Responses to Reviewer 2's comments (*in blue):*

General comments: This is a challenging and valuable paper to attempt to map the distribution of snow depth, sea ice thickness, and ice volume for Antarctic sea ice on a hemispheric scale for the first time, by combining satellite lidar (ICESat-2) and radar (CryoSat-2) altimeters. The major motivation is to improve our understanding of the recent decreasing trend of Antarctic sea ice extents. For this purpose, the authors estimated the surface elevation with ICESat-2 and the ice freeboard with CryoSat-2 and obtained the snow depth distribution from the difference between these datasets and the ice thickness and ice volume distribution assuming isostatic balance. They also conducted the error estimates from uncertainties of various factors that contribute to the freeboard measurements. As a result, the geographical and seasonal properties of freeboard, snow depth, and ice thickness were revealed on a hemispheric for the first time. Besides, by comparting the two datasets, some unique features are suggested; such as more than 60-70% of the total freeboard is snow. It is well known that the behavior of the Antarctic sea ice extents has different characteristics from that of the Arctic sea ice extents. However, the mechanism has not been well understood due to the lack of the hemispheric scale information of the Antarctic sea ice so far. While Worby et al. (2008) showed the hemispheric ice thickness distribution of Antarctic sea ice by compiling the visual observations conducted according to the ASPeCt protocol, there has been a lot of uncertainties about the seasonality and the biases caused by the observational methods. I think many scientists have been waiting for the estimation of the hemispheric snow depth, ice thickness, and ice volume distribution based on the satellite datasets. This paper can provide a breakthrough about this topic and contain a lot of implications. Therefore, I recommend publication with minor revisions. Having said that, I have several concerns. I would appreciate it if the authors address them before publication.

We thank the reviewer for his/her time in reviewing the manuscript and providing helpful comments for improving the revised manuscript.

The major points are as follows:

1) The lack of discussion about the different footprints of the two satellite sensors. Since the distributions of snow depth and ice thickness are usually anisotropic especially at deformed ice area, I am wondering if difference in footprint might affect the results. Even though the precise discussion might be difficult, I recommend some discussion about this.

All our calculations are performed with 25-km averages to avoid some of the pitfalls of sampling disparities between the two altimeters. We will note this in the sampling description (Section 4) to alert the reader to the potential differences due to the resolution in freeboard retrievals from IS2 and CS2.

2) Units of parameters In the manuscript, the CGS unit (cm, g, g/cm3) and MKS unit (m, kg, kg/m3) are mixed, which might be confusing. I think it would be better to unify them to SI unit.

Because of difference in the magnitude of snow depth and ice thickness (a factor of ten) we have consistently kept snow depths in centimeters and thicknesses in meters. We believe the community (at least the remote sensing community) generally thinks in those units.

3) Discussions with the correlation between IS-2 and CS-2 (Fig. 4) There are several speculations about the dominant growth processes based on the correlation between the IS-2 derived and the CS-2 derived freeboards at each subsection in section 3.2 (for example, P6L39-P7L3, PL14-L19). However, I feel there are some other possible reasons for good correlations between them and the ground for their speculation is not necessarily strong. So further evidence might be needed. Please first explain in what kind situation the correlation becomes high, and then discuss the possible processes in each sector.

The key processes that affect the variability and co-variability of the total and ice freeboards are addressed in the Section 3.1. The discussion, where we examined the contribution of the processes that affect freeboards, provided the basis for our interpretation of the time-varying IS-2 and CS-2 freeboard estimates in subsequent section.

4) The suggestions of future field observation based on the results I would recommend the authors to suggest what kind of field observations will be required in the future to improve the accuracy of their estimations, based on their results, in the conclusion section. In the Antarctic sea ice area, there are complex snow-ice conditions, such as the presence of slush layers caused by flooding, a wide range of snow density caused by snow metamorphosis, the presence of void layers caused by deformation processes. Such suggestions would be very useful for the research community.

Our last bullet in the conclusion highlighted the need for field and other observations for validation of these satellite data sets. The suggestions of specific observations and spacetime sampling are quite beyond the scope of the current manuscript (which already is quite lengthy). However, we added that coordinated field/remote sensing observations are needed if large-scale satellite retrievals are to be validated and made more useful to the broader community.

Specific comments:

**(P2L23-24) "the first approach. . . The second. . .. The third method. . ." Please add citation.*

These different approaches are cited beforehand, P2L20-22.

**(P2, section 2) Please add the footprint of each sensor. *(P4L18) "signs indication" might be "signs indicate".*

Section 2 (page 2) describes the products used in this study. We added the size of the footprints of the sea ice retrievals in the ICESat-2 and CS-2 height estimates.

**(P4L19) "Snowfall adds to the snow layer" To be exact, "Snowfall precipitation minus evaporation (P-E)".*

Yes, we have clarified this in the text.

**(P4L20) "fvalue" might be "value"?*

Corrected.

**(P6L19-20) "Both the total and CS-2 freeboards…" What do you mean by "a balance of different processes"?*

We explain the rather low-variability of the total and radar freeboards by a balance of competing processes that affect them (thermodynamics and dynamics).

**(P6L25) "0.75x10^6 km^2" might be "0.75x10^6 km^2 per year"?*
The value of the average annual export (a 34-year average) – this has been clarified in the text.

**(P7L4) "160°W and 90°E" might be "160°E and 90°E"?*

Corrected.

**(P8L7) "one free parameter" Could you explain what this parameter means physically?*

The free parameter here is the refractive index of the medium, which is described P8L8-9. Physically, it describes the speed of light in the snow layer, to first order, is dependent on the bulk density of snow.

**(P8L11) Please add ", respectively" after snow-ice interface".*

Corrected.

**(P9L2) What caused the uncertainty in snow density? Spatial variation, or measurement error?*

This is largely due to the spatial variability of the snow layer, which is dependent on age of the snow, the prevailing and weather conditions.

**(P9L3) What do you mean by "one free parameter"?*

The one free parameter in our approach is the snow density (that is used to compute the refractive index – see above). By free parameter we mean that all the other parameters in

the equation are determined by observations and the only parameter left is the refractive index.

**(P9L5) I would recommend the authors to change the name of this subsection title to "sensitivity of the sampling frequency to calculations" or something like that. The current title might not be straightforward.*

We appreciate the reviewer's suggestion; we have added sensitivity to the title.

**(P9L30-32) I am wondering if this explanation is sufficient. I think more detailed discussion about the spatial scales of deformation and the sensor's footprint.*

See our comment above.

**(P10L6) "is likely due to.." You can add "and also smaller amount of P-E compared with other regions" The annual mean P-E distribution around the Antarctica is given by the following paper:*

Cullather, R.I., Bromwich, D.H., and Van Woert, M.L. (1998) Spatial and temporal variability of Antarctic precipitation from atmospheric methods. Journal of Climate, 11, 334-367.

Toyota T., Massom R., Lecomte O., Nomura D., Heil P., Tamura T. and Fraser A.D. (2016) On the extraordinary snow on the sea ice off East Antarctica in late winter, 2012. Deep-Sea Res. II, 131, 53-67.

We think that the largest contribution to the thin snow cover is the age of the ice produced in the polynya. Perhaps a higher order process is the smaller P-E in the region. We have cited the above as a potential explanation of the observed retrieval.

**(P10L7-8) "The spatial patterns show…" It might be possible that this is just because the ice-covered period becomes shorter toward the marginal ice zone. What do you think?*

Yes, this is what we meant to imply – the ice-covered period becomes progressively shorter on average towards the MIZ.

**(P10L14-15) "In all other sectors, we find. . ." The result is quite interesting. This might be a good evidence especially for the loss into leads, as suggested by the above paper.*

Yes, we agree although this is a different process compared to P-E.

**(P10L30-37) In the end, what du you think is the major reason for the negative bias?*

The discussion about the different reason for the observed biases are described P11L1-16.

(P11L26) "by assuming that the snow depth is equal to the total (or IS-2) freeboard." Is this based on the observational facts? If so, please cite some papers which support this idea. If you can justify this assumption, it would be supportive of your results.

There is no physical evidence that the total freeboard everywhere in the Antarctic is composed of snow. The calculation (in Equation 12) only allows us to obtain a lower bound of ice thickness by assuming that total freeboard to be equal to snow depth (i.e., lower density than ice).

(P14L31) "an indication of total freeboard changes rather actual change in ice thickness" Then, what caused the change in freeboard?

Due to a change in snow depth - we clarified this in the text.

(Figure 4) "Total freeboard" might be changed to "Total (IS-2) freeboard" to avoid confusion. Please add the explanation about what the color means in Fig.4a.

Changed and added the explanation of colors.

(Figure 5) It is hard to detect what the color means. The color bar should be placed at the bottom of the figure.

Modified as suggested.

(Figure 6) Please add the explanation about what the thick solid line means.

Added.