We thank the editor for his assistance with this submission. Our responses to the reviews are below.

Note to Editor: Request for typsetting
We echo comments from both reviewers with respect to Fig. 6. This figure should be reproduced as full page size in the final copy.

Response to Reviewer 1
We thank the reviewer for their constructive comments which have helped to clarify the manuscript.

L 4178-02: ..and throughout the whole paper the term sub-shelf bathymetry is misleading, since both ice shelf and continental shelf are subject of the investigation. The term sub-ice shelf is more appropriate.

- This clarification has been made throughout the manuscript at the suggestion of both reviewers.

L4180-12: Shepherd et al. (2003) argue that increased basal melting and LISC thinning is rather caused by warmer shelf water on the western Weddell Sea continental shelf than a change in sub-ice shelf circulation.

- This has been amended in the text.

L4180-25: It comes as a surprise that the paper by Pozdeev and Kurinin (1987) is not listed as one of the seismic surveys which has contributed significantly to the available maps of sub-ice shelf bathymetry (in this case Filchner-Ronne Ice Shelf).

- We have chosen not to include this reference. Although Pozdeev and Kurinin (1987) is a valid example of seismic bathymetry measurements the list of previous work here was not exhaustive and only 3 example studies have been included. The paper referred to by the reviewer is not a standard English-language text and therefore not widely available.

L4192-7: It is a little bit counter intuitive to learn that basal accumulation of marine ice occurs close to the grounding line - normally the locus of strong basal melting. Though there is no doubt that it happens, the authors should state that the accumulation of marine ice might occur in crevasses, which are quite numerous close to the LISC grounding line.

- This point has been clarified in the text. The marine ice forms proximal to the grounding line at shallow-draft areas downstream of the peninsulas.

L4193-22: This paragraph is almost redundant with L4194-3 - please rephrase.

- Agreed. This duplication has been removed.

Technical corrections

L4188-17: "...visible in Fig.1?? directly east of Marmelon Point)."

- Although visible in Fig. 2 these features are more obvious in Fig. 1 and so will be referred to as such in the text as suggested.

L4192-14: "...water column thickness."

- Done

Fig. 6: Has to be reproduced as full page.

- We agree and will request this at the publication stage.

Response to Reviewer 2

We would like to thank Leo Peters for the thorough and constructive review of the manuscript. We have addressed all the comments below. We have chosen not to include all suggestions in the manuscript as we wish to maintain the emphasis of the paper on the bathymetry results acquired and their implications. Attempting to improve the gravity inversion with what is still a sparse seismic data set was beyond the original intention of the field campaign due to the time available to cover such a large area.

1. The authors do a good job of outlining how they constrain ice thickness and water column thickness at each site. They, however, make no mention of the (in)ability to identify sub-seafloor reflectors that would identify sedimentary or volcanic sequences beneath the ice shelf. The authors should consider touching on this subject, as this is a major point they bring up in their 2D gravity modeling exercise and the work of Cochran and Bell (2012).

- The acquisition geometry used (4 m shot holes; 24 channels; 10 m intervals; 20 or 30 m offset; >3 km station spacing) was optimised for rapid acquisition of ice thickness and seabed depth data. Unambiguous identification of sub-seabed reflectors is therefore difficult. Potentially, along with the bathymetry, seabed properties inferred from these data could be used in conjunction with full 3D gravity data and provincial geological parameterisation to invert for a better-constrained bathymetry map or detailed sub-surface geology. Although beyond the scope of this study, as requested we outline this possibility for future campaigns in the conclusions.

2. The authors mention the data collected were of varying quality and provide sample data in Figure 3. The authors should consider discussing the far right panel in the text some, as it would be helpful for a non-seismologist in understanding why multiples of the ice bottom could be observed in the data, while sub-seafloor reflectors aren't identifiable (i.e., multiples may be interfering, high attenuation within sub-seafloor strata, small impedance contrasts between these strata and the underlying basement).

- As the reviewer rightly points out, on top of the geometry issues outlined above, there are numerous reasons why ice base and seabed multiples dominate the record. As stated in both reviews, the significant result of this study is highlighting the problems associated with inversions of gravity data in areas of poorly constrained geology. The next step, using seismic data to better constrain gravity inversions, is regarded as beyond the scope of this article and we choose to keep the emphasis on the bathymetry measurements rather than possible improvements to the gravity inversion.

3. The authors focused their seismic data collection to the interior of the Larsen C Ice Shelf, primarily to capture ocean cavity structure near the grounding line; this is quickly summed up on P4182 L4-11. A little more detail on the choice of these locations would be helpful. Could the authors also comment on why they chose to not collect any data from the central or eastern regions of the ice shelf in an effort to better image the overall 3D geometry of the ocean cavity? I realize this could be something as simple as logistical/time constraints, surface crevassing, or prioritization of the seismic acquisition efforts; however, it would be good to let the reader know why these areas were not covered.

- Additional text in Section 2 explains that logistical and time constraints prevented the survey covering the entire ice shelf in a single season. Seismic sites were targeted at restrictions in the over-deepenings along the grounding line inferred by the CB12 cavity geometry. Narrowing of this potential whole-shelf circulation pathway would be oceanographically highly-significant, and were therefore prioritised.

4. If I am understanding this correctly, the authors perform a simple 2D gravity modelling exercise in Section 4 to demonstrate that a heterogeneous sub-seafloor geology can produce the same free-air *anomaly as observed in a subset of the IceBridge gravity data. The authors should make sure this is clear in the text here, such that a non-geophysicist can follow this better. They should more clearly state that they are purely running a forward gravity model here to show that the the same free-air gravity anomaly can be achieved by using their seismically derived water cavity geometry and a more complex deeper geology, thus demonstrating the non-uniqueness of gravity models. After their forward modeling exercise, they should also touch on the difficulties of including a complex sub-seafloor geology (density structure) for the Larsen C Ice Shelf region, particularly since no knowledge on the geology of the region exists. This would, in turn, highlight a major limitation in using gravity data alone to model the ocean cavity geometry beneath ice shelves.*

- Additional text has been included in Section 4 discussing the non-uniqueness of gravity inversion.

SPECIFIC COMMENTS:

It is not stated in the manuscript until P4187 L15-16 that there were 87 seismic sites used in this study. This should be stated much earlier within the manuscript, as this amount of seismic data collection is quite a feat over the course of one field season and deserves greater acknowledgment/recognition.

- This has been included in Data and Methods (Section 2).

Throughout the manuscript: Use sub-ice shelf instead of sub-shelf

- This clarification has been made throughout the manuscript at the suggestion of both reviewers.

P4180 L22-23: The sentence "...seismic surveys, on the other hand..." downplays the significance of seismic work on ice shelves. This geophysical method provides the only means of concisely measuring ice thickness, water column thickness, and potential sub-seafloor layer thickness in an ice shelf setting. The authors should consider rewording this to highlight the power of seismics in really capturing the full details of the ocean-ice shelf-seafloor system.

- This amendment has been made in the manuscript.

P4181 L12-13: Consider including the references for the seismic and borehole observations used in the gravity inversion, given that these observations are so sparse.

- The seismic reference used in the gravity inversion has been included here. The other in situ measurements were not available to Cochran and Bell at the time.

P4182 L5-7: Change to "Consequently, a series of point measurements were collected along lines radiating from coastal promontories, where the IceBridge bathymetry model would predict restricted water flow (Fig. 2)."

- This change has been made in the manuscript.

P4182 L10-11. Consider including the references for the seismic and borehole observations here.

- The references have been included in the text and were already listed in the caption of Fig. 1.

P4183 L24-27: When describing the density variations between the three sites across the ice shelf, it may be better to state as "Densification rates were higher down to pore close-off.." instead of "For a given depth, seismic velocities/densities were higher...".

- This change has been made in the manuscript.

P4184 L10-12: Figure 4 shows that seismic velocity-depth profiles were derived to 120m depth. How does this match with using 3825 m/sec at 100m depth, as stated here? It would be worth stating that this velocity is in agreement with the shallow refraction work, as this would lend further support to the seismic velocity structure of the ice and the low uncertainties presented. If there is a considerable discrepancy between the modeled seismic velocity at 100m depth and the shallow refraction work, it should be stated and explained here.

- Scatter in traveltime picks and insufficient offsets preclude inversion for well-constrained deep velocities with the refraction data. The velocity derived from temperature measurements is therefore used to constrain the deepest velocities in the traveltime inversion. Section 2.2 has been updated to reflect this.

P4184 L26: Change to "...normal moveout (NMO) of the ice bottom or water bottom reflection...", in case the reader does not know what NMO is and what reflection(s) are being used here.

- Done.

P4187 L15-16: Consider providing the minimum and maximum RMS errors between the gravity inversion and the seismic observations across all of the sites to quickly give the reader a feel for how uniform or variable the resultant RMS errors are.

- The range of errors in the gravity-inversion derived cavity thickness have been added here.

P4188 L15: Do the authors mean "strain cracks" instead of "strand cracks" here?

- "Strand cracks" as defined by Swithinbank, C., 1955, Geogr. J., 121, 64-76.

P4188 L17: Do the authors mean Figure 1 here?

- Although visible in Fig. 2 these features are more obvious in Fig. 1 and so will be referred to as such in the text as suggested.

P4190 L10-24: The authors discuss the non-uniqueness of gravity inversions in general here. They should consider stating that most gravity models are limited to applying only a single density for the sub-seafloor geology when there are limited to no constraints on this geology, particularly for a region as large as the Larsen C Ice Shelf. The only way to feasibly get around this is to have considerable a priori knowledge on the sub- seafloor geologic structure of the region and any larger-scale heterogeneities present. Such a short discussion would support the statement they make in the abstract (P4178 L19-21) on this assumption in the gravity inversion process.

- A sentence has been added early in Section 4 to clarify non-uniqueness in gravity inversions, both for subsurface structure and bathymetry.

P4191 L4-6: The authors should also mention the possibility of basal crevasses in damping the ice bottom reflection. Thin water-filled (or slushy-ice-filled) crevasses near the ice bottom could also produce a weakened reflection.

- This comment is referring to P4192 L4-6 and has been added as suggested.

P4192 L12-16: Is this paragraph necessary? It doesn't appear to provide any actual conclusions from this study. Maybe consider rewording the last two sentences of this paragraph and working them into the beginning of the next paragraph to drive home that seismics are the most effective means of imaging an ice shelf environment.

- This is a good point. This paragraph mirrors part of the introduction and does not present conclusions directly from this study. It has been cut and a sentence inserted at the beginning of the following paragraph.

P4193 L5-7: This sentence sounds quite harsh, given that the seismic data only cover a small portion of the entire gravity-derived model of the ocean cavity beneath the Larsen C Ice Shelf.

- This sentence has been amended to clarify the geographical limitations of the seismic survey. The errors in the gravity-derived depths are however significant and this are still emphasised.

What this study essentially does is highlight the need for solid constraints (in terms of water cavity thickness, and ideally, geologic constraints beneath the seafloor as well) across an ice shelf when performing a gravity inversion to model the subsurface. The authors should spend some time discussing this in the conclusions, as it is one of the key points/results of this study.

- Whether inverting gravity data for bathymetry (the main aim of this study) or subsurface structure (as the reviewer states), over complex regions a priori information is essential to constrain non-uniqueness. This work highlights that it is not valid to invert for bathymetry where subsurface structure is poorly constrained. The Parker-Oldenburg method is inherently unsuitable in areas of complexity where a single density contrast and a single ground truth point are insufficient constraints. A sentence has been added at the end of the conclusions to highlight these deficiencies.

P4193 L22-25: The authors should state that, while this is preferred, more knowledge on the deeper geology of the region is needed to for gravity inversions to accurately model the structure of Larsen C Ice Shelf region.

- Following comments from Reviewer 1 this paragraph has been removed due to repetition. A sentence has been added to the manuscript in the following paragraph.

Conclusion section: The authors present areas for future work on the Larsen C Ice Shelf, namely more seismic data acquisition and an improved gravity inversion of the IceBridge data in light of these new seismic results. The authors should quickly speak on what could be done on the seismic side to image sub-seafloor geology and structure, as this is a vital constraint needed for improved gravity modeling of the region.

- A sentence has been added to the conclusions to highlight this possibility in future seismic campaigns.

Make Figure 6 a full page to better view and compare the seismic and gravity results

- Agreed. This will be requested at the publication stage.