Dear Editors and Reviewers,

Thank you for considering our manuscript, and the reviewers' comments concerning our manuscript entitled Assessment of Arctic Sea Ice Thickness Retrieval Ability of the Chinese HY-2B Radar Altimeter (manuscript ID: egusphere-2022-870). The comments are all valuable and very helpful for improving upon our paper. We have now carefully reviewed and addressed all of comments which we hope meet with approval, with revisions to the original manuscript shown in red. The primary corrections in the paper and the responds to the reviewer's comments are as flowing:

Responses to Reviewer's Comments:

Reviewer #3:

General comments

This manuscript introduces the retrieval of Arctic sea ice freeboard and thickness with the radar altimeter onboard HY-2B. The inclination angle of HY-2B allows the coverage of up to 82° N, and the satellite potentially constitutes an important source of information for sea ice of both polar regions. Specifically in the manuscript, the authors focus on the processing of converting existing range (or elevation) product of HY-2B into radar/ice freeboard and thickness. I consider the data from HY2B and this submission a good contribution to the community, but I do have the following comments that in my opinion that should be addressed first.

GC0: The overall uncertainty analysis needs to be more clear and precise, especially in terms of the determination of freeboard uncertainty. First, the (claimed) uncertainty used for further analysis is σ_{SGDR}, which is only 2cm and should be a lower bound of the actual range uncertainty. This uncertainty, in its true quantity, applies to both SSHA and individual freeboard. Since SGDR is the upstream dataset this work relies on, it is not necessary a quantity that needs much elaboration within this work. However, its value needs to be justified. For example, what is the gate resolution of HY-2B? Is the 2cm uncertainty due to the combination of several footprints (therefore smaller)? Furthermore, the authors state that Ricker et al. (2014) `believed' the random uncertainty of radar freeboard to be determined by radar speckle noise. Is it possible to provide any other proof of how is the reference relevance to the treatment here?

Response: Thank you for the valuable comments. c is the speed of light in vacuum, c = 299792485.0 m/s, B is the measured chirp bandwidth, B = 320,000,000 Hz. Each waveform sample covers a range of $\Delta R = c/2B$ = 0.4684 m or a delay of $\Delta t = 1/B$ = 3.125 ns. The instrument system error of HY-2B is 2 cm. It maybe caused by orbit error and the footprint resolution. According to Wingham et al. (2006) and CryoSat-2 Product Handbook Baseline D 1.1, there are three operating modes, low resolution mode (LRM), synthetic aperture mode (SARM), and synthetic aperture interferometric mode (SARInM). LRM provides for conventional, pulse-limited altimetry using a single antenna. The radio frequency (13.575 GHz), pulse bandwidth (320 MHz), samples in echo (128 in LRM) and range bin sample (0.4684 m for LRM) are same with HY-2B altimeter. In addition, the instrument system error of LRM is 0.07 m (Wingham et al., 2006). Therefore, we adopted relevant treatment to HY-2B. Acording to the instructions for HY-2B satellite data, we know the range error is 0.02 m (https://osdds.nsoas.org.cn/HY2B_introduce).

GC1: Second, the uncertainty of SSH is computed as the standard deviation (SD) of SSH points (of the along-track 25km segment). I think this is a crude guess, and unfortunately, probably an underestimation of SSH-induced uncertainty. Because the along-track points that are not used for determining SSH share the same uncertainty caused by the same set of SSH points, and therefore the uncertainty of the retrieved freeboard samples on the same track is systematic (rather than random). Therefore, in Eq. (11) it should be averaged out and diminished much more slowly.

Response: Thank you for the valuable comments. If the points in the 25 km segment are more than 15, the average of the 15 lowest values is taken as the SSHA. Otherwise, the SSHA is obtained by nearest interpolation. We change to use the standard deviation of SSHAs within a 25-km moving window as the uncertainty of SSHA (σ_{SSA}). The all SSHAs are used for determining radar freeboard. The sea ice thickness uncertainty can be divided into random uncertainty and systematic uncertainty. According to Ricker et al (2014) and Hendricks et al (2020), the uncertainty of SSHA is random uncertainty. The gridded uncertainty of parameters with only random uncertainty is computed as the error of the weighted mean. This approach applies only to the radar freeboard, whose two error contributions range noise and sea surface height interpolation uncertainty are both defined as random error contributions (Hendricks et al., 2020). Ricker et al. (2014) hypothesized that the uncertainties of the modified W99 snow depth and snow density resulting from interannual variabilities are systematic and cannot be regarded as random uncertainty. However, the AWI snow depth product is a composite snow depth product obtained by integrating the W99 climatology snow depths and the daily average AMSR-2 snow depths of Bremen University. Therefore, we assumed that the uncertainties in the AWI snow depth and snow density products are systematic uncertainty. In addition, the density of snow and sea ice are also treated as systematic errors. Due to the variability in seawater density, the contribution of its uncertainty is ignored (Kurtz et al., 2014; Ricker et al., 2014) (line 1281-1288). The grid uncertainty of radar freeboard, sea ice freeboard and sea ice thickness can be expressed as shown in Eq. (1) to (4):

$$\hat{\sigma}_{l3,rf} = \sqrt{\frac{\sigma^{2}_{SSA} + \sigma^{2}_{SGDR}}{n}} \quad (1)$$

$$\sigma_{l3,f} = \sqrt{\left(\left(\frac{c}{c_S} - 1\right)\bullet\bar{\sigma}_{sd}\right)^2 + (\hat{\sigma}_{l3,rf})^2} \quad (2)$$

$$c_S = c \bullet (1 + 5.1 \bullet 10^{-4} \rho_S)^{-1.5} \quad (3)$$

$$\sigma_{l3,T} = \sqrt{(\frac{\bar{\rho}_w}{\bar{\rho}_w - \bar{\rho}_i}\sigma_{l3,f})^2 + (\frac{\bar{f} \bullet \bar{\rho}_w + \overline{sd} \bullet \bar{\rho}_i}{(\bar{\rho}_w - \bar{\rho}_i)^2}\bar{\sigma}_{\rho}^{i})^2 + (\frac{\bar{\rho}_S}{\bar{\rho}_W - \bar{\rho}_i}\bar{\sigma}_{sd})^2 + (\frac{\overline{sd}}{\bar{\rho}_W - \bar{\rho}_i}\bar{\sigma}_{\rho}^{s})^2} \quad (4)$$

GC2: Third, although the authors treat the snow-induced uncertainty as random error (possibly a typo on line 400), it is hardly the case, despite that the snow depth is based on both climatology and PMI retrieval. A simple counter argument is that: the PMI product is based on C-band PMI onboard AMSR-E/2, which is at about 60km in resolution. Not to mention the 8-grid smoothing that is carried out over the snow depth retrieval. Then there exists large local correlation of the snow depth uncertainty, given that 25km grid is used in this study. Arguably more importantly, the climatology of snow depth from W99 plays a very important role in the snow-depth composite of AWI, which is evident in the respective technical report. Given that W99 is halved for the combined product, its induced uncertainty is still very large and will dominate the portion caused by snow in the uncertainty of the final ice thickness product. Therefore, I will be very cautions to treat the snow depth related uncertainty as random errors.

Response: Thank you for the valuable comments. Actually, we assumed that the uncertainties of AWI snow depth and snow density were systematic in the manuscript (line 1286-1287). We have recalculated the sea ice freeboard grid uncertainty and sea ice thickness uncertainty using averages.

GC3: Finally, the density of snow and ice are also treated as random errors. This should be also a very 'optimistic' estimation, especially the effect on the final ice thickness uncertainty. Overall, I suggest that the authors reconsider the uncertainty quantification process and divide into the random part and the systematic part, and be cautious about which category each term belongs to. Differentiation of the uncertainty also ensures fairer comparison with the AWI product, and the author seemed to have used the random error of it, which is much lower in may part of the basin (e.g., Beaufort Sea).

Response: Thank you for the valuable comments. The weighted mean ($\hat{\sigma}$) applies only to the radar freeboard, whose two error contributions range noise and sea surface height interpolation uncertainty are both defined as random error contributions. The error contribution of other physical variables to ice thickness is averaged ($\bar{\sigma}$). The grid uncertainty of radar freeboard, sea ice freeboard and sea ice thickness can be expressed as shown in Eq. (1) to (4).

GC4: Another major issue I noticed is the limited data availability of HY-2B even in the later months of the winter. As shown in Figure 6 and 8, there are large areas with no valid radar freeboard on the monthly scale: on the Eurasia continental shelf,

Beaufort Sea, etc. What is the cause of the missing data? Invalid waveforms. I suppose that at this latitude HY-2B should have better coverage than CS2.

Response: Thank you for the valuable comments. There are two main reasons for the missing data. Firstly, the HY-2B altimeter uses two different tracking modes: suboptimal maximum likelihood estimation (SMLE) and offset center of gravity (OCOG). The two tacking modes can exchange according to the observation surfaces. The HY-2B Level-2 altimetry products (SGDR products) we used do not have OCOG data. The measurement data point is sparse (line 96-98). Secondly, the SGDR data has nan values in the geophysical correction items such as the dry and wet tropospheric delay correction, inverse barometric correction, ionospheric correction, ocean tidal correction, ocean load tidal correction, earth tidal correction and polar tidal correction (line 187). We will try to use HY-2B L1 data to retrieve radar freeboard.

GC5: Also, the authors mainly compared the HY-2B retrieval with CS2. However, Sentinel-3 and AltiKa have the same inclination angle as HY-2B, and especially Sentinel-3 satellites work on Ku-band (although they are of delay-Doppler type). Is it better to compare against Sentinel-3 retrievals? This is only a suggestion, out of my curiosity. The authors can decide whether this is an option or not.

Response: Thank you for the valuable comments. We will conduct a comparative study between HY-2B and Sentinel-3 using HY-2B L1 data.

GC6: The comparison against CS2-IS2 data contains inconsistencies in the methodology. The comparison of radar freeboard is inherently between two CS2 retrievals (one from AWI and the other one carried out by Kwok). Therefore, it's not a fair comparison, since the two products based on CS2 arises from the same source of information. So many issues are not present, such as limited representation by altimetry.

Response: Thank you for the valuable comments. We use AWI snow depth to calculate HY-2B, CS-2 sea ice freeboard and sea ice thickness. We also used AWI snow depth to obtain IS-2 sea ice freeboard to make sure the final comparison is fair (line 339-340).

Specific comments:

Some figures contain maps that are too small to read, such as Fig. 6 and 8. Pls increase the font and maps accordingly.

Response: Thank you for the valuable comments. We have drawn Fig. 6 and 8 to make them as clear as possible (Fig. 5, 6,11 and 12).

For the third-party and auxiliary datasets, I suggest that the authors just introduce them, without too much comments on the specific advantages. For each product there

are potentially uncertainties that are fully addressed. I think just stating the basic status quo of the products is already enough.

Response: Thank you for the valuable comment. We have removed the description of Kwok snow depth product.

The reference list is not strictly ordered.

Response: Thank you for the valuable comments. We have checked the order of the references.

The language usage needs improvements. General suggestions include avoiding long sentences, and avoiding complex statements. Several typos are present. I suggest that the authors give an overhaul of the manuscript after the major issues are addressed.

Response: Thank you for the valuable comments. We have checked the manuscript, and we revised the manuscript using red fonts.