Review - Huw J. Horgan

How dynamic are ice-stream beds? Davies et al. November 21st 2017

Davies et al use repeat radio echo sounding profiles to investigate how the shape of the bed of Pine Island Glacier has changed (or has not changed) over an interval during which the glacier has accelerated and thinned significantly. This study is notable for several reasons. First, Pine Island and the neighboring Thwaites Glacier have experienced substantial mass loss over recent decades and will continue to form a major component of Antarctica's mass balance for the foreseeable future. Second, ground based geophysical observations from this region are rare and provide important constraints on bed structure and properties that influence ice flow. Third, repeat geophysical observation are extremely rare, and are the most practical way of assessing changes at the bed.

This study is topical, well conceived, and generally well presented. The comments I make in the following are intended to support and clarify the manuscript.

Comparing repeat geophysical surveys.
Comparing different frequencies of RES is tricky due to the dependence of resolution on frequency. Considering the commonly used resolution limits illustrates the problem. In theory, for a circular wavefront, bed features with a horizontal extent less than $\sqrt{2d\lambda + \frac{\lambda^2}{4}}$ will appear as point diffractors. At these depths (d $\sim$ 2070 m), a 1.2 MHz wavelet will image features smaller than 1025 m as point diffractors, and a 3 MHz wave will do the same for features smaller than 645 m. This is not to say that these features will not be resolved at all, but the bed will appear different at different frequencies depending on how rough it is. Vertical resolution is also frequency dependent. Vertically, layers thinner than $\lambda/30$ will not be resolved (8.3 m at 1.2 MHz, 3.3 m at 3 MHz). This is perhaps not important when considering an abrupt change in dielectric properties at the base of the ice sheet but a layered or gradual bed will resolve differently.

The main conclusion of this paper is, however, that the bed has not changed along the profiles beyond the resolution limits. With a little additional wording regarding the different resolution of the two vintages I have not issue with this conclusion and the resulting interpretation. The reader is, however, drawn to the one location where a change is shown. Resolution differences should be considered here. Also, as pointed out in the manuscript, navigation is a concern. The cross over analysis is useful, but I don't think the method used (mean of the standard deviation of for available intersecting lines) does provide 'the maximum variability in bed elevation'. To add confidence in the interpretation a simple subplot showing minimum distance between the two profiles along the profile would be helpful. This would make it clear to the reader that the region where the bed is different does not correspond to a region of large navigation mismatch.

One last note on the differences between the two data vintages. The 2013/14 data (Fig5c) show more spatial variability in the picks than the 2007/08 data. This may be due simply to signal to noise ratio being lower in the higher frequency 2013/14 data but it would be nice to see a right hand panel showing representative wiggle traces for each of the data vintages. That way the reader could be assured that similar waveforms are being compared.

Subglacial deformation. Would we expect a change in bed morphology to result from a change in ice surface elevation and ice velocity?

Estimates of subglacial sediment transport vary widely with the thickness of mobile till and the velocity profile within the till both poorly known. What is accepted is that the till velocity is a function of the overriding ice velocity. Simplistically, a uniform change in ice velocity will result in a uniform change in sediment transport, with no resulting change in bed morphology. If sediment deformation is occurring, as indicated by active source seismic constraints, the total transported through the profile must however have changed and some change in the bed morphology must be taking place upstream and downstream. To address this some discussion of sediment deformation would be useful as would some comment on how uniform the changes in surface elevation and velocity have been.

Minor Points

Pg 3 L 28. '5 m intervals' Ambiguous, change to 5 m horizontal intervals

Pg 3 L 29. Please define automation method (e.g. cross correlation).

Pg 3 L 30. 'of 0.168 m ns^{-1}' and no additional firn correction.

Pg 3 L 33-37. I can appreciate that the differences in firn composition, and triggering could result in a static shift between the two systems. To clarify this, you should state here that the difference is a constant shift as you don't expect the firn to have varied spatially.

Pg 4 L 1-2. Again, I understand what you have done, but as worded it doesn't as quantitative as it is. You have static corrected both surveys to a common bed-datum, allowing direct comparison.

Pg 4. L 21. '$\pm$3 m' Worth a note here that this is not the same as repeatability or resolution. This also depends on what part of the wavelet is being picked. When picking the peak amplitude the wavelet shape will matter. Showing typical wavelets will help with this.

Pg 6. L 22. High temporal resolution

Pg 6. L35. In the absence of a dynamic hydrological system sediment mobility is also likely to be more stable over time.

Pg 7. L 10. 'erosion/deposition' erosion and deposition.

Pg 7. L 19-21. Here's it's probably worth having caveats regarding navigation and the differing resolutions of the two vintages of RES.

Pg 8. L 1. '..'.

Pg 8. L5 ‘an’ a.
Pg 8. L 31. ’seismic survey’ seismic surveying.

Figures

Figure 1. Is there a good reason to have Antarctica oriented in this direction. We have enough issues with 180 degree flips causing confusion. Caption: ‘dashed lines’ can’t tell they are dashed at this resolution, perhaps gray contours?
Figure 2d should have the same xaxis as b,c,e, and f.
Figure 3. Caption ‘2km’ 2 km
Figure 5a. If it doesn’t clutter the figure, can you show the bed prior to smoothing? Figure 5b 5c, show characteristic traces so we can assess waveform similarity and peak amplitude picking suitability.

In closing, I thank the authors for their well considered and presented study.

Sincerely, Huw Horgan