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 #2:

General comments

GC0: The HY-2B satellite is carrying a dual frequency Ku- and C- band radar altimeter. The data are used for deriving the sea ice thickness and it is compared to similar retrievals from CryoSat2 and airborne campaign data (Operation Ice Bridge). This is an urgent and welcome topic. However, important details are missing from the MS about the instrument and data and discussion of the processing steps and choices made. I did not see it stated clearly, but this study is not using the dual-frequency capability of HY-2B when deriving the freeboard? Only Ku-band? I think that the answers to these questions are important for evaluating the MS and the novelty of it.

Response: Thank you for the valuable comments. We have supplied the descriptions of instrument, data, and processing steps and choices made (line 87-93, 96-98, 196-197, 200-201, 209-210).

In this manuscript, we didn't use C-band of HY-2B to retrieve radar freeboard, just only Ku-band. **We have revised the title to 'Assessment of Arctic Sea Ice Thickness Retrieval Ability of the Chinese HY-2B Ku-band Radar Altimeter'. C**urrently, there is no research about using C-band to retrieve radar freeboard. We are searching the possibility of C-band to retrieve radar freeboard based on HY-2B L1 data. We will describe in detail in subsequent articles.

GC1: The snow data used in the processing are the same as the AWI snow depth (line 224). This is logical when HY-2B data are compared to AWI CS2 data. Are all the other processing steps and auxiliary data used in the processing identical to the AWI processing so that a proper comparison can be made? In line 24 it is mentioned that some of the differences were due to the applied sea surface height anomaly extraction method. Is it due to differences in the methodology or sensor specific differences? Please clarify.

Response: Thank you for the valuable comments. The sea ice concentration, sea ice type data used in the processing are identical to the AWI processing. But the MSS model used is the DTU 18, which is not identical to the DTU 15 of the AWI. We used DTU 15 to calculate the radar freeboard and compared with the radar freeboard calculated by DTU 18. We found that the difference between the two was small and the impact on the results was negligible, so we adopted DTU 18 to retrieve radar freeboard. The other processing steps are different with the AWI, including the retrack algorithm, the extraction of SSHA, and the criterion of filtering. These different processing steps can result in the discrepancies between both HY-2B and CS-2. We think it is due to differences in the methodology, sensor specific differences and measurement mode. We have supplied the reason of the differences in the section of result (line 263-264, 267-268, 297-300, 346-348). We will improve the processing method to obtain radar freeboard with higher precision using HY-2B L1 data.

GC2: A number of studies focused on Ku- and Ka-band radar altimeter applications from AltiKa and CryoSat and for preparation of the planned CRISTAL mission. This MS does not continue that discussion using C- and Ku-band radar altimetry for sea ice applications. Anyway, I think that some justification of the choices made in this paper are needed, for example, it is implicitly understood that radar scattering is at the snow-ice interface. Is that a good assumption? And how would that differ for Ku- and C-band. Would the different foot-print sizes at the two frequencies have an impact for the derived ice thickness?

Response: Thank you for the valuable comments. We assumed that the radar pulses penetrate through any snow cover on ice floes and scatter from the snow-ice interface, which has been shown in laboratory experiments where the snow cover on sea ice is cold and dry (Beaven et al., 1995; Tilling et al., 2018). Despite some evidence that the scattering horizon migrates as temperature rises (Willatt et al., 2010), Tilling et al. (2017) did not observe any bias in their thickness retrieval when compared to year-round ice draft data, and so they thought that the impact of this effect was not significant (line 215-220). The differences between C band and Ku band are mainly reflected in footprint size, waveform (retrack algorithm) and radar penetration factor. Two different frequencies maybe have an impact for the radar penetration factor, which will impact the radar freeboard. The different footprint sizes at the two frequencies also have an impact for the spatial resolution of radar freeboard. The spatial aliasing situation has long existed in sea ice thickness (Geiger et al., 2015), where the different instrument footprint sizes bring about artificial modes in thickness distribution (Zhou et al., 2020) .

The HY-2B altimeter uses two different tracking modes: suboptimal maximum likelihood estimation (SMLE) and offset centre 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.

We will explore the possibility of C-band to retrieve radar freeboard using L1 data. Because the L1 data can contribute to assess the comprehensive retrieval ability of C-band without missing OCOG data.

GC3: The snow depth dataset is a strange combination of retrieved snow depth over first-year ice and snow depth climatology over multiyear ice and some smoothing and filtering. What does the different snow depths and ice densities in first-year ice and multiyear ice areas mean for the retrieved ice thickness? How does this compare to the variation in derived freeboards for the ice thickness variability? What is the impact of the fixed ice densities and the ice type classification with its different snow depths etc.? Is the snow depth needed at all? To me it seems that the snow data are massaged until the "right" ice thickness is achieved.

Response: Thank you for the valuable comments. Based on the snow depth and density measured at Soviet drifting stations on multiyear Arctic sea ice from 1954 to 1991, a two-dimensional quadratic model named W99 Climatology Snow Depth model is fitted to represent the geographical and seasonal variation in snow depth for a particular month, irrespective of the year (Warren et al., 1999). The climatology was based on observations from drift stations in a period where the Arctic Ocean was dominated by multiyear sea ice. It is therefore likely that the reduction of multiyear sea ice in the recent decade (Nghiem et al., 2007) may have impacted the distribution of snow depth in areas that are now more often covered by seasonal sea ice (Ricker et al., 2014). Rostosky et al., (2018) analyzed the correlation between the gradient ratio of different channels and OIB snow depth data and tried to expand the snow depth retrieval onto MYI. Since the OIB flight is conducted in March and April of every year in the Arctic, the retrieved snow depth on the MYI of the algorithm is only applicable to March and April of spring. Therefore, Hendricks et al. (2020) introduced a monthly snow depth and density parametrization based on merging of the W99 snow climatology and daily snow depth over first-year sea ice from AMSR2 data provided by the Institute for Environmental Physics of the University Bremen (IUP).

Dong et al. (2022) found that the spatial patterns in six products (W99, AWI, Bremen, Kwok, Neural Network and LSTM) are in broad agreement; that is, snow cover is thicker over the sea ice of northern Greenland and the northern Canadian Archipelago, while snow cover is thinner over the sea ice of the Eurasian marginal Sea and Baffin Bay region. The spatial pattern of snow depth is similar with sea ice thickness.

The radar freeboard (*f*) can be converted into sea-ice thickness *T* depending on the snow depth (h_S) and the densities of snow (ρ_S), sea ice (ρ_i) and sea water (ρ_W), as shown in Eq. (5).

$$T = \frac{\rho_w}{\rho_w - \rho_i} \bullet f + \frac{\rho_s}{\rho_w - \rho_i} \bullet h_s \quad (5)$$

where T is the sea ice thickness, ρ_w is the seawater density, ρ_s is the snow density, ρ_i is the sea ice density and h_s is the snow depth. Consistent with the approach of Laxon et al. (2013) we use ice densities (ρ_i) of 916.7 kg m^{-3} for first-year ice (FYI) and 882.0 kg m^{-3} for MYI (Alexandrov et al., 2010). Furthermore, we assume a value of 1024 kg m^{-3} for the water density (ρ_w) (Ricker et al., 2014).

Specific comments:

Line 13: "… it is of great significance…" this is a subjective statement without real justification. Please reformulate.

Response: Thank you for the valuable comment. We have revised to 'it is urgent to explore the potential application of this dataset in Arctic sea ice thickness retrievals' (line 8-9).

Line 14: delete "values".

Response: According to your valuable comment, we have removed the vocabulary of 'values' (line 10).

Line 15: "… ice growing cycles" replace by "winters".

Response: Thank you for the valuable comment. We have revised 'sea ice growing cycles' to 'cycles', as we distinguish it to winter and spring (line 10).

Line 17: delete "recorded".

Response: According to your valuable comment, we have removed the vocabulary of 'recorded' (line 17).

Line 18: replace "verified" with "compared"..

Response: Thank you for the valuable comment. We have removed the sentence.

Line 40: delete "effect".

Response: According to your valuable comment, we have removed the vocabulary of 'effect' (line 30).

Line 45: It is confusing and inaccurate what is written about AMOC. Please reformulate or delete.

Response: According to your valuable comment, we have removed the sentence.

Line 52: add “and extent” after “density”.

Response: According to your valuable comment, we have revised 'density' to 'extent' (line 40).

Line 57: use “derive” instead of “estimate”, also line 61.

Response: According to your valuable comment, we have revised 'estimated' to 'derived' (line 45 and 47).

Line 75: “few reports” please list these few reports as references.

Response: According to your valuable comment, we have supplied the references, 'Jiang et al. (2022) preliminarily estimated the Arctic radar freeboard from October 2020 to April 2021, compared them with radar freeboard products from the Alfred Wegener Institute (AWI). The overall difference between the HY-2B radar freeboard estimates and the AWI data is 0.088 ± 0.057 m. The radar freeboards are generally higher for HY-2B than CS - 2' (line 66-69).

Line 77: delete “as a supplementary means”

Response: According to your valuable comment, we have removed the 'as a supplementary means' (line 70).

Line 79: delete sentence starting with “Therefore…”.

Response: According to your valuable comment, we have removed the sentence (line 70).

Line 90: Add some details about the HY-2B altimeter.

Response: According to your valuable comment, we have added some details about the HY-2B altimeter. 'The HY-2 radar altimeter adopt the same reference ellipsoid of the TOPEX/Poseidon and the Jason-1/2/3. The HY-2B radar altimeter is a dual-band pulse-limited radar altimeter that comprised of the Ku band and C band to remove the impacts of ionospheric delays. The HY-2B satellite adopts an orbit with a repeat cycle of 14 days in the early stage, and an orbit with a repeat cycle of 168 days in the late stage. Waveforms have been sampled to 128 range bins, each of which is 0.4864 m in range' (line 87-92). 'The SGDR products contain waveform data and have been re-tracked using the Brown model. In addition, 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' (line 96-98).

Line 91: delete "successfully".

Response: According to your valuable comment, we have removed the vocabulary of 'successfully' (line 102).

Line 168: "Snow depth" it is unclear which snow depth dataset is actually used. Please clarify this and explain if you are using AWI snow depths or IS-2/CS2 snow depths.

Response: According to your valuable comment, we have used AWI snow depth to retrieve radar freeboard.

Line 224: delete "depth".

Response: According to your valuable comment, we have revised to 'snowpack' (line 214).

Line 226: Eq. 3 units in meters? Please add units, sometimes [m] sometimes [cm]… use the same units throughout.

Response: According to your valuable comment, we have added the units in meter (line 204, 205, 212 and 213).

Line 230: Eq. 4, what is the sea water density? Sometimes units are [kg m^{-3}] sometimes [kg/m^3], stick to one form. Multiplication is sometimes a dot and sometimes x?

Response: According to your valuable comment, we stick to use unit [kg m^{-3}] and a dot in multiplication (Eq. (4), Eq. (5), Eq. (6), Eq. (8), Eq. (10) and Eq. (13)). We have revised 'sea water density' to 'water density' (line 230).

Line 322: I think that I know, but this is confusing: what is a "deviation"? standard deviation? or bias? Throughout the MS.

Response: According to your valuable comment, we have revised to 'In general, the HY-2B sea ice thicknesses exhibit a MAE of approximately 0.2 m with respect to CS-2' (line 315).

Line 324: replace "independent" with "OIB".

Response: According to your valuable comment, we have revised 'independent' to 'OIB and IS-2' (line 323).