Responses to Reviewer 1's comments (*in blue*):

This article documents the improvements of sea-surface identification with ICESat-2 altimetric measurements for sea ice, and the ensuing changes in the new release (i.e., ver. 3) of sea ice freeboard. Specifically, photon rate on dark leads can be reduced by cloud, which may cause mis-categorization as sea level tie points and result in under-estimation of sea ice freeboard. A case study with collocating airborne measurements is carried out, and a correction is introduced to utilize only specular returns for lead detection and sea-level computation. Basin-scale effects on freeboard estimation is also studied for Arctic and Antarctic retrieval. Given the importance of the ICESat-2 measurements for the ongoing and future observation of sea ice thickness, this work is an important and timely update for the polar research community. The article is also well-written, and the representation of the results are very good. However, I find several aspects that can be improved especially in the results and analysis part. My major comments and questions are as follows.

We thank the reviewer for the valuable comments and suggested revisions.

Major comment 1: one key analysis that I suggest to add, is the study/validation with collocating tracks of ICESat-2 and OIB. For example, the 4 OIB tracks as used in Kwok et al (2019), which showed very good consistency between OIB and IS-2 elevation, can be utilized. In fact, in Kwok et al. (2019), the effect on freeboard retrieval is discussed. But key info (including the systematic differences of freeboard, as shown Tab. 1 of the reference) may be different from the current version of the IS-2 data, including protocols, etc. Besides the basin-scale comparisons as in Sec. 5 of the manuscript, the study on the fine spatial scale may be more informative of the performance of the new treatments, as well as the consistency with OIB which feature a sea level retrieval with more comprehensive measurements. This revision is also necessary to improve the overall content of Sec. 5, which in its current form is too short and contains limited result and analysis.

As suggested, we have repeated the analysis in Kwok et al. (2019). There were only two days where there were sea surfaces identified in the IS-2 data (April 12 and April 22). As mentioned in Kwok et al. (2019) the winds were light and the ice cover was extremely compact along these flight lines. While these conditions were ideal for acquiring coincident sea ice data sets, they were not conducive to ice deformation or open water production (i.e., leads) required for computing freeboard. Only 4 segments (10 km in length) were available for assessment of the retrieved freeboards. The results show that the IS-2 freeboards were lower than the ATM freeboards by between 3-4 cm. For the small number of samples, we did not conclude at the time that these biases were significant.

In repeating the analysis, the sea surfaces in Release 2 were not available in Release 3. This indicated that the sea surfaces used in the Kwok et al. analysis were dark leads (i.e., not classified as sea surfaces) and no longer designated as sea level references for use in freeboard calculations. This suggests that the lower IS-2 freeboards in the previous analysis may be (because of the small number of samples) due to the impact of dark leads – providing a higher (biased) sea surface and thus lower IS-2 freeboards.

Major comment 2: previous release (ver. 2) of sea ice freeboard (ATL07) contains swath-wide freeboard estimations, by using sea-level estimations across all 3 strong beams. This effectively mitigates the problem of missing parts of the beam ground segments when ssh is computed within a single beam. Besides, there also exists effect on the freeboard value for each beam segment. Since about 10% to 20% coverage is lost due to the new treatments (that excludes dark leads), this cross-beam processing could be potentially important in salvaging more data. The authors are suggested to clarify both ends of the comparison. First, whether the previous version of freeboard (R002) is based on per-beam freeboard OR swath-wide freeboard. Second, whether the new version of freeboard (R003) is based on per-beam freeboard OR swath-wide freeboard. Furthermore, whether there is a swath-wide freeboard estimation in the newly-released version of the ATL data.

Good point. Indeed, previous releases (vers. 1 & 2) of sea ice freeboards (in ATL10) included swath-wide freeboard estimations, by using sea-level estimations across all 3 strong beams. The swath-wide freeboard estimations should not have been and are no longer provided to users in Release 3 of ATL10 (discussed in the 'Notes to users and known issues document' – URL below). The release of the multi-beam estimates was due to an error in software implementation, which allowed the multi-beam estimates to be released. The reason for not distributing the swath-based estimates is that there are residual range biases between the heights of the three beams and until that calibration of the inter- and intra-beam range biases are available, the multi-beam biases will not be released.

https://nsidc.org/sites/nsidc.org/files/technical-references/ICESat2_ATL07_ATL10_Known_Issues_v003_Sept2020.pdf

Major comment 3: the discussion of the potential effect of the new scheme on sea ice thickness is suggested to be added. During wintertime (first row in Fig. 5 and third row in Fig. 6), the average total freeboard increased by about 3cm with the new treatments. This directly translates into about 30cm systematic increase in sea ice thickness (if the snow conditions stay the same). Does this help to mitigate the observed differences between ICESat-2 thickness and CryoSat-2 estimations? [Fig. 14 of Petty et al (2020), and related text contents] The lack of detectable leads can be especially prominent within the packed ice region in the Arctic. What is the impact of losing 10% to 20% ICESat-2 measurements on the estimation of ice thickness in this region and the total volume?

We are currently exploring the impact on sea ice thickness and the comparisons with CryoSat-2 thickness estimates, following on from the initial results shown in Petty et al., (2020). The reviewer is correct that the increased freeboards correspond to a significant increase in ice thickness, with the exact magnitude depending on the region and season. Our preliminary analysis across the CS-2 products suggests this pretty consistently improves the correspondence between the ICESat-2 and CryoSat-2 thickness when calculated using hydrostatic equilibrium and the same input assumptions. We choose not to show these results in this paper to keep the focus on the publicly available ICESat-2 sea ice freeboard product distributed by the ICESat-2 mission. We plan to write up the thickness comparisons in a forthcoming paper. We have yet to calculate sea ice volume, but do expect that the decreased coverage will pose a challenge, and potentially the need to introduce spatial interpolation if one was to do so.

Minor comments:

The analysis has been focused on strong beams of IS-2. What is the effect on the retrieval of weak beams? Does the loss of 10% to 20% of coverage include statistics from weak beams? Given the lower power of these beams (#2, #4 and #6) and the lower photon rates, is the data loss rate higher in weak beams than strong beams with the new treatments in R003?

The analysis is only on the strong beams. Yes, the data loss is higher. However, at this time the ICESat-2 project does not recommend the use of the weak beams because of the long integration distance needed to construct height and sea surface estimates. This is discussed in the 'known issues' document at NSIDC.

Line 33, page 4: delete extra '.' after 'use'.

Done.

Line 11, page 5: "the second percentile in . . .".
Corrected.

Line 12, page 5: ". . . for smooth surfaces in IS-2 the retrieved heights" should be ". . . for smooth surfaces in the retrieved heights of IS-2".
Corrected.

Line 25, page 5: the definition of H_lower is missing.
Corrected.

Line 11, page 6: add the missing ".".
Done.

Line 17, page 8: delete the extra space.

Done.

Fig. 1 (on pg. 13): the second mode of lead width for Arctic winter by beam #3 is offset from those of beam #1 and #5 by 10 meters [top-right and bottom right sub-figure of subfigure (a)] . Why?
The reason for this is that transmitted energy for Beam 3 is approximately 80% that of Beams 1 and 3. Thus, it takes a longer distance to aggregate the 150 photons used for height estimate in the surface finding procedure. This is now discussed in the text.