

Mapping the Antarctic Grounding Zone from ICESat-2 Laser Altimetry
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This paper uses ICESat-2 data to identify the grounding zone of the Larsen C Ice Shelf, Antarctica. It builds off of methods developed for ICESat and automates some of these processes. The authors describe a modified repeat-track analysis (that uses 6.5 months of ICESat-2 data) and a crossover analysis (that uses 1 year of data) to determine a GZ that is in close proximity to the continuous GL assessment from the DInSAR GL of Rignot et al., 2016; this agreement is heavily based on the increased resolution of the ICESat-2 data, and not a measure of precision, as the authors contest.

The paper overall needs a fair bit of rewriting, with some text being repetitive and other sections feeling out of place. More care needs to be taken with respect to using uniform language with respect to terms that are introduced. And more care needs to be taken with respect to references ('et al.' is often, but not always, missing).

The method presented here builds off of methods developed for ICESat (please change all references of 'ICESat-1' to 'ICESat'). Some of the modifications may be relevant (such as the across-track slope correction) but are not strongly justified; other changes (or additions) do not seem to add to the results on this ice shelf (such as the crossover analysis).

My major comments include:

1) Why do the authors utilize a across-track slope correction and migrate the analysis to the 'nominal reference track'? In line 97, the authors state that the ICESat-2 "separation between same side ground tracks in a pair from different repeat cycles is less than 10 m". I do not expect substantial across-track slope, or rough terrain, at 10-m length scales. Uncorrected elevations in Figures 5a and 5b confirm this. The authors could instead produce repeat-track assessments through the GZ for all 6 ground tracks, increasing the number of point F and point H assessments substantially. If the across-track slope correction is needed for more subtle reasons, the authors need to better justify this.

2) I do not believe that the crossover analysis provides any additional merit to the existing repeat-track analysis for the Larsen C. As the authors mention, it might be more useful in more southerly ice shelves. I suggest removing that element from the paper and using it at a later date.

3) The authors state that the agreement between this GZ and the GL of DInSAR is an indicator of increased precision, relative to ICESat; 'precision' is not a great term for this. The close agreement is undoubtedly due to the increased across-track and along-track data density associated with ICESat-2; this is a spatial resolution improvement, not a 'precision' improvement.

Specific comments:

Throughout: 'ICESat', not 'ICESat-1'

Throughout: Clean up the references (missing 'et al.' often)

Title: this is a bit misleading, suggesting that this is a result for the entire Antarctic. The definite article is not appropriate here. I suggest somehow adding 'Larsen C' to the title.

Line 10: the results *should* show a three-fold increase; why only 2?

Line 30: Point I is poorly characterized in Fig 1 and not mentioned in this paragraph. Suggest removing it from figure.

Lines 49 – 51: "The launch of ICESat-2 on 15 September 2018, as a successor to the ICESat-1 satellite mission, can achieve higher along track spatial resolution as well as nine times better coverage compared with its predecessor, providing the potential to map the GZ with greater accuracy and spatio-temporal coverage."

This needs to be better described. There are both along-track and across-track data density issues here. And there are more repeats within a calendar year. But that's not captured explicitly in this text.

Lines 64 – 68: The time span is unnecessarily complicated in this section. A couple options: 1) remove the crossover analysis. 2) reduce the time span of the crossover analysis to match the repeat-track analysis.

Lines 67 – 68: Note that ICESat-2 was not operational for much of July. And the analysis stops halfway through November. Thus, there are really only 6.5 months of repeat track analysis, and cycle 4 (?) is not a complete cycle.

Line 69: "... ICESat-2 did not point at the Reference Pair Track (RPT)" Careful here; ICESat-2 points at the RGT; the RPTs are specific to the ATL06 data product.

Line 73: The start of this paragraph could be smoother; something like, ICESat data were corrected for ocean tides and had to be retided; ICESat-2 ATL06 data are not...

Lines 81 – 82: "In addition, the surface elevation was also compared with the reference DEM Reference Elevation Model of Antarctica (REMA) (Howat et al. 2019) provided in the ATL06 product..." This is extremely challenging in the region of the GZ. REMA elevations are not tide corrected; thus, their elevations in the GZ are time/scene dependent.

Line 83: "elevation differences with REMA fell outside a ± 150 m threshold"
What? 150 m of elevation differences?

Line 108: "300 m were removed as the surface elevation of GZ"

How many points did this remove? Were many of these points picked up by the ATL06 quality summary?

Line 112: “The elevation change calculated from repeat tracks is a combination of cross-track slope induced elevation change ...”

You say above that the repeatability is 10 m; I do not think that there is appreciable slope on 10-m length scales. I think what you are trying to say is that 1) you are prescribing height changes to the Nominal Reference Track (language from figure) or the RPT (language from above); 2) slope on 90 m length scales are important. Suggest 2 things here: 1) get the language between figure 4 and the text above more common; and 2) state from the onset that your analysis is being done on the RPT. Although, as I stated above, I do not think a slope correction is needed with 10 m repeatability.

Lines 113 – 114: “As only 8 months of repeat cycles from March to November 2019 were used, ...” As stated above, it’s really only 6.5 months with the loss of July.

Line 121: Define these terms before equation 2 is introduced. Spell out h_{LI} is (I assume) height for ‘land ice’; but what is y_{ATC} ? What does ATC stand for?

Line 125: RGT? Or the actual surveyed ground track?

Line 126: Nominal? Or calculated mid-point for the actual surveyed ground tracks?

Line 126: “The average of all cross-track slope corrected elevations...” I’d be clearer and uniform with language. For clarity, start with ‘elevations’ (that’s what they are) and then use a single term throughout (e.g., the start of the next paragraph); I’d call these ‘elevations corrected for cross-track slope’.

Line 129: “After the cross-track slope correction for each ground track in a pair, ...” This is not clear.

Line 130: ‘reference elevation profile ...’ Use uniform language when defining terms; make this match the language from the last paragraph.

Lines 131 – 132: Watch the order of how you introduce Figures.

Line 141: “consistent with the local tidal amplitude...” Cite the source of that amplitude.

Line 152: This paragraph needs a rewrite; it’s overall confusing

Line 158: “predictions at 10 km offshore...” 10 km may be too large to extend the methods to complex GZs; suggest 1 km.

Line 163: The sentence starting on this line is confusing. I think the authors are using the KDTree to get data in proximity to crossover points, and then finding the absolute location using the quadratic functions? This needs to be cleaner/clearer.

Line 164: Wrote out and partially describe KDTrees.

Line 168: What is 'THE valid elevation measurements'?

Line 173: "where the elevation exceeded 20 m": It's totally fair to have a cutoff; but suggesting that 20 m is a temporal (accumulation?) change is not the right justification.

Line 175: cite CATS.

Line 177: The sentence starting on this line isn't clear to me; I think you used a 40 cm offset for the crossovers based on 20 cm offsets from the repeat-track analysis. But it needs to be cleaner/clearer.

Lines 184 – 191: Every reference in this section is missing an 'et al.'; this is common throughout. I'm not looking for all of them.

Line 192: "ESA CCI DInSAR GL (ESA Antarctic Ice Sheet Climate Change Initiative, 2017)" Delete the abbreviation part of this.

Line 192: How is 'separation' defined? Absolute distance? Distance along the ground tracks?

Line 199: For the sentence that starts here, this really isn't a validation; these results just suggest that the point H identified using the repeat-track method is actually on the fully hydrostatic part of the ice shelf; but it doesn't validate that it's the first point of hydrostatic equilibrium, or point H.

Lines 206 – 209: I am not sure what this is saying.

Lines 206 – 216: I do not follow the line of thought here and therefore am not convinced that this rationale and Figure 7 suggest an ice plain.

Line 215: 'Coupling Line' is not fully defined; the authors should also cite Hugh Corr's work on Pine Island Glacier.

Line 219: "... crossover analysis can provide additional information on the GL location." I don't think that this is true for Larsen C; there isn't the spatial resolution for this to add (or validate) the locations of points F and H. I suggest saving this method (crossover analysis) for a later paper, where the method is more appropriate.

Lines 225 – 226: I do not think that this method provides a validation. What about the pink point above the black F in 8c?

Line 231: “By assuming that the reference GL used in section 3.1 ...” Cite Depoorter again to remind people what you are referring to.

Line 234: ‘9.73 km’: Why such a large outlier?

Lines 238 – 240: “The aim of this study is to assess the capability and the accuracy of ICESat-2 laser altimetry data for estimating the GZ features of the Antarctic Ice Sheet including flexural point F and hydrostatic point H.” I'd remove this; it doesn't offer anything new. But the next sentence does.

Lines 244 – 245: “... the new method takes two ground tracks of one beam pair from one repeat cycle as two repeat tracks.” I do not understand this sentence.

Lines 253 – 254: “...ICESat-1 repeat track analysis which required multiple repeat tracks (normally from at least five repeat cycles) with large temporal differences (Brunt et al. 2010; Brunt et al. 2011).” This statement is not accurate and was not a result in the references provided. There are figures in those papers that use fewer repeats.

Line 258: (and throughout) As noted in my initial comments, ‘precision’ is not a great term for this. The close agreement is undoubtedly due to the increased across-track and along-track data density associated with ICESat-2; this is a spatial resolution improvement, not a precision improvement.

Line 267: ‘and’; the 2 clauses on either side of this have nothing to do with one another.

Line 272: The results in this paragraph are a direct repeat of the results from Fricker & Padman 2006, and Brunt et al., 2010, 2011. The authors need to present how they have added to these results.

Lines 279 – 280: “provide valuable information about the position of GL in the Antarctic Ice Sheet.” I don't think this is accurate. I don't see what these assessments add, with respect to location of the GZ.

Line 281: “it still can show the general location of the GL” I just don't see this.

Figure 1: Consider removing point I or including it in the text with detail. From the figure, it is hard to discern if this is capturing I_m or I_b.

Figure 4b: I would not repeat the color scheme of 4a; this suggests that different cycles are required for this method.

Figure 5: Trim the caption. For the legend next to 5b: why are they ordered like this? Why are the purple and olive lines not included? What are the purple and olive lines?? I think they are elevations. It looks like there are 4 lines there (blue and orange??). That is confusing.

Figure 7: Trim the caption. Some of the language (e.g., defining MAEA again) is repetitive and can be removed. Overall, this figure is confusing and does not convince me that this is an ice plain. Figure 7d is especially confusing.

Figure 8: 8b shows that the spatial resolution of these crossovers does not add to the results associated with the repeat-track analysis. Suggest removing this.