Dear Editor, dear reviewer,

Thanks for the valuable comments, which help to improve the quality of the paper. The detailed replies are addressed below point by point in blue. The key issue raised by reviewer is we need more validation. The following table shows the update of validation in the revised version.

	Current version	Revised version
Number of site(s)	1	7
Total observation length	1 month	~10 years

Best regards,

Linlu Mei on behalf of all co-authors

General Comments

This paper describes the results and validation of the XBAER algorithm that retrieves snow grain size (SGS), specific surface area (SSA), and particle shape (SPS) from Sentinel-3 SLSTR instrument. The paper presents the results and evaluate them using the MODSCAG product, in-situ measurements from SnowEx17, and airborne-based retrievals. The validation for cloud-free and partial cloud cover shows promising results from the XBAER algorithm; however, there are some issues related to the validation process and the paper's writing structure.

Response: The validation is largely extended by including all possible existing campaign during 2016-2020. The analysis, including the writing structure is also re-ranged. The extended dataset for validation is shown in the figure below
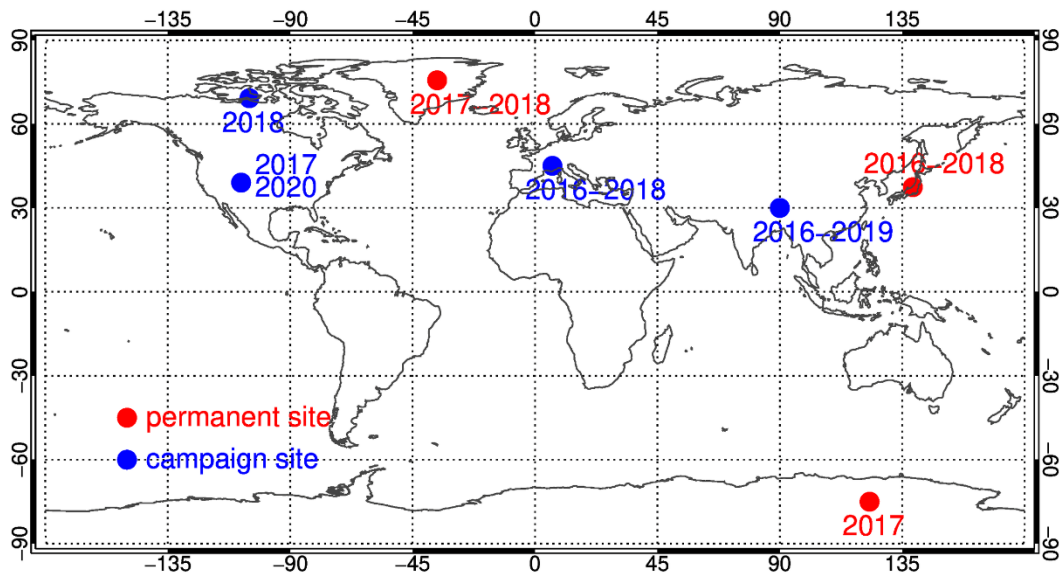
Fig. 1 Geographic distribution of the validation sites. The colors represent the type of each site while the observation period used in this manuscript is indicated near each site.

Regarding the validation process, the main negative point is that the authors state that these are preliminary results and that they are waiting for more data from the MOSAiC project to increase the number of observations for validation. However, this paper accompanies another paper on the development of the XBAER algorithm. If these are preliminary results, it would make more sense to fit some of these results in the first paper, and then wait for the MOSAiC data to submit a more comprehensive validation in the second paper. I understand that it is hard to obtain enough data for remote sensing validation, but since there is ongoing data collection, the wisest decision will be to wait until the MOSAiC dataset is fully collected.

Response: Beside the extended validation dataset above, we have also contacted the MOSAiC team, however, the latest information is that we properly have to wait quite some time for the dataset, and we believe that the extended validation is enough for a comprehensive understanding of XBAER algorithm. We will move the content with respect to the MOSAiC comparison in the summery part to indicate our future work.

Regarding the paper's writing structure, in general, the paper lacks conciseness. A few general comments about this topic are the following: - There are long sentences on multiple occasions. - The authors should be more careful about using quantitative adjectives when describing their results or other authors' results. I would recommend using the actual number instead. - I would suggest that the authors make a thorough revision of the use of articles, prepositions, and verb agreements in the paper. - The purpose of this paper should be more clearly stated in the introduction. - There is excessive use of quotes. - The discussion paragraph is too long and speculative. There is

a lot of discussion in the results section already. I would recommend the authors to create a section for results and discussion together instead. - The conclusion is too long and with too much redundancy. It should state the main findings, limitations, and future studies, and if it was able to meet the goals of the study. In addition, the main findings in the conclusion should follow the same order that the results are presented.

Response: We have thoroughly improved the presentation in the revised version. More specifically (1) We have updated the introduction part; (2) We have cut long sentences into short ones; (3) we have fixed possible grammar issues (4) We have merged section 4 and 6 to create a "result and discussion section" (5) We have shorten the conclusion part, with the same order as that the results are presented

More detail is provided in the Specific Comments and Technical Corrections sections below.

Other general comments on the scientific soundness of the paper are the following: How have you dealt with the forest in the Grand Mesa site? - One way to improve the SGS validation would be perhaps to extend the validation using more MODSCAG scenes.

Response: We have performed the simple collocation, according to our understanding, the impact of the forest within an SLSTR pixel is mitigated due to the usage of "effective Lambertian albedo". We include MODSCAG for the SnowEx17 validation in the revised paper.

It is not appropriate to use full cloud cover field measurements to validate a remote sensing retrieval that only works with cloud-free conditions. Using partially covered skies might still be a reasonable assumption, as long as the limitations of the retrievals under these conditions are addressed, but not full cloud cover as on Feb. 11, 2017. Retrieving snow properties for full cloud cover only shows that your model is able to characterize the properties of cloud ice crystals, but that has no implications for snow properties on the ground.

Response: With the largely extended validation, this issue will not be so critical. However, we believe that the validation using the fully cloudy scene is also helpful. We have presented our results in the Sentinel 3 validation meeting held last month (hosted by ESA/EUMETSAT), and most snow scientists show great interest to see how we can avoid a pre-cloud-identification in our snow retrieval because cloud screening above snow always brings large uncertainties in the dataset.

Specific Comments

Line 14: The OLCI instrument was not used directly to retrieve snow properties; therefore, it would be better to only mention it when talking about the cloud screening

process.

Response: We removed OLCI here

Line 52: Melting snow does have lower albedo, but the main mechanism that decreases albedo is actually the absence of snow cover.

Response: We updated this sentence in the revised version.

Line 62: The terms field- based and in-situ are synonyms; there is no need to use them together.

Response: We removed field-based in the revised version

Lines 62 to 67: Consider splitting or rearranging this sentence to improve its clarity.

Response: We updated this sentenced and spitted in the revised version.

Line 82: When you mentioned snow fraction. Did you mean snow cover fraction?

Response: Yes, snow cover fraction

Line 100: You should drop "imagery" if you are talking about instruments. You should also add one space before "(EO-1)" in the previous line.

Response: Done

Line 104: I would rewrite this sentence as: "to partly take into account irregular shape impacts on snow reflectance".

Response: Done

Lines 106 to 108: I am not sure if this information is relevant in this paragraph.

Response: We believe it fits here because it gives the reader an overview of the change of SPS with respect to meteorological conditions.

Lines 108 to 109: It is unclear what the classification system is for. Is it for classifying SPS? If yes, it would be a good idea to specify that and explain how the system classifies SPS.

Response: We extended the explanation of the classification of snow from Kikuchi et al (2013) in the revised version.

Lines 130 to 131: In this sentence, the last "retrieval" is redundant. For the sake of conciseness, try to avoid doing this in other sentences of the paper.

Response: We have checked thoroughly of this presentation-related issues and ask our native speaker to double-check as well.

Line 150: Try to be more specific when mentioning pieces of the part 1 paper. You could

maybe mention the section number to help the reader find it in the other paper.

Response: We have made a short summery of information from Part 1, if needed in part 2, rather than use "see part 1" in the current form.

Line 152: I would suggest changing the title of the point to: "Difference between field-measured and satellite-derived SPS".

Response: Done

Line 183: The acronym BRDF was not introduced in the text yet.

Response: It is introduced in the revised version.

Line 189: Try to be consistent with the terminology. I have seen in-situ, field-based, field-measured, and ground-based, used interchangeably. Better if you choose the most appropriate and use it consistently throughout the text.

Response: We harmonized in the revised version.

Line 199: European Space Agency (ESA) was previously introduced.

Response: Removed

Figure 1: It would be good to add a picture of the Senator Beck Basin site as well. In the map, make sure to increase the font and include the name of the two sites. Ideally, it would be good to have an inset zoomed to the two sites together with the US map.

Response: We updated the figures according to the suggestion.

Table 2: I am not sure if the SnowEx17 column is necessary here, since there is no linkage to the Yang columns, and it was previously mentioned.

Response: Together with comments from reviewer 1, we included the classification system from Fierz et al. (2009) in Table 2. The SnowE17 is also based on the Fierz et al. (2009)

Line 239: The sentence "masking by gases and molecules" is not the most accurate. I would suggest changing it for "attenuation and scattering by gases and aerosols".

Response: Done

Figure 2: I would suggest trying to minimize the amount of text in this flowchart. Also, you would have to connect the two biggest green boxes inside the dashed line to represent better that this is an iteration process.

Response: There is an arrow missing which should link the two green boxes.
As to the texts in the flowchart, since XBAER algorithm includes quite some other previous published algorithms, we would like to take the heritage of it.

Figure 3: I am impressed with the spatial detail of XBAER retrievals, but I noticed two geometrical-shaped features in Eastern Greenland. Could you please comment on why this is happening in that region?

Response: Thank you for the positive feedback of our retrievals. The two geometrical-shape features in Eastern Greenland are explained by the impact of large viewing zenith angle. This Figure is created by three SLSTR swaths, the two geometrical-shaped features occur at the edge of the middle swath (large viewing zenith angles). In XBAER, the "effective Lambertian albedo" assumption is used and this assumption will introduce error under large viewing zenith angle condition. We included the explanation in the revised version.

Line 336: This parenthesis is probably unnecessary: "(humidity, temperature, … etc.)".

Response: We removed it

Lines 336 to 347: I appreciate that you tried to compile as many studies as possible to perform a qualitative validation, but this section is too long. Instead of listing all the values, you can try to summarize what you found by the other authors focusing only on what you used for your validation.

Response: We reduced certain previous studies in this section, to make sure that only close-related publications are cited here.

Line 348: There is no need to use quotations here.

Response: We removed it

Figure 5: It seems that the legend of the cloud maps is wrong. It should be cloud (light blue) and cloud-free (white).

Response: The current legend is a little bit mis-leading, the "snow-free" legend refers to the area where XBAER retrieval is not performed, this includes (1) snow-free and cloud free (2) cloud above snow; (3) cloud above snow-free. The light blue is snow. We updated the legend in the revised version.

Line 529: I am not sure if time series would be the best term to describe this analysis. The Sentinel-3 image is a snapshot of time, while the aircraft surveying takes about 2 hours to complete. It would be better to relate this to space (coordinates), and probably some correction would be needed to address differences in solar zenith angle between the two instruments. Was that addressed? Differences in solar zenith angle can also represent different amounts of shadows, which might explain some of the differences between XBAER and SMART.

Response: We have published another paper for this topic (Jäkel et al., 2021), in which more detailed comparison between XBAER and SMART is given. We included some findings from the new publication in the revised version. Specifically, possible shadow

effect on the retrieval accuracy is detailed discussed in the paper of Jäkel et al (2021).

Jäkel, E., Carlsen, T., Ehrlich, A., Wendisch, M., Schäfer, M., Rosenburg, S., Nakoudi, K., Zanatta, M., Birnbaum, G., Helm, V., Herber, A., Istomina, L., Mei, L., and Rohde, A.: Comparison of optical-equivalent snow grain size estimates under Arctic low Sun conditions during PAMARCMiP 2018, The Cryosphere Discuss. [preprint], https://doi.org/10.5194/tc-2021-14, in review, 2021.

Lines 533 to 534: The mean SGS from SMART is actually higher than for XBAER.
Response: We fixed this word in the revised version.

Lines 578 to 579: That depends on environmental conditions.
Response: We included more information for these sentences to clarify the dependent of length of time scale on environmental conditions.

Lines 587 to 589: It is unlikely that blowing snow would transport fresh snow from the ground to such long distances in such a short period.
Response: We included the ECMWF wind information in the revised version, and an updated explanation for this sentence will be included.

Line 636: There is extra space before the parenthesis. In addition, there is no need to repeat the ice crystal types in the conclusions.
Response: extra space before the parenthesis is removed and we have deleted the ice crystal types in the conclusion.

Line 656: It would be better to use "inversely correlated" than "anti-correlated".
Response: Done

Technical Corrections
Line 54: Replace "of change snow properties" to "of snow properties change".
Response: Done

Line 54: Replace "annular" for "annual".
Response: Done

Line 60: Replace "temperatures surrounding" for "surrounding temperatures".
Response: Done

Line 70: Replace "summery" for "summarize".
Response: Done

Line 86: Replace "Jin et al (2008)" for "Jin et al. (2008)".
Response: Done

Line 90: Replace "usage" for "use".
Response: Done

Line 96: Replace "the in-situ measurement" for "in-situ measurements". This sentence would be clearer if you add a comma after Antarctica.
Response: Done

Line 114: Replace "e.g." for "e.g.,". This repeats a couple more times throughout the text.
Response: Done

Line 116: There is a missing space before the citation parenthesis.
Response: We have included a space

Line 182: Replace "SLSTR/AATSR" for "SLSTR and AATSR".
Response: Done

Line 217: There is a missing period. Also, you should replace "have not linkage" for "have no linkage".
Response: The problems are fixed and phase updated.

Line 226: Replace "is" for "was".
Response: Done

Line 233: Replace "present" for "presented", and add a comma after "(about 80° SZA)".
Response: Done

Line 263: Replace "details" for "detailed". Line 373: Replace "is" for "are".
Response: Done

Line 439: Should replace "the warmer conditions leads to" for "which leads to".
Response: Done

Line 527: Remove hyphen after "SGS".
Response: Done

Line 645: Replace "minimization" for "minimizations".

Response: Done

Line 671: Replace "usage" for "use".
Response: Done