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Discussions

Interactive comment on "Validation of satellite altimetry by kinematic GNSS in central East Antarctica" *by* Ludwig Schröder et al.

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This study provides an extensive validation of several important satellite altimetry data sets used for mass-balance studies of the Antarctic Ice Sheet. It provides an important state of the art summary of the current capabilities of these altimetric products for monitoring the Antarctic Ice Sheet using validation data around Lake Vostok. The main novelty of the study is the introduction of large-scale GNSS-derived surface elevation profiles along several traverses from Vostok station to the East Antarctic coast. This has allowed for high-accuracy and independent validation of satellite derived surface elevation in Central-East Antarctica, where limited validation data has been available previously. This is an important step forward as this region of Antarctica has emerged as a special area of interest for mass-balance studies. The study compares three different altimeter missions (Envisat, CryoSat-2 and ICESat) and four digital elevation

models. The validation performed in this study confirms previous findings; that threshold retrackers should be preferred over model-based retrackers to reduce the volume – scattering effect on long-term radar altimetric-derived time series, superior results of the relocation versus direct method for slope correction. However, the main novelty and major improvement here is the introduction of a new inter-campaign bias for the ICESat mission (release 34), crucial for mass-balance studies, especially for East Antarctica. The novelty arises in the use of both ICESat and GNSS elevation crossover difference in the least-squares bias adjustment scheme, allowing for determination of absolute biases for the ICESat mission. Further, the study also clearly identifies Lake Vostok as an excellent validation site for satellite altimetry, supporting the conclusions of similar studies. I find the manuscript to be very well written, the data well presented and carefully analyzed. I recommend this study for publications if the following issues are addressed and solved:

General comments:

(1) One can clearly see that the inter-campaign biases differ from each other depending on the surface type or region used to derive them. What is the sensitivity of your or other solutions to surface type or possible location bias? I would like, if possible, some more discussion about this. This as the estimation of the inter-campaign bias I find to be the main outcome of this study.

(2) The choice of the crossover methods for the validation procedure, though very accurate and mature, has the limitations of limited spatial coverage and data density. It would be useful to include, or at least compare, the use of another method to judge the stability of the distribution used to derive the statistics. A small-scale study using the "average footprint method", which was initially discussed in the paper and applied in Wouters et al. (2015), might be of interest?

(3) The application of the 67 cm elevation bias in the CryoSat-2 Baseline C products I think needs to be discussed in a bit more detail, as this is one of the main differences

between the two ESA baselines. One can clearly see that the application of the bias pushes the radar horizon closer to the reference surface. For full-waveform retrackers, like ESA's, this has no major effect as they usually show high surface penetration. However, leading edge retrackers, which track closer to the surface (not using the entire waveform), will in many cases produce positive biases. This could, for example, be seen in your presentation at ESA living planet. As it forces the radar-laser surface bias to be positive, which is unphysical for radars, it begs the question: should the bias be applied?

(4) Stated in the manuscript is the preference for threshold retrackers over model based ones, as they are less affected by volume scattering, which has also been proven in other studies. However, I can't find any information about which threshold is used for the OCOG retracker for Envisat (25% for CryoSat-2)? It would be good to state them clearly in the manuscript.

(5) Figure 6 shows the relation between the relative change in elevation and backscatter at crossover locations over Lake Vostok. It would be interesting to see the effect of other waveform parameters, like LeW and TeS, in the same type of plot (preferably for both Envisat and CryoSat-2). Remy et al. (2012) suggested that the addition of these parameters would be more valuable understanding snow characteristic fluctuations using Envisat and CryoSat-2 derived time series. These parameters are already available or can be easily computed for the two products. I think the inclusion of these parameters in your analysis would provide heavier weight to your argument.

(6) I might be misunderstanding you, but what is the crossover time-span used to derive your validation statistics? I'm guessing you use all crossovers independent of time-span, as your elevation change signal is very small? If so, it would be good to state this in more detail in the manuscript, as crossover difference of less than 30 days has been the norm for previous validation studies, see (Khvorostovsky 2012).

(7) The Bernese software has been used for the processing of the GNSS data. How

does this software compare to the other available packages, like GIPSY? I think it would be good to discuss the impact (or differences) of different software packages on the results, maybe in sentence or two? Further, maybe direct the reader to a set of references for the curious.

(8) Has there been any attempt to validate or compare elevations over Lake Vostok using NASA's Operation IceBridge, to acquire another reference surface? If so how do they compare?

(9) The difference between the Bamber et al. (2009) DEM and Bedmap-2 is very interesting! Clearly the rounding will have an effect on the precision, but the -1 m bias is surprising? Is this bias spatially dependent, as different datasets have been merged together?

Detailed comments:

As no line-number has been provided in this version (available in editors version) in the manuscript I have added an annotated PDF-document instead.

Reference:

Bamber, J. L., J. L. Gomez-Dans, and J. A. Griggs. "A new 1 km digital elevation model of the Antarctic derived from combined satellite radar and laser data-Part 1: Data and methods." The Cryosphere 3.1 (2009): 101.

Khvorostovsky, Kirill S. "Merging and analysis of elevation time series over Greenland Ice Sheet from satellite radar altimetry." IEEE Transactions on Geoscience and Remote Sensing 50.1 (2012): 23-36.

Remy, F., et al. "Radar altimetry measurements over Antarctic Ice Sheet: A focus on antenna polarization and change in backscatter problems." Advances in Space Research 50.8 (2012): 998-1006.

Wouters, B., et al. "Dynamic thinning of glaciers on the Southern Antarctic Peninsula."

Science 348.6237 (2015): 899-903.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-282/tc-2016-282-RC1-supplement.pdf

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