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Interactive comment on "Two independent methods for mapping the grounding line of an outlet glacier – example from the Astrolabe Glacier, Terre Adélie, Antarctica" *by* E. Le Meur et al.

Anonymous Referee #1

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General comments

This manuscript of Le Meur et al. is about the mapping of the Astrolabe glacier grounding line (GL) using radar profiles and GPS data (static and dynamic methods respectively). Static groundings lines from imagery are available for this glacier but there are known issues associated with these datasets for outlet glaciers. Their study manages to better constrain the Astrolabe glacier grounding line position to 2-20 km downstream of the latest GL from Bindschadler et al. (2011) from discreet points 5-10 km apart. While the study goes in depth into both methodologies, it doesn't really produce any

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new method for detecting the grounding line except by combining the two different methods. The section on the normalized tidal displacement (d) from GPS profile is very interesting in that it shows how the hydrostatic equilibrium changes across the grounding zone and across a narrow outlet glacier section. Representing and looking at the grounding zone on a cross section is unusual and rather interesting as well.

There is however a major issue regarding the hydrostatic equilibrium assumption throughout the manuscript. Indeed this narrow outlet glacier is shown to be far from fully floating, yet their calculation assumes a fully floating criteria. This contradiction has to be resolved. While the GPS measurements give good constraints for the grounding line position, the inaccuracy of the fully floating assumption is problematic. This doesn't mean that the radar data is not usable for grounding line detection but that a correction has to be applied, maybe with the floating ratio obtained by comparing tidal and GPS amplitude. At the very least, the uncertainty regarding the hydrostatic assumption has to be discussed and taken into account.

Therefore the delineation of the grounding line should start with the GPS analysis. From the GPS transects and stationary stations, the West flank of the final grounding line should be placed inland of points 1 and 2, and of the second half of section AB (from points 3-4). GPS transect CD should be discarded, as noise seems as important as the actual signal.

Smaller scientific issues are outlined in the following section. Addressing them along with the specific comments should enhance the quality of the manuscript.

Scientific comments

-p.3972, l.1-5: It is only when radar thickness closely upstream of GL is not available that grounding line flux is computed for surface elevation at GL. For the main fraction of the Antarctic ice flow budget, radar thickness closely upstream of the grounding line is used in order to avoid important melting downstream of the GL (Depoorter et al., 2013).

- P3972, l.9: "...evaluate two methods..." Indeed you do not use the whole range of GL detection methods.

-P3972, l.14-15: I wouldn't use "high resolution" here, "medium" at most. Your GL is made of discrete points 5-10 km apart which is comparable to the best cases of ICESat points (Brunt et al., 2010). High resolution is more appropriate for the 15-250 m resolution of Scambos et al. (2007), Bindschadler et al. (2011) and Rignot et al. (2011).

-P3972, l.24-27: It is not correct to assume hydrostatic equilibrium close to the grounding line. In the grounding zone, ice is partly supported by water and partly supported by internal stresses. More over you demonstrate through your GPS profiles that the ice is not in hydrostatic equilibrium even in the middle of the ice shelf (cross section E-F).

-P3973, l.5-6: The short term tidal oscillation (and deformation) is both up and down, not just up as depicted in Fig. 3. While it is ok to simplify the oscillation movement to a "push" for the sake of section 5 experiments, it is not correct on a conceptual perspective of the grounding line. G is the point where ice leaves the bedrock for a local average sea level, not for low tide. This has to be clarified.

-P3973, l.10: Brunt at al. (2010) finds GZ width to be 3.2 km on average (2.6 km standard deviation) with some of them exceeding 10 km. This should be included here and/or in your discussion and compared to the width of the Astrolabe glacier of 20-30 km.

-P3973, l.10-12: Deviation from hydrostatic equilibrium in GZ is mainly from internal stresses to which minor tidal oscillation is superimposed.

-P3973, l.27-P3974,l.1-2: Statement "finite time required for ice to equilibrate once coming ungrounded" is not clear. Also, errors for the hydrostatic methods are mainly from the ice density assumption and the hydrostatic assumption regarding the internal forces of the ice slab (not regarding tidal oscillations).

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- P3974, l.7-13: This estimate of the distance between F and G is based solely on one Greenland outlet glacier (Rignot 1996, 1998; Rignot et al., 2011). It is unreasonable to extrapolate this to all marine terminating outlet glaciers and ice streams.

- P3979, l.9-11: If this ice is not in hydrostatic equilibrium, you will end up with a denser ice than 890 kgm-3 and a more upstream grounding line. A denser ice could be explained by the relatively reduced firn layer and/or by marine ice accretion.

- P3979, l.17-18: Why should a good match between GPR and hydrostatic thicknesses at transect TU indicate that the value of 890 kgm-3 is correct? It is at a place where ice is grounded or close to being grounded according the four 'grounding lines' depicted in Fig.18. Ice is therefore not floating for at least a part of the TU transect.

- P3979, l.20-21: What are the uncertainties for the radar method? It would help the interpretation if the uncertainty for the radar thickness was plotted as for the blue curve on Fig. 6.

- P3981, l.17-19: Give an uncertainty on the final grounding line placement.

- P3983, l.19-23: Is there another reason other than the reference to Rignot et al., 2011 for saying that X is within 0.5-1.0 km of G? Again the analysis for F-G distance was done for one glacier and is therefore not "usual" or "for instance". Your figure 16 shows that the X-G distance should be larger than 1 km for most cases in Antarctica.

- P3984, l.6-7: On the AB transect: the red inset in Fig.7 is close to point 2 in Fig.8 and not 2km away from point 3 towards point B. According to GPS signal of Fig.13, point 2 responds to a tidal signal so that area should be floating.

- P3984, l.8-9: What do you mean by "partial grounding"? Do you mean less freely floating because closer to the grounding line?

- P3984, l.14: Same comment for "local grounding".

- P3985, l.14: "slightly grounded point" should be replaced by something else. Slightly grounded means grounded but close to floatation (10-20 meters from it), as for an ice plain. This is not the case here as P2 is floating.

- P3985, l.19: Why is the final GL not placed between points 3 and 4 then?

- P3989, l.8: What is this “suspected rock apron upstream of control point E”?

- P3990, l.4: “such small glaciers” may be more appropriate as most outlet glaciers in Antarctica are larger than this one.

- P3990, l.23-P3991, l.6: This paragraph shouldn’t appear in the conclusion as it is a comparison of the new versus the old. I suggest to change point 5.4 into a new section 6. and add this paragraph to it.

Specific comments

-P3972, l.14: “method” refers here to hydrostatic and tidal. Change it to “data”.

-P3972, l.23: Change “measure” to “proxy”.

-P3973, l.4: Change “under the form of respectively” to “as the limit between”

-P3973, l.13: Not clear. There are no measurements of the grounding line (GL). It is all proxy for it. Also, change ‘GL’ into ‘G’ as you are comparing points.

-P3973, l.20-21: Rephrase the sentence “... all work by identifying characteristic GZ feature” to something like “... allow identification of GZ features. Combining these methods helps define the GL location.”

- P3974, l.5: The citation of Joughin et al., 2006 is not relevant here. You might want to drop any references here and leave them for the enumeration that follows.

- P3974, l.7: Maybe add Goldstein et al. (1993) here.

- P3978, l.23-25: It could also be marine ice accretion/intrusion.

- P3980, l.25-27: Give a value for the lateral shift.

- P3981, l.7-10: Not clear. Place arrows or points in Fig. 7.

- P3983, l.14: Replace “scaled displacement” with “observed tidal displacement normalized to tidal predictions”.

- P3983, l.19: Replace “Sect. 1” with something else.

- P3983, l.25: “G” not “GL”.

- P3984, l.3: Precise what figure and what profile.

- P3985, l.22-25: You might want to rephrase this sentence.

- P3986, l.8: Delete the unnecessary “about”, “down”, and “or so”.

- P3987, l.4: Confirm.

- P3989, l.2: The location of those A,C,D,E,F points is not clear. Are you talking about the actual points or the red crosses in Fig.8 that more or less correspond to those points? If it is the later, you should go for A’,B’, etc.

- P3989, l.17-18: Again “slightly grounded”.

- P3989, l.20-23: This is not so clear.

- P3990, l.17: Delete “basically”.

Figures

-Figure 2: The inflexion point Ib is not well depicted in the figure, see Brunt et al., 2010.

-Figure 3: See previous comment on that figure.

-Figure 5: It would read more easily if QR, RV and IJ were added (as in Fig.6), and if the left and right sides were swapped so that it corresponded to Fig. 4.

-Figure 7: Add “respectively” at the very end of the legend.

-Figure 8: The figure could do with a larger font size.

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-Figure 11: Put the last three panels to the same primary y-axes range (-0.5-1.0).

References

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- Brunt, K. M., H. A. Fricker, L. Padman, T. A. Scambos, and S. O'Neel (2010), Mapping the grounding zone of the Ross Ice Shelf, Antarctica, using ICESat laser altimetry, Annals of Glaciology, 51(55), 71-79.

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Interactive comment on The Cryosphere Discuss., 7, 3969, 2013.