Response to Anonymous Referee#2

First we would like to thank Referee#2 for taking the time to review our paper. We appreciated your comments that have helped to clarify our paper. We will address your comments in the order of the review below.

Response to general comment on mentioning other IceBridge instruments and specifically Accumulation Radar: In Section 3.1 we added the following to address this comment, "Operation IceBridge flights operate multiple instruments, including lidars and radars, spanning a range of frequencies (Koenig et al., 2010; Rodriguez-Morales et al., 2014). The Snow Radar was chosen for this study because the vertical resolution and penetration depth are optimized for our research goal of detecting annual layers from the surface of the ice sheet. It is noted that the CReSIS Accumulation Radar and MCoRDs radars are also capable of detecting accumulation rates on decadal and millennial time scales, respectively, using dated isochrones (e.g. Miège et al., 2013; MacGregor et al., 2015)"

<table>
<tr><th>Specific Comments</th><th>Response</th></tr>
<tr><td>2.1-Modeled density bias below 2.5 m</td><td>We do not see an overestimation bias in the actual data shown in the table below. As you can see the standard deviation is always larger in MAR but the average value is both high and low depending on the depth range. The following sentence is in the paper for clarification, "Below 1 m, the model and observed densities are similar (4% mean difference)"
<table>
<tr><td></td><td>Observed</td><td>MAR</td></tr>
<tr><td>0-1 m</td><td>338 ± 39</td><td>280 ± 40</td></tr>
<tr><td>1 – 15 m</td><td>472 ± 99</td><td>454 ± 158</td></tr>
<tr><td>1 – 2.5 m</td><td>381 ± 54</td><td>387 ± 149</td></tr>
<tr><td>2.5 – 5 m</td><td>436 ± 75</td><td>452 ± 155</td></tr>
<tr><td>5 – 15 m</td><td>531 ± 83</td><td>522 ± 139</td></tr>
</table></td></tr>
<tr><td>2.1- Depth to which analysis was carried out.</td><td>To address this comment we have added a histogram of the depths of the top layer (Figure 7) and added to section 5.1 "Figure 7 shows a histogram of depths for the first layer detected for years 2009 through 2012 where 63% are within the top 1 meter of snow." We additionally address this more fully in the discussion section.</td></tr>
<tr><td>2.2- Deriving Accumulation from Snow Radar- Standard equation for equation 1 provide more clarity</td><td>We have changed equation 1 into two equations for clarity to show both the accumulation derivation (new equation 1) and the radar travel-time to depth equation (new equation 2) as well as the combined equation (3).. We have also added additional citations to Looyengy, 1965 and Medely et al. 2013, Das et al., 2015 to fully cite these</td></tr>
</table>

	equations. Also added clarification statement on relation of z*rho to cumulative mass in text. Please see section 4.2 in paper for changes as it too extensive to paste here.
2.3 When aligning the surface, outliers in alignment (25 cm out) are discarded. This is fine, but you should state what portion of the data are discarded in this process.	Unfortunately we cannot quantify the amount of data that was discarded due to no surface detection or surface misalignment with our processing chain. We did not keep track of this data and because we also reduce the data size in the process we cannot estimate this based on bytes. We do note that most of these omissions occur when the radar data switched nyquist zones due to airplane altitude adjustments occurring faster than radar adjustments causing the radar data to invert. There is no way to correct this inverted data after the fact and our code was written to just eliminate it from further processing.
2.3 Why stack to 50 meters in one 2011 and 2012, and 10 meters in 2009 and 2010?	Added the following to the paper for clarification in section 4.3.1, "The change in along- track spacing between 2009–2010 and 2011–2012 is due to additional incoherent averaging introduced in 2011. " We keep the number of stacks equal at 10 but the amount of data released due to the post processing change from 2010 to 2011 changes the along track spacing.
2.3-4.3.2 and 4.3.3 sections are not entirely clear. Clarify Spatial and time/depth dimension.	We have attempted to clarify these sections and add description on the along track vs depth/time dimension. Please see sections for changes. We have left only figure 3 for illustration as this is the only graphical output of this process.
2.3-4.3.4 either eliminate or expand.	The authors chose not to eliminate this section as the GUI interface has already been distributed to other researchers and is being use to manually adjust layer for many radar applications for multiple radar systems and needs to be documented. We have expanded as follows," A graphical user interface (GUI) was developed to verify the automated layer detections by displaying the snow-radar radargram and the resulting automated-layer detections. An analyst used the GUI to quickly compare the picked layers and the radargram. The GUI application allows for editing of the output layers as needed including tools for. layers, or parts of layers to be added, deleted, gap-filled, and re-indexed. The GUI saves the analyst time by providing the ability to scroll through all the radargrams and picked layers, including the previous and subsequent along-track

	data, to detect errors. Statistics on the error rates of the automatic algorithm were not keep, however, it is noted that the error rates depend on the quality of the radar data, influenced by both radar and aircraft operations, and the regional characteristics of the firn microstructure which can either preserve or erode layering. “
2.4 Results- Why not normalize to 12 months.	Intentionally we do not want to normalize to 1 year. When comparing to modeled data we can compare on a monthly (or daily) basis. The Snow Radar performance is best on identifying the top layer, a partial year, and we compare it to modeled data from the same time. We do spend a full paragraph describing this because it does need to be documented for comparison with other data, like ice cores, in which case you would likely want to normalize to a year. We do not make this assumption since the modeled data is run over the same period for accumulation.
2.4 Figure 5	We prefer to keep figure 5 as it shows the year to year variability in the model as well as differences in spatial patterns between MAR and snow radar maps such as the lack of the higher accumulation region in Northeast Greenland in the MAR maps which is seen in snow radar and discussed in the paper.
2.4 Section 5.2 Interpolation of MAR, Year 2010 comment	Because MAR is generating accumulation based on topography we do not feel it is appropriate to downscale the model. Theoretically the radar should be sampling the accumulation variability across the MAR grid cell and the average would be simulated by MAR, hence, we have averaged all samples within a MAR grid cell for this comparison. This is similar to techniques used by Medley et al., 2013 in a similar study in Antarctica. Yes 2010 is a particularly difficult year. This could be do to a few reasons 1) MAR did not do well that season 2) the snow radar data is more limited in spatial extent and is sampling preferentially in the North and Southeast where MAR seems to have more trouble even in other years. It always must be kept in mind that airborne data is not a systematic spatial sampling and in years that the aircraft targeted different geographic regions the model may look worse but it is a spatial sampling bias due to the aircraft data. 2010 is likely a combination of both of these effects.
2.4-Page 6731 Figure 11- Illustrate as step plots	We have changed the figure a step plot to

	accurately represent the dates over which the accumulation is average. Your final comment in this section in reference to Camp Century, "you should report you 11will actually probably make your result look in better agreement.." is unclear and likely a typo. Please let us know what this comment was aimed at so we can address.
2.4 Single 2001 date	Yes there is an explanation for this and that is the 2001 and 2002 layers were dated from the surface in the interior of the ice sheet along the flight line going into Camp Century. The 2001.5 and 2002.5 layers were strong reflectors and were traced continuously to Camp Century. The layers above were not as strong and were not traced over that distance. This doesn't occur very often in our dataset but there are a few layers at depth, particularly in Northern Greenland, that are continuously traced and dated from the interior. In short this data comes from a traced layer date, not from the surface at the exact location of Camp Century.
Technical Corrections	**Response**
Page 6699, lines 21-24: This sentence is awkward and not entirely clear. Clarify	Change to "As GrIS mass loss has accelerated, a fundamental change the mass loss process has occurred. The dominant mass loss process for the GrIS has changed from being dominated by ice dynamics to being dominated by surface mass balance (SMB) processes, which include accumulation and runoff (van den Broeke, 2009; Enderlin et al., 2014)."
Page 7600, line 3: "here after" should be "hereafter"	Corrected.
Page 7601, line 6: "to monitor decadal-scale..." monitor is not really appropriate here- change to "measure"	Changed.
Page 7601, line 6: "to monitor decadal-scale..." monitor is not really appropriate here- change to "measure"	Changed.
Page 7601, line 27: GCM is more frequently a "General Circulation Model" as opposed to "Global Climate Model". However, since you only are using RCMs here, why not just eliminate the mention of GCM?	Changed to General Circulation Model as they too can provide spatially and temporally extensive estimates of accumulation-rate fields at ice-sheet scales
Page 6703, line 25: "an additionally" should be "an additional"	Changed.
Page 6704, line 5: this sentence is awkward- the phrase "that cover and vary" in	Removed.

particular is kind of confusing. Suggest just removing "and vary" since the statement that there are multiple profiles implies variability.	
Page 6704, line 6: "from the MAR model" is redundant- just use "from MAR" which is what you use elsewhere.	Changed.
Page 6706, line 4-6" The sentence "Equation (1) is written to show the relationship between the density profile, which is used for ... This is not a "between" situation, as we're talking about one thing. I suspect this is a copy/paste error.	Changed to "Equation 1 is written to show that the density profile is used both for calculating depth and water equivalent"
Page 6706, line 16: No need to mention the Onana et al layer picker, as you don't use it! Remove this sentence.	Removed.
Page 6706, line 13 and throughout: Active voice is much easier to read than passive voice, though this is a style thing and should be left to the discretion of the editor.	Changed.
Page 6707, line 1: "minimize data noise" eliminate 'data' from this, not a useful word here. It's all data...	Removed.
Page 6711, line 4: "whereas as the" delete 'as'.	Removed.
Page 6712, line 24: "filled to broaden with" delete 'to broaden'	Removed
Page 6726, Caption to figure 6: English usage- "less than three layers" should be "fewer than three layers" since we cannot have a fraction of a layer.	Changed.