Response to Referee 2

We thank the referee for her/his valuable suggestions. They have substantially improved the manuscript. Referee comments are in plain text below, with our responses in bold.

General
This paper provides the description of the recently released REMA dataset for Antarctica. The dataset is revolutionary, providing high resolution continuous surface elevations for the entire continent. The amount of data processed alone is a remarkable accomplishment, and then combined with the heavy validation performed with ICESat/Cryosat and ICEBridge will ensure the repeated and steady use of this dataset in the future for all Antarctic science. I congratulate the authors for making this possible, great job.

Thank you!

In general, the manuscript is well written, short and concise. In some ways, a bit too short, as there are many detailed processing steps that are somewhat brushed over which would make it difficult to reproduce the complicated merging and mosaicking of all individual DEMs. In light of this, I think it would have been useful for the authors to also show/focus on some of the pitfalls of REMA showing a few examples of some of the more common problems and artifacts. This would help users of the dataset to easily spot artifacts when using REMA in their own research, especially those that are not accustomed to analyzing DEMs. In addition, It would have also been nice to see some advertising of the beauty of the dataset generated, for example by having a figure that exemplifies the precision using elevation profiles compared to ICESat and TanDEM-X, maybe one over some mountains, and another over the flat ice sheet with moderate topography. As of now, the figures all focus on the compilation of DEMs and their compiled accuracy, but no figures show the actual data at its natural resolution. . .

We have added the suggested examples to the Supplementary Materials. We did not add the ICESat or TanDEM-X transects because those data ~10x lower resolution and do not show a "natural resolution" comparison. These data, as well as the airborne data, also have there own errors which makes such comparisons not straightforward - e.g. allocating which errors are REMA and which are the altimeter.

Here are a few comments towards the methods applied and described.

I am particularly confused by the description and quantification of errors. By error (Fig 4a), do you mean the combined accuracy and precision (bias + random error). Maybe it would be useful to provide a final equation for how you attribute error to the individual tiles. This will be absolutely necessary for users to properly acknowledge and understand the abilities and constraints of the dataset.

Expanded the the figure 4 caption to clarify this: "Figure 4: Maps of REMA (A) elevation error, obtained from the root-mean-square of the differences in elevation between the DEM and altimetry data following registration, or the differences between co-registered DEMs in the case of alignment (note the logarithmic color scale), and (B) date stamp obtained from the date of image acquisition."

In terms of co-registration, it is often stated "coregistration residuals" which does not make much sense to me. Do you mean the elevation difference residuals after applying a 3D linear co-registration shift? Or do you mean the absolute vector of the co-registration shift. This needs to be clarified and used consistently through the text.

This has been clarified in the text as described in the responses to the specific comments below.

Then, in terms of co-registration, the Nuth and Kääb (2011) approach is not solvable on flat terrain as the approach requires some slope and a bunch of aspects to solve properly. I imagine there is some consistent small scale topography of the ice sheet that was useful to use this approach. But in some areas where the distribution of slopes and aspects is limited, then the approach will probably only solve for a vertical bias. It would be useful to discuss this issue briefly, or at least mention it. . .

Added the statement to section 2.1: "We note that the coregistration procedure may not provide correct horizontal offsets in extremely flat, or uniformly sloping, terrain because the small range in slopes and aspects may not yield a confident regression. We could not identify such cases, however, suggesting that there is enough surface variation at these high resolutions (2-8 m) for the method to be successful."

Last, in terms of the correction inferred to derive from Cryosat-2 penetration, Since Cryosat is only used around perimeters in this study while ICESat is used in the interior, then, Do you think your spatial sampling biases the results here?

At the end of section 2.3: "We do not find a clear spatial or elevation-related dependence of this correction and, therefore, we applied the same correction to all strips regardless of location and surface type."

In summary, this manuscript provides a good description of a revolutionary dataset for Antarctica, and will thereby be used and cited immensely. While there are limited major comments in this review, I hope the authors will find this useful to make their description even more transparent and clearer in order to help the plethora of users that will eventually integrate this dataset into their science.

Minor Comments

P3, L29. I was confused by this header title. I suppose you are not combining individual images into strips, then processing DEMS from the combined strip images? Consider calling this section "Merging single scene DEM into along track strips" as this is what I inferred from this section. Please correct me if I am wrong.

The description of merging scenes into strips and the coverage of strips have now been merged into section 2.2. Section 2.3 is now titled "DEM Strip Quality Control and Registration"

P4, L1: What is meant by "co-registration errors" ? Do you mean the magnitude of the vertical shift? How was this determined?

Edited to read: "Extensive erroneous surfaces due to, e.g., clouds or water bodies will cause errors in coregistration. Therefore, the scene was not merged if the root-mean-square of the residual differences in elevation between the overlapping area of the coregistered scenes was greater than 1 m. In this case, the strip was broken into separate segments and were treated as separate DEMs during the global mosaicking step described in Section 3."

P4, L11-17. What type of criteria is used in the visual inspection? And what is needed to pass quality control? Please provide additional details to make this process transparent, even though it is subjective to the inspector.

Edited to read: "Such erroneous surfaces appear as chaotic textures in the hillshade image that contrast with the actual topography. DEMs were either accepted if no erroneous surfaces were identified in the hillshade image, manually edited to mask erroneous surfaces where errors were small and isolated, or rejected if errors were to extensive to be edited."

P4, L31- . Was the sample used for this comparison spatially biased? Are all the points in this comparison located in one spot, or generally on the lower ice sheet. Additional details to clarify this would be helpful. Also, I wonder how the selective data approach (L26-27) by removing all strips that had a significant vertical bias (e.g. potential penetration '?) affected the interpretation of bias? If so, it could explain why you observe a "quasi" constant radar penetration estimate in Fig. 2, especially if all those scene residual statistics are spatially constrained on the continent.

We have added "These strips were distributed across the entire area of Cryosat-2 SARIn coverage."

The DEM selection criteria would not bias the offset between Icesat and Cryosat-2 (due to retracking and/or pentration) because the filter thresholds are applied to deviations in

residuals between the registered DEM and altimetry over each strip, not the mean of the residuals.

P5, L15. What is meant by “coregistration residual”? Do you mean the absolute magnitude of the co-registration vector? Did you apply the co-registration as well before filling the holes?

Edited to read: “Each quality-controlled, unregistered strip that overlaps a data gap was tested for the precision of three-dimensional coregistration, using the Nuth and Kaab (2011) algorithm, with the strip with the smallest coregistration error, defined as the root-mean-square of the elevation difference between the mosaic and the coregistered DEM, selected to fill the gap with the coregistration offset applied.”

P5, L19. Do you mean “absolute” reference? It would be relative reference if the strip was not aligned with ICESat/Cryosat, no?

Correct and this is what is stated: “If <u>neither</u> Cryosat-2 or ICESat registered data were available, the quality-controlled strip with the most coverage of the tile was added first and served as a relative reference.”

P5, L25-29. I am still confused about the “registration residuals”? If these are simply co-registration vectors, then I do not understand why they are used as residuals? For me, co-registration residuals would be the combined offsets between three or more datasets and subsequent triangulation of the co-registration vectors... (See Paul et. al. 2015)

“Residuals” should have been “error”. The section now reads: “..the lack of registration was caused by a registration error larger than the thresholds defined in Section 2.3…”

LAST: In such a massive undertaking for automated processing of DEMS and merging into a consistent product for the entire Antarctic Continent, would it not be useful to provide a flow diagram showing the sequential processing, merging, and then mosaicking processing steps? I imagine that this procedure may happen again (repeat processing), from which others may learn significantly from the pipeline devised and implemented here. . .

A flow chart is now provided in the Supplementary Materials.

References: Paul, F.; Bolch, T.; Kääb, Andreas; Nagler, T.F.; Nuth, Christopher; Scharrer, Killian; Shepherd, Andrew; Strozzi, T.; Ticconi, Francesca; Bhambri, Rakesh; Berthier, E.; Bevan, S; Gourmelen, Noel; Heid, Torborg; Jeong, Seongsu; Kunz, M.; Lauknes, Tom Rune; Luckmann, Adrian; Merryman, J.; Moholdt, G.; Muir, A; Neelmeijer, Julia; Rankl, Melanie; VanLooy, Jeffrey & Van Niel, Thomas (2015). The glaciers climate change initiative: Methods for creating glacier area, elevation change and velocity products.Remote Sensing of Environment. ISSN 0034-4257. 162, s 408- 426 . doi: 10.1016/j.rse.2013.07.043