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The Cryosphere Discussions

Interactive comment on "Improved GNSS-R bi-static altimetry and independent DEMs of Greenland and Antarctica from TechDemoSat-1" *by* Jessica Cartwright et al.

Anonymous Referee #1

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Summary

The authors derived new, static digital elevation models (DEMs) satellite Global Navigation Satellite Systems-Reflectometry (GNSS-R) for both the Greenland and Antarctic Ice Sheets. The DEMs are built off of 46 months of data collected between November 2014 and December 2018 and are posted at 25 km horizontal resolution. The work builds off a previous paper with an improved methodology to incorporate more measurements and shows that the resulting DEMs have better coverage, spatial resolution, and reduced bias in elevation.

Evaluation

Overall, the paper was adequately organized, and there were very few grammatical corrections needed. The methods were laid out sufficiently, although in some cases more detail than a simple citation to the prior paper by Cartwright et al. (2018) would have improved clarity. The largest concern is related to the potential use of the technique for cryospheric purposes. The coarse spatial resolution, coupled with the large uncertainties, makes it challenging to envision a crysopheric research question that would benefit from the technique as presented. The paper would largely benefit from the advice of a glaciologist that is familiar with ice sheet altimetry to strengthen their argument for future potential of ice sheet monitoring with satellite GNSS-R.

A few comments:

1. Line 27 states that the technique is "highly beneficial" to the cryosphere, but without further elaboration, the readers are forced to surmise what applications would benefit. With the results as presented, I was unable to make that connection. More descriptive cryosphere applications would improve the relevance of the paper for the Cryosphere

2. Line 91-92 describes how the vertical resolution varies depending on the satellite geometries, which is completely understandable. However, without any typical range, it really makes it difficult to determine for which applications the technique would be applicable. NASA launched ICESat-2 (laser altimeter) in late 2018, which is capable of monitoring the ice sheets to a precision of 4 mm per year, covering the planet every 91 days. This technique provides a static map and does not have nearly the same precision nor spatial resolution as other existing altimeters (ICESat/ICESat-2/CryoSat-2/etc). Any more insight into the vertical resolution would be largely valuable.

3. Beginning on Line 119, the authors describe the development of the DEM. It would be helpful to know the typical range of measurements that fall within one 25 km grid cell. Or even better, to show a map of the measurement counts within each grid cell for both ice sheets.

4. The Tables and Figures must have the units displayed.

5. Line 169: How much would consideration of slope effects improve the location accuracy of the point location? This seems like an opportunity for improvement of the technique, which could then lend itself to improved potential in future cryospheric applications.

6. Figure 1, please include the units and mask out the regions outside of your DEM (e.g., the southern ocean, etc.)

7. Figure 3, it appears that there are a line of TechDemoSat-2 heights that are biased low against the CryoSat-2 heights near the bottom of both plots. Any idea what this is related, too? Strongly sloping surfaces?

8. As stated by the authors in lines 210-211, there is large uncertainty in L-Band radiation penetration in the snow/firn. Is this fact the reason why the DEM is built over such a large spatial scale? This uncertainty is a very big limitation to the use of this data over the cryosphere where changes at the sub-centimeter scale are quite important.

9. Even with all of the limitations, I was hoping for more discussion of how to best move forward with improving the technique. A completely valid paper on the subject would state all of the limitations (and how we are nowhere near ready to produce numbers that are scientifically useable), but that future improvements will continue to nail down uncertainties and start to answer some of the more relevant concerns regarding the technique. A section at the end describing some of the largest uncertainties in surface elevation retrievals, along with potential future solutions, and what they would mean for the precision of the results would make this paper more relevant for the Cryosphere.

10. In section 6, please state where the TechDemoSat-1 DEMs that were generated are available.

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