

Reviewer 1 Response

Thank you for your comments and suggestions. Each of them will be addressed individually in the following and respective changes will be made to the manuscript.

Major Comments.:

1. *The paper lacks a comparison of the algorithm against a completely independent (of ICESat-2) in-situ source of ice freeboard data. One possible in-situ data source could be long-term time-series records of upper looking sonar data in the Beaufort Sea, in particular Mooring B, that is located above 78 degree north. The authors may suggest an alternative in-situ source of ice freeboard data, but I believe that an assessment against independent in-situ data is absolutely necessary to demonstrate the usefulness of the proposed approach.*

Thank you for the idea of comparing to upward looking sonar data. We agree that an additional comparison with entirely independent data would be a good addition to the manuscript. Unfortunately, there is no available above snow freeboard for the investigated time period, that could be used as validation. However, a comparison with upward looking sonar would be a good demonstration of the type of capabilities that an extrapolated freeboard product provides. We will work on including such a comparison in the next version of the manuscript.

We also want to set the expectations of such a comparison. The question we ask in the paper currently is "how well can we extrapolate ICESat-2 data using Sentinel-1?". The only way to answer that question is to compare the extrapolated data with real ICESat-2 data. From the coincident flights we have gathered a dataset consisting of approximately 500.000 datapoints. We believe this dataset is comprehensive enough to answer the question raised (for sea ice conditions similar to the ones investigated). The additional comparison with ULS will not give us a qualitative assessment of the extrapolation algorithms accuracy, because of the limited physical connection between ice draft and above snow freeboard. However, it will show how two measurement that could previously not be collocated can be brought together. We also expect that the same trends should be visible in both measurements.

2. *The algorithm is based on HV backscatter, that is much lower than HH, so HV is substantially affected by the thermal noise. Noise floor in Sentinel-1 EW data is very high (e.g., compared to the noise floor in RCM data); additionally, the noise exhibits a scalloping pattern in the image azimuth direction. The authors applied a noise correction routine in SNAP, but while this correction makes the HV image look nicer (less affected by noise), it does not really make HV signal more informative (i.e., it does not increase the HV signal dynamic range over darker targets like first-year sea ice). The different noise floor levels in different SAR instruments could substantially affect the correlations/relationships between HV and the freeboard/roughness. Therefore, the authors should investigate how the relatively high noise floor in Sentinel-1 affects their freeboard/roughness retrievals. This is especially important for thinner first-year ice where the HV signal could be very low reaching the noise floor level. I also wonder if it is feasible to build and assess the algorithm without the noise correction, but with using noise floor information as auxiliary input piece of information.*

Thank you for your suggestion. We applied the thermal noise removal by Park, Korosov et al, (see Data section, L. 73) which does help with the overall brightness

and therefore the accuracy of the extrapolation. You are right that locally no information is gained in areas with higher noise floors and therefore the extrapolation there is expected to perform worse. Currently I see no way of incorporating the noise floor information to sharpen the CDF-mapping.

To investigate the contribution of this noise to the errors is a fruitful idea. We will conduct an ablation study where the noisiest parts of the Sentinel-1 imagery are not used for the extrapolation to determine the impact of SAR signal noise and report the results.

3. *HV backscatter is sensitive to the incidence angle. The authors should discuss how the incidence angle variation in the image (20-50 degrees) affects the accuracy of the freeboard*

While HV backscatter is sensitive to the incidence angle, the dependencies are quite small (compared to HH). So, we do not expect there to be a large impact. We will include some additional discussion in the revised version and try to quantify the influence of this effect on the accuracy of extrapolation.

Minor Comments:

Thank you for finding and pointing out these errors. We will do our best to clean up the spelling and formatting for the rest of the document too.