Dear Reviewer:

We would like to express our gratitude to you for the comments to improve this manuscript. However, we need to clarify that the purpose of this paper is to give a comprehensive and statistical comparison between Envisat and ICESat sea ice thickness data. Only when the significant differences are admitted, the importance of dealing with the uncertainties of these products is revealed. Besides, we have already discussed the probable causes of the differences in section 4 and we supply more experiments following your suggestions.
The specific responses and revisions are shown below. They are in blue font for clarity.

Qinghua Yang, Qian Shi, Robert Ricker, Stefan Hendricks
On behalf of all the authors

Major concerns:
L90-92. I think the comparison of the two SIT products with ULS is not appropriate since the single measurement point (6-8 m) cannot represent a grid with 50 km or even 100 km. Moreover, only the uncertainty of sea ice draft derived with ULS 5-12 cm is presented (L152-153), the uncertainty of SIT derived with Eq. 4 is missing and Fig.3 also lacks error bars for ULS, thus making the comparison unreliable. "Both Envisat and ICESat SIT have been interpolated onto each ULS location in the nearest neighbour way" (L183-184) further introduces huge uncertainties. Based on these considerations, it is not recommended to use ULS as a comparison data source. ULS can be used if the Envisat or ICESat footprints spatio-temporally coincide with it, and the uncertainty of SIT derived with ULS is clear.
Thanks for your comments. However, we think that you are biased in denying the feasibility of using ULS data as comparison data with ICESat-1/Envisat due to their relatively narrow footprint. As we know, ULS indeed measures the continuous ice draft in a fixed location with a diameter of several meters. Considering the ice motion, ULS acquired dozens to hundreds of kilometers records along the trajectory of sea ice motion on a monthly basis, which have enough spatial representativeness compared with ICESat-1/Envisat. Here, we track the source of sea ice that flows over the ULS in a specified month by backward tracking method based on NSIDC Pathfinder data sets. We find the ice draft records included in ULS monthly mean calculation come from a wide range area (Fig. 1). Therefore, we think this is enough to prove that the spatial representativeness of the monthly average ULS data can be compared with that of ICESat-1/Envisat.
Besides, ULS data was generally used for ice thickness comparison in the previous studies. ULS is used for comparison with the ice thickness derived from AVHRR (Yu and Rothrock, 1996; Drucker et al., 2003). It was also used to compare with ICESat-1 ice thickness in the Fram Strait (Spreen et al., 2009). In addition, the ULS data sets have also been used for comparison with reanalyses data in the polar region (Mu et al., 2018; Shi et al., 2021). In addition, the comparison with ULS data sets is also a convention for assessing the quality of ice thickness derived from altimeters in the European Space Agency (Kern et al., 2018).
In summary, we think that the reason for rejecting us due to the spatial representativeness of ULS ice thickness is untenable. Previous studies (referred to above) have shown that using ULS for validation of satellite-derived sea-ice thickness data sets can be considered as state of the art.

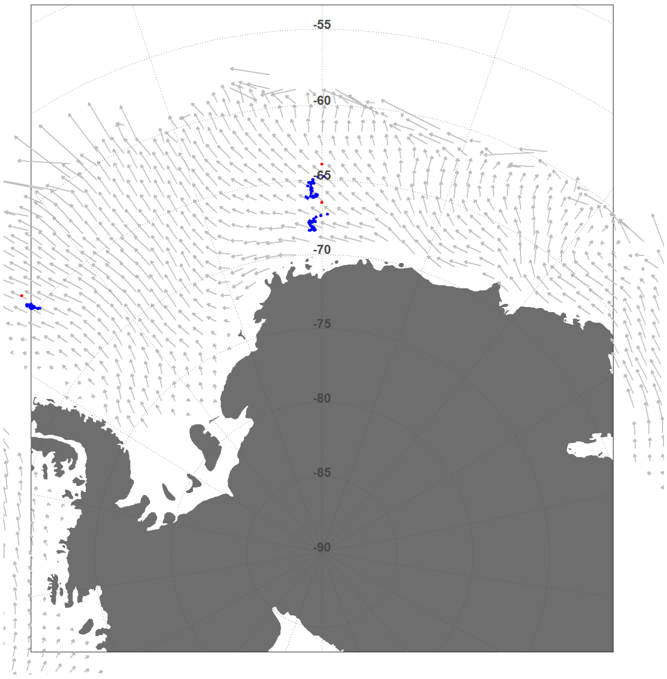

Fig. 1 The 30-day origins of the sea ice passing the three ULS sites in July 2011. The red dots stand for the ULS locations and the blue dots stand for the original locations of the sea ice using backward tracking method.

The difference between the Envisat-based actual SIT, i.e., the mean thickness of the icecovered fraction of the grid cell area (without open water areas) (L122-123), and the ICESat effective sea ice thickness, i.e., mean thickness per grid cell including open water areas (L141-142), is not tackled nor discussed for the two datasets.

We point out the different thickness representations for Envisat and ICESat. And we choose to compare the effective sea ice thickness during the intercomparison process. We have clarified this in the paper (L229).

Considering the huge differences between Envisat and ICESat SIT products (as can be seen in Fig. 9 and Table 7), the main object of this work should not stay at just comparing those products, but concentrating on the qualitative and quantitative analysis of the causes leading to the differences. Currently, these issures are only simply discussed in Section 4. Following works may be considered by the authors:

L253-254 About the sentence "Probably inferring that …" Is it really the key reason for SIT overestimation of Envisat than ICESat in autumn? The similar doubt also appears in summer (L262-263).
L21 and L256-257. Why on earth the mean Envisat SIT decreases while the mean ICESat SIT increases from autumn to spring? This should be supported with supplement experiments.
L360-361. "The largest effect might not come from the impact of ice deformation on the snow-depth retrieval but might be due to the difference between actual snow depth from that represented by the climatology." Can the influence of climatology quantified?
I didn't see solid evidences supporting the statement "The potential overestimation of sea ice freeboard caused by range biases accounts for much of the differences between Envisat and ICESat SIT in summer and autumn, while the biases of snow depth are not the dominant cause of the differences."

(1) We realized that the statement is correct only for along-track data. Firstly, given the sparseness of ICESat overpasses with valid data such a 100 km grid SIT estimate in that region might be biased by the presence of thick landfast ice. Besides, ocean swell can result in anomalously high freeboard values which then convert into too high sea-ice thickness values. While this is a local phenomenon, the sparseness of ICESat overpasses with valid data can results in a similar effect as for landfast ice. Therefore, we considered the two issues here carefully and decided to remove this statement.

(2) We conduct the forward tracking on daily FDD with the NSIDC sea ice motion data to add the dynamic effects on the purely thermodynamic growth pattern (Fig. 2). We find that with the aid of sea ice motion, thick ice in the Weddell Sea and Ross Sea can be moved northward. However, the Envisat SIT decrease during MJON still cannot be explained considering the dynamic processes. Therefore, we assume the main reason of the SIT decrease is the overestimation of Envisat SIT in autumn. As for the snow fall patterns, we think it difficult to quantify the impact of snow, i.e., in which way the snow fall would lead to the sea ice thickness growth.

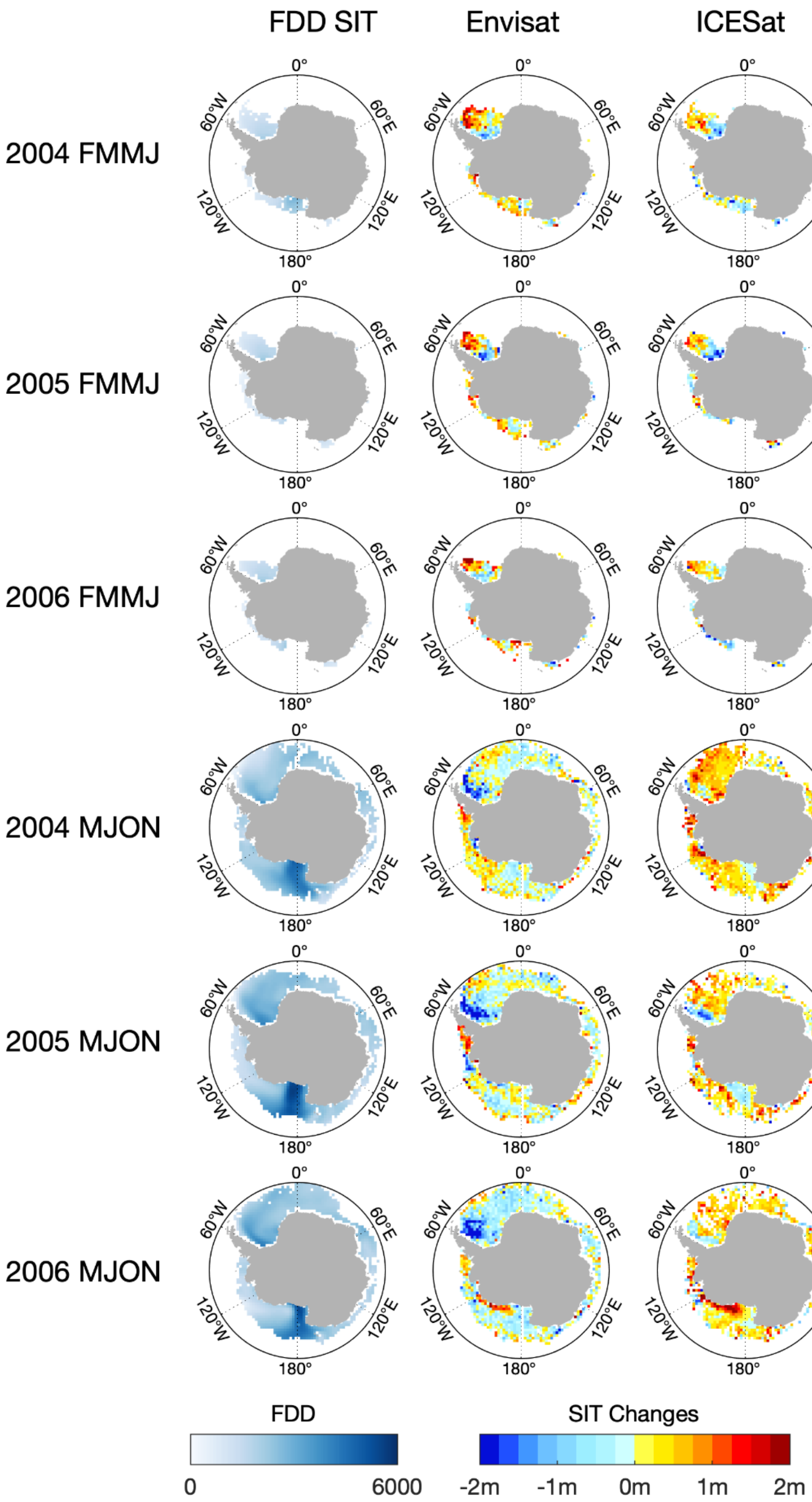

Fig. 2 The FDD differences and sea ice thickness differences from summer to autumn (FMMJ) and from autumn to spring (MJON) derived from Envisat and ICESat in 2004, 2005 and 2006. The FDD patterns are derived by forward tracking daily FDD with sea ice motion data.

(3) We quantify the contribution of the usage of snow depth climatology instead of actual snow depth

during the Envisat SIT retrieval, in response to one of the RC2's major concerns. We redo the retrieval of Envisat SIT by replacing the snow depth climatology with SICCI AMSR-E snow depth on level-3 sea ice freeboard data. The new Envisat SIT is compared with ICESat SIT and the variations of their differences are shown in Fig. 3. This figure reveals that the impact of snow depth climatology is relatively small, with a maximum variation of 0.34 m. The variations are larger in the Amundsen and Bellingshausen Sea and the Western Weddell Sea, compared to other sectors. Among the three seasons, the variations are larger in summer.

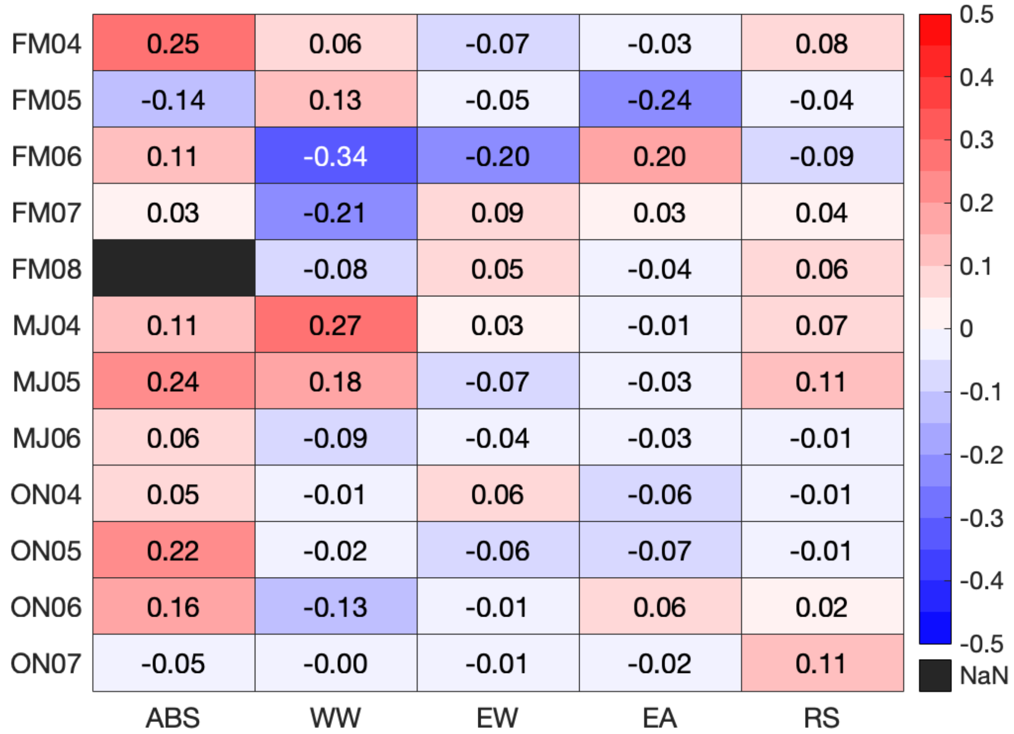

Fig. 3 Changes in the differences between Envisat and ICESat SIT for each comparison period and each region under the experiment of the snow depth climatology impacts.

(4) We conclude the sensitivity of the SIT changes to freeboard biases, snow depth biases and sea ice density in Fig. 4 by analyzing Eq. (1):

$$I = \frac{F\rho_{water} + S\rho_{snow}}{\rho_{water} - \rho_{ice}} \quad (1)$$

The sensitivities to freeboard biases and to snow depth biases are calculated by:

$$\frac{dI}{dF} = \frac{\rho_{water}}{\rho_{water} - \rho_{ice}} \quad (2)$$

$$\frac{dI}{dS} = \frac{\rho_{snow}}{\rho_{water} - \rho_{ice}} \quad (3)$$

From Fig. 4, we can see that though the magnitudes of the resulting thickness changes are quite similar, the SIT changes are more sensitive to sea ice freeboard biases than to snow depth biases. Besides, with the increase of sea ice density, the SIT changes rise. For typical sea ice freeboard biases (7 cm for the Arctic nominal adjustment suggested by Nandan et al. (2017, 2020)), the sea ice density variations induce the thickness changes ranging from ~0.5 m to ~0.8 m. For typical snow depth biases (20 cm for the monthly mean retrieval uncertainty in Kern and Ozsoy-Cicek (2016)), the thickness changes from ~0.4 m to ~0.7 m. Although this sensitivity analysis is not solid enough for the explanation for the SIT differences in three seasons, it can provide a reasonable conjecture that freeboard biases are the main cause of the positive differences in summer and autumn.

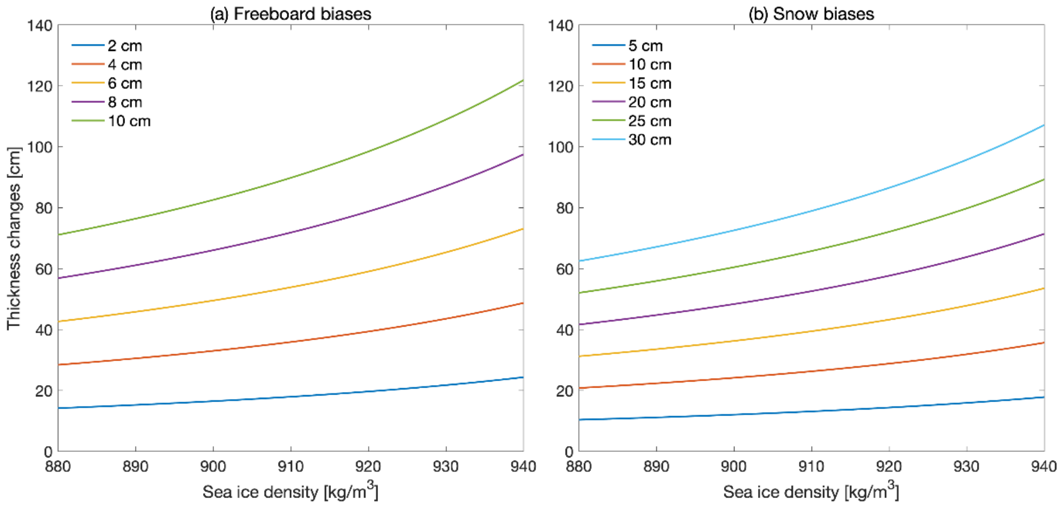

Fig. 4 Sensitivity of sea ice thickness changes to sea ice freeboard biases and snow depth biases as function of sea ice density. (a) SIT changes computed with Eq. (1) for different sea ice freeboard biases (2 cm to 10 cm). (b) Similar to (a) but computed for different snow depth biases (5 cm to 30 cm).

L124 The sea ice thickness derived with the modified ice density approach, i.e., Eq.3 can be considered to be updated to the new OLMi method (Xu, et al. (2021). "Deriving Antarctic Sea-Ice Thickness from Satellite Altimetry and Estimating Consistency for NASA's ICESat/ICESat-2 Missions." Geophysical Research Letters. http://dx.doi.org/10.1029/2021GL093425), which showed the modified ice density approach in Kern et al. (2016) would overestimate SIT.

Thanks for your information. We conduct the comparison between the Envisat SIT and the new ICESat SIT derived by Xu et al. (2021). Figure 5 shows consistent positive variations, with larger ones in summer, especially in the Amundsen and the Bellingshausen Sea and the Western Weddell Sea. However, we decide not to focus on the quality of different ICESat SIT, but investigate the causes of the differences between Envisat and ICESat SIT. Therefore, we keep using the ICESat product from Kern et al. (2016) and discuss its uncertainties in section 4.3.

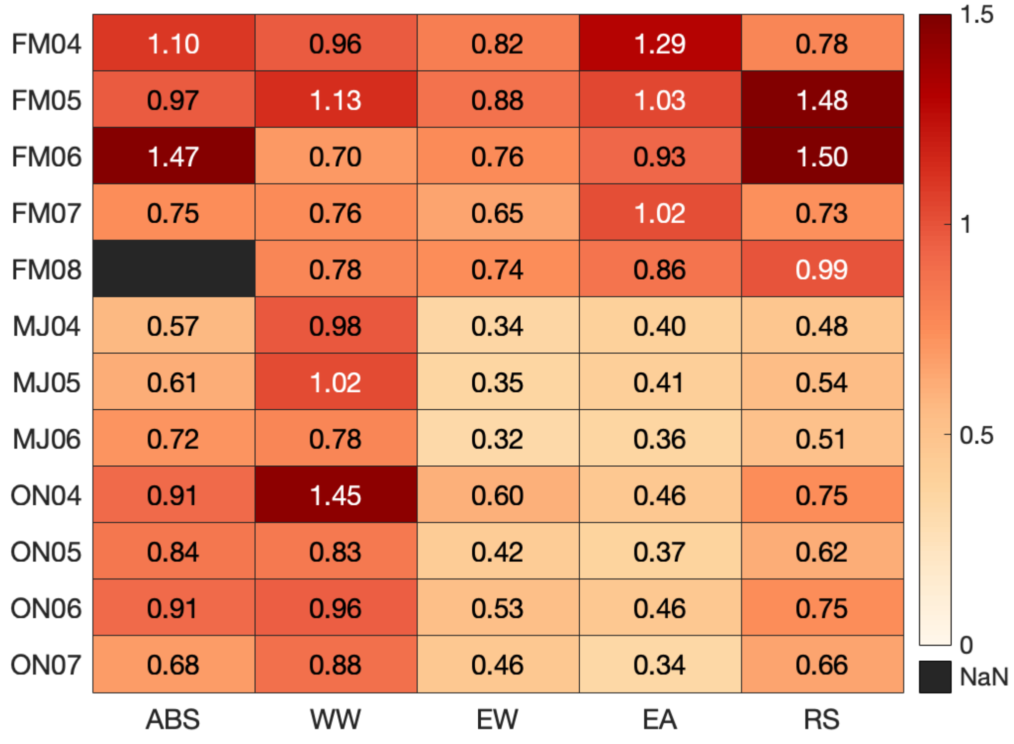

Fig. 5 Changes in the differences between Envisat and ICESat SIT for each comparison period and each region under the experiment of the new OLMi ICESat SIT.

Minor concerns:

L22-24 Please quantify the percentage of the uncertainties caused by the radar backscatter and snow depth products respectively.

The new sensitivity analyses are shown above. Since the exact freeboard biases and snow depth biases cannot be quantified, we can only achieve a general SIT change coming from either of them.

L64 “the radar altimetry SIT retrievals” to “SIT retrieval by the radar altimetry”

We modified it as you suggested.

Are the densities used in Eq. 1 and Eq.2/3 the same? If not, how does it influence the SIT retrieved by the two sensors?

Yes, the densities are similar. The ρ_water in Eq.1 is 1024 kg m^{-3} while in Eq.3 is 1023.9 kg m^{-3}. The ρ_ice in Eq.1 is 916.7 kg m^{-3} while in Eq. 2 is 915.1 kg m^{-3}. The ρ_snow in Eq.1 and Eq.2 are the same of 300 kg m^{-3}.

L166 and L271 MF-MJ or MJ-MF? MJ-ON or ON-MJ? Please unify them throughout the paper, such as those 'MJ-ON' (in the text) or 'ON-MJ' (Fig. 8).

We unified the descriptions to “FMMJ” and “MJON” throughout the paper.

Why is it called snow depth climatology (L66, L118), snow-depth climatology (L119), or snow climatology (L363), and what is the real difference between them and the actual snow depth? Besides, what is the meaning of “have the character of a climatology” (L386)?

We unified the descriptions to “snow depth climatology”. This snow depth climatology is an average snow depth based on 2002-2011 and it neglects the interannual variations of the snow depth. “Have the character if a climatology" means that the sea ice thickness derived from Li et al. (2018) is still affected by the usage of climatology data.

L270 "from the model" is unclear.

We corrected this sentence to: "We calculate the period-average FDD corresponding to ICESat operating periods for the same spatial coverage."

L274-276 I don't think it is an adverse pattern comparing MJ-ON with FM-MJ. Please also make "different abilities" clear.

We replaced "adverse" with "opposite". "Different abilities" represent the ability to detect small-scale deformation processes.

L284-285 the weighted average is in the first row instead of in the last column?

We meant to explain the numbers in the last column and we moved this sentence to the caption in Table 7: "N is the numbers of comparison pairs, taking into account the actual number of values per season."

L379-381. The sentence "Therefore, …the ice-snow column" is hard to understand. For example, "underestimations of sea ice and snow observations" is not clear, is it sea ice thickness and snow depth underestimation? What is the "apparent ice density"?

Since visual ship-based observations of sea ice thickness and snow depth are used in the ICESat SIT retrieval, the underestimations of these data can have effects on the modified ice-snow density. We amended the sentence to: "Therefore, the largest uncertainty of ICESat comes from the potential underestimations of the ship-based sea ice thickness and snow depth observations for the computation of the bulk density of the ice-snow column (Kern et al., 2016)."

Fig.8 Suggest to use the same Antarctica background (in grey) as that in the other figures such as Fig. 4/5/6 since we can notice the big blank area along the Ross Sea coast in this figure.

We modified this figure as shown in Fig. 2.

Table 4 what's N? It should be introduced in the title. Same happens in Table 5/6/7.

N is the number of comparison pairs. We added this introduction in the captions of the tables.

Table 5. I suggest to also compute the difference between ENV and ICE at grid scale instead of just subtract with the computed statistical values (the "Difference" column). I mean, the mean of the third column of Figure 4/5/6 should be computed. Based on the figures, I think the two values would be different.

The averages of the difference patterns are calculated only for the grid cells with both available Envisat and ICESat SIT. Therefore, the two ways would lead to the same results.

Table 6. "sea ice thickness differences" should be followed by "with standard deviation in brackets".

We added this information in the caption.

References:

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