Review

Assessment of Sentinel-3 Altimeter Performance over Antarctica using High Resolution Digital Elevation Models

This study assesses how well the Sentinel-3 SAR altimeters measure surface elevation across the diverse topography of the Antarctic Ice Sheet. Using new slope and roughness datasets derived from the REMA model, the authors examine how topographic conditions affect key steps in altimeter processing and the quality of the returned waveforms. The newer Sentinel-3 thematic product performs better than earlier versions, though altimeter accuracy still declines in areas with complex terrain, where not all surface features can be fully captured. The findings can help improve understanding of Sentinel-3 performance over ice sheets and offer guidance for enhancing future missions such as CRISTAL and the next-generation Sentinel-3 topography mission.

General notes:

I think this manuscript has been substantially improved and can be published once a few concerns have been addressed. In general, the manuscript is well written but quite long, with a strong focus on the derivation of surface slope and roughness, as well as the along-track correlation. In my view, these are not the most interesting or important aspects of the study; the key contributions are found in Sections 6.2 and 6.3. I suggest shortening the sections on slope/roughness and along-track analyses, and placing greater emphasis on window optimization and POCA analysis. Additionally, there is considerable back-and-forth between the BC-004 and BC-005 products. The focus should be on the latest version, as the older one is now redundant. This would also help streamline and clarify the manuscript. Nonetheless, I acknowledge that the paper is currently mature enough, and these suggestions are meant to help further refine the focus on the most important findings.

Line by line comments:

L40: "Subsequently, Sentinel-3 (S3), which to date comprises two satellites launched in 2016 and 2018, ushered in an era of operational monitoring and global Synthetic Aperture Radar (SAR) coverage, thus representing another significant milestone in the historical progression of satellite altimetry (Abdalla et al., 2021)" I think you have missed CryoSat-2 here as it lead the way for the operational use of SAR and SARIn. You should add an extra sentence of how CS2 has pawed the way for S3 in the form of technology development, especially as you dicuss ERS and Enivsat more than CS2. CS2 is just mentioned in passing, so add what CS2 have done for ice sheet application with a sentence or two.

L46: “the failure of assumptions used in Level-2 processing under such conditions, and the limitations of the instrument’s spatial resolution” — The assumptions and limitations should be stated explicitly for the reader.

L69: “due to numerous discrete regions of backscatter within the illuminated beam-limited footprint” — I would rephrase this as “due to differences in elevation within the illuminated pattern, as each peak in the waveform corresponds to a scattering surface at a different elevation.”

L103: The references (Villadsen et al., 2016; Passaro et al., 2022) are somewhat unusual here, as they relate to inland water and ocean processing. Adding ice-sheet-focused references would improve clarity, for example:

Aublanc, J., Boy, F., Borde, F., & Féménias, P. (2024). A facet based numerical model to retrieve ice sheet topography from Sentinel-3 altimetry. EGUsphere.

L122: “the magnitude of this slope correction can reach tens of meters vertically” — It can actually be much larger. I suggest noting that it can exceed 100 m for a 1° surface slope.

L124: I would also add the following reference:

Schröder et al. (2017). Validation of satellite altimetry by kinematic GNSS in central East Antarctica, The Cryosphere.

L195: “which operates with a delay-Doppler beam-limited footprint of ~300 m along-track by ~18.2 km across-track…” — This sentence is unclear. The 300 m along-track dimension is not beam-limited, and it’s ambiguous whether 18.2 km is a radius or diameter. Consider rewriting along the lines of:

“Sentinel-3 provides ~300 m along-track resolution through delay–Doppler processing, with a pulse-limited along-track footprint of XXX km and an overall beam-limited footprint of XXX.”

L303: Add a reference to the figure and associated table here, if they exist.

L397: The purpose of the aggregation step is unclear. A decorrelation length is relevant for multilooking because it directly affects waveform formation and retracking. However, elevation-change products are typically generated or compared at scales of ~1 km. Are you aiming to quantify how slope or roughness influences correlation in elevation-change estimates?

L441–445: This section could be shortened, as the information can be readily estimated by most algorithms and does not appear to represent a major new result.

L552: "The most substantial improvement occurs between 60 m and 120 m, with diminishing returns at larger window sizes." — This is an important conclusion and could benefit from more detailed discussion. This seems more impactful than the analysis of heading, which does not appear to be a major factor. Additionally, since BC-004 is now outdated, the focus should likely shift to BC-005, with the BC-004 analysis minimized.

L670: It is good that new algorithms were tested for deriving slope and roughness, but the manuscript states that they produce results similar to standard approaches. For that reason, this does not seem to be a major conclusion of the study. The more significant findings relate to window optimization and POCA capture.

L686: This is an interesting result, but it is not discussed in sufficient depth in the results section. More detail would add value, potentially replacing some of the extensive slope/roughness analysis.

L699: This may not be a new insight — it has long been understood that decorrelation increases over more complex surfaces.