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The Cryosphere Discussions
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Interactive comment on "The Antarctic sea ice cover from ICESat-2 and CryoSat-2: freeboard, snow depth and ice thickness" *by* Sahra Kacimi and Ron Kwok

Anonymous Referee #2

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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

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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. 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.

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.

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

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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.

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.

Specific comments:

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

*(P2, section 2) Please add the footprint of each sensor.

*(P4L18) “signs indication” might be “signs indicate”.

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

*(P4L20) “fvalue” might be “value”?

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

*(P6L25) “0.75x10ˆ6 kmˆ2” might be “0.75x10ˆ6 kmˆ2 per year”?

*(P7L4) “160oW and 90oE” might be “160oE and 90oE”?

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

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

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

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

*(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.

*(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.

*(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.

*(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?

*(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.

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

*(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.

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

*(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.

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

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

That is all. Faithfully yours.

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