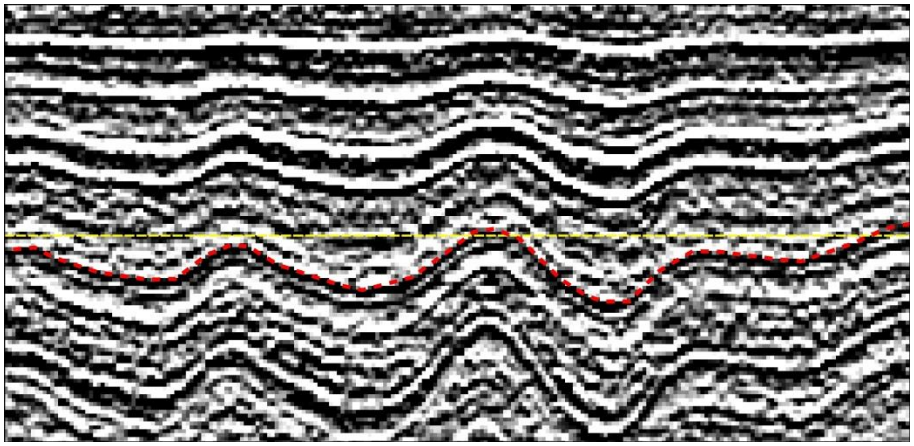
Response to Anonymous review

General Comments This paper presents a better understanding of the mass balance of Pine Island and Thwaites glacier using radar-derived accumulation rates and flux gate analysis. It is a very well written and relevant paper introducing a new grid of recent accumulation (1985-2009) over the Pine Island Thwaites region. This research uses cutting edge technologies and sound methodologies. The paper also presents a very well laid out comparison of the new accumulation map to reanalysis and modeled data. This paper should be published with minor revisions.

We thank the review for the thoughtful comments. We respond to each comment below in bold.

Specific Comments I only have one major scientific issue with this paper, the assumption that manual digitization of a layer can be +/-1 range bin. This should be increase to at least 3 bins or further, substantial justification needs to be given for the +/- 1 range bin. In the end it is likely that this does not matter in the final result because the 25 km smoothing would take out this noise assuming picked layers oscillate horizontally by more than 3 range bins over 25 km which is likely. Nonetheless the +/- 1 range bin is too small of an error on a manual pick. If a new error is selected it should be used to recreate the final error map in Figure 7C.

The reviewer makes a very insightful comment concerning the use of a ±1 range bin digitization error. Attempting to track the same horizon over such large distances and over many accumulation regimes can prove difficult at points. The reviewer states that the error should be at least 3 range bins (or greater) rather than just one. For this radar setup, our range bins varies in thickness from ~0.35 m at the surface to ~0.30 m at 40 m depth (the max depth of H1 is < 40 m) - due to the variable density with depth - values which are more than or just at half the range resolution (see Rodriguez-Morales et al., 2013) of the radar system. This fact, coupled with a close look at the radar data below (see Figure 1: red line is H1, yellow line is 20 m depth), indicates that a ±1 range bin error is sufficient. We digitize the contact between horizons, many of which are no more than 2-3 range bins in thickness. We checked recent papers (e.g., Miege et al., 2013; Spikes et al., 2004) for their inclusion of a digitization error but it appears they did not include the error in the formal error analysis. We were also unable to find literature that justifies use of a ±3 range bin digitization error. Therefore, we feel confident using a ±1 range bin digitization error in our analysis.



A minor issue is the use of a constant density profile for the entire catchment. Previous studies (Spike et al., 2004) use a linear interpolation of density along radar transects. Please justify why the +/- 1 standard deviation was chosen as opposed to a linear interpolation. A one sentence justification in the paper should address this.

The reviewer makes a valid point here. We know that the accumulation rate varies substantially over small distances in this region (Medley and others, 2013), but the sampling of ice-core density measurements is inadequate to resolve the density profile variability resulting from accumulation variability. Therefore, we assume that nine recently acquired density profile measurements represent a broad enough sample of different climate regimes to provide a regional mean profile. This assumption results in a constant conversion between two-way travel time and depth over the entire surveyed region while allowing us to use the standard deviation of the measured profiles in our estimates of the error. We added the following sentences to Section 3.1 to explain our reasoning: "Previous studies have interpolated the density profile between two ice cores (e.g., Spikes et al., 2004), thereby presuming that the dominant variation is a linear trend and that the cores represent the average conditions at either end (i.e., are not biased substantially in an area of higher/lower accumulation). Because accumulation is highly variable over short distances, both the former and latter inherent assumptions are challenged, and thus, we use the regional mean profile and attempt to capture the potential error in using a prescribed profile in our error estimates."

Page 958 Line 4- Need to add a reference to the Burgener et al., 2013 paper and include additional comments on the slightly negative trend observed in these cores.

We acknowledge that the Burgener et al., 2013 cores indicate a decreasing trend in accumulation but also that the study is limited in its spatial representativeness as related to this study. We find that the three ices cores we present within the PIG/THW basins, which represent a broader area, show no recent trend in accumulation. This finding is consistent with the snow radar measurements from Medley et al., 2013, which cover a significant portion of the Thwaites basin and are derived independently of the ice core records. We have included a sentence at the end of Section 2 to reference the work by Burgener et al. 2013: "While recent work by Burgener et al. (2013) found a negative trend in several shallow cores straddling the divide between the Ross and Amundsen drainages, the three cores presented in this work indicate that accumulation rates within the Pine Island-Thwaites drainage system do not exhibit a recent trend, consistent with the snow radar record."

Page 959 Line 17- epsilon should be used for Dielectric permittivity

In our version, we find that epsilon is used properly for the dielectric permittivity. No action taken.

Page 959 second paragraph- clarify if reflection and/or refraction is accounted for in depth conversion.

Because the instrument is pointed at nadir, there should not be much deviation from a vertical raypath. Since measurements are not made at strongly banking turns, this assumption should generally hold. No action taken.

Page 959 line 21- Are the 9 cores from the same time period? Add a sentence on how the cores from the early and late 2000's compare given the suggested change in accumulation from H1 and H2.

The cores used are from 2000, 2001, 2005, and 2010, and they are averaged together assuming they represent the steady-state density profile. We know that the density profile can change over short timescales (Ligtenberg et al., 2012), however, due to the lack of cores in this region, we are forced into this assumption. At the same time, accumulation rates in this region have not changed dramatically over the past 30 years (see above on Burgener cores); therefore, any issues with using cores from 2000, 2001, 2005, and 2010 would only be manifested in the uppermost part of the firn column from the interannual variability in accumulation. We added two sentences to address this: "The density profiles should approximate the steady-state density profile from the late 2000s, even though the cores were collected between 2000 and 2010, because no recent trend in accumulation is found over the past 30 years. Any variations from steady-state would be manifested in the near-surface firn, which is most susceptible to the interannual variability in accumulation."

Figure 1 Caption- Change to radar-derived accumulation measurements were taken from Medley et al. (2013).

The reviewer makes a good point. We clarify that these are from the snow radar: "The solid black lines show where snow radar accumulation measurements were taken from Medley et al. (2013)"

Page 960 line 1- Sentence beginning with Tracking is unclear. What is meant by steepened, do you mean dynamical processes or surface redistribution? Please clarify.

We have attempted to clarify that we are referring to the fact that the undulations due to variations in the accumulation rate have not steepened because there has not been enough time passed. The steepness from accumulation variability is due to the magnitude of the difference in accumulation rates and the time interval over which they have been accumulating. Therefore, the undulations steepen with depth. We changed the sentence to: "Tracking such a shallow (and thus young) horizon is possible because any undulations in the stratigraphy due to accumulation rate variations have not yet been substantially steepened over the short time interval"

Page 963 line 16- 500 m do you mean ~500 m given changes in aircraft speed or did you grid along the flight line. Please clarify. Also with OIB snow radar data along track should be 10's of m along track. Please clarify.

The reviewer makes a good point. All the radar data was sampled to exactly 500 m to have a consistent measurement interval and not bias our results by having some areas of tight spacing. We have clarified our statement: "While the along-track resolution of the radar data is ~10's m, we extract horizon depths at a sampling interval of 500 m, which is small relative to the catchment size."

Page 963 line 19- the sentence including accumulation was not appropriately sampled. . . is confusing. It is certainly appropriately sampled along track. Please clarify what this is in reference too i.e. the grid spacing of the flight lines/distance between flight lines. (This is nicely stated in the conclusion). Perhaps just deleting the section after the semicolon will get the point across.

The point is well taken. We added "at the catchment-scale." to the end of the sentence because as the reviewer mentioned, the statement "was not appropriately sampled to recover high-frequency (<10 km) variations" was contradictory to the first sentence. We meant that even with the radar coverage we have, we are still unable to capture those variations at the catchment-scale because the gaps between the flight paths are too large.

Technical Corrections

Throughout the paper Greek letters should be double checked. Likely this was just a conversion issue.

We found that in our version of the paper the Greek symbols appeared correct. No further action taken.

Page 957 line 19 and 20 Make asl and a.s.l. consistent.

Done.

Page 962 Tao should be sigma.

See above on Greek letters

Page 967 Line 8-fromating issue with parentheses.

We found in our version that the parenthetical was correctly formatted.

Page 967 line 23- Tau to sigma.

See above on Greek letters

Page 968 line 3- Tau to sigma.

See above on Greek letters

Maps should have latitude and longitudes on axes.

All maps now include Lat/Lon graticules

Figure 1- The resolution of this figure needs to be increased. Legend text is not readable. Additionally the flightlines and catchments are difficult to distinguish with color scheme and elevation contours confusing. I suggest reducing line width slightly on flightlines(layer picks), using a red line for the catchments for distinction and a thin dashed line for contours.

We have increased the font size for all the text on Figure 1. We changed the elevation contours to a dashed line as suggested and reduced the thickness of the flight lines slightly.

Figure 2 Caption- Are the sub basins labeled in Figue1? With the resolution difficult to tell please make clearer.

The sub-basins were labelled, but difficult to see. We hope with the increased font size that they are more easily viewed.

Figure 3 Caption- change deviation to the +/- 1 standard deviation for clarity.

Done

Figure 3 Caption-Depth equation is incorrect. Change to same as page 959.

We find the equation is correctly displayed in our version

Figure 4 Caption- second line, delete the

Done

Figure 6 and 7-Again the catchment lines at this resolution are difficult to see. Consider a red solid line.

We changed the catchment boundaries to a solid white line, which is much clearer.

Figure 9 add full caption from 8 or combine the figures.

We added a full caption for Figure 9.

We would once again like to thank the anonymous reviewer for his/her many thoughtful and useful comments on our paper.

References

Burgener, L., Rupper, S., Koenig, L., Forster, R., Christensen, W. F., Williams, J. & Riley, L. (2013). An observed negative trend in West Antarctic accumulation rates from 1975 to 2010: Evidence from new observed and simulated records. *J. Geophys. Res.*, *118*(10), 4205-4216.

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Miege, C., Forster, R. R., Box, J. E., Burgess, E. W., McConnell, J. R., Pasteris, D. R., & Spikes, V. B. (2013). Southeast Greenland high accumulation rates derived from firn cores and ground-penetrating radar. *Ann. Glaciol.*, *54*(63), 322-332.

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