

## ***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.***

### **Anonymous Referee #2**

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The study demonstrates a significant improvement in accuracy and precision of the CryoSat-2 data over ESA’s L2 product by implementing novel processing schemes for both the LRM and SIN modes. Detailed comparisons with NASA’s ATM and ICESat laser altimetry observations are used to quantify the improvement, indicating that the JPL products accurately depict ice sheet elevations, and elevation/volume changes at individual drainage basin and entire ice sheet scales. While I found the results impressive, the manuscript can be improved by (1) explaining the workflow of the study in the introduction, (2) including more details about the authors’ new method, and (3) presenting the different change detection and gridding methods used in a more rigorous and integrated fashion.

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(1) I recommend to include an overview describing the rationale for applying different change detection methods. For example, why was the DEM method used to examine the monthly elevation time series (Figure 3), and the surface-fit method to determine the magnitude and phase of seasonal variability (Figure 5)?

(2) the main result of the study is the introduction of novel procedures for determining the location of the radar returns on the ground. However, the methods are only briefly explained. For example, the validation of the LGM SIN retracking algorithm is presented only in the supplemental information.

(3) the description of the different change detection and gridding algorithms seem to follow the notation of the original publications, without attempting using a unified presentation. For example, the basic equation of the surface fitting model (eq.3) does not include random measurement error, but such an error is included in elevation residuals from the same method (eq.6) and in the elevation changes estimated using the crossover method (eq.7). Moreover, often the same notation is used for very different parameters. For example,  $a_0$  is the coefficient of one of the linear components of the surface shape in eq.3, the coefficient of the seasonal variation in eq.4, and the across-track slope in eq.8. Or  $a_6$  is used to describe the elevation change rate in eq.3,  $\Delta h / \Delta t$  in eq.6, and  $dh/dt$  in line 223. Also, I assume that the left-hand side in (eq.6) should be  $h(t,x,y)$ , rather than  $h(t)$ . Finally, there seems to be a discrepancy between the use of  $x,y$  as spatial coordinates in section 3.1-3.3 and the description of the Least Squares Collocation (LSC) solution in section 3.4.

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.

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

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estimate. This error is not referred in the manuscript.

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 (ICESSE). 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.

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

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

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.

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.

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