2317	9807		4368	5243	3 (4%)	72 (96%)
	Absolute		4490 ± 2777	295	9807	0.6	4368	5066		
Antarctica Peninsula: Total 29 glaciers and ice streams										
F	Signed	235	130 ± 376	-930	996		65	404	86 (37%)	149 (63%)
	Absolute		288 ± 275	0.4	996	1	191	378		
I _b	Signed	781	57 ± 807	-4235	4660		33	341	337 (43%)	444 (57%)
	Absolute		433 ± 684	0.1	4660	1.6	187	426		
H	Signed	125	4424 ± 2706	-1907	9939		4547	4144	2 (2%)	123 (98%)
	Absolute		4467 ± 2635	168	9939	0.6	4547	4144		
Antarctica: Total 73 glaciers and ice streams										
F	Signed	969	167 ± 395	-988	996		96	500	331 (34%)	638 (66%)
	Absolute		321 ± 283	0.4	996	0.9	230	469		
I _b	Signed	3743	74 ± 1180	-4962	4981		43	587	1591 (43%)	2152 (57%)
	Absolute		708 ± 948	0.1	4981	1.3	307	816		
H	Signed	444	4657 ± 3413	-5712	9968		4848	5148	29 (7%)	415 (93%)
	Absolute		5059 ± 2783	29	9968	0.6	4906	4749		

We also performed sensitivity tests on the spatial filtering/ buffer criteria used to identify the relevant grounding-zone proxies. Specifically, the buffer for F proxies is increased from 1km to 2km, for I_b proxies from 5 km to 7 km and 10km, and for H proxies from 10 km to 15 km. We compared the resulting sample sizes and distance statistics with those from the original analysis. These tests quantify the sensitivity of the reported offsets to the choice of buffer distance. We have included the analysis of buffer simulation in the Results and Discussion section on page nos.10-14 of the revised manuscript.

The results show that the number of included proxies increased from 1253 to 1392 for F (11%), from 4104 to 4162 for I_b (1.4%) with a 7 km buffer, from 4104 to 4225 for I_b (2.9%) with a 10 km buffer, and from 1147 to 1221 for H (6.5%) (Table R6). Thus, the original buffers capture most of the proxies included by the wider tested buffers. Widening the buffer does not change the ranking by absolute distance, but each buffer defines the range of the distances included in its distribution, and the F statistics depend on the buffer size. Specifically, no absolute F distance exceeds 995 m with the 1 km buffer. These results demonstrate the sensitivity of the F distance statistics to buffer choice, while the ranking by absolute distance remains unchanged.

The corresponding mean distances also remained overall consistent, with F changing from 178 ± 328 m (1 km) to 266 ± 508 m (2 km), I_b from 42 ± 904 m (5 km) to 83 ± 1663 m (10 km), and H from 4566 ± 2744 m (10 km) to 4930 ± 3327 m (15 km). These results indicate that widening the buffers slightly increases the sample size but does not substantially alter the overall spatial patterns observed in the comparison.

We have also revisited the original proxies selection procedure and identified some ICESat-2 grounding-zone (GZ) proxies that had been excluded because they did not satisfy the strict angular constraint applied to the perpendicular projection between an ICESat-2 GZ proxy and the initially selected nearest DInSAR-derived grounding line. In some cases, neighboring grounding-line segments are located in the immediate vicinity, but the proxy did not meet the angular criterion when evaluated against the initially selected segment. We therefore revised the selection procedure to account for such nearby grounding-line segments and included previously excluded ICESat-2 GZ proxies where a clear spatial correspondence with a DInSAR-derived grounding-line segment could be established. This revision provides a more complete representation of the available ICESat-2 grounding zone proxies. The revised procedure is described in Section 2.3 on page no.8 of the revised manuscript.

The positional uncertainties of the grounding-zone features, and the methodological sensitivity of the distance calculation are considered separately. Li et al. (2022) report (page no.542) positional uncertainties of approximately 80 m for F proxies, 10 m for the I_b proxies, and 560 m for H proxies. For the CSK DInSAR-derived grounding lines, Ross et al. 2025 (page no.2) report a grounding-line mapping accuracy of approximately 100-200 m. These values characterize the positional accuracy of the respective grounding-zone products and are distinct from the spatial variability of the offsets calculated between them. We have mentioned this on page no.9, line no. 158-160 as given below:

Li et al. (2022) report positional uncertainties of approximately 80 m for F proxies, 10 m for the I_b proxies, and 560 m for H proxies. For the CSK DInSAR-derived grounding lines, Ross et al. (2025a) report a grounding-line mapping accuracy of approximately 100-200 m.

Table R6. Cross-comparison of F, I_b , and H ICESat-2-derived grounding zone proxy data with DInSAR-derived Grounding lines for buffer simulation.

Proxy	Distance Type	Buffer (km)	N	Mean ± SD (m)	Min (m)	Max (m)	CV	Median (m)	IQR (m)	Upstream (N)	Down Stream (N)
East Antarctica: Total 25 glaciers and ice streams											
F	Signed	2	650	241 ± 484	-1940	1989		143	483	185 (28%)	465 (72%)
	Absolute			361 ± 403	1	1989	1.1	208	466		
I _b	Signed	7	1727	-164 ± 1238	-6667	6810		-3	604	889 (51%)	838 (49%)
	Absolute			683 ± 1045	0.1	6810	1.5	296	751		
I _b	Signed	10	1747	-164 ± 1528	-7903	9844		-3	616	901 (52%)	846 (48%)
	Absolute			775 ± 1327	0.1	9844	1.7	306	798		
H	Signed	15	636	4949 ± 2918	-4970	14910		5013	3692	24 (4%)	612 (96%)
	Absolute			5105 ± 2636	8.2	14910	0.5	5013	3641		
West Antarctica: Total 19 glaciers and ice streams											
F	Signed	2	456	362 ± 573	-1896	1981		257	653	106 (23%)	350 (77%)
	Absolute			482 ± 475	0.5	1981	1	337	650		
I _b	Signed	7	1586	272 ± 962	-6678	6682		105	501	518 (33%)	1068 (67%)
	Absolute			523 ± 852	0.1	6682	1.6	235	548		
I _b	Signed	10	1608	337 ± 1573	-9720	9731		107	534	529 (33%)	1079 (67%)
	Absolute			706 ± 1446	0.1	9731	2	243	582		
H	Signed	15	343	6079 ± 3373	-5363	13125		6598	5114	11 (3%)	332 (97%)
	Absolute			6258 ± 3028	59	13125	0.5	6598	5091		
Antarctica Peninsula: Total 29 glaciers and ice streams											
F	Signed	2	286	164 ± 409	-851	1759		66	337	97 (34%)	189 (66%)
	Absolute			282 ± 338	0.3	1759	1.2	167	346		
I _b	Signed	7	849	86 ± 1319	-6969	6855		22	268	374 (44%)	475 (56%)
	Absolute			554 ± 1200	0.1	6969	2.2	141	375		
I _b	Signed	10	870	78 ± 1973	-9921	9924		22	283	386 (44%)	484 (56%)
	Absolute			794 ± 1808	0.1	9924	2.3	148	439		
H	Signed	15	242	3346 ± 3547	-13375	14367		3059	2410	9 (4%)	233 (96%)
	Absolute			3843 ± 2890	153	14367	0.8	3123	2448		
Antarctica: Total 73 glaciers and ice streams											
F	Signed	2	1392	266 ± 508	-1940	1989		150	528	388 (28%)	1004 (72%)
	Absolute			386 ± 424	0.3	1989	1.1	223	497		
I _b	Signed	7	4162	58 ± 1172	-6969	6855		31	435	1781 (43%)	2381 (57%)
	Absolute			594 ± 1013	0.1	6969	1.7	226	583		
I _b	Signed	10	4225	83 ± 1663	-9921	9924		32	460	1816 (43%)	2409 (57%)
	Absolute			752 ± 1485	0.1	9924	2	237	624		
H	Signed	15	1221	4930 ± 3327	-13375	14910		4759	4240	44 (4%)	1177 (96%)
	Absolute			5180 ± 2922	8.2	14910	0.6	4835	4214		

4. Point H comparison

The rationale for comparing ICESat-2 Point H directly with a DInSAR Point F proxy is unclear. These features are expected to be offset from each other, as they provide the bounds of the flexure zone. Point H can also be identified from the DInSAR observations, so suggest a comparison of the ICESat-2 Point H with the DInSAR Point H would be more appropriate. Otherwise, the authors should explain the physical purpose of the H–F comparison and avoid presenting the separation simply as disagreement between measurement techniques. A comparison of flexure zone width, defined by the separation between Points F and H in the ICESat-2 and DInSAR observations, may be more physically meaningful.

We agree that H proxy represents the seaward limit of the flexure zone and therefore is not expected to coincide spatially with the DInSAR-derived F proxies or grounding-line position. Our intention in comparing the ICESat-2 H proxies with the DInSAR-derived grounding line position is not to interpret their separation as a disagreement between the two measurement techniques. Rather, the comparison is

designed to characterize the spatial extent of the flexure zone by examining the position of the seaward ICESat-2 H proxies relative to the DInSAR-derived grounding line position across the analyzed glaciers.

We have therefore revised the manuscript to clarify that the H-GL separation is interpreted as a spatial indicator of the extent of the flexure zone, rather than as a measurement discrepancy or validation error, and explained it in Results Section 3.1 on page nos.11-12.

The primary objective of our analysis is to examine the spatial distribution of the ICESat-2 F, I_b, and H features relative to the DInSAR-derived grounding line positions.

Regarding the suggested comparison with DInSAR-derived H proxies, the product of Ross et al. (2025a) delineates only the landward limit of flexure. Therefore, a DInSAR-derived H is not available, and its delineation would require additional analysis of the interferograms, which is beyond the scope of this paper. Section 3.1 in the revised manuscript now states this and describes the H-GL distance as approximately the ICESat-2-detected flexure-zone width plus the F offset between the two techniques (quoted above), not as a disagreement in the position of H.

We have done a comparison of the flexure-zone width between grounding zone proxies F and H, as this provides a more physically meaningful basis for evaluating the observed H-GL separation. Following this suggestion, we calculated the ICESat-2 F-H flexure-zone width for the H observations for which F-H pairs could be identified based on tidal range and track number. A total of 856 of 1147 H proxies (75%) have an associated F-H flexure width and are therefore included in this analysis (Table R7). For these 856 observations, the mean F-H flexure-zone width is 5873 ± 2994 m, with a median of 5582 m and an IQR of 4452 m. The corresponding absolute H-GL separation is 4701 ± 2501 m, with a median of 4538 m and an IQR of 4066 m. The H-GL separation exhibited a strong positive linear relationship with the F-H flexure-zone width, with Pearson correlation coefficients of 0.84 for East Antarctica, 0.82 for West Antarctica, 0.82 for the Antarctic Peninsula, and 0.85 for the combined dataset (Figure R1). The consistency of the relationship across all three regions indicates that larger H-GL separations tend to occur where the independently observed ICESat-2 tidal flexure zone is wider.

The regional statistics also show that H-GL separation is predominantly downstream. Of the 856 observations, 840 (98%) have positive signed H-GL distance, while only 16 (2%) are upstream. The mean signed H-GL distances are 4649 ± 2386 m in East Antarctica, 5984 ± 2880 m in West Antarctica, 2811 ± 1430 m in Antarctica Peninsula and 4647 ± 2599 m for entire Antarctica.

These results provide an independent physical consistency check on the derived H-GL separations. Rather than interpreting the H-GL offset solely as a discrepancy between ICESat-2 and DInSAR grounding-line measurements, the strong and spatially consistent relationship with the ICESat-2 F-H flexure-zone width demonstrates that the magnitude of the observed separation scales with the characteristic width of the tidal flexure zone. We have therefore added this analysis to the revised manuscript and now discuss the H-GL separation in the context of the physically meaningful F-H flexure-zone extent.

Table R7. Statistics for comparing the tidal flexure widths with H offsets from nearest Grounding line

Region	Measure	N	Mean $\pm$ Std	Min (m)	Max (m)	CV	Median (m)	IQR (m)	Upstream	Downstream
East	Signed H offset	472	4649 $\pm$ 2386	-2590	9974	0.51	4855	3547	12 (3%)	460 (97%)
	Absolute H offset		4715 $\pm$ 2254	8	9974	0.48	4855	3547		
	Tidal flexure width (F-H)		5868 $\pm$ 2634	625	15127	0.45	5721	3397		
West	Signed H offset	220	5984 $\pm$ 2880	-4279	9991	0.48	6675	5119	2 (1%)	218 (99%)
	Absolute H offset		6023 $\pm$ 2798	59	9991	0.46	6675	4897		
	Tidal flexure width (F-H)		7373 $\pm$ 3354	690	15273	0.45	8276	5061		
Peninsula	Signed H offset	164	2811 $\pm$ 1430	-2369	6210	0.51	2928	2044	2 (1%)	162 (99%)
	Absolute H offset		2848 $\pm$ 1353	153	6210	0.48	2928	2042		
	Tidal flexure width (F-H)		3833 $\pm$ 2173	684	12491	0.57	3755	2814		
Overall	Signed H offset	856	4647 $\pm$ 2599	-4279	9991	0.56	4538	4077	16 (2%)	840 (98%)
	Absolute H offset		4701 $\pm$ 2501	8	9991	0.53	4538	4066		
	Tidal flexure width (F-H)		5873 $\pm$ 2994	625	15273	0.51	5582	4452		

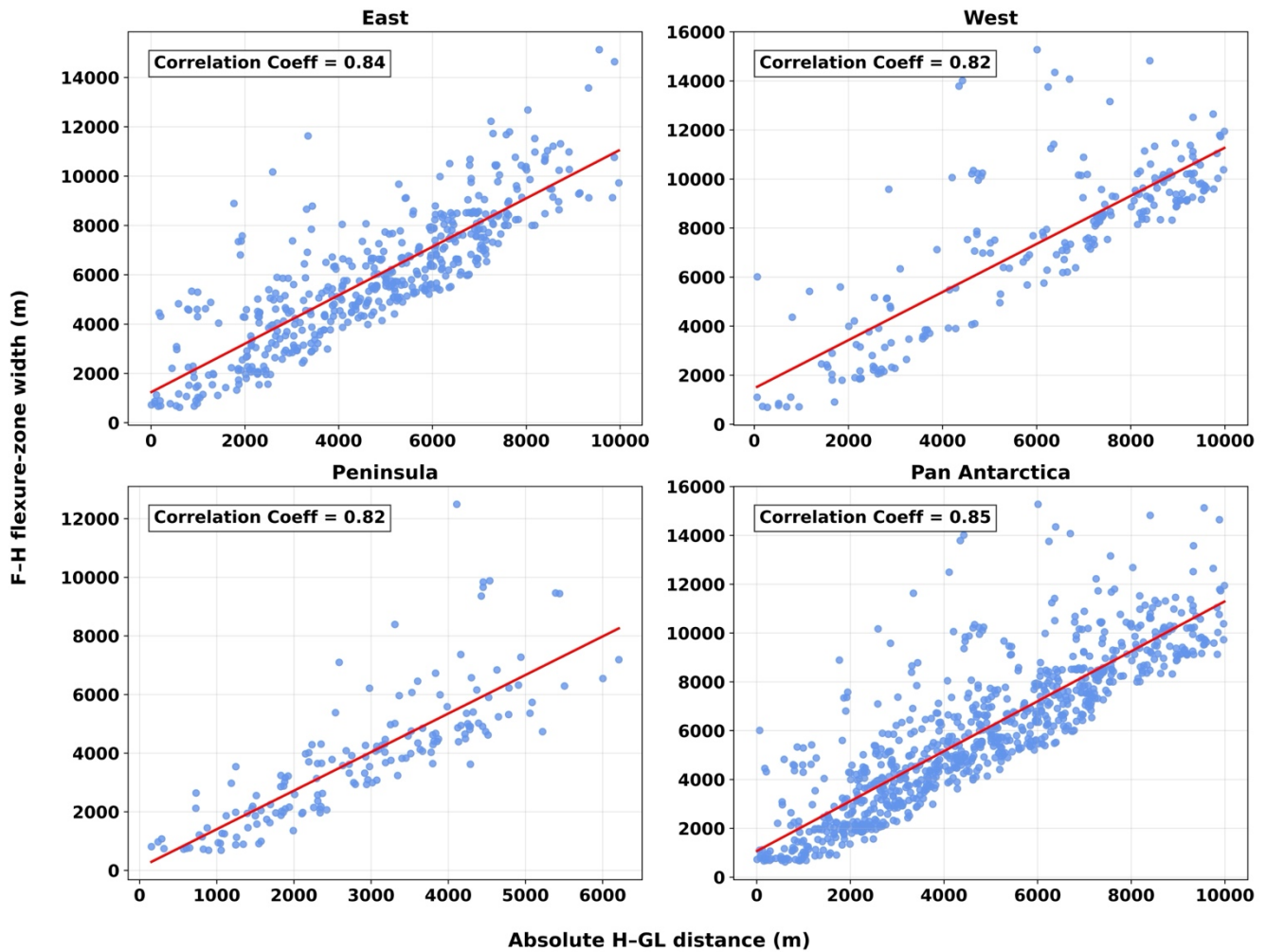


Figure R1. Comparison of Absolute H-GL distance with F-H tidal flexure-zone for East, West, Peninsula and Pan Antarctica regions.

5. Regional statistics

The comparison of offsets between methods in East Antarctica vs West Antarctica vs Antarctic Peninsula is too broad, and likely obscures the physical controls that may explain the observed differences. Each region contains glaciers with widely varying dynamic settings, ice thicknesses, bed slopes, tidal ranges, grounding zone widths, etc., all of which may influence the relationships between the mapped GZ proxies.

For example, the discrepancy between ICESat-2 Point I_b and the DInSAR GL is found to be -108 ± 972 in East Antarctica, 206 ± 674 m in West Antarctica, and 12 ± 732 m in the Antarctic Peninsula. These values are not especially informative because the standard deviations are an order of magnitude higher than the mean values, suggesting the mean is not representative of the underlying distributions.

I recommend a more detailed statistical analysis, breaking the analysis to the glacier or ice shelf level, and including additional statistics like median, IQR, and respective sample sizes. Some large

discrepancies may contain geophysical information rather than simply representing measurement error. For example, the expected ordering of GZ proxies has been found to differ at ice plains and other non-idealized GZs, where Point I_b may be located upstream of Point F. Relevant studies discussing these settings, including Corr et al. (2001), Fricker et al. (2009), Brunt et al. (2011), Ochwat et al. (2025), should be considered when interpreting these results.

We agree that regional-scale statistics may obscure the variability among individual glaciers and their different grounding-zone settings. We had already provided glacier-wise statistics in the supplementary Excel sheets; following the reviewer's suggestion, we have now additionally included the interquartile range (IQR) in these statistics. The sample size for each glacier is already included in the supplementary tables. We have also included the analysis using absolute distances, which provides a clearer measure of the physical spread of the dataset.

We have also revised the interpretation of the observed glacier-to-glacier variability and incorporated the discussions of Corr et al. (2001), Fricker et al. (2009), Brunt et al. (2011), and Ochwat et al. (2025) in Section 3.3 of the revised manuscript.

We acknowledge that large offsets between the ICESat-2 grounding-zone data proxies and the DInSAR-derived grounding line may contain geophysical information and may reflect variations in grounding-zone morphology and the spatial relationship between different grounding-zone indicators, rather than simply representing measurement error. We have therefore mentioned this in the Results and Discussion section 3.3 on page no.13-14.

Specific Comments:

- **The manuscript would benefit from a careful proofread to address typographical errors, missing spaces, and inconsistent capitalization. Some figures also appear stretched and should be reproduced with their original aspect ratios. I have not identified every instance individually here.**

We have corrected the revised manuscript for all typographical errors, missing spaces, and inconsistent capitalization. We have also corrected the figure shapes.

- **There is a notable imbalance between length of the Results and Discussion section (1 page) and Conclusions section (2 pages). I suggest moving much of the discussion material currently in the Conclusions into the Results and Discussion. This restructuring may also help the authors align the conclusions more clearly with the presented results, which in places appear to be inconsistent.**

We have restructured the Results and Discussion and Conclusions sections accordingly. Relevant discussion material has been moved from the conclusions into the Results and Discussion section, and the conclusion has been revised to focus more directly on the principal findings of the study. We have also revised the organization of these sections to improve the consistency between the presented results and the conclusions. The Results and Discussion now has four subsections (3.1 to 3.4), and the Conclusions has three paragraphs.

- **L30-33. Please provide appropriate citations for these statements and engage more fully with the relevant literature.**

We have provided citations for these sentences on page no.1-2, line no.31-36 in the revised manuscript as given below:

The grounding zone (GZ) marks the critical transition where ice, firmly anchored to bedrock, gives way to ice that floats freely as part of the ice shelves (Friedl et al., 2020). This boundary is essential for understanding ice sheet stability, as its position reflects the balance between ice-flow dynamics and ocean-driven melting (Brunt et al., 2010). Changes in the GZ location can serve as an early indicator of ice sheet retreat or advance and directly influence sea level projections. Accurate mapping of the grounding zone is fundamental for assessing ice mass loss and predicting potential contributions to global sea level rise (Fricker & Padman, 2006; Fricker et al., 2009).

- **L34. This section would benefit from a brief explanation of why the ‘true’ GL is challenging to directly observe, and why several surface proxies are therefore used to infer its location. I also suggest using the term “proxies” rather than “points”.**

We have added this explanation in the introduction on page no.2, line no.38-43 as given below:

Because the GL is a subglacial boundary between grounded and floating ice, it is difficult to identify directly from surface observations (Horgan & Anandakrishnan, 2006). Therefore, satellite-observable GZ features such as F and I_b are commonly used as proxies for GL position, while H provides an estimate of GZ width and can support ice-thickness estimation (Rignot et al., 2011; Dawson & Bamber, 2017). These proxies represent different physical or morphological characteristics and therefore do not necessarily coincide with each other or with the grounding line.

- **L37-40. Here and elsewhere, the manuscript relies heavily on the review by Friedl et al. (2020). It would strengthen the paper to cite more of the original studies that developed and applied each measurement technique.**

We have made this correction on page no.2, line no.44 in the revised manuscript. Now, in the revised manuscript, Friedl et al. 2020 is cited only 3 times.

- **L42. Please check the citations associated with this statement. Li et al. (2020/2022) use altimetry to determine the break in slope, not digital elevation models or optical imagery.**

We have clarified the wording and checked the citations. Li et al. (2020,2022) derive the ICESat-2 grounding zone features from laser-altimetry observations. However, Li et al. (2020,2022) also used the REMA DEM to independently examine the surface break in slope and compare it with

the ICESat-2-derived grounding zone features. We have revised this sentence on page no.2, line no.50-52 in the revised manuscript as given below:

In addition, ~~Click or tap here to enter text.~~the break in surface slope (I_b) has been mapped from optical imagery as a proxy for grounding-line position (Scambos et al., 2007; Bindshadler et al., 2011), and ICESat-2 altimetry identifies I_b directly from along-track elevation profiles (Li et al., 2020, 2022).

- **Figure 1 –**
 - **The labeled GL proxies in the DInSAR and the cross section do not appear to line up with either the DInSAR, BedMachine, or ICESat-2 features. Please check these and explain how you are identifying each of these points.**

We have examined the placement and labeling of the grounding-zone proxies in Figure 2 (previously Figure 1) on page no.6. We corrected the “Grounding Line” label in the figure itself and updated the caption to clarify the relationship between the illustrated features. The F, I_b , and H locations shown in panel C (previously panel D) are conceptual representations of the grounding-zone proxies, not locations extracted from the ICESat-2 track over Bailey Ice Stream shown in panel B (previously panel C). The caption now states: "The F, I_b and H positions in (C) are conceptual and are not extracted from an ICESat-2 elevation profile."

- **Adding the ICESat-2 ground tracks to panel C would provide useful spatial context.**

Our analysis uses the published grounding-zone proxies product of Li et al. (2022), rather than the underlying ICESat-2 ATL06 repeat-track data. The product provides the locations and classifications of the F, I_b , and H grounding-zone proxies. In response to the reviewer’s suggestion, we have added the ICESat-2 ground tracks obtained from NASA’s ICESat-2 Technical Specifications site to panel C to provide additional spatial context. The figure and its caption have been updated accordingly.

Link to the site:

<https://icesat-2.gsfc.nasa.gov/science/specs>

- **As discussed in major comment 1, the DInSAR inland flexure limit should not be labelled as the “Grounding Line”.**

We have made this correction in the Figure 2 (previously Figure 1) caption on page no.6 in the revised manuscript.

- **Please include citations for the Ross et al. (2025) and Li et al. (2022) datasets in the figure caption.**

We have made this correction in the Figure 2 (previously Figure 1) caption on page no.6 in the revised manuscript.

- **L69. The phrase “ideal location of GZ points” is potentially ambiguous, as it could imply that the positions were selected based on an expected configuration rather than identified from the observations. Please clarify what is meant here.**

By “ideal location,” we intended to describe the typical or conceptual spatial arrangement of the F, I_b, and H grounding-zone features, rather than imply that their locations were predetermined based on an expected configuration. To avoid ambiguity, we have replaced “ideal location” with “spatial arrangement of the grounding-zone proxies” in the caption of Figure 2 (previously Figure 1) in the revised manuscript.

- **Figure 2 –**
 - **The inset panels are currently too small to interpret easily. I would suggest presenting a smaller subset of glaciers in this main figure and, if permitted by the journal format, providing the remaining examples in the Supplementary Material.**

We have divided the inset panels in Figure 1 (previously Figure 2) and shown the remaining panels in Figure A2 in the revised manuscript.

- **L81. This section requires additional detail. Please explain which DInSAR proxy is mapped (i.e. Point F), and describe the number and temporal separation of SAR scenes used to derive each GL. The precise date range of the DInSAR dataset should also be provided; the Introduction currently states that the observations were collected during 2020-2021.**

We have added the description of the DInSAR methodology and dataset in the revised manuscript. As mentioned by Ross et al. (2025), the DInSAR-derived grounding line is manually delineated at the most inland interferometric fringe where vertical tidal displacement is detected. This location represents the landward limit of the detectable tidal flexure zone and therefore corresponds approximately to the F limit of the grounding zone. We have clarified this relationship in the revised manuscript while noting that the DInSAR-derived grounding line and the ICESat-2 F proxy are independently derived grounding-zone indicators. We have corrected Section 2.1 on page no.6 in the revised manuscript and added the timeline of grounding lines dates in this section.

We have added the details of grounding line dates in Table A3 on page no.19-21 in the revised manuscript.

- **L94. Please revise this section to make clear that the analysis uses the existing published dataset of Li et al., (2022) and that this text is describing the method used in that study to produce the dataset. As currently written, it could be misinterpreted that the authors have generated these ICESat-2 GLs from the ATL06 product themselves.**

We have corrected Section 2.2 on page no.7-8 in the revised manuscript and briefly explained the methodology used by Li et al. (2022) to generate the ICESat-2 grounding zone proxies.

- **L107. To avoid ambiguity, I suggest specifying “ICESat-2-derived” or “DInSAR-derived” when referring to each GZ product, GL proxy, or point throughout the manuscript.**

We have corrected this in the revised manuscript.

- **L111. Should be “grounding zone” not “ground zone”.**

We have corrected this on page no.8, line no. 143 in the revised manuscript.

Table 1 – The table contains a large amount of information and is difficult to read in its current format. The authors could consider narrowing some columns, simplifying the content, or moving less essential information to a supplementary table so that it fits more clearly on a single page.

We agree that Table 1 contains substantial information and have revised its formatting to improve readability and clarity. Because all columns provide information directly relevant to the comparison of the ICESat-2 grounding-zone proxies and their spatial relationship with the DInSAR grounding line, we have retained the full set of variables. We have instead adjusted the column widths, abbreviated the column headings where appropriate, and optimized the table layout.

- **L122. Please clarify whether the number is ‘about’ 6305 or exactly 6305 points.**

We have corrected this on page no.10, line no.170 in the revised manuscript. The revised count is exact: 6504 proxies (Table 1 in the revised manuscript), and "about" has been removed. This count has been changed as per the revised methodology mentioned in section 2.3 on page no.8 in the revised manuscript.

- **L149. Presumably the H points are mostly downstream, not upstream?**

We have corrected this on page no. 11, line no. 216 in the revised manuscript.

- **L152. It is unclear what trend this is referring to.**

We have removed this line from page no.12 in the revised manuscript.

- **L156. This wording suggests that the authors have derived a new set of ICESat-2 observations themselves, rather than using the Li et al. (2022) dataset. This is misleading.**

We have corrected this sentence on page no.10, line no. 170 in the revised manuscript as given below:

We cross-compare a total of 6504 ICESat-2-derived grounding zone proxies of Li et al. (2022) (Table 1).

- **L157. Please explain the basis for the conclusion made that “DInSAR grounding lines serve as a primary reference for validation”? As discussed in Major Comment 1, both datasets represent observational GZ proxies with their own sampling characteristics and uncertainties, rather than one providing a direct measurement of the “true” GL.**

We have removed the statement that the DInSAR-derived grounding lines serve as a “primary reference for validation” and revised the text to describe the analysis as a comparison between two independently derived GZ indicators. In the revised manuscript, we have mentioned in Section 3.4 on page no. 14 in the revised manuscript that both the ICESat-2 GZ proxies and the DInSAR-derived grounding lines have their own sampling characteristics, physical definitions, and positional uncertainties.

The objective of this work is to assess the spatial consistency and differences between the ICESat-2 F, I_b, and H proxies and the DInSAR-derived grounding lines, rather than to validate the ICESat-2 proxies against a presumed true grounding-line position. We have revised the interpretation of the observed offsets, accordingly, emphasizing that differences between the datasets may reflect both methodological characteristics and genuine variability in GZ morphology in Section 3.3 on page no.13-14 in the revised manuscript.

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