

## ***Interactive comment on “Improved retrieval of land ice topography from CryoSat-2 data and its impact for volume change estimation of the Greenland Ice Sheet” by J. Nilsson et al.***

**J. Nilsson et al.**

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Firstly we would like to thank the reviewer for taking the time to review our manuscript. We are thankful for the insightful and constructive comments that have been provided, which we feel will improve our manuscript.

The reviewer's remarks (line number and question) have been included, while the author's response is indicated by [A] below the remark.

General remarks:

(1) In response to the rational of using different elevation change methods we have included a sentence in the introduction describing the choice of different methods. Fur-

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ther, we have also chosen to remove the DEM-method from the manuscript, as we feel that this method does not bring any new insight to the study and can be reproduced by the SF-method (as seen with the ICESat/CryoSat time series). We hope that this will make the manuscript more concise.

(2) To produce a manuscript of reasonable length we chose to keep the general description of the processing chain generic and highlight the details that make the processing scheme unique but agree that more details on the retracker in the main document would be beneficial. We have therefore moved the retracker comparison from the SI to the validation section of the main manuscript. For the curious or more technical reader we have supplied reference that provides a more technical description of the algorithms used.

(3) We agree with the reviewer that the notations in the different equations have to be improved. This has been changed accordingly through out the manuscript. Please see track changes version of the revised manuscript.

Detailed remarks:

Describing the error of the volume change estimations (lines 436-446) the authors treat the errors as systematic errors rather than random errors and thus overestimate the volume change errors.

[A] - We have changed Equation 12 to correct for this and we are grateful that this was pointed out to us. All volume change errors have been updated to encompass the corrected error propagation. The error of the elevation change (lines 447-459) describes the error of the mean elevation change of the entire ice sheet rather than the error of a single elevation change estimate. This error is not referred in the manuscript.

The single-observation uncertainty, or  $\sigma_{obs}$ , is estimated from the CryoSat-2 – ATM residuals as the RMSE. The derivation of this error source is described in the “Error Budget” section on line 583. We have rewritten this section to make it clearer how the

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single observation error and interpolation errors are defined.

Lines 327-333: what ATM products were used for the study and from where were those obtained? NSIDC distributes both individual ATM footprint locations and average ice sheet elevations for larger regions (ICESS). Ice sheet elevation accuracies are 0.071-0.085 m according to Krabill et al., 2002 – more like 0.1 m than cm level as quoted in the manuscript.

[A] - The ATM data obtain from the NSIDC was the ILATM2 product (IceBridge ATM L2 Icessn Elevation, Slope, and Roughness, Version 2), which contains the measured surface elevation, slope and roughness for each measurement averaged to 80 resolution with 40 m spacing. We have changed the manuscript to reflect this, where we have put in the source of the data and the accuracies.

Lines 463-491: this section provides a verbal description of tables. Adding the percentage of improvement would be more informative.

[A] - If we understand correctly the reviewer asks for the percentage after each numbered value? This, as far as we believe, has been met, as the percentage values for RMSE is stated in the manuscript, which encompasses both the mean and standard deviation.

Lines 573-583 and later: please use the accepted names of these glaciers: Zachariæ Isstrøm, Nioghalvfjerdingsfjorden and Storstrømmen glaciers.

[A] - This has been changed accordingly.

Lines 686-697: this seems to be a missed opportunity to emphasize the good spatial and temporal resolution of CryoSat-2 observations. The recovering surge of Storstrømmen glacier has been well documented, and additional references would improve the manuscript.

[A] - The reviewer has a good point here and we have added additional references documenting the recovery at Storstrømmen. We thank the reviewer for suggesting this

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improvement.

Table 2. Please include the period the elevation changes refer to Figure 2. What ice sheet mask was used to define the boundary of the ice sheet? Figure 3. Were the monthly changes determined by the DEM method? Figure 4. There is no reference to this figure in the text. Can this figure be merged with Figure 2? Does not seem to include additional information. Figure 5. I assume that all the values here are average/mean values. If yes, this should be stated in the caption

[A] - We have added the periods to the figures showing time period of elevation change. The ice sheet mask was provided by personal communication with Frank Paul at University of Zurich. This has also been added to the manuscript.

In the case of the monthly time-series they where generated using the DEM-method. However, as the DEM-method has been removed these have been replaced by the time-series from the surface-fit method.

Figure-2 and 4 has now been merged into one main figure to reduce the number of figures overall.

Figure-5 contains the median-values inside each 100 m elevation interval using. This has been added to the caption to make it clear

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Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-109, 2016.

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