We sincerely thank the Reviewer for the constructive comments on the manuscript. The reviewer's insights and suggestions have been extremely helpful in improving the quality of our work. We have thoroughly considered each comment and have made the following responses and revisions. The amendments are marked in red in the revision.

Next, we respond point by point to the comments.

General Comments

This paper presents a new time series of Arctic sea ice thickness over nearly 30 years based on altimetry observations with an unprecedented resolution of 5km. This is an important subject because only one other series of this length exists to date, and it may help to confirm the initial results and the relevance of this type of monitoring of the state of the sea ice. The comparison is even more interesting as the method used is new and totally independent of the previous ones. It relies on the multiplication of altimetric freeboard measurements in each 5km x 5km grid cell, to determine the thickness of the ice without preconceived ideas about parameters such as density or snow depth. For these reasons, I believe that this work deserves to be published.

Nevertheless, some important concepts have been overlooked, leading to dubious interpretations of certain results. In particular, the authors do not distinguish between the freeboard measured by Ku-band radar altimeters and the freeboard of the ice, which leads to erroneous equations that mainly affect the validation part. Because snow reduces the speed of propagation of the radar wave, the radar freeboard is necessarily smaller than the ice freeboard, and these 2 freeboards cannot be compared directly. The comparisons with OIB freeboard Figure 3 are therefore questionable. For the comparisons with ULS the used ice density is not specified. No correlation is calculated when comparing with other solutions or within-situ measurements.

While ERS2 is a hard point because of the problem of blurring of its waveforms, no resulting map is shown. Although the data supplied with the paper seems to give consistent results, it would be useful to present comparisons with Envisat over a common month and to discuss any problems encountered, such as the extent of filtering used (Pauta criterion). Also, very strangely, the quality of the results deteriorates sharply, with extremely moth-eaten maps for the Envisat period from October 2002, even though the Envisat measurements are of much better quality than those of ERS2 and their orbits are the same. Coverage became good again with CryoSat-2 from November 2010, but visually the resolution seemed closer to 25km than 5km. This seems to indicate that you forgot to apply the coarse resolution to Envisat, but also that the 5km resolution is far too low to cover the

Arctic basin.

All this raises questions about the choice of such a small resolution (5km), compensated by a relatively coarse resolution (25km). For a future study, wouldn't a resolution of 12.5km be more appropriate? Or do you think that 5km really adds value (relevant signal at this scale)?

Finally I would recommend analysing and exporting in the data the parameters a5 and a6, which depend on the densities and the snow depth. This should allow evaluating the consistency of these parameters, and thus the model used.

From a practical viewpoint I would recommend to use the Lambert-Azimuthal-Equal-Area projection with lon0=0, which becomes the reference in our domain, but it's not mandatory as it represents a lot of work without changing the results (see EASE v2 in https://nsidc.org/data/user-resources/help-center/guide-ease-grids). Strangely, while the figures in the paper show maps with lon0=0, the data are centred on lon0=-45.

Response: We appreciate your recognition of the significance of our work and the potential it holds for the study of Arctic sea ice thickness. We will address your concerns one by one:

(1) Concepts on freeboard

As shown in the following figure, we define the terminology of freeboard:

- ice freeboard (FB_i): refers to the elevation of the snow–ice interface above the local sea level;
- total freeboard (FB_t): refers to the elevation of the air–snow interface above the local sea level, which is sensed by laser altimetry;
- radar freeboard: as the radar waves do not fully penetrate snow above ice, we here define the term radar freeboard as the elevation of penetration interface above the local sea level (Ricker et al., 2014).

As for the ice freeboard the lower wave propagation speed in the snow layer requires a correction, the radar-ku-freeboard (FB_{ku}) is defined, but is not applied for the radar freeboard in this study. Therefore, the freeboard mentioned in this study refers to radar freeboard.

We have added supplementary instructions on the radar freeboard at the beginning of Sec. 3.1.

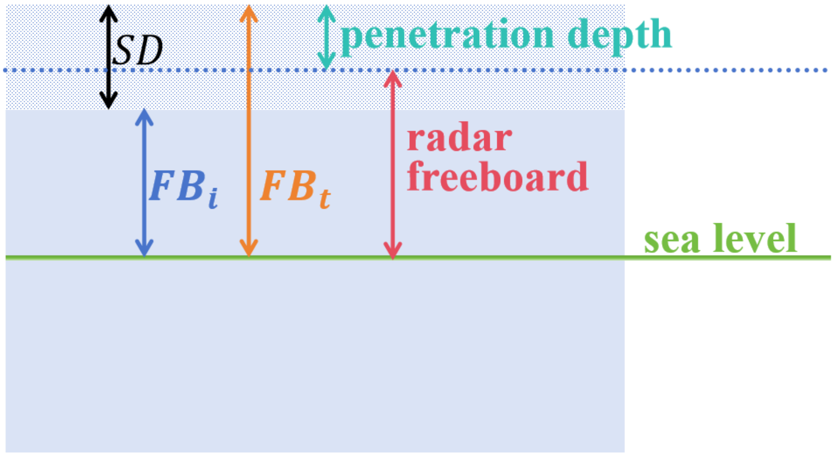

Figure 1 Schematic diagram of parameters regarding different freeboards.

(2) ULS Draft to SIT

The sea ice draft (h_{draft}) from ULS were converted to SIT under hydrostatic equilibrium:

$$h_{si} = \frac{\rho_{sw} h_{draft} - \rho_s h_s}{\rho_{si}}$$

As shown in Figure 11, the ice drafts at the four ULS were larger than 0 at summer time, we therefore assume the ice type as MYI. Consequently, we used a fixed sea ice density of 917 kg/m^3 and a seawater density of 1024 kg/m^3. The snow depth and density are from W99.

(3) Adding correlations while comparing

We have added the mean error (ME) and correlations according to your suggestion in Tables 4, 5, 6, 7.

(4) Calibration of ERS-2

We acknowledge the issue of waveform blurring over sea ice for ERS-2. Our data processing methods inherently address this problem to some extent.

Regarding lead detection, we use a combination of waveform parameter thresholds and the lowest elevation method (LEM). For ERS - 2, we use the pulse peakiness (PP) parameter for lead identification. However, we are aware that the waveform blurring may affect the accuracy of this method, especially in thin ice-covered areas. The LEM, which is based on the premise that the surface height of leads is lower than that of nearby sea ice, helps to correct for misidentifications caused by waveform blurring. This combined approach is a form of correction for the waveform-related issues in ERS-2 data.

As for calibration between ERS-2 and Envisat, while the altimeters on ERS-2 and Envisat are similar in some aspects, we did not conduct a separate calibration specifically for ERS-2 and Envisat as we did for Envisat and CryoSat-2. The reason is that the difference in thickness between ERS-2 and Envisat during their common mission period is approximately -0.39 m, which is negligible compared with the difference between CryoSat-2 and Envisat. We applied the monthly correction grid generated from the Envisat-CryoSat-2 comparison to the ERS-2-based thickness for correction, which also helps to account for any systematic differences related to waveform blurring or other factors between ERS-2 and Envisat. If we apply another calibration between ERS-2 and Envisat, the residuals between Envisat and CryoSat-2 will be introduced, which could lead to the superposition of multiple errors.

(5) Coverage and Resolution issues

The discrepancy in spatial coverage is caused by multiple factors, such as changes in sea ice extent and data exclusion. The resolution during the Envisat period appears to be higher than that of CryoSat-2. This is mainly because the Envisat results have more noise, while the Cryosat-2 results are smoother. In fact, we uniformly used a grid with a resolution of 5 km.

The choice of 5 km resolution was made to balance the need for high-resolution details and the availability of data. A 5 km resolution allows us to capture more fine -scale features of sea ice thickness compared to coarser resolutions. Although visually the resolution might seem closer to 25 km in some cases, this could be due to data interpolation and the characteristics of sea ice distribution. We believe that the 5 km resolution provides valuable information, especially in areas with complex sea ice dynamics. However, we also understand the advantages of a 12.5 km resolution, such as better coverage and potentially less noise. In future studies, we will consider using a 12.5 km resolution as an alternative and compare the results to further explore the optimal resolution for Arctic sea ice thickness monitoring.

(6) On the parameters of a_5 and a_6

As explained in *SP*(20), $a_5 = 1 - \frac{\rho_{si}}{\rho_{sw}}$ and $a_6 = (1 - \frac{\rho_s}{\rho_{sw}} - \theta)h_s$. a_5 is a combination of densities of sea ice and seawater, while a_6 is much more complex. In Xiao et al. (2020), we derived sea ice density from a_5 by setting seawater density as a fixed value (1024 kg/m³). Figure 2 shows the sea ice density distribution for the 2018 -2019

Arctic sea ice growth season from October to April. It can be easily found that the thin ice density is larger than thick ice density. Thin ice density ranges from 915 ~ 920 kg/m³, while the thick ice density ranges from 880 ~ 885 kg/m³.

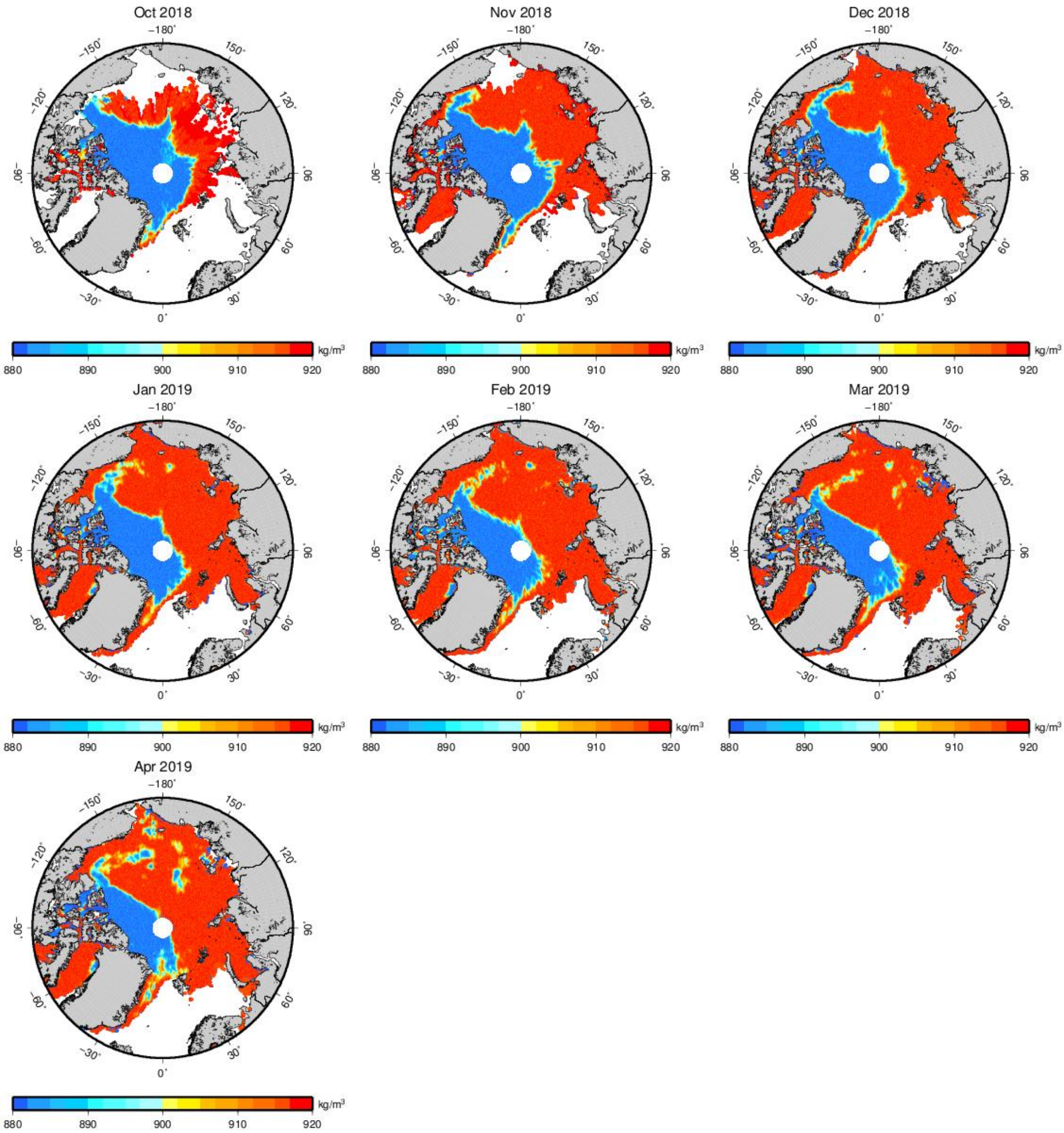

Figure 2 Arctic sea ice density with the LSA method for the 2018 – 2019 Arctic sea ice growth season from October to April.

(7) On the projection

In this study, we used the NSIDC's Polar Stereographic Projection, detailed information can be found in https://nsidc.org/data/user-resources/help-center/guide-nsidcs-polar-stereographic-projection.

In the .nc file, the key parameters of this projection are set as follows: +proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs.

In the manuscript, we used the Generic Mapping Tools (GMT, https://www.generic-mapping-tools.org/) to present the distributions of SIT. The following command was used:

gmt plot -R-180/180/60/88 -Js0/90/2i/45 *thicknessfile* -Sp -C

Specifically, we adopt the polar stereographic projection with a central longitude of 0° and a central latitude of 90°, which means we choose the North Pole as the projection center. The standard parallel of this projection is set at 45°.

Specific Comments

1. l.24 : The only mention of the projection used. Should be specify within the paper with all the requested parameters to use this projection, in particular the True Latitude (lat_ts). Also we would recommend to use the EASE v2 https://nsidc.org/data/user-resources/help-center/guide-ease-grids, which becomes the reference and which is much more convenient as the resulting grid is a regular Cartesian grid in meters and allows to compute directly distances, surfaces and volumes in ISU, which is not the case for the stereopolar projection.

Response: Thanks for your suggestion. As you mentioned, we indeed use the NSIDC's Polar Stereographic Projection, detailed information can be found in https://nsidc.org/data/user-resources/help-center/guide-nsidcs-polar-stereographic-projection.

In the .nc file, the key parameters of this projection are set as follows: +proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs.

Regarding the EASE v2 projection you recommended, we understand that it has many advantages. For example, the resulting grid is a regular Cartesian grid, which allows for direct calculation of distances, areas, and volumes in ISU, making it more convenient to use. However, our choice of the Polar Stereographic Projection is mainly due to the focus of our research on sea-ice-related applications. The Polar Stereographic Projection has unique advantages in sea-ice research in polar regions. It is tangent to the Earth's surface at 70°N/S, resulting in minimal grid distortion near the marginal ice zone. This is crucial for accurately analyzing the distribution, movement, and change characteristics of sea ice. Many NSIDC-archived datasets, including a large number of brightness temperature and sea-ice products, also use this projection, which demonstrates its reliability and applicability in the field of sea-ice research. It might be feasible for us to provide an alternative data version in the EASE grid format. This could potentially meet the diverse requirements of users who prefer or require data in this particular grid system for their analysis and research work.

2. l.46: please specify that the Arctic could become ice free in less than a decade in summer.

Response: The statement has been modified.

3. l.95: I was surprised by these snow depth reduction announced over FYI and MYI but in fact in Webster et al. 2014, they do not speak about FYI/MYI but about specific seas: "For the 2009–2013 period, the products show that snow has decreased by 37 ± 29% in the western Arctic and by 56 ± 33% in the Beaufort and Chukchi seas, compared to the 1954 - 1991 snow depth climatology produced by W99." Please correct it or provide the original citation if any.

Response: It has been corrected.

4. l.148: I suppose there is an error in this sentence: "coarse across-track spacing of 25 km at 75° and 4 km at 60° provided by ERS-2 and Envisat" as the across track spacing decreases with the latitude.

Response: This sentence has been corrected as: The across-track spacing of CryoSat-2 is approximately 2.5 km at 75° and 4 km at 60°, which is a significant improvement compared with the coarse across-track spacing of 25 km at 75° and 40 km at 60° provided by ERS-2 and Envisat.

5. l.152: CryoSat-2 orbit is not any more a repeat cycle since several years, however there is still a sub-cycle of about 30 days.

Response: It is revised.

6. l.185,248,270,285,286,293,294: It's very pertinent to recall the uncertainties for each product. I would just recommend to always use the same units (meters or centimetres).

Response: The units have been unified.

7. l.195: CryoSat-2 ICE baseline-E L1B is the official ESA product, not an AWI product. Please specify if you use the AWI product or the ESA product.

Response: This statement is introducing the AWI-CS2 product. According to the Product User Guide (Hendricks and Paul, 2023), CryoSat-2 ICE baseline-E L1B data are the input data for AWI-CS2 sea ice thickness product.
Hendricks, S. and Paul, S. (2023): Product User Guide & Algorithm Specification - AWI CryoSat-2 Sea Ice Thickness (version 2.6), https://doi.org/10.5281/zenodo.10044554.

8. l.238: This longtime series is described in Bocquetetal. 2024 https://doi.org/10.1029/2023JC020848. Bocquet et al. 2023 explains the methodology and is only over Arctic from 1995 to 2021 (without ERS1).

Response: The reference has been updated.

9. l.249: "RMSE of 12-28 cm for Envisat period and 15-21 cm for CryoSat-2 period (Guerreiroetal., 2017)." Guerreiro or Bocquet? It's not the sametime series.

Response: This sentence has been revised as:
The draft of CTOH, compared with ULS measurements in BGEP and in Fram Strait, was overestimated by about 0.2 m for CryoSat-2 period and underestimated by 0.11 m and 0.16 m for Envisat and ERS-2, respectively (Bocquet et al., 2024).

10. l.300: DTU18MSS is endowed with discontinuity problems close to the MIZ and you should use DTU21MSS. See: "The DTU21 global mean sea surface and first evaluation" in Earth System Science Data 15(9):4065-4075 10.5194/essd-15-4065-2023

Response: Thank you for pointing out this issue. When we initiated this work, DTU21MSS had not been released yet. Given the discontinuity problems of DTU18MSS near the MIZ, we fully recognize the importance of using DTU21MSS. In our next step, we have planned to upgrade our product and will definitely adopt DTU21MSS. This will not only help us address the existing issues related to the MSS data source but also enhance the overall quality and reliability of our product.

11. l.366: The MSS includes the geoid (MSS=geoid+MDT). Also I'm surprise that you don't correct for the usual altimetry corrections such as the wet tropo, the dry tropo, the ocean tide, load tide, pole tide, DAC, etc. You would get even more flat measurements.

Response: The geoid undulations and mean dynamic topography (MDT) were removed in the relative elevation. Geophysical corrections were applied using the models or datasets provided in CryoSat-2/Envisat/ERS-2 product before subtracting the MSS height.

12. l.367: I did not know about Pauta criterion, I think it would be interesting to explain it here in few words.

Response: The Pauta Criterion, also known as the 3σ rule, is a statistical method used to identify outliers in a data set. It is based on the characteristics of the normal distribution. In a normal distribution, about 99.73% of the data lies within the interval of the mean plus or minus three standard deviations ($\mu \pm 3\sigma$). According to this criterion, data points that fall outside this range ($x < \mu - 3\sigma\ or\ x > \mu + 3\sigma$) are considered outliers.
Reference: Shi, H., Guo, J., Deng, Y. et al. Machine learning-based anomaly detection of groundwater microdynamics: case study of Chengdu, China. Sci Rep 13, 14718 (2023). https://doi.org/10.1038/s41598-023-38447-5.

13. l.375: interpolated is between 2 measures, here I would say extrapolated.

Response: Thanks for your advice, it has been revised.

14. l.380-388: this part is not clear at all because you mixed-up the ice-freeboard (FB_i, the real freeboard of the ice), the radar-ku-freeboard (FB_{ku}, the freeboard

measured by the radar) and the total-freeboard (FB_t, ice+snow freeboard that is measured by the lidar of OIB or ICESat-2). They are linked by the following relations: $FB_t = FB_i + SD$ and $FB_{ku} = FB_i - (c_v/c_s - 1) \times SD$, where SD is the Snow Depth and c_v/c_s is the ratio of the speed of light in vaccum and in snow. This ratio depends on the snow density ρ_{snow}. From Ulaby 1986 we have: $c_v/c_s = (1 + 0.00051 \times \rho_{snow})^{1.5}$ (Tiuri et al. 1984 suggest: $c_v/c_s = (1 + 1.7\rho_{snow} + 0.7\rho_{snow}^2)^{0.5}$. Each time you speak about freeboard you must specify which freeboard you are speaking about.

Response: As shown in the following figure, we define the terminology of freeboard:

- ice freeboard (FB_i): refers to the elevation of the snow–ice interface above the local sea level;
- total freeboard (FB_t): refers to the elevation of the air–snow interface above the local sea level, which is sensed by laser altimetry;
- radar freeboard: as the radar waves do not fully penetrate snow above ice, we here define the term radar freeboard as the elevation of penetration interface above the local sea level (Ricker et al., 2014).

As for the ice freeboard the lower wave propagation speed in the snow layer requires a correction, the radar-ku-freeboard (FB_{ku}) is defined, but is not applied for the radar freeboard in this study. Therefore, the freeboard mentioned in this study refers to radar freeboard.

We have added supplementary instructions on the radar freeboard at the beginning of Sec. 3.1.

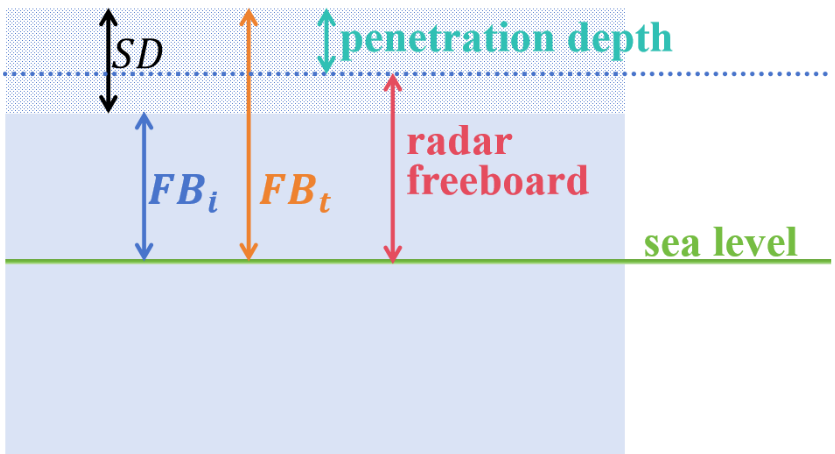

Figure 1 Schematic diagram of parameters regarding different freeboards.

15. l.381: "The OIB **total (or lidar)** freeboard was modified with snow depth". Here you should also specify if you have just removed the snow depth to get an **ice freeboard** or if you also have corrected for the speed propagation to get a **radar-ku-freeboard** for the following comparisons.

Response: The OIB total freeboard was firstly modified to ice freeboard using snow depth from the snow radar before comparison.

16. l.382: "The mean **radar? ice? yours from OIB? yours from satellite?** freeboard along this track in this study"

Response: Here it refers to the mean radar freeboard.

17. l.383: "while the mean **radar** freeboard from the Baseline E".

Response: It is revised.

18. l.384: "The mean value of the modified OIB freeboard was 0.261" -> The mean value of the **ice? radar?** freeboard obtained from OIB was 0.261 m.

Response: Here it refers to the ice freeboard.

19. l.387: The following sentence is wrong: "the waveform threshold method leads to an underestimation of the freeboard ... ". The threshold method sometimes overestimates the FB and sometimes underestimates it as you show it later on in this paper. It mainly depends on the roughness of the ice, i.e. on ice type (FYI/MYI).
"*... which explains why the freeboard in the Baseline E product was smaller than our estimates and the modified OIB freeboard*." No, this is explained by the following equation $FB_{ku} = FB_i - (c_v/c_s - 1) \times SD$, which shows that the **radar freeboard is always smaller than the ice freeboard** and it can even be negative for small FB_{ice} and large SD.

Response: The freeboard in Baseline E product refers to the radar freeboard and is computed as: [radar_freeboard_20_ku] = [height_1_20_ku] - [ssha_interp_20_ku]. A correction for pulse delay due to snow depth is provided in [snow_depth_cor_20_ku] but is not applied.

Also, as explained above, the radar freeboard in this study refers to the elevation of penetration interface above the local sea level, while the ice freeboard refers to the elevation of the snow–ice interface above the local sea level. Therefore, the radar freeboard will be larger than the ice freeboard.

As shown in Figure 3 in the revision, when the radar burst is reflected from thin ice, specular echoes occur and will be misidentified as leads. Thus, an overestimation will occur on the SSH determination and leading to an underestimation of the ice radar freeboard.

To avoid misconception, this statement has been revised as:

The misidentification of leads in waveform threshold method leads to an underestimation of the radar freeboard, which explains why the freeboard in the Baseline E product was smaller than our radar freeboard.

Reference: CryoSat Ice netCDF L2 Product Format Specification, Issue 2.1. IPF1 L1B Product Formats (esa.int)

20. l.406: This equation is not the equation of the hydrostatic equilibrium between FBi, SIT and SD!

    Here it is: $FB_i = SIT(1 - \rho_{ice}/\rho_{water}) - SD \times \rho_{snow}/\rho_{water}$

    What you have written is the equation that links FB_{ku} with SIT and SD (ie, what you call h_{fb} is in fact FB_{ku} and what you call theta is c_v/c_s including possibly a penetration factor $P * c_v/c_s$).

Response: Under the assumption of hydrostatic equilibrium, sea ice thickness can be calculated as (Ricker et al., 2014; Tilling et al., 2018):

$$h_{si} = \frac{\rho_{sw}}{\rho_{sw} - \rho_{si}} h_{fb\_ice} + \frac{\rho_s}{\rho_{sw} - \rho_{si}} h_s \qquad (1)$$

where h_{si} is the sea ice thickness; h_s is the snow depth on sea ice; and ρ_{sw}, ρ_{si}, and ρ_s are the densities of sea water, sea ice, and snow, respectively. We have to be aware that h_{fb_ice} here refers to the ice freeboard.

As the radar signal cannot penetrate the snow thoroughly, we defined the radar freeboard in this study. As shown in Figure 1 and Figure 2 below, the radar freeboard

(h_{fb}) refers to the elevation of penetration interface above the local sea level, and h_{ps} is the penetration depth of radar signals. The model for the conversion of freeboard to thickness can be modified as:

$$\begin{aligned} h_{si} &= \frac{\rho_{sw}}{\rho_{sw}-\rho_{si}} h_{fb} + \frac{\rho_s - \rho_{sw}}{\rho_{sw}-\rho_{si}} h_s + \frac{\rho_{sw}}{\rho_{sw}-\rho_{si}} h_{ps} \\ &= \frac{\rho_{sw}}{\rho_{sw}-\rho_{si}} h_{fb} + \frac{\rho_s - \rho_{sw}}{\rho_{sw}-\rho_{si}} h_s + \frac{\rho_{sw}}{\rho_{sw}-\rho_{si}} \theta \cdot h_s \end{aligned} \tag{2}$$

where θ is the penetration factor of radar signals.

We firstly model the freeboard as a quadratic function of the local ice surface terrain within the grid:

$$h_{fb}(x, y) = \overline{h_{fb}} + a_0 x + a_1 y + a_2 x^2 + a_3 y^2 + a_4 xy \tag{3}$$

where $\overline{h_{fb}}$ indicates the mean freeboard of the grid cell and x and y represent the longitudinal and latitudinal surface distances between the observation and the central point of the grid cell, respectively. According to Equation (2),

$$\overline{h_{fb}} = (1 - \frac{\rho_{si}}{\rho_{sw}})\overline{h_{si}} + (1 - \frac{\rho_s}{\rho_{sw}} - \theta) h_s \tag{4}$$

Thus, Equation (3) can be rewritten as follows:

$$\begin{aligned} h_{fb}(x, y) &= (1 - \frac{\rho_{si}}{\rho_{sw}})\overline{h_{si}} + (1 - \frac{\rho_s}{\rho_{sw}} - \theta) h_s + a_0 x + a_1 y + a_2 x^2 + a_3 y^2 + a_4 xy \\ &= a_0 x + a_1 y + a_2 x^2 + a_3 y^2 + a_4 xy + a_5 \overline{h_{si}} + a_6 \end{aligned} \tag{5}$$

Details of the LSA method are introduced in Xiao et al. (2020).

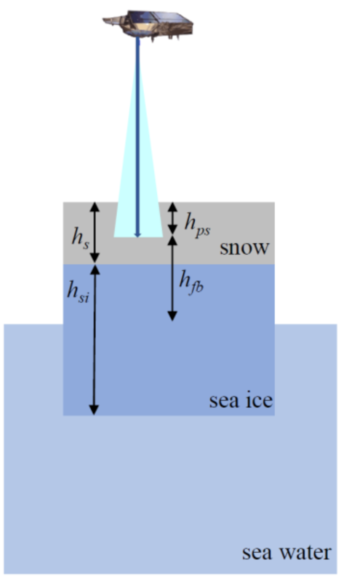

Figure 2 Schematic of the radar altimeter observing the sea ice thickness

21. l.407-409: Please specify which are the inputs and which are the unknown. It looks like that h_{fb}, x and y are the inputs and a0-a7 and h_{si} are the 8 unknown, right?

Response: Yes, h_{fb}, x and y are the inputs, $a_0 - a_6$ and $\overline{h_{si}}$ are the 8 unknown parameters.

22. l.410: x and y are really lat and lon? It's strange with your grid projection. Using EASE2 they could be directly in meters ;-)

Response: *x* and *y* represent the longitudinal and latitudinal surface distances between the observation point and the central point of the grid cell.

23. l.418: I suppose it's 25km here, not 10km. as you have just computed the 25km x 25km grids. However, when you look at the data supplied, the maps appear very patchy. Can you explain this? (not enough measurements, even at 25km resolution?).

Response: Thank you for bringing this to our attention. It should be 25 km as we've been working with 25 km x 25 km grids.

Regarding the patchy appearance of the maps, it is indeed due to insufficient measurements. Despite the 25 km resolution, the data collection in certain areas has been limited, as we need at least 8 observations to figure out the SIT in a certain grid. Although, we can use interpolation methods to fill these gaps, but it will bring new error sources. In the future study, we will reduce the number of necessary observations by fixing some parameters (such as the seawater density), thereby decreasing the amount of blank data.

24. l.426: typo: antimeres -> altimeters

Response: It has been corrected.

25. l.427: "The pulse-limited altimeters have a large footprint of 2–10 km" radius or diameter?

Response: The pulse-limited altimeters have a large footprint of 2–10 km in diameter.

26. l.441: typo: Bocquest -> Bocquet

Response: It has been corrected.

27. l.442: "for calibrating freeboard measurements from Envisat and ERS-2." -> for calibrating Envisat freeboard measurements from CryoSat-2 and ERS-2 from calibrated Envisat.

Response: It has been corrected.

28. l.443: "Tilling et al. (2019) developed a physical-based approach to correct Envisat SIT … " Could be confusing with the retracker physical-based approach and it's not more physical than considering the ice roughness as it is usually done, I would avoid this term.

Response: Thanks for your advice. This statement has been revised as:
Tilling et al. (2019) developed a physical-based approach to corrected Envisat SIT according to the relationship between the thickness differences between Envisat and CryoSat-2 and the along-track distance between leads and the closest floe in the Envisat measurements.

29. l.453: I do not agree with this conclusion: "Compared with CryoSat-2 thickness, Envisat thickness showed an overestimation of 0.19 ± 0.67 m in January 2011." As it is shown in your maps and histograms, LRM gets thinner ice over thin ice and thicker over thick ice relatively to SAR as it was explained in Laforge et al 2021 https://doi.org/10.1016/j.asr.2020.02.001

Response: Thanks for your comments. Indeed, the original expression was not quite accurate. The overestimation refers to the overall difference between CS-2 and Envisat thickness.

30. l.473, Table 5: Is 'Mean' the Mean Bias? Is STD the STD of the difference or of the product? Would be very pertinent to add the Correlations.

Response: Yes, Table 5 is the statistics of the mean values and STDs of the difference between Envisat and CryoSat-2 thickness during the common mission period. We have added the correlations in the Table.

31. l.480: The main problem with ERS-1 and ERS-2 is related to the blurring of their waveforms over sea ice. You don't mention it and it looks like that you don't have applied specific correction for this problem. Any other calibration between ERS2 and Envisat, as for Envisat versus CryoSat2? As it is an important problem it would also be important to see the maps you obtain in front of Envisat map for the same period. And once again the correlation is an important criteria that should also be added.

Response: Thanks for your valuable comments and suggestion. We acknowledge the issue of waveform blurring over sea ice for ERS-2. Our data processing methods inherently address this problem to some extent.

Regarding lead detection, we use a combination of waveform parameter thresholds and the lowest elevation method (LEM). For ERS - 2, we use the pulse peakiness (PP) parameter for lead identification. However, we are aware that the waveform blurring may affect the accuracy of this method, especially in thin ice-covered areas. The LEM, which is based on the premise that the surface height of leads is lower than that of nearby sea ice, helps to correct for misidentifications caused by waveform blurring. This combined approach is a form of correction for the waveform-related issues in ERS-2 data.

As for calibration between ERS-2 and Envisat, while the altimeters on ERS-2 and Envisat are similar in some aspects, we did not conduct a separate calibration specifically for ERS-2 and Envisat as we did for Envisat and CryoSat-2. The reason is that the difference in thickness between ERS-2 and Envisat during their common mission period is approximately -0.39 m, which is negligible compared with the difference between CryoSat-2 and Envisat. We applied the monthly correction grid generated from the Envisat-CryoSat-2 comparison to the ERS-2-based thickness for correction, which also helps to account for any systematic differences related to waveform blurring or other factors between ERS-2 and Envisat. If we apply another calibration between ERS-2 and Envisat, the residuals between Envisat and CryoSat-2 will be introduced, which could lead to the superposition of multiple errors.

We have added the correlations in Table 4 according to your suggestion.

32. l.484: typo: gird -> grid

Response: It is corrected.

33. l.487, caption Fig 8: what is kermesinus?

Response: It is revised to red.

34. l.497: "The sea ice extent did not show any significant changes during this growth." How do you determine the sea ice extent? It's from NSIDC-0051 with concentration>75%? Would worth to recall it here. It is a very important point as the mean SIT highly depends on it (if you consider or not the thin ice in MIZ).

Response: As introduced in Sec. 2.4, we define ice floe regions as those with a sea ice concentration in NSIDC-0051 greater than 75%. We have recalled it here.

35. l.505: what do you mean by "normal distribution"?

Response: A normal distribution, also known as a Gaussian distribution, is a probability distribution that is symmetric about the mean. In a normal distribution, the data is distributed in a bell - shaped curve.

36. l.510: what do you mean by "sinistrality"?

Response: It is revised to left – skewed.

37. l.535: "The mean MYI thickness decreased by 0.017 m/yr during the research period,". Please provide explicitly the period.

Response: The research period refers to the period from 1995/1996 to 2022/2023.

38. l.538-570: I'm not fully convinced of the interest of mean SIT for all the Arctic as this value mainly depends on the considered sea ice extent. For instance it can remains about no ice but only some remaining fast ice at the coast to obtain large mean SIT but it means nothing. To make this type of comparison meaningful you could for instance always consider the same mask (region) for each given month.

Or an alternative would be to compute to total volume instead of the mean SIT. However I will not ask you to change this, but at least you should explain specifically how you define the mask, for instance do you always use the area provided by NSIDC-0051 with concentration>75% for each month of each year?

Response: Thanks for your suggestion. I do completely agree your opinions on applying the same mask. In the current version, the mask was defined by NSIDC-0051 with concentration > 75% for each month of each year. We will have a further analysis on the Arctic sea ice variation by presenting the total volume in our next step research, as this study is focused on presenting a new Arctic SIT product.

39. l.574: Please specify if you use the same mask for all the products. It's important to make them comparable.
    l.582: The information of the mask is even more important for the CS2SMOS product because it can cover larger region as it also considers thin ice at the margins thanks to SMOS.

Response: When comparing different products, we exclusively calculated the differences for those grids in which every product had values. For grids where any one of the products has a missing value, the difference within that grid cell was not computed.

40. l.592, Table 6: The mean bias and the correlation should be added.

Response: Thanks for your suggestion. We have added the statistics of ME and R for the comparison. Our product has the highest correlation with CPOM, reaching 0.937. Its correlation with the products of AWI-CS2, GSFC-CS2 and AWI-CS2+SMOS also exceeds 0.9, while the correlation with CCI is the lowest.

41. l.598: it's really important to know which ice density and which snow depth you have chosen to convert the draft to SIT. If these values are not coherent with the product you compare you will necessarily get higher differences for this product. Please also provide the used equation and the input parameters (mainly ice density, SD is based on WC or MWC?).

Response: The sea ice draft (h_{draft}) from ULS were converted to SIT under hydrostatic equilibrium:

$$h_{si} = \frac{\rho_{sw} h_{draft} - \rho_s h_s}{\rho_{si}}$$

As shown in Figure 11, the ice drafts at the four ULS were larger than 0 at summer time, we therefore assume the ice type as MYI. Consequently, we used a fixed sea ice density of 917 kg/m^3 and a seawater density of 1024 kg/m^3. The snow depth and density are from W99.

42. l.606: typo: "The STDs of WHU were close …" -> "The STDs of WHU are close … "

Response: It is revised.

43. l.618-620, Tables 7 & 8: Please add the Mean Bias and the Correlation in these tables. Indeed, if there is a significant bias, both the MAE and the STD will be high, but if the correlation is good it will indicate that the tendencies are coherent, which is the most important point to study change rate. (Also it is not necessary to recall the units in each column ;-).

Response: We have added the Mean Bias and the Correlations. The correlations between ULS thickness and the products prior to October 2010 are substantially lower compared to those after October 2010. This disparity can be attributed to the limited time series available for the pre-October 2010 period. The correlations of WHU after October 2010 at the three ULSs all exceed 0.7, demonstrating a significant correspondence between the two datasets.

44. l.624: "Then, the mean thickness of the OIB within the grid was compared with the corresponding grid values." OIB products do not include SIT, how do you compute it? Please provide the equation and the input parameters used from OIB data.

Response: The IceBridge L4 and Quick Look Sea Ice Freeboard, Snow Depth, and Thickness products includes the SIT.

45. l.636, Figure 16: For some products the count reaches nearly 1500 and for others it is lower than 300. The shape of the histograms being similar, it means that the number of measurements from one product to another can differ by a factor 3. How can you explain it? Is it because of the resolution of the original product?

Response: Yes, this disparity is mainly caused by the resolution of the original product. For example, WHU and CPOM feature a higher resolution of 5 km, the numbers of the two products are larger than those of other products.

46. l.643, Table 9: Please add the correlations.

Response: The correlations are added. The correlations between OIB thickness and satellite-based products all exceed than 0.85. This indicates a remarkably strong relationship, suggesting that the OIB thickness values show a high degree of correspondence with the estimations provided by the satellite-based products.

47. l.647: "… error propagation of the input uncertainties including radar freeboard, ice density, snow depth … "

Response: It is revised.

48. l.655: "Thus, the uncertainties of the SIT can be calculated by the difference of h_{si} in the last two iterations.". I don't understand why the last two iterations are more relevant than the previous ones. To me, this is more a reflection of the speed of convergence of the LSA than the uncertainties. Please justify this solution. For example, you could more naturally assess the distance between the model and the measurements by calculating the STD or MAE between the model and the measurements.

Response: The reason we use the difference of h_{si} in the last two iterations to calculate the uncertainties of the SIT is related to the convergence behavior of the iterative process.

As the iterations progress, the calculated values of the SIT gradually converge towards a stable solution. In the early iterations, the values can fluctuate significantly as the model is still adjusting to find the optimal fit. However, as convergence is approached, the changes between consecutive iterations become smaller. The difference between the values in the last two iterations thus represents the residual change just before the model reaches its final, or near - final, state.

This residual change can be considered as an indication of the uncertainty in the calculated SIT. It shows how much the value is still changing as the model converges, and this remaining variability is a good measure of the uncertainty associated with the calculated SIT.

While metrics like STD or MAE between the model and the measurements can also provide valuable information about the model-measurement distance, in our case, there is a complication. The data we input into our model is the freeboard, while the outputs are the SITs. Therefore, we are unable to directly calculate the STD and MAE.

49. l.678: Please replace the link https://www.legos.omp.eu/ctoh/fr/produits-ctoh/ by a more direct one: http://dx.doi.org/10.6096/ctoh_sit_2023_01

Response: It is revised.