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Discussions

Interactive comment on "Getz Ice Shelf melt enhanced by freshwater discharge from beneath the West Antarctic Ice Sheet" *by* Wei Wei et al.

Anonymous Referee #2

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This paper sets out to define the sub-ice-shelf bathymetry beneath the Getz Ice Shelf using a combination of Operation ICE Bridge (OIB) and new helicopter-borne gravity data. It goes on to calculate ice-shelf basal melt rates and discuss the links to subglacial bathymetry and freshwater discharge from beneath the grounded ice sheet.

The overall concept of this paper is good, and the correlation of predicted onshore-melt pathways and ice shelf channels is striking. However, recovery of sub-ice-shelf bathymetry is challenging. A number of points regarding the inversion method should therefore be addressed and clarified before publication. In addition the assertion that "the pattern of basal melt is correlated with bathymetric troughs" and that ice-shelf basal melt is concentrated in "deep troughs" is not clearly backed up by the presented figures.

Specific comments: L61-62 "The gravity anomaly follows the topography in this region quite well (Fig. S2), which suggests the effectiveness of combining OIB and helicopter data".

Fig. S2 shows the gravity data overlain by the satellite imagery. It therefore does not strictly show that the gravity anomaly follows the topography. Rather it shows that the gravity highs are clearly associated with regions of ice shelf grounding and more elevated islands within the ice shelf system.

In addition this image (Fig. S2) does not really show the effectiveness of combining OIB and helicopter data. A shaded relief map of the free air gravity data with no satellite overlay would be significantly more revealing of the quality of the join between the OIB and helicopter data. I would strongly recommend adding this at least to the supplementary material. The subsequent cross-over analysis does confirm the two data sets match well, but this cannot be seen from the presented figure.

Section 2.2 Bathymetric Inversion Approach.

Given that 2D modelling underpins the inversion approach this section should be expanded. Firstly at least some of the constructed 2D models should be shown as supplementary figures. These should include input gravity, constraining radar derived topography or swath derived bathymetry if available, and the resulting modelled gravity field. This would give significant confidence in the robustness of the recovered bathymetry. In addition it is not clear if all, or only some of the flight lines shown in Figure 1 were modelled, or if the models were constructed separately using the gridded gravity data. Locations of actual models could simply be highlighted in Figure 1.

It is not clear if/how the different bathymetric 2D profile models are tied together. Were the models forced to the same level at intersecting points, or were the different derived bathymetric profiles simply merged through a gridding process? This latter strategy could introduce gridding artefacts – see next point. Adding the offsets at profile intersections could be a good additional estimate of the robustness of the2D modelling method.

How was the bathymetric grid presented created, i.e. what interpolation method was used (e.g. spline, kriging, nearest neighbour). What was the grid mesh size of the interpolated grid? Were any steps implemented to prevent aliasing and high frequency signals on the lines generating spurious patterns in the derived bathymetric grid?

Related to the point above was onshore line radar data, or offshore swath bathymetric data included in generating the final bathymetric grid (beyond constraining the 2D gravity models)? This would be my recommendation, as it will help generate a seamless transition between the 'observed' bathymetry and the bathymetric estimates derived from gravity data.

Was any pre-processing done on the gravity data to account for long wavelength geological factors such as sedimentary basins or changes in crustal thickness? Such factors might be expected in a region like the Getz Ice Shelf which is relatively close to the continent ocean boundary.

Figure 2c. In addition to the basal melt rate and bathymetry it would be good to show the free air gravity field along this profile. This would give additional confidence in the inversion result, as individual bathymetric features could be linked to observed gravity anomalies.

L75-76 "The bathymetry model is updated iteratively until the difference between modeled gravity and observed gravity values is minimized". What is the limit on this convergence? Typically this should be (at most) the error of the observed data. Allowing the model to fit the data more precisely runs the risk of over-fitting the anomalies with more extreme topographic undulations not truly supported by the data.

L79 and Fig. S3 denotes the polygon densities applied in this region. How were these densities chosen? The densities presented are significantly higher than the standard Bouguer correction (2670 kgm-3) which is generally accepted as the typical density

of upper continental crust. Use of an unreasonably high rock density could lead to underestimation of the true amplitude of the bathymetry. The presence of apparent volcanic cones on the islands would suggest a higher than usual density (depending on lithology), however, granites seen in outcrop just the west of the survey region would indicate a density closer to the continental crustal average would be suitable. Some discussion of where these numbers come from is therefore needed.

L129 Talking about the least squares relationship between ice shelf thickness and melt rate. What is the quality of this fit (e.g. r2 value)? It would be good to show the trend line over the data point cloud to allow a more intuitive assessment of this fit.

L147-148 states "We discover that melt is concentrated along the grounding line of Getz and in deep troughs". Also L185-186. Figure 2b does show melt concentrated near the grounding line. However, it is not totally clear that melt is associated with all the deep troughs identified in the gravity data. For example in Fig. 2b along profile X-Y melt rate is relatively low, but this region is underlain by a major trough. In contrast Fig. 2c shows that the peak in melt rate around Y is associated with relatively shallow bathymetry. In addition the very deep trough identified east of Wright Island is not associated with very major basal melting, despite the ice shelf being >500m deep. It is probably fine to say deep troughs are present allowing warm water to access the grounding line region, but this is not a clear correlation between melting and deep troughs.

Technical corrections:

L31 "feasibility of gravity observations from a ship at sea" would be better as "feasibility of gravity observations from a helicopter operating from a ship at sea"

L36 "By pairing location. . .. . .." might be better as "By comparing locations. . ..."

L42-43 This sentence appears to repeat itself.

L51 "non-discharge melt rates". This is the 1st introduction of this term, which I did not find self-explanatory. I would suggest either defining it here, or simply saying: “The observed basal melt rates were computed using a mass conservation approach from Jenkins (1991) and Gourmelen et al. (2017b), and corrected for melting driven by warm ocean waters using ice bottom elevation and nearby ocean temperature profiles (Holland et al., 2008)”.

L97 “The observed basal melt rates” might be better as “the observed ice-shelf basal melt rates” to distinguish this calculation from anything onshore.

L107/108 I would define “non-discharge melt rate” up-front at this point, as it is somewhat confusing, until it is explained.

L154 Suggest subheading should be “Melt rate with no sub-glacial discharge”.

L215 “Therefore, a similar study over other massive ice shelves such as Getz should be addressed in the future” might be better as “Therefore, a similar study over other massive ice shelves similar to Getz should be addressed in the future”.

All maps – it would be useful to have the coastlines of the islands shown, not just the edge of the ice shelf.

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