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Interactive comment on "The sub-ice platelet layer and its influence on freeboard to thickness conversion of Antarctic sea ice" *by* D. Price et al.

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The authors would like to thank the two anonymous reviewers for their comments and suggestions.

Our responses are given below.

Response to review 1:

Abstract: What is 'close proximity to the ice shelves'? What distance away could the sub-platelet layer reasonably be expected to be a significant factor in satellite retrievals of sea ice thickness?

Thank you for this comment. This is still an unanswered research question but we need

to clarify the distances that we estimate. The sub-ice platelet layer has been recorded at a maximum distance of 80 km from the McMurdo Ice Shelf margin in the south-western Ross Sea. Its thickness was 0.2 m at this location when measured in late November 2013. This is similar to measurements carried out by Jones and Hill (2001) reported in Dempsey et al (2010) of incorporated platelet ice in the sea ice structure at a similar distance. In addition Stevens et al (2009) have estimated that supercooled water, that causes the sub-ice platelet layer, can persist for 250 km from the ice shelf edge. This information has been added to the abstract "It is concluded that within 200 km of an ice shelf this influence might need to be considered when undertaking sea ice thickness investigations using remote sensing surface elevation measurements."

We have also modified the second half of the first paragraph in the conclusion by adding "The influence of the ice shelf is expected to extend beyond 200 km from the edge of the McMurdo Ice Shelf (Stevens et al., 2009). Platelet ice observations confirm this and have been recorded in sea ice cores 80 km north of the ice shelf edge (Dempsey et al., 2010). During fieldwork in 2013 the authors also measured a sub-ice platelet layer of 0.20 m in thickness at approximately the same distance. Therefore, we conclude that its influence may need to be considered in sea ice thickness investigations using satellite altimetry in such proximities to ice shelves. It should be noted however that ice shelf thickness is likely influential on whether supercooled water and platelet crystals can reach the upper few meters of the ocean and interact with sea ice."

Figure 2: What is meant by 'snow depth measured at 0.5 m intervals', is this vertical or horizontal? Looks to be horizontal in the text, it would be good to state this in the figure.

This is snow depth as measured with a ruler at 0.5 m horizontal intervals. This has now been indicated in Figure 2.

Page 1004 5-10: How were these estimates for the uncertainties derived? It would be good to provide some justification. At this point in the manuscript I am assuming the low error estimates for SE and Ti are from the in-situ measurements, but it is not clear in the text. One additional point to note is that this excludes sampling or interpolation errors.

These uncertainties were derived from in situ measurements. The solid fraction and the propagation of its error were estimated without interpolation so no interpolation errors need be included. All thickness value uncertainties are estimates from experience. Sea ice density (i) uncertainty is provided by the spread in measured data in McMurdo Sound from 915 to 935 kgm-3. Snow density (s) uncertainty is given by the standard deviation of measurements from the 18 separate measurement sites at which s was measured. This sentence has been added to the text “i uncertainty is given by the spread of values recorded for i in McMurdo Sound between 915 and 934 kg m-3. s uncertainty is indicated by the standard deviation of measurements carried out in 2011.”

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Section 5: What is GNSS elevation data? The acronym should be spelled out.

Global Navigation Satellite System. This has been written out in the section title and abbreviated later in the text.

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Page 1008, 18-20: How many hours maximum was the transit time?

The maximum transit time was approximately two hours.

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Note also that the temporal variation is not just due to tides, but the inverse barometer as well.

The influence of the inverse barometer effect is expected to be negligible due to the relatively short distances covered in McMurdo Sound and stable weather conditions on days when fieldwork was carried out.

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How was the information from the static GNSS stations used to correct for temporal variations? Was some sort of weighting used between the three stations based on distance? Was there a noticeable gradient in the three station values?

No noticeable spatial gradients in tidal influence were recorded between the three static GNSS stations. Temporal variations in the surface elevation measurements were corrected for by using the nearest GNSS station to the rover GNSS station at the time of acquisition.

We have also renamed ‘static GNSS stations” to “tidal GNSS stations” to better reflect their role.

The sentences in this section have now been amended to “In order to compensate for the tidal influence on the GNSS height and subsequently the SEGNSS retrieval, three separate GNSS stations were deployed on the fast ice (see Figure 1 for locations). These tidal stations logged height information at 30 second intervals, which was subsequently down-sampled to 10 minute intervals. As the transit time of the mobile GNSS on the sea ice was hours, this information was used to correct the rover GNSS information for tidal height variation between drill-hole cross-over points. There was no discernible gradient in the tidal signal between the three tidal GNSS stations. Changes in elevation due to tides were taken from the closest tidal GNSS station to the mobile observation to correct SEGNSS at the time of acquisition.”

The relevant sentence in the Figure 1 caption has also been amended to “The GNSS survey lines, Northern, Central, Southern and Eastern are indicated by the orange lines and tidal GNSS stations for tide correction by the green triangles.”

Response to review number 2:

The standout issue with this paper is:

The description of the method. There are a few inconsistencies, and the methodology could be clearer and better structured. The paper would also benefit from a little more justification as to why things were done a certain way. This is mostly in relation to the authors' measurements of i and the selection of a i value for the equations used in the paper.

The authors have addressed these issues under the specific comments made below.

Specific Comments

Page 1003, line 27 – Page 1004, line 1 "Given this information, and considering the uncertainties we use a value of i = 925 kgm-3 in our calculations". This doesn't seem an adequate justification for using a i value of 925 kgm-3. It is not explicitly stated why the authors have selected this i value from the numerous values they present. It would be informative to state here the justification presented on Page 1011, line 7-8 ("We used 925 kgm-3 for i as it represents the middle range of expected i in the study area"), which confirms that the value has been selected as more of a 'common sense' value, rather than through statistical analysis of i values from this and previous work.

Thank you for this comment, we have amended this sentence to "Given this information, and considering the uncertainties we use a value of i = 925 kg m-3 in our calculations which represents the middle range of expected i in McMurdo Sound. We evaluate and discuss the density dependent sensitivity of sf in the following sections."

Page 1005, lines 13-14 It would be interesting to know which sites were used for snow

density measurements, and to have a justification as to why it was only measured at half of the sites.

We agree that more information should be included. Snow density was measured at sites when there was enough time for the fieldwork team to do so given time constraints. The snow morphology was homogeneous. The sites at which it was measured are now indicated in Figure 1 as blue circles on sites. We have also amended the text to "For s we use the values measured in the field at 18 sites in McMurdo Sound in November and December 2011 (Figure 1) ranging between 281 and 461 kg m-3. At sites where no data are available we use the mean value of all the measurements of 385 kg m-3."

Page 1006, lines 1-2 "The mean sea ice thickness as derived from all 39 drill-hole measurement sites" Previously the authors have stated that there were 40 drill hole sites (Page 1004, line 18: "Measurements were undertaken at 40 sites"), not 39. Fig. 1 and Fig. 3 only shows 39 drill hole sites (there is a site number 40, but not a site number 24). This inconsistency is confusing, and if there is a reason for it, it should be explained.

This is a typo, there were only 39 measurement sites. This has now been amended in the text. Site 24 was a repeat site and therefore not included.

Page 1011, line 23 "our estimate [of i] is an average of 35 separate drill-holes". It is not clear why only 35 drill holes were used, rather than all 39. If i was not measured at every site, this should be stated in section 3.1. As it stands, there is no mention in section 3.1 of the method or locations of i measurement. This should certainly be included.

This is referring to actual drill-holes, five of which were drilled at each of the measurement sites. To make this more clear this sentence has been amended to "We do

not expect this to have significantly influenced the mean of our freeboard values, and subsequently our i estimate as most of our drill-holes were drilled at least 15 m away from such loading, and our estimate is based on an average of 35 separate drill-hole measurements (5 measurements at each site, 7 in total)."

Further information has also been added in Section 2 (see next comment).

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Page 1003, line 25-27 "Using an amended method at seven of our drill-hole sites in 2011 where no sub-ice platelet layer was measured we obtain a mean value [of i] of 927 kgm-3." This relates to the uncertainty discussed above regarding the authors' measurement of i. It is not clear from this statement whether i was measured at all sites, but with a different method used at the seven sites when the sub-ice platelet layer was absent, or if it was only measured at the seven absent sites. From Page 10011, line 23 it becomes clear that the former is the case, but this should be clearly stated in this section.

The locations of i measurements carried out in 2011 by the authors have now been indicated on the map in Figure 1.

Measurements were carried out at 7 sites where the sub-ice platelet layer was absent.

The sentences in section 2 have been amended to "i can also be estimated using the hydrostatic equilibrium assumption. However this must be carried out in areas where no sub-ice platelet layer is present. Using this method in McMurdo Sound, Gough et al. (2012) report i as 934 kg m-3. Using an amended method at seven of our measurement sites in 2011 (where i estimate for each site is the mean of i derived from 5 drill-hole measurements - see Figure 2b) where no sub-ice platelet layer was measured we obtain a mean value of 927 kg m-3. The locations of these sites are indicated in Figure 1."

This text was added to the Figure 1 caption "The 18 sites at which snow density was

measured are indicated with blue circles. The 7 sites at which sea ice density was estimated using the hydrostatic equilibrium assumption are shown with 'i' underneath the measurement site."

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Other comments:

We have added to the reference list;

Stevens, CL, Robinson, NJ, Williams, MJM and Haskell, TG (2009) Observations of turbulence beneath sea ice in southern McMurdo Sound, Antarctica. Ocean Science, 5(4), 435-445.

after adding further information on the extent of the sub-ice platelet influence beyond the ice shelf edge.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/8/C362/2014/tcd-8-C362-2014-supplement.pdf

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Interactive comment on The Cryosphere Discuss., 8, 999, 2014.

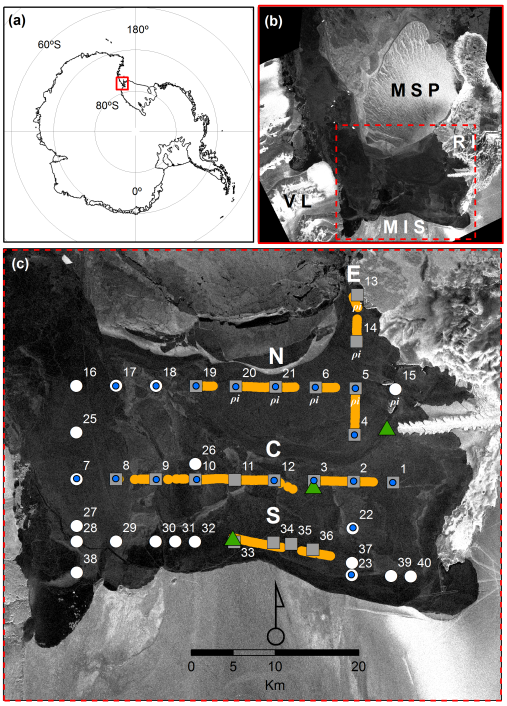
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Fig. 1.

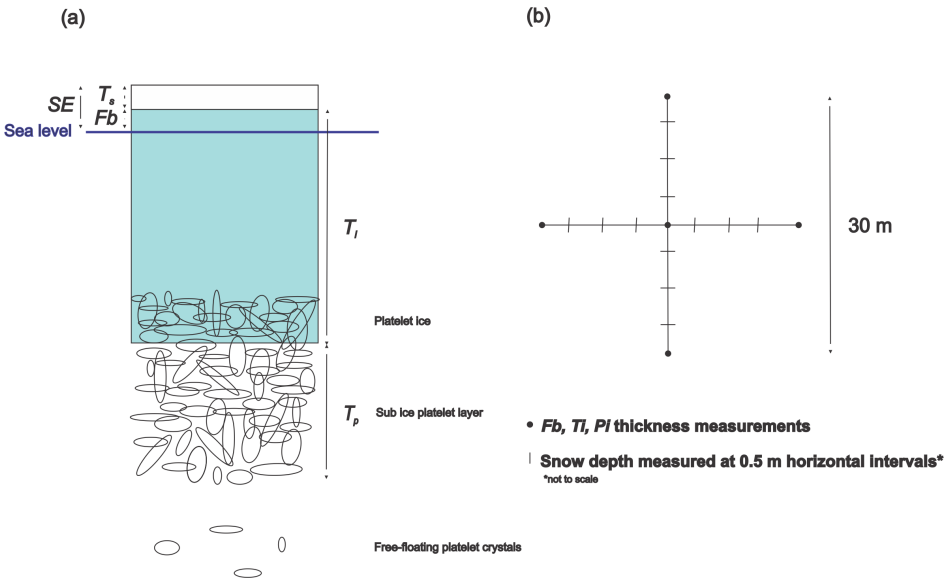
(a)
(b)
SE
Sea level
Platelet ice
Sub ice platelet layer
Free-floating platelet crystals
30 m
• Fb, TI, PI thickness measurements
Snow depth measured at 0.5 m horizontal intervals*
*not to scale

Fig. 2.