Review of "*Mapping the Antarctic Grounding Zone from ICESat-2 Laser Altimetry*" by Tian Li et al.

Li et al. use 12 months of observations from the newly launched ICESat-2 laser altimeter to recover two key components of Larsen C Ice Shelf's grounding zone (GZ). Building upon the repeat-track methodology first applied to ICESat GLAS data (e.g. Fricker & Padman, 2006; Fricker et al., 2009; Brunt et al., 2010; 2011), the authors use elevation departures from mean tidal state to infer the landward limit of tidal flexure and point of hydrostatic equilibrium over successive repeat passes. By exploiting the beam-pair imaging capabilities of the ATLAS instrument on-board ICESat-2, the authors also apply a cross-track slope correction to their dataset, greatly improving the signal-to-noise ratio of GZ detection over areas of rough terrain compared with single-beam ICESat methods. Elevation changes derived from ICESat-2 ascending and descending cross-over passes are also used to approximate the position of the GZ (although at much degraded resolution c/w their repeat-track observations), thereby acting as a part-validation of their repeat-track-derived GZ picks.

Given the close agreement between ICESat-2 and independent InSAR-based GZ observations (~+/- 0.5 km separation, assuming no GL migration between acquisition dates) and the fact that this technique is fully automated, I believe that Li et al's technique will be of large interest to the readership of *The Cryosphere*, and look forward to seeing this paper published. The prospect of applying this technique to the entirety of Antarctica's grounding zone is also an exciting one. Before acceptance, however, I feel that moderate revisions must be implemented to improve the clarity and flow of the manuscript, and to address several technical points pertaining to the GZ detection technique and comparison with other data sources. My suggested revisions and other comments are included below.

General / Major Comments

While it's clear that the authors have invested a large amount of time and effort in the development of their GZ detection technique, I feel that large parts of the manuscript should be thoroughly edited by all authors to increase the overall clarity, flow and standard of English presented in the text. At present, the main text is at times highly verbose and/or repetitive, which – together with the use of non-standard sentence/paragraph structure throughout the manuscript – makes it difficult for the reader to easily follow the narrative of the paper. This is especially true in the methodology and results sections, where, for example, the reader must repeatedly flick back and forth between the discussion of Points F and H - this has the potential to be extremely confusing, especially to those unfamiliar with the anatomy of the GZ. As I outline in my specific comments, these sections could easily be restructured to offer a more streamlined discussion. I would also strongly encourage the authors to correct the numerous instances of incorrect grammar contained in their manuscript (I have indicated some, but not all instances of this in my specific comments).

Lines 183-216 – To my knowledge, the 2017 ESA CCI dataset provides near-complete coverage of Larsen C's GL as constrained from Sentinel-1a/b DInSAR-based observations acquired in 2016/2017. I am therefore surprised to read that the majority of the ICESat-2-DInSAR comparisons made in this manuscript refer to the earlier (mostly 1990s ERS-1/2-based) GL products provided by Rignot et al., (2016), and not those more temporally contemporaneous with the authors' ICESat-2 observations.

Furthermore, while the authors correctly mention in lines 106/107 that recent (2010-2016) GL migration has been fairly minimal, a comparison of the Rignot and ESA CCI products reveal large retreats (up to 4 km) along parts of Larsen C's GL (including Churchill and Kenyon

Peninsulas), presumably in response to the sustained period of ice-thinning between 1979 and 2008 noted in the literature (Fricker et al., 2012, JGR: Oceans; Adusumilli et al., 2018, GRL). (NB. Since 2008, Larsen C has largely thickened, consistent with the more stable rates of GL migration reported by Konrad et al. (2018)).

As such, I believe making primary reference to the old Rignot GL dataset is inappropriate in this context, and would strongly suggest the modification of the abstract, lines 183-216, discussion/conclusion and Figures 2, 5, 6 and 7 to refer only to the newer ESA CCI GL. Also, be sure to include the appropriate citation for the ESA CCI dataset in the reference list.

Technical Comments

Line 71 and Figs 5 and 7 – The authors mention the use of data from repeat cycles 3-5 in their repeat track analyses, but Figures 5 and 7 only show the solution as derived from repeat tracks 3 and 4. Why is this? For consistency with the main text, I'd update Figures 5 and 7 to show the full complement of data acquired over the entire range of images tidal states.

Line 102 – As the authors know, the Depoorter GL is a compilation of multiple GL datasets, derived from a variety of techniques (e.g. InSAR, break-in-slope, ICESat) applied to satellite imagery acquired at different times. For absolute clarity here, I'd consider adding an overview of the imaging times and techniques used over this region of Antarctica.

Lines 120-125 – For clarity, I suggest defining each of the terms included in Eq. 1 before discussing Eq. 2. Also note the lack of any explicit definition of $Y_{ATC,G}$ in the current version of the manuscript.

Lines 136-160 – In Figure 1 the authors show the position of I_b, the ice-sheet-shelf inflexion point (otherwise known as the break-in-slope), which is obtainable from optical-, DEM- and altimetry-based methods. As the authors are aware, I_b has been used extensively in the literature (including Christie et al. (2016) as mentioned in the text, but also e.g. Bindschadler et al. (2011, *The Cryosphere*) and Scambos (2007, *Remote Sensing of Environment*)) to supplement our understanding of the GZ in areas where DInSAR coverage is poor. I was therefore a little surprised to see no discussion or method of deriving this important GZ component using ICESat-2 in the text. This is despite the break-in-slope being clearly visible in e.g. Figures 5a and 5c. Was any attempt to automate this component of the GZ made? If not, why not? I think a brief discussion of I_b, its manifestation in the ICESat-2 data and any attempts to automate it should therefore be added to the Section 3.1. If easily obtainable, then an additional figure similar to Figure 5c could also be added to show any differences in ICESat-2-derived I_b and the break-in-slope mapped by ICESat-1 (Brunt et al., 2011) and/or the ASAID team (Bindschadler et al. 2011).

On a related note, I have noticed occasional large errors in the positioning of DInSAR-derived GLs (Rignot, ESA CCI) over the Antarctic Peninsula (including Larsen C), presumably related to the geo-coding of SAR data over the Peninsula's steep terrain using old DEMs, and/or the misattribution of the Point *F* on ice landward of nunataks or other mountainous exposures at the GZ. These positional errors are not seen in e.g. the ASAID product due to the on-nadir viewing angle of Landsat and the ability to distinguish between mountains and ice more easily. Therefore, any comparison of ICESat-2- and ASAID-derived I_b picks may be more representative of the true GL (in lieu of Point *F*) in these areas. (As a relatively slow flowing

region with a well-defined break-in-slope, I_b will fall close to Point *G* (as it does in Fig. 5), making it reliable proxy for Point *G* and *F*).

In light of the above and if not already done, the authors should thoroughly QC the DInSAR product for such offsets – their omission could actually improve your mean absolute separation statistics!

Lines 150 and 156 – How sensitive is the pinpointing of Point *H* to the prescribed variance threshold used in the error function, and why was the fourth derivative of this function chosen? In other words, how would e.g. a 3rd order fit look on Figure 5d, and where would *H* be placed as a result? Some discussion of your choice is needed in the text here.

Line 190 – With the exception Churchill Peninsula (Figure 6a) where ***one*** ICESat-1 *F* point falls very close to the ICESat-2 *F*, spatially coincident ICESat-ICESat-2 observations do not exist anywhere else along the Larsen C coastline. I would therefore excise any comparison between the two datasets from the text as I don't think such statements can be made with confidence. Instead, I'd solely report on the close agreement between ICESat-2 and DInSAR observations. (the discussion of the enhanced coverage between ICESat-1 and ICESat-2 is okay, however!).

Sentence beginning line 196 – The GZ information contained in Dawson and Bamber (2017) refers to Siple Coast, not Larsen C. Are the reported separation values mentioned in the text derived from those observations over the Siple coastline, or has the methodology of Dawson and Bamber been extended to Larsen C? This is essential information to state here.

Lines 217-226 – In Figure 8 (b and c especially), I see numerous instances of dark blues over the ice shelf which, following the main text, readers might incorrectly interpret as grounded ice. The opposite is true over grounded ice, which may be interpreted to be floating. What is the explanation for these observations? Surface processes? A few sentences explaining these blips are essential here.

Lines 233-235 – Similar to my comments on the potential derivation of I_b from ICESat-2 data and its comparison with e.g. the ASAID product, I am surprised to see no comparison of the authors results with ASAID-derived *H*. At present this our best pan-ice sheet understanding of *H*, so it would be very useful to see a discussion of how your results compare here.

Line 275 – As no reference is included to support this assertion, the discussion of crevasses and their influence of GZ reads like something of an afterthought, potentially degrading the reader's confidence in this otherwise highly impressive technique. Since this is predominantly a methods paper, I'd encourage the authors to elaborate on a) why they didn't (couldn't?) clean up these data, b) exactly how they think these phenomena may influence the overall accuracy of their technique and, if needed, c) briefly mention how future work may address this issue. I imagine a lot of this could (and should) go into Section 3 so that the reader can bear these uncertainties in mind while reading Section 4. In addition, it is generally poor grammatical form to begin new sentences with 'Also', 'However', 'It' etc., so the readers should consider revising the structure of the next sentence (and several other similar instances throughout the manuscript) to address these minor niggles.

Line 277 – Good point. Does the processing chain provide a means in which the user can obtain the number of repeat-track observations your GL picks are based on? Such information could be used to calculate a 'GZ pick reliability rating', and/or inform data users about the range of tidal frequencies the GZ is mapped over.

Specific Comments

Line 6 – While it's beyond the scope of this review to provide detailed corrections to the style of English and grammar used throughout the manuscript, I've re-structured the abstract to greatly condense and more effectively convey the key selling points of paper here. The authors should feel free to amend/disregard as necessary. Authors should also note the omission of greater 'precision' relative to ICESat-1, as I strongly believe this is not convincingly addressed in the manuscript (see my comment above on line 190).

"*We present a new, fully automated method of mapping the Antarctic Ice Sheet's grounding zone using repeat-pass and cross-over analyses of newly acquired ICESat-2 laser altimeter data. Our method recovers the position of the landward limit of tidal flexure and the inshore limit of hydrostatic equilibrium, as demonstrated over the mountainous and hitherto difficult to survey grounding zone of Larsen C Ice Shelf. Since launching in 2018, our method has already doubled the number of grounding zone observations acquired from ICESat-1, which operated between 2003 and 2008. Acting as a reliable proxy for the grounding line, which cannot be directly imaged by satellites, our ICESat-2-derived limit of tidal flexure locations agree well with independently constrained measurements, with a mean absolute separation and the standard deviation of 0.29 km and 0.31 km, respectively, from interferometric synthetic aperture radar-based observations. Our results demonstrate the efficiency, high spatial precision and density in which ICESat-2 can image complex grounding zones, and its clear potential for future pan-ice sheet grounding-zone mapping efforts."*

Lines 18-21 – I think these opening sentences could be worded more eloquently to say something like: "*Long-term satellite observations have linked the on-going thinning of Antarctica's ice shelves (Paolo et al., 2015) to enhanced rates of ice mass discharge beyond the grounding line (hereafter GL) – the point where the grounded ice sheet first detaches from the bedrock and begins to float (Fricker & Padman, 2006). Ice discharge calculations are sensitive …*".

Line 28 – Provide references for mass balance studies and those assessing overall ice sheet stability. The latest offering from the IMBIE crowd (Shepherd et al., *Nature*, 2018) would be good here.

Line 33 – Following my comment regarding Line 275, the authors should aim to avoid ambiguous terms like '*Its*' to begin sentences. Suggest rewording to *"The precise width of the grounding zone depends on …".*

Lines 35-36 – This is a good example of many instances of repetition in the manuscript. The true GL (*G*) and limits of tidal flexure (*F*) have already been defined on line 30/31, so don't need to be repeated here. Saying something like the following would be much more concise and easier to understand.

"… *While Point G cannot be detected directly from satellite-based observations, Point F resides within close proximity of this location, and is thus widely considered to be the most robust satellite-observable proxy for the "true" grounding line (insert references here)*."

(Note that this rewrite also gets round the incorrect notion that the limit of tidal flexure is something only present on the ice sheet surface, when reality it is the surface manifestation of a variety of mechanical processes going on at the ice-bed-ocean interface)

I also suggest you replace any further mention of "*the true grounding line*", "*the landward limit*", "*limit of hydrostatic equilibrium*" etc. in the manuscript with 'Point *G*', 'Point *F*' and 'Point *H*'.

Also, in this instance '*Point*' is a pronoun, and so should always be capitalized. (be sure to change this universally throughout the text and fig. captions).

Line 38 – Remove '*to date*' (as it probably always will be …).

Line 41 – Change to "*Points F and H (Figure 1) have previously also been derived using ICESat-1 laser altimetry …*"

Line 43 – The use of the word '*these*' is unneeded and can be removed.

Line 44 – Suggest replacing '*data*' with "*additional GZ information across regions …*". Also hyphenate '*DInSAR-derived*'. For consistency with the above paragraph, please also refer to '*DInSAR-derived GZ information*' rather than '*GL information'* (since DInSAR recovers *F*, a *proxy* for *G*).

Line 46 – Change to "… *In addition, ICESat-1-based GZ detection is heavily based on visual interpretation which requires a large amount of manual …*" for brevity.

Line 51 – Poor grammar. Suggest rewording and merging with the next sentence for clarity and conciseness. Something like: "*ICESat-2 has a repeat-pass orbit time of 91 days, and – compared to the single Geoscience Laser Altimeter System (GLAS) onboard ICESat-1 – measures the surface elevation of Earth's ice sheets using three photon-counting beam pairs emitted from the Advanced Topographic Laser Altimeter System (ATLAS)*".

Line 58 – Suggest shortening to: "… *Point H by analyzing repeat-track and ascending/descending cross-over data. We chose the …*". The following sentence is also very long and verbose, and should be condensed and/or split up for clarity.

Line 64 – Saying that you used 12 months of data (5 cycles) when in reality the bulk of your analyses only used 8 (3 cycles) is somewhat misleading, so I'd consider splitting this paragraph up into 2 parts. One part discussing the repeat track analyses (8 months of data), and a standalone, follow-up part discussing the cross-over analysis (extended dataset covering 12 months). At present there's a lot of back-and-forth discussion between techniques, which took me several readings to fully understand what you meant.

Line 69 – For absolute clarity, do these RPT's refer simply to the 'Pair Track' files included in the ATL06 products, or is this something you have calculated the position of? If the former, then I'd suggest just referring to them as 'pair tracks' (PTs) for consistency with ATL06 naming convention, and to avoid any possible confusion with the Reference Ground Track (RGT) information provided as part of the ICESat-2 orbit files (see: https://icesat-2.gsfc.nasa.gov/science/specs).

Line 83 – Should this say +/-15 m as opposed to 150 m? This value seems excessive, and I wonder how many values actually fell out with this range after your initial cleaning of the data?

Lines 87-90 – Check grammar, punctuation and sentence tense. The first sentence is also repetitive and could easily be reworded to avoid double use of '*repeat track'*. Also, how/why does your cross-track slope correction 'facilitate' the automation of GZ mapping? Do you mean that it reduced the occurrence of incorrectly identified GZ features? I think a little more elaboration is needed here to explain this point. Sentence beginning line 90 should also be reworded to avoid the use of the word '*It*'.

Line 91 – Incorrect use of semi-colon and multiple unneeded uses of the work '*the*'. Also suggest changing '*features estimation*' to '*feature identification*'.

Paragraph beginning Line 93 – This is a good example of the 'back-and-forth' organization of the paper I mentioned in my general comments. That is, whereas reader expects this paragraph to involve a discussion of steps 1 and 2 detailed in line 91, the reader now has to go back to a discussion of repeat cycles and the grounding line reference product. In accordance with processing steps shown in Figure 3, I suggest the authors separate this part of the methods section into several distinct subheadings possibly labelled "*3.1.1: Repeat-track data preprocessing*" (to include discussion of nominal ref track calculation and search window size from reference GL dataset), "*3.1.2: Cross-track slope correction*" and "*3.1.3: GZ component identification*". If the authors choose to do this, then each section should also be explicitly cross-referenced in line 91. The processing steps corresponding to each sub-section could also be indicated on Fig. 3 by enclosing each sub-section in a box.

Lines 93-96 – Be sure to emphasize here that you used all three beam pairs in your analyses, as readers may interpret from the current version of the text that only one beam was used.

Line 99 – As per my comment on line 69. Should '*RPT*' be '*PT*'? Also consider putting inverted commas around '*nominal reference track'* to emphasize that this is a newly introduced term.

Line 101 – Needed to do what? I suspect set a GZ detection search window size, but this isn't obvious from the text.

Line 103 – Why was the Mouginot dataset used over the ice rise information documented in Depoorter? Is it more accurate? More up-to-date? Explicitly state why you used this product here.

Line 104 – What is an '*initial GL product'*? I see no mention of it in the text or Figure 3, and don't know how it differs from the 'reference GL product' discussed in the same sentence.

Line 111 – In 2017 Larsen C calved massive iceberg A-68 from its ice front, exposing an ~6000 km2 area of previously ice-shelf covered ocean water. Mouginot's coastline precedes this calving (and the ICESat-2 observational period), meaning that the authors have inadvertently included this huge section of open water in their analyses. This is clearly seen in Figure 2. I suggest the authors re-clip their dataset using a more up-to-date coastline, such as the one available at: https://www.add.scar.org/. The authors may also wish to consider clipping the velocity dataset shown in Figure 5 for consistency between figures.

Line 112 – This sentence is highly repetitive and includes '*elevation change'* three times. Consider condensing.

Line 119 – Insert comma after $h_{Li,G}$. Also, I presume here that '*Li*' means linearly interpolated? Your choice of interpolation isn't explicitly stated here, so if so, include that info here.

Line 125 – "… *are the y coordinates measured perpendicular to the RGT*". Can this be reworded to say "… *are the across-track y-coordinates measured perpendicular to the RGT*"? (I guess, after all, that this is what '*ATC*' in e.g. '$y_{ATC,\,X}$' means?)

Also, following my comments on Line 69, the use of *RGT* here particularly qualifies the need to abbreviate '*Reference Pair Track (RPT)*' to '*PT*' in the text.

Line 127 – Suggest changing *"in GZ estimation"* to *"used in our identification of the grounding zone".* Remove unneeded period at the end of the last sentence.

Line 129 – Suggest changing to *"After applying the cross-slope track…".* Also consider splitting this very long sentence in two between '*track*' and '*which*', and opening the new sentence with "*These profiles are shown in Figure 5a*".

Also note here the irregular ordering of the Figures in text. Figures should generally be referenced in the text in alphabetical order, so in this instance I suggest swapping Figures 5a and b in Figure 5, and changing Line 131 to say '*5a*'. Same for line 132 ('*5b*'). Also, remove "*color-coded dot curves*" here and in line 132; this is non-essential information best left for the caption.

Line 133 – Suggest: "*To estimate Points F and H from the elevation anomalies … was calculated from the corrected* …"

Lines 136-160 – Following my general comment, these paragraphs are very difficult to follow, as a) they flick back and forth between the identification of *F* and *H*, and b) it is highly unclear what 'new' identification procedures the authors have used versus that discussed in Fricker & Padman (2006). There is also a lot of repetition of content already mentioned in the introduction. I strongly suggest re-structuring these paragraphs to closely follow the structure outlined below:

First paragraph: Very brief overview of the anatomy of the GZ with respect to Points *F* and *H* and the work of Fricker & Padman (1-2 sentences). Then, a few sentences on how **they** identified the grounding zone.

Second paragraph: A discussion of how the authors expanded upon this earlier work and identified Point *F* using new slope-corrected techniques, MAEA and its second derivative. No mention of *H* here.

Third Paragraph: Discussion of how using MAEA alone is likely more difficult to identify Point *H*, and subsequently: how the authors used MAEA together with their error function to locate *H*. When discussing the error function, elaborate more on what "*as a guide*" means (readers should be able to replicate this method, so as written this seems vague/ambiguous).

Line 163 – unneeded '*the*' before elevation change. Also, this and next sentence are almost complete repetition, and should be condensed (and possibly merged with the following sentence). Also define '*KDTree*' (and any other abbreviation) in full when using for the first time.

Sentence beginning line 168 – Poor grammatical structure.

Line 170 – Should this say '*from*' instead of '*for*'?

Line 175 – Add Padman et al. citation after reference to the CATS2008a model. '*Movement*' should be singular.

Line 178 – '*based on the results in section 4*'. What does this mean? State the explicit steps you took to derive this number here, and then refer to the results section, if still necessary.

Sentence beginning line 180 – It is implicit in the above sentence that you did this, so suggest the removal of the sentence from the text.

Line 183 – suggest rewording to better match the structure of my suggested abstract changes. Suggest something like:

"*Using our newly developed ICESat-2-based GZ detection algorithm, we recover a two-fold increase in the number of GZ features identified over Larsen C Ice Shelf by ICESat-1 (69 and 71 picks of Points F and H, respectively, versus 30 of each by ICESat-1). The spatial distribution of each platform's GZ picks is shown in Figure 6, together with a comparison of Point F as determined from independent DInSAR observations. The improvement in our ability to image the GZ using ICESat-2 data is especially notable in heavily crevassed regions like*

Jason Peninsula and Churchill Peninsula (Jansen et al. 2010), which were previously difficult to image using single-beam ICESat-1 observations alone".

Lines 189-195 – As per my technical comments on Lines 183-216. Suggest restructuring this paragraph and Figure 5 to only make reference the more up-to-date ESA CCI product.

Lines 189-201 – This paragraph is another example of the somewhat unorganized writing style discussed above, this time pertaining to the back-and-forth comparison of different sensor observations. Mirroring my suggested edits to the methods section regarding the derivation of *F* and *H*, I suggest re-structuring this and the following paragraph in the following order to greatly improve clarity.

First para: Discussion of how the author's results compare with DInSAR observations (ESA CCI only). (Any comparison of ICESat-1 and -2 GZ points are largely unconvincing and should be excised from the text here).

Second para: Discussion of where your DInSAR and ICESat-2 *F* points don't agree (i.e. the para beginning line 202. Nice findings, by the way!).

Third para: Discussion of how your *F* points compare with those imaged by other sensors, including CryoSat-2 (nb. A discussion of CryoSat-2 vs. ICESat-1/DinSAR observations is outwith the confines of this study, and as a predominantly ICESat-2 methods study, should be removed. Also note the incorrect spelling of *CryoSat-2*). In accordance with my earlier comments, I think this paragraph would also be the place to add in comparison of your I_b picks vs. those of the ASAID product).

Fourth Para: Discussion of Point *H*, encompassing my comments on lines 233-235 above.

Lines 206-210 – *"(vertical red dash line)*", *"(blue dash curve)*" etc. is non-essential information best placed in the caption instead.

Lines 209-210 – Highly verbose sentence, and repetitive use of 'left' and 'right'. This sentence should be condensed.

Line 220 – Insert comma before and after |*dh*|.

Line 221 – Change "*the repeat track analysis*" to "*our repeat track analysis*"

Line 223 – What does "*same time difference*" mean? Suggest rewording for clarity.

Line 224 – Suggest changing to "*The locations of Point F identified using our repeat-pass technique (black dots in Figure 8c) are located in the middle of high and low |dh| observations, indicating the presence of floating and grounded ice either side of Point F, respectively*".

Paragraph beginning line 227 – For simplicity and clarity, I would restructure this paragraph to first mention why we're interested in knowing the width of the GZ, then discuss how it has been calculated in the past and then how the authors have calculated it in this paper. Then finish with a discussion of your results. Similar to the discussion of Points *F* and *H* within the context of independent observations, some brief words on how measured GZ widths compare with e.g. ASAID GZ widths would also be well placed here. Also, the first sentence of this para is repeated directly from the introduction, so suggest rewording.

Line 239 – Suggest changing to: "… *for recovering several commonly imaged components of the ice-sheet-shelf grounding zone, including the inland limit of tidal flexure (Point F) and the limit of hydrostatic equilibrium (Point H). The new method presented in this study should* …"

Line 240 – *"The new automated method presented in this study should allow a more efficient and consistent mapping of the Antarctic GZ features".* I see what the authors are trying to suggest here, but don't think it's articulated quite correctly. The authors should bear in mind that due to recent advances in polar-orbiting EO capabilities (incl. the launch of Sentinel-1a/b), we can in theory now generate a precise understanding of the GZ every 6 days using DInSAR. The spatial-temporal coverage of e.g. DInSAR-derived *F* will therefore *always* be better than ICESat-2 *F*, so I think this sentence (and any similar arguments made further down in the discussion and conclusion sections) should be re-worded to reflect this. What I think the authors want to say is that ICESat-2 provides an automated, efficient means of characterizing the Antarctic Ice Sheet's GZ, to complement the high-accuracy observations afforded by other modern Earth Observation sensors.

Line 241 – This sentence should go into more detail about why we are interested in GZ position change and width (e.g. for improving numerical models aiming to constrain SLR predictions, identifying Antarctica's most vulnerable regions to climate change etc.).

Line 244 – Suggest rewording to "*To maximize repeat-track coverage over the GZ, our method considers the ground tracks of one ICESat-2 repeat cycle beam pair as two individual repeat tracks*".

Line 247 – Should say *"… which was an issue when using ICESat-1 data to identify the GZ (Brunt et al, 2010) …*". *Estimation* implies imprecision, so *identify* or similar is better".

Line 248 – "*In addition, this also allows us to calculate the GZ features from just two time stamps of tidal amplitudes*". It's obvious to me why the authors say this, but to some this might imply an element of inaccuracy in the author's results. This is because recent research has shown that the GL can undergo significant changes in its position over a range of tidal frequencies, in some cases by as much as 4 km (e.g. Milillo et al., 2017, *GRL*).

I suggest the authors acknowledge this important point, and mention that while their technique does indeed work using only 2 repeat cycle's worth of data, the identification of longer-term GZ change completely distinct from tidal variability (e.g. Friedl et al. 2019) may only be possible as/when more ICESat-2 observations become available.

Line 240 – see my comments re: Line 240. While this was perhaps once true, with the launch of Sentinel-1a/b (and soon -1c) I think the authors should reword this to state how the two datasets will *complement* each other.

Paragraph beginning Line 257 – This paragraph is a bit 'matter-of-fact' or bullet-point-like, and at times not merited within the context of this paper (e.g. the review-like discussion of CS2 vs. ICESat-1 observations, which are independent of the method presented here). In any case, for simplicity I would reword the paragraph to echo the structure the results section (see my comments on Lines 189-201), and again excise any discussion of ICESat-2 vs. ICESat-1 precision from the text. As this is the discussion section, a regurgitation of the exact separation distances is also not essential here. Also, to avoid any possible confusion, I would refrain from referring to '*GL detection*' when referring to non-Point *G* components of the GZ.

Line 264 – *" ice plains that are difficult to capture from DInSAR* …". Careful! Sentinel-1 DInSAR can capture it just fine (see below), so I'd reword this.

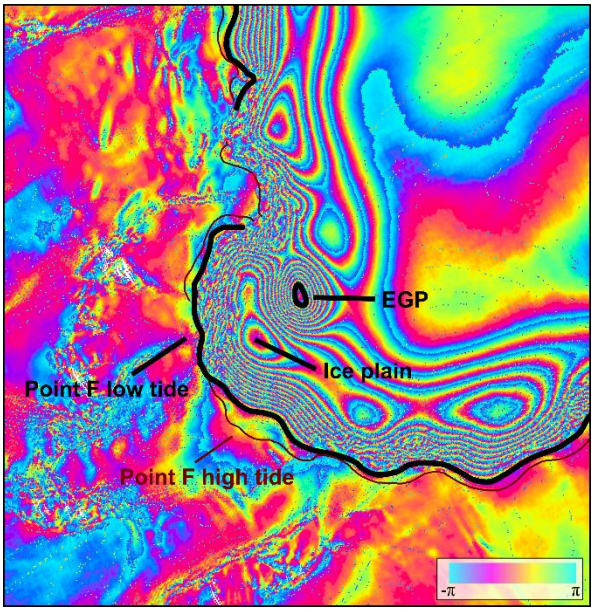

Figure 1 – Churchill Peninsula ice plain detected from double-difference InSAR applied to 2019 Sentinel-1a/b data.

Line 268 – "*…, it demonstrates*". What demonstrates?

Lines 270/271 – Where are these tidal estimates derived from? CATS2008a? Cite the appropriate reference here. Also, remove the space separating this and the next paragraph.

Lines 279 – Suggest rewording to something more concise like "*Surface elevation changes derived from ICESat-2 cross-over data also provide valuable information about the approximate location of Antarctic grounding zones*".

Line 281 – should say "… *separation afforded by repeat track observations*, *it can still reveal the approximate location of the GZ*". I also suggest the next sentence reads: "*In doing so, this method has the potential to provide important validation of repeat-track-derived GZ features, including along fast-flowing ice streams where the GZ often undergoes rapid changes …*" or similar.

Line 283 – Restructure sentence to condense and avoid the use of '*Also*…'. This and the next sentence could also be easily merged.

Line 288 – This sentence is rather verbose, and I think it could easily be shortened and/or restructured to convey the key selling point of paper more effectively (see my wording of the abstract above).

Sentence beginning Line 288 – '*the* 8-month period'.

Sentence beginning Line 293 – Larsen C Ice Shelf is a pronoun and so the preceding use of the word '*the*' is incorrect and should be removed. Next sentence once again begins with '*it*'. What does '*it*' refer to? Reword for clarity.

Sentences beginning Line 294 – I would let the readers decide if the separation between your ICESat-2 and DInSAR observation are small, so remove '*small*' here. Also change all instances of '*GL'* to '*GZ*' for accuracy, and hyphenate all uses of the word "*derived*".

Line 296 – Again, I'm just not sure you can confidently talk about ICESat-2 vs. ICESat-1 precision that way. Also, as far as I can tell, in the current version of the manuscript the authors make no direct comparison between their ICESat-2- and any CryoSat-2-derived *F*

products, so don't think any robust statements can be made regarding precision in that sense either. As a result, I think this sentence should be restructured to echo my suggested restructuring of the results section.

Line 297 – Change '*this method'* to '*our method'* and remove '*the*' before Larsen C Ice Shelf.

Line 298 – Insert a comma after '*range*'.

Line 299 – rephrase to avoid "*it still shows*". Also '*GL'* should say '*GZ'*.

Line 301 – Suggest changing to *"…Antarctic Ice Sheet, similar cross-over-based analyses have the potential to provide more accurate depictions of the GZ*".

Sentence beginning line 301 – This is almost complete repetition of lines 293-295, so I suggest removing it from the text.

Line 310 – Where can the ESA CCI DInSAR data be found?

Line 333 – Incorrect dataset cited.

Figure 1 – It may just be the way the PDF has rendered the image, but as printed, the vertical lines pointing to each of the GZ components have different line thicknesses and slightly different colors. Suggest the authors standardize all thicknesses and colors if this is not a rendering issue.

Figure 1 caption – Capitalize all instances of '*Point*'.

Figure 2 – As previously discussed, suggest the authors clip their dataset to the modern-day coastline (i.e., account for A-68's calving where elevation clearly equals zero over open water in the fig) and only show the 2017 (ESA CCI) grounding line. I also wonder if the authors inadvertently clipped Bawden Ice Rise out of their analyses? Like Gipps Ice Rise, this is an important pinning point for Larsen C (c.f. Borstad et al., 2017; *GRL*), so it'd be interesting to see any available GZ picks here. I suggest also standardizing the font size of all labels on the main map, and instead assigning track labels a different font color to better contrast against place-names. I also suggest center justifying the scale bar relative to the other items of the legend, and moving all items slightly to the left (at the moment the 1000 m label intercepts the figure border and looks untidy). Taking potentially color-blind readers into consideration, I'd also encourage the authors to choose another, non-jet/rainbow color ramp.

Figure 2 caption – Capitalize '*Ice Shelf*' and amend caption to reflect the addition of the 2017 (ESA CCI) grounding line. Remove '*in Antarctica'* as the inset clearly shows this. As the grid is shown in meters, please also state the coordinate reference system used (e.g. EPSG:3031 Antarctic Polar Stereographic) (same for Figs. 6 and 8).

Figure 3 – As per my comments on the paragraph beginning Line 93, authors might consider enclosing the various sub-sections of their methodology with boxes. '*Nominal Reference Track'* and '*Hydrostatic Point H*' should also be shifted so as to not impinge on the boxes. Capitalize '*Point F*' and '*Point H*'.

Figure 3 caption – Suggest "*The ICESat-2 repeat-track workflow used to identify the grounding zone (GZ) in this study, including the limits of inland tidal flexure (Point F) and hydrostatic equilibrium (Point H)*" (note: In general, abbreviations should be written in full in figure captions, which is why I have done so here).

Figure 4 caption – Suggest either amending the figure or stressing in the caption that this image only refers to 1 of the 3 beam pairs imaged by ICESat-2 at any one time (not all readers will be familiar with the 3-beam imaging capabilities of ICESat-2).

Figure 5 – Why is repeat cycle 5 not shown? In the main text it is stated that this dataset is used, so its omission here is rather odd. Suggest also ordering the repeat cycle legend in numerical order (*3l, 3r, 4l, 4r* and so on)

Also, I don't quite understand the inclusion of elevation by latitude (dashed profiles) here? The only reason I can think of is because track 1192 overpasses two GZs on the north and south of the unnamed ice rise seen in Fig.2 (and so should have some easily identifiable break-in-slope), but even then it's unclear where this happens. In any case, when superimposed over the anomalies and other info it makes for a rather busy diagram, so I'd suggest removing it for simplicity. If the authors feel this is essential information, then I recommend they include it either as an additional sub-panel to this figure (cf. Fricker et al., 2006) or as a supplement.

In all panels, some of the axis and other labels appear cut-off, so care should be taken to fix these minor blips.

Figure 5 caption – This is a very long and difficult to comprehend sentence (and caption overall). Can it be condensed somehow? I'm also not sure the second sentence makes grammatical sense, and could be shortened to: "*in the legend, c03_1r refers to the right ground track of ICESat-2 pair 1, repeat pass 3*".

After the Padman reference, insert "*following Fricker & Padman, 2006*". Information about the derivation of MAEA has already been discussed in the text, and so should not be included in the caption. Capitalize all instances of the word '*Point*'.

Figure 6 – Same comments as Figure 2 regarding the center justification and movement of the items in each of the legends. Authors may also wish to consider clipping the velocity map for consistency with Fig. 2. Update DInSAR coverage to only show the 2017 Point *F*. In *c* what do boxes *A* and *B* refer to? (This isn't stated in the caption). I think they refer to the spatial extent of Figs. 8a/b - if so, suggest labelling '*Fig. 8a'* and '*Fig. 8b*' here, and similarly indicating the extent of Fig. 8c. Also standardize the thickness of the DInSAR Point *F* line in all plots.

Figure 6 caption – Once again, '*estimates*' inherently suggests imprecision, so suggest rewriting caption to begin: "*ICESat-2-derived inland limits of tidal flexure (Point F; red dots). For comparison, ICESat-1-derived Point F (Brunt et al., 2010) picks are also shown (blue dots), and data are superimposed over on recent ice surface velocity magnitudes (Rignot et al., 2017). b) same as a), but showing …*". Then, at the end, "*in all plots, DInSAR derived Point F is also shown*".

Figure 7 – As per my comments on Fig 5. Also, is there any way to re-size the labels in *c* and *d* so that they don't cross over the reference lines and data? At present these look messy.

Figure 7 caption – Another long and verbose caption which, being very similar to the caption of Figure 5, can be easily shortened to "*Same as Figure 5, but showing …*".

Figure 8 – In all subplots, show only the 2017 ESA CCI Point *F* lines. In *c*, a black circle appears to be obscuring a blue circle. Suggest using unfilled black circles (i.e. outline only) in all subplots to avoid this. Suggest also scaling the black circle in the legend to match the its size as shown in the sub plots.

Figure 8 caption – Incorrect grammar. Suggest "*Spatial distribution of ICESat-2 crossovers analyzed in this study. The spatial extent of plots a-c is shown in Figure 6c. At each location, the absolute change in elevation, |dh|, is shown. Background is …".*

References cited in this review

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