Author's Response to Referee #1 comments on "Snow depth uncertainty and its implications on satellite derived Antarctic sea ice thickness" - Price et al.

We thank Referee #1 for their review and detailed comments. Our responses are below after each point made by the referee and are highlighted in bold.

General comments

The presentation of the different snow depths was pretty bad. I'm very surprised you didn't even show maps of the evolution of the snow depth in SnowModel, AMSRE and the ERA-I precip. I really struggled to get a sense of what they were all doing through this accumulation season. You use passive microwave snow depths, snow depths converted from ERA-I precip, and snow depths from SnowModel. I was pleased to see such a comparison of different approaches, but the use of SnowModel seemed not well justified considering the uncertainty in precipitation over this study region. In the discussion you mention the benefits of having this sophisticated SnowModel framework, but then also highlight that actually just converting ERA-I precip to snow depth gives arguably better results (through comparisons of the means), so how do you reconcile that? I think you needed to do a lot more comparison of available precipitation/snowfall datasets to get a better idea of what the model is actually doing. How do the PWRF and ERA-I precip/snowfall data differ? It also wasn't clear to me if you were using precip or snowfall in SnowModel and ERA-I..

Thank you for this comment, we appreciate that certain aspects need clarifying. The point of this study was not to prove that SnowModel was superior to other snow products in the Antarctic. This was a first attempt using SnowModel over Antarctic sea ice and the point of the investigation was to evaluate its usefulness by comparing it against other readily available snow products and in situ data. One of the problems with current snow products is that their resolution in comparison to the altimeter satellite footprint is too coarse. There are also accuracy issues associated with passive microwave techniques over rough and deformed sea ice, this of course typical of Antarctic pack ice. If a more comparable, higher resolution snow product was available this would be a step in the right direction, helping to facilitate the useful combination of satellite altimeter data and snow information. We do not see how the uncertainty in precipitation has anything to do with the research approach and if anything justifies the assessment of different snow products in the region, especially given the availability of a rare in situ measurement dataset.

Although the ERA-Interim reanalysis has provided a good resource for snow on sea ice in this study it doesn't mean this applies across the wider Antarctic. This is discussed in section 6. Also ERA-Interim performs well with one precipitation value for the entire region and it was not possible to segment it by freeze up area. We do not feel there is a need to reconcile the differences between the models in this respect, we can only compare the pros and cons of each and discuss how they could be applied to a larger area. When the mean of Snow Model across the entire study area is used (so actually comparing to ERA-Interim – apples to apples) Snow Model is + 2 cm against in situ, while ERA-Interim is – 1 cm. We do not think these are colossal differences that the comment infers they are. We have added the sentence "The SnowModel mean swe for all areas at the end of the simulation is 2 cm higher than *in situ* swe mean." in section 4 to reiterate this. This point is already in the abstract and discussion.

We understand the referee's point about not showing maps, but the authors don't think this would provide much additional information to the reader. Given the differing spatial resolution of different snow datasets, maps would not allow visualisation of differences (e.g. ERA-Interim a singular grid cell at 80 km resolution and SnowModel at 200 m resolution) and this is why the authors opted for a time series plot of snow depth for all of the snow products. However, we do see the value in showing the SnowModel swe and in situ swe on a map in November to compare how well SnowModel produces the in situ observed snow distribution pattern. We have added this as Fig. 4 (below) and added text to the results section:

"*This general overestimation is clearly seen in Figure 4. Values in the eastern most section of the sea ice cover in McMurdo Sound, adjacent to Ross Island are in the order of 20 to 45 cm swe. These values are all larger than the highest in situ measured swe of 17.7 cm and for large areas, they are over double the measured value. In the central area of the Sound, modelled swe decreases in agreement with measured swe with 5 in situ sites agreeing within ± 0.5 cm of SnowModel swe (Fig. 3 and Fig. 4). The extremes, where there is a lot of snow and where there is very little snow both seem to be exaggerated by the model.*"

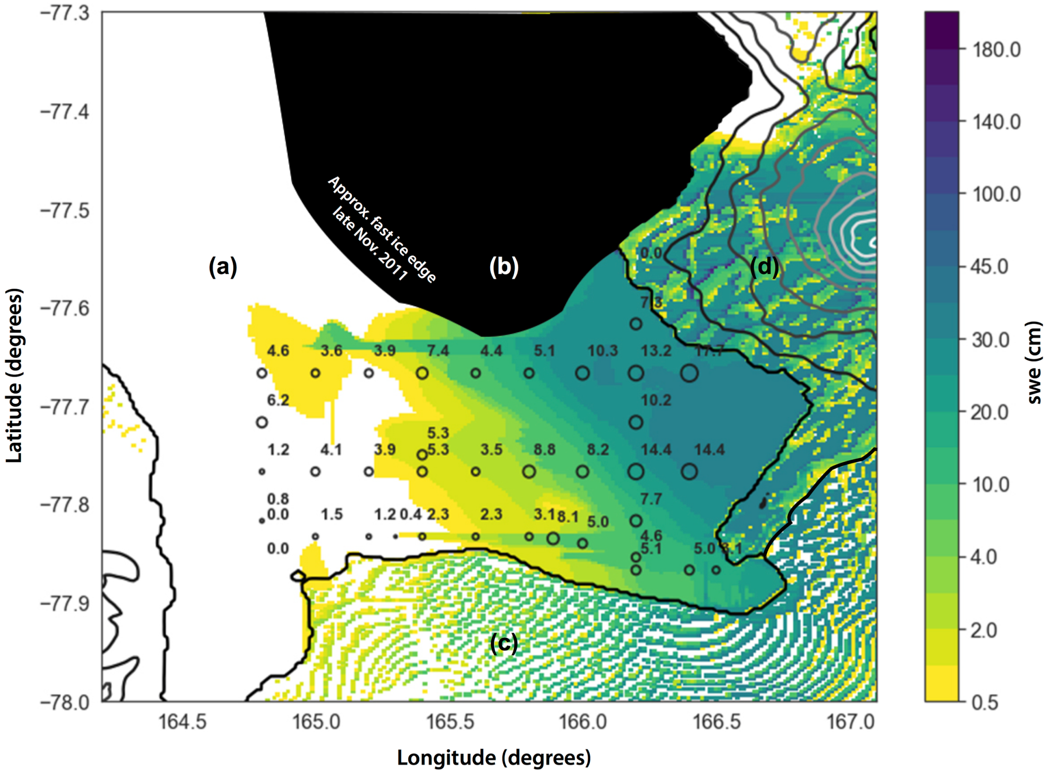

Figure 4. SnowModel distribution map displayed as swe over McMurdo Sound, (a) fast ice, (b) open water/pack ice, (c) McMurdo Ice Shelf, (d) Ross Island. The model swe distribution is the mean of the simulation over the *in situ* measurement period (25th November-1[st] December). The *in situ* measurements were converted to swe via the density measured at each site, if no measurement was taken (21 sites) the average *in situ* snow density was used (385 kgm^{-3}). *In situ* measurement locations are shown as black circles and are the mean of the 60 snow measurements taken at each site. The circle sizes are weighted for swe to allow visualisation of the decreasing swe distribution from east to west. Elevation contours are spaced at 400 m intervals; Mt Erebus is the dominant topographic feature on Ross Island to the east of the fast ice.

Only the temporal differences in precipitation between ERA-Interim and SnowModel can be compared given the low resolution of ERA. These differences can be visualised in Figure 2. The time series shows a gradual increase in ERA-Interim swe as this model includes no redistribution mechanism. SnowModel exhibits both increases and decreases in swe driven by both precipitation and transport respectively. These differences are described in the manuscript.

ERA-Interim used precipitation (water equivalent) which is clearly stated in the text. SnowModel was run to produce a swe product and a snow depth. This was not clear in the text and we have clarified this with "*SnowModel outputs snow depth and swe. The model has a varying density over time. The swe output is important as it allows comparison of the model to the other snow products which have different density assumptions.*" at the end of section 3.1.

I was also very confused by the SnowModel configuration and components needed to produce snow depths from this model. What is the Noah-LSM and why is this needed?

Noah-LSM is a Land Surface Model and one of the many components of the PolarWRF. The reason that this scheme has been highlighted in this paper is that LSMs are responsible for the near-surface exchanges between atmosphere-cryosphere and other climate sub-systems. Particularly the Noah LSM has adapted specific parameterizations that makes it ideal to be used over Arctic and Antarctic regions with varying sea ice thickness and snow distributions.

Seems like this is maybe running an entire atmospheric regional model without any real validation, so why not keep it simple and force this model with a reanalysis like ASR, which is based on Polar WRF?

ASR is only available over the Arctic and to the best knowledge of the authors no equivalent product for Antarctica exists. The WRF and PolarWRF models have been widely verified across the meteorological community and the results have been reflected in many peer reviewed articles, some of which have been cited in this paper. The main challenge with snow verification in this region is the lack of adequate in situ precipitation observations especially over the sea ice. Yet, the validity of the coupled PolarWRF-SnowModel outcomes are reflected in the sensible snow distribution across the area of study.

The use of Pd in this study seemed odd to me, and I think is the wrong way of thinking about this problem. The main issue here is that we have a distribution of returns across the snow layer, including likely some return from no penetration (the snow-air interface) to returns from various penetration depths into the snow layer. What you are showing is a simplification of this high complexity. I get that you need to do something, but how you've presented this was overly simplistic (a fixed value) in my view and needs to be better explained.

We understand this is a simplistic approach regarding the interaction of radar energy and the overlying snow pack but with the available information it is justified. Advancing this approach should be the subject of another, far more detailed study focusing on actual CS-2 waveforms over different types of snow and ice types with validation data. This is a future goal of the authors research group.

Further, the ESA retracker has already identified a surface, we are not attempting a retracking procedure ourselves in this study. Given that a surface height has already been identified we are simply evaluating which surface best represents the dominant backscattering surface by varying where this surface might be (using a penetration depth which is essentially just changing the thickness equation to account for different elevations above sea level) and comparing the results to the thickness measured in situ.

To make this immediately clear to the reader at the end of section 1, we have added the following to the manuscript: "*The interaction of radar energy with the snow pack is highly complex and here we take a simplified approach given the surface height has already been established by the ESA retracking procedure. Given the uncertainty of the position of the retracking point with reference to the height above sea level we alter the proportion of snow and ice in the thickness estimation assuming different penetration depths and compare the inferred CS-2 thicknesses with in situ information.*"

And this in section 2.4: "*Given this uncertainty we apply a simple methodology to discover the range of thicknesses as inferred via this CS-2 data.*"

I think you need to provide more context for the survey and the snow data that exists around Antarctica. You say snow depth data are lacking but then present this nice in-situ snow depth dataset. Are similar datasets available elsewhere to see how consistent these ideas are in other areas?

This is a first attempt at using SnowModel and a first attempt at combining multiple snow products with CS-2 data in the Antarctic. Therefore, the scope of this study is at the local scale. We understand the title may have been misleading in this respect and thank the reviewer for indicating this. We have made changes to the title and abstract as suggested by both reviewers.

We have a detailed knowledge of this region and with validation can develop ideas and methods for the combination of snow products and satellite altimetry data that could then be applied at the regional/hemispheric scale. We are not currently attempting this, these are early days for this work. The authors are unaware of other satellite validation datasets for CS-2 that would be appropriate for use with these snow products and if they are available we don't have collaborations with other partners for access to these datasets.

Your title needs changing as I don't really think the results here can help us say anything about snow depth uncertainty and satellite derived Antarctic sea ice other than it being a challenging topic!

Agreed, the title was misleading and has been changed to "*Antarctic fast ice thickness from CryoSat-2 using different snow product information*". We have slightly modified the abstract to better align with the new title.

The satellite data are described and introduced very crudely throughout. You need to provide better a description of these datasets, especially the Envisat data section.

Thanks for pointing out this weakness, we have added the following to the Envisat, CryoSat-2 and AMSR-E sections. We think this is enough relevant information for the reader.

Envisat: "*To identify the dates and the pattern in which the sea ice fastens across the study area, we use a string of C-band Advanced Synthetic Aperture Radar (ASAR) images from Envisat acquired in Wide Swath mode with a spatial resolution of 150 x 150 m.*"

CryoSat-2: "*CS-2 is a Ku-band (center frequency 13.6 GHz) radar altimeter launched in 2010. Its on-board altimeter has an approximate footprint size of 380 m x 1560 m and samples along-track at 300 m intervals. The instrument has three modes and operates its interferometric (SIN) mode in the coastal Antarctic. This mode uses both of the satellites antennas to identify the location of off-nadir returns accurately. This is not the dedicated sea ice mode but is still suitable for sea ice freeboard retrieval.*"

AMSR-E (reworded and additional information added): "*The snow depth product is gridded to a 12.5 x 12.5 km^2 polar stereographic projection and reported as a 5-day running mean, that mean inclusive of that day and the prior 4 days. We remove data where ice concentrations are lower than 20%. Gridded snow depth values are calculated using the spectral gradient ratio of the 18.7 and 36.5 GHz vertical polarisation channels. For snow free sea ice the emissivity is similar for both frequencies. Snow depth increases attenuation from scattering but is more pronounced at 36.5 GHz than at 18.7 GHz, resulting in higher brightness temperatures at 18.7 GHz (Comiso et al., 2003, Markus and Cavalieri, 1998). Using coefficients derived from a linear regression of in situ snow depth measurements on microwave data, and a 36.5-18.7 GHz ratio corrected for sea ice concentration, snow depth can be estimated (Comiso et al., 2003).*"

You mention in the discussion (finally!) the issue of initial conditions, but say are hindered by the fact you don't have good freeze-up info at high resolution, but I would think the passive microwave data is fine for this purpose, especially with the ERA-I analysis? You must have some idea of the bias you introduce if you don't start accumulating until the ice fastens, instead of simply forming.. Is the idea that the ice that forms before fastening is all transported northwards and away from the region? Are there no drift products available to understand that?

Passive microwave data could be used for freeze-up analysis but its resolution (at best AMSR-E sea ice drift at 6.25 km and concentration at 12.5 km) is too low to be used effectively with SnowModel. Passive microwave could be used for AMSR-E and ERA-Interim but given the paper is a comparison of the different snow products it does not make sense to consider earlier snowfall for one product and not the others as is suggested above. We also have other concerns which resulted in us deciding to use freeze-up instead. These concerns are explained in a paragraph that has now been added in section 2.2:

"*The sea ice freeze-up provides a point from which snow can begin to accumulate on the sea ice surface. Freeze-up could be identified using passive microwave information, but this data*

***does not provide the spatial resolution to segment the sea ice area appropriately for SnowModel's 200 m resolution. Also, snowfall before fastening is subject to uncertainty from floe movement, flooding events and snow loss to leads, three influences on the eventual snow depth that we have no way of accurately monitoring. With these uncertainties, we have selected the sea ice fastening date to begin snow accumulation.*"**

This sentence has also been added to the discussion:

"*Early snowfall on more dynamic pack ice will also be subject to flooding, sea spray (both likely to result in snow-ice formation) and loss to leads. These uncertainties must all be considered in future work.*"

I think you should compare using meters, not SWE, as that is what is going into the thickness model. You also didn't even say what the in-situ snow density was.

The authors do not agree that using meters will provide a better comparison as the densities used in SnowModel and those used for ERA-Interim and AMSR-E are different. We reduce snow depth to swe when appropriate to remove the density bias.

As mentioned in an earlier response, the following has also been added to section 3.1 to help clarify this:

***"SnowModel outputs snow depth and swe. The model has a varying density over time. The swe output is important as it allows comparison of the model to the other snow products which have different density assumptions.*"**

AMSR-E provides a snow depth, we convert this to swe using the in situ measured density of 385 kgm^{-3}. The in situ measured snow density was mentioned (L173, L244 old manuscript) but not clearly enough, we have revised this and added more detail around all densities in section 2.4.

Specific comments

L27 Not sure I agree with the first line of the introduction!

We are not sure why the reviewer does not agree with this statement as it is not specified. The understanding of Antarctic sea ice processes and properties, extent, area, drift and roughness have all been greatly advanced over the satellite era. Some confusion could be introduced by the vague use of '*few decades*'. We also see how disagreement around advancements in satellite technology is justified. To be more specific we have amended the sentence to '*The knowledge of Antarctic sea ice extent, area, drift and roughness have been greatly improved over the last forty years, principally supported by satellite remote sensing.* '

L42 Decadal trends is pushing it considering we have data from 2003. I think you could be more specific here about the relevant altimetry missions from which thickness data is still lacking.

This sentence is referring to satellite altimetry information available from 1995 (Giles et al. 2008 – from ERS-2) to the present day (23 years). The authors agree that more advanced altimeters are only available from 2003 (ICESat). However, the Giles paper shows antecedent instruments are useful and work is also being carried out using Envisat altimetry (Paul et al. 2018). In light of this we feel the decadal time frame is justified. We do not feel it is necessary to name individual missions here especially as the relevant literature is cited prior.

L43 Completed is strange language to use here.

Agreed. '*have been completed'* amended to '*are available*'.

L54 I think what you want to say here is that there is a long, but old, record of in-situ data of Arctic snow depth from which a climatology has been produced.

End of sentence amended to "*longer period than the Antarctic so climatologies can be produced*"

L58-59 Reword. Passive microwave data of snow depth available over both poles (where we have FYI).

Sentence amended to "*The research community lacks snow climatology information in the Southern Ocean; to date only AMSR-E passive microwave data have been used in combination with altimetry to estimate sea ice thickness.*"

L73 This terminology doesn't make much sense to me. What is sea ice fast-day-zero?!

Fast-day-zero refers to the first day that the ice is identified as having fastened. This terminology is clearly confusing and has now been removed throughout the manuscript. We have amended this sentence to "*With a high-resolution snow accumulation model called SnowModel (Liston and Elder, 2006a) and the use of synthetic aperture radar imagery we are able to establish when the sea ice fastens and accumulate snow from those dates for three areas of fast ice in McMurdo Sound in the south-western Ross Sea.*"

L78 Maybe say you compare against in-situ data. Assess uncertainty sounds odd.

Sentence amended to "*With these different snow depth datasets we infer sea ice thickness via freeboard measurements from CryoSat-2 and compare these results with in situ information.*"

L99 Virtual weather station?! Is this not simply the location of an overlapping ERA-I grid cell?

This terminology has been amended to "*The position at which ERA-Interim atmospheric reanalysis data are retrieved is identified by the black circle.*"

This sentence has also been added in section 3.2 for clarification: "*Splines were used to interpolate to this position from the three-dimensional ERA-Interim grid.*"

L114 I don't get this gridding discussion. Is this true? It's produced at 25 km then down sampled??

For AMSR-E the spatial resolution at observation frequencies of 18.7GHz and 36.5GHz are reported as 25 km and 15 km respectively. The spatial resolution is variable as determined by the footprint which is influenced by satellite altitude, off-nadir angle and beamwidth (Please see table 2.3-12 below from the JAXA AMSR-E Data Users Handbook below).

Table 2.3-12 Beam Width and Footprint

Frequency	Beam Width (Nominal)	Footprint (Scanning × Proceeding)	Remarks
6.925 GHz	2.2°	43.2 x 75.4 km	In case of; Satellite Altitude: 705 km Earth Radius: 6378 km
10.65 GHz	1.5°	29.4 x 51.4 km	
18.7 GHz	0.8°	15.7 x 27.4 km	
23.8 GHz	0.9°	18.1 x 31.5 km	
36.5 GHz	0.4°	8.2 x 14.4 km	
89 GHz A	0.2°	3.7 x 6.5 km	
89 GHz B	0.2°	3.5 x 5.9 km	

Please refer to the JAXA AMSR-E Data Users Handbook for more detail (http://www.eorc.jaxa.jp/en/hatoyama/amsr-e/amsr-e_handbook_e.pdf)

The 25 km to 12.5 km downsizing is described in Worby et al. (2008) - '*Snow depth on sea ice is a standard product of the EOS Aqua Advanced Microwave Scanning Radiometer (AMSR-E) instrument. This represents an average over an area of about 25 × 25 km2, gridded to a 12.5 × 12.5 km2 polar stereographic grid [Comiso et al., 2003].*' But little detail is provided beyond this. Comiso et al. (2003) describe the spatial resolution of AMSR-E with the following table:

TABLE I
AMSR-E LEVEL 3 T_B AND SEA ICE DATASETS

PARAMETER	APPROX. RESOL.	GRID RESOL. SIZE	PRODUCT FREQUENCY
TB (6.9 GHz)	58 km	25.0 km	Daily Asc., Desc., & Ave.
TB (10.7 GHz)	37 km	25.0 km	Daily Asc., Desc., & Ave.
TB (18.7 GHz)	21 km	25.0, 12.5 km	Daily Asc., Desc., & Ave.
TB (23.8 GHz)	21 km	25.0, 12.5 km	Daily Asc., Desc., & Ave.
TB (36.5 GHz)	11 km	25.0, 12.5 km	Daily Asc., Desc., & Ave.
TB (89.0 GHz)	5 km	25.0, 12.5, 6.25 km	Daily Asc., Desc., & Ave.
Sea Ice Conc. (%)		25.0, 12.5 km	Daily Asc., Desc., & Ave.
Sea Ice Temp. (K)		25.0 km	Daily Asc., Desc., & Ave.
Snow Depth (cm)		12.5 km	5-day average

The snow depth derived via the equations in Comiso et al. (2003) combine brightness temperatures from the 18.7 and 36.5 channels at 21 km and 11 km resolution respectively. With the information provided in the JAXA document and supporting literature there must be some downscaling or mechanism to combine the 21 km and 11 km data resolution to the 12.5 km x 12.5 km^2 grid spacing. We do not feel this detail is required here as the grid cell size is all that is relevant to the reader to understand our analysis. The AMSR-E section has been reorganised (see amended manuscript) and we have simplified the resolution sentence to: "*The snow depth product is gridded to a 12.5 x 12.5 km^2 polar stereographic projection and reported as a 5-day running mean, that mean inclusive of that day and the prior 4 days.*"

L116 You don't need to state the flag number here..

Agreed, not immediately relevant to the reader. The reference to flag number has been removed.

L133 You need to reword this! Strange sentence structure at the start.

Sentence amended to: "*CS-2 was launched in 2010 and houses a Ku-band radar altimeter (centre frequency 13.6 GHz).*"

L135 Provide a citation to the CS2 L2 data.

Citation not appropriate but we have added a URL for the CS-2 data after 'SIR_SIN_L2' "- available at: http://science-pds.cryosat.esa.int/"

L143 Is this max freeboard based on anything? Surprised this is so low..

Yes, this is based on in situ measurements in 2011. The largest measured total freeboard (ice-plus-snow) was 0.46 m.

L155 Reword Beyond Wingham etc..

Amended to: **"*Wingham et al. (2006) indicate the snow-ice interface is represented by the ESA retracked height. No other information is available about the assumptions made here, only that for diffuse echoes in SAR processing, for baseline C, a new retracker was implemented (Bouffard, 2015).*"**

L172 Which investigations? Are these the same as other altimetry studies?

We have added more detail about our density values and amended this section to: "*where ρw (1027 kgm^{-3}), ρi (925 kgm^{-3}) and ρs (385 kgm^{-3}) are the densities of water, sea ice and snow respectively. ρw is informed by an unpublished time series of surface salinity measurements taken from October 2008 to October 2009 along the front of the McMurdo Ice Shelf. The range in ρw during this period is less than 1 kgm^{-3}. The ρi value used here is in the middle of the measured range in McMurdo Sound, the use of which is discussed in Price et al. (2014). ρs is the mean of snow pit measurements at 18 of the in situ measurement sites in 2011.*"

L173 Need to reword this. What do you mean by when required? When is this required?!

This refers to the correction for the speed of light in snow. This only applies when snow is present and/or some penetration is assumed. If no snow is present the correction is not applied and equally if the air-snow interface is assumed i.e. *Pd* = 0 then no correction is applied.

We have amended this sentence to: "*When snow is present and penetration is assumed (i.e. Pd > 0), reduction of the speed of the radar wave through the snow pack is corrected following the procedure described in Kurtz et al (2014).*"

L191 Has it ever been used for Antarctic snow on sea ice?

No and this is mentioned in the sentence beginning L235 (old manuscript). We have moved this sentence earlier to L233 (new manuscript) as it establishes this earlier to avoid confusion.

L241 Aren't you using snowfall, not precip? Why can't you also comapre this with the precip from pWRF (or ASR as suggested)

No the original data from ERA-Interim is precipitation water equivalent. We convert this to snow depth with the average snow density measured in situ. The objective here is to advance PWRF with SnowModel, so simply comparing precipitation from PWRF would not advance the study.

L244-245 So this is the location of the only ERA-I grid-cell in the study area?

ERA-Interim is only available on a 0.75° x 0.75° grid which results in an approximate spatial resolution of 80 km. This is larger than the sea ice area in question and is too coarse to resolve at a higher resolution in the study area. Data was extracted from the reanalysis product at 77.7S 165.8E via a spline interpolation and more detail has been included about this in section 3.2 – "*Splines were used to interpolate to this position from the three-dimensional ERA-Interim grid*". Therefore, the resultant ERA-Interim value at this position represents the spline interpolation value with respect to the local ERA-Interim grid cells.

Figure 2 Pretty unclear figure with no legend and lines that are hard to distinguish.

We are not sure why the reviewer finds this plot unclear. It is a time series of swe for each of the products with clearly distinguishable lines. The figure caption describes these lines.

L315-318 Ok so two provide snow depth and ERA-I is converted using in-situ density. Reword.

Amended to "*Snow depths for each CS-2 freeboard measurement are retrieved from the SnowModel and AMSR-E products directly, while ERA-Interim swe is converted to snow depth using the mean in situ measured density.*"

Figure 4 I can't even work out what is being shown here.

This is a key figure to the paper and shows the range in inferred sea ice thickness assuming different heights represented by the ESA retracker between the air-snow and snow-ice interface. These varying penetration depths are plotted for each snow product. We have moved the penetration depth information (*Pd*) off the plot for clarity and attempted to provide the reader with better information about the figure by reworking the text. We have reworded section 5 to try and make it clearer what is going on in this Figure (please see in new manuscript).

L424 I'm not sure what you mean here.

This sentence is referring to the fact it is a perfect study area for AMSR-E with no interference from open water, or leads and that most of the fast ice is flat. However, this sentence isn't really necessary and has been removed.

L480 Good point, was ice density not measured directly in this study?!

Yes, the value we have used for sea ice density has been measured and is supported by the literature and previous work by the lead author of this work (expanded upon section 2.4 – L210 – new manuscript). The sentence in the discussion is referring to the fact that if the sea ice density was varied through a given range it would change the sea ice thickness estimated from CS-2 freeboard. We have decided to ignore this in this investigation as we are focusing on the combination of snow depth information and altimeter data, but mention it here as it is an additional source of uncertainty in the eventual sea ice thickness estimate.

The sentence in the discussion has been amended to: "*As this analysis was focused on the combination of independent snow products and CS-2 altimeter data, the range in sea ice density has not been taken into account. We have confidence in the middle ground ρi value used from previous work in McMurdo Sound (Price et al., 2014).*"

L485 Unclear how these results indicate accurate snow depths.

This sentence states that "*The snow distribution from SnowModel <u>accurately captures the measured distribution in November 2011</u> and produces a swe mean value that is 0.02 m above the mean of in situ validation, but when sea ice is segmented by fastening date large deviations of up to 0.05 m are present in the east where the model has overestimated snow depth.*"

'*Accurately*' only refers to the snow distribution produced by SnowModel which is correct. We then directly state actual means for comparisons after this statement. We have clarified this accurate representation of the snow distribution and other concerns with the addition of a snow distribution map – see response to first 'General comment'. We have added a map as Fig.4 to help visualise this.

Figure 3 and 4 showed big differences (especially as a percentage), and ERA-I perhaps performing better..?

SnowModel does exhibit large differences from in situ measurements and the entire snow data set is biased high, likely driven by too much accumulation in the east driven by the topographic barrier of Ross Island in the model. This captures reality but the result is exaggerated in the model. This is all stated in the text. The focus of this paper was to compare SnowModel against existing snow datasets, not to prove it was better.

Also to reiterate when the SnowModel mean across all areas is taken it is only 2 cm higher than the in situ mean (ERA-Interim) is 1 cm lower. These are not huge differences and do not justify the elevation of ERA-Interim as a superior product.

It would be clearer if you used centimeter units for the snow depth results throughout!

We have changed the units to centimeters for all snow plots in the manuscript. Sea ice thickness, related plots and references in the text remain in meters.

References

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