

Interactive comment on “Seabed topography beneath Larsen C Ice Shelf from seismic soundings” by A. M. Brisbourne et al.

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This paper presents a concise and rapid dissemination of seismic soundings from across the Larsen C Ice Shelf to better constrain the geometry of the water cavity beneath the ice shelf. Prior to this study, only a handful of seismic and borehole observations provided insight on the geometry of the sub-ice shelf cavity. The addition of 87 point measurements across the ice shelf, collected in linear transects, provides invaluable information on the structure of this sub-ice shelf cavity. It also highlights the limitations of gravity models in the absence of ground-truthing (in the instance of providing more constraints on water cavity thickness here). Such information will be helpful to oceanographers in better modeling ocean circulation and ocean-ice interactions beneath the Larsen Ice Shelf. It will also provide ice sheet modelers with more

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constraints on modeling the evolution of regional ice dynamics along this sector of the Antarctic Peninsula.

GENERAL COMMENTS:

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).
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).
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.
4. If I am understanding this correctly, the authors perform a simple 2D gravity-modeling 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

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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.

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.

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

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.

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.

P4182 L5-7: Change to "Consequently, a series of point measurements were collected along lines radiating from coastal promontories, where the IceBridge bathymetry model

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would predict restricted water flow (Fig. 2)."

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

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...".

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.

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.

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.

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

P4188 L17: Do the authors mean Figure 1 here?

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-

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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.

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.

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.

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. 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.

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.

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.

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

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Interactive comment on The Cryosphere Discuss., 7, 4177, 2013.

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