Dear Editor, dear Dr. Ghislain Picard,

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. In short:

(1) More validation is included

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

(2) The discussion with respect to snow particle shape, especially under different classification systems in different scientific communities.

To retrieve snow properties from satellite observations, what we need is the local optical properties for an "effective particle shape" to perform the radiative transfer calculation, we will emphasize that we should not over-interpret the effective particle shape we retrieved in the revised version. As highlighted in Picard et al (2009), "information is urgently needed to know which model shape best approximates the different type of fresh snow", to address "the uncertainty of SSA retrieval based on the SSA-albedo relationships when grain shape is unknown". We believe our work, as a first step/attempt, provides some new/useful way/information for this issue. And of course, we will introduce a more sophisticated way in our future work, for example, to mix different shapes.

Picard, G., Arnaud, L., Domine, F. and Fily, M., Determining snow specific surface area from near-infrared reflectance measurements: numerical study of the influence of grain shape, Cold regions and science and technology, 56, 10-17,2009

Best regards,

Linlu Mei on behalf of all co-authors

Review "The retrieval of snow properties from SLSTR/Sentinel-3 -part 2: results and validation" by Mei and colleagues. The paper aims at validating an algorithm to retrieve snow grain size and shape, and snow specific surface area from the space-borne SLSTR sensor. The algorithm was described in another paper in review (companion part 1), the present manuscript is dedicated to the validation. The overall goal of these two parts is of interest for the cryosphere community, in particular because SLSTR is on the Sentinel 3 series of satellite which will be able for decades.

The paper is original and clear. Nevertheless, my recommendation is to postpone the acceptance of this paper for three main reasons:

Response: Thanks for the very valuable comments from Dr. Ghislain Picard, after detailed discussion with him by emails, we hope we have a good understanding of all comments here. The key issue, as raised by Dr. Ghislain Picard, is about more validation. This is also raised by the second reviewer of part 2. Although, as mentioned by the reviewer, "I understand that it is hard to obtain enough data for remote sensing validation", we have started to collect more validation data since we saw the comments on 10 Nov. 2020.

The reason why only SnowEx17 was considered for the validation in the current form, is that, to our best knowledge, this is possible the only campaign providing all three satellite retrieved parameters (SGS, SPS and SSA). Now, the new understanding is that we can use any campaign data, even when only one satellite retrieved parameter is provided in the campaign. Thus, the following campaign data have been collected for an enhanced validation, in short, the validation is largely extended from one single month from the SnowEx17 campaign to a couple of years worldwide (see Fig 1). We believe, that the extended validation will provide a comprehensive understating of the performance of XBAER algorithm.

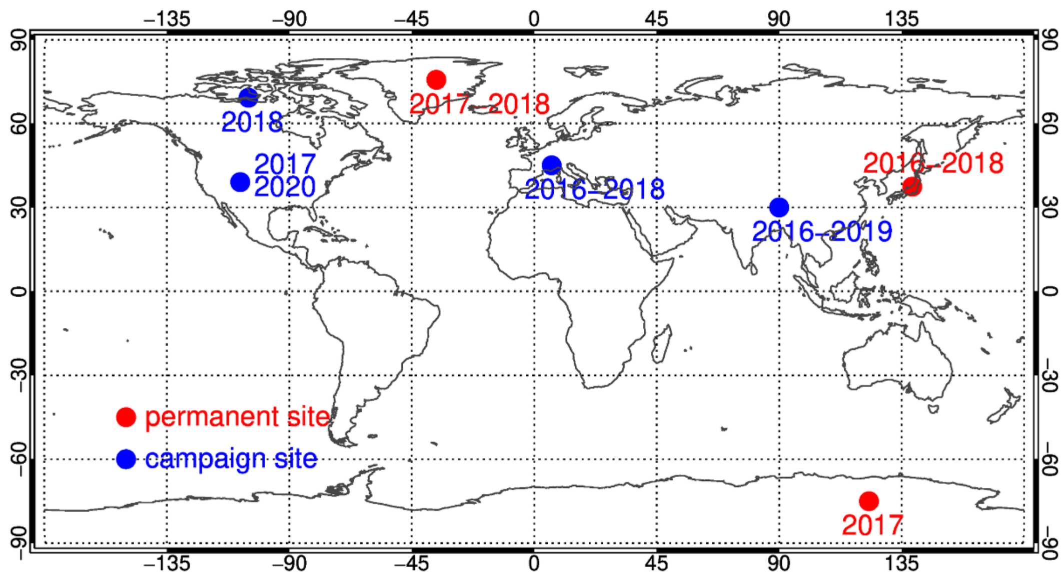


Fig. 1 Geographic distribution of the validation sites. The colors represent the type of each site while the observation period used in this manuscript is indicated near each site.

Please be noted that the above campaign data, covering all typical snow-covered geographic regions, will also provide deeper understanding of potential atmosphere/surface effects. For instance, if we make a cross-validation between the Japanese site and Dome C site, we may have a much better understanding of the impact of aerosol contamination, while the comparison between French Alps and North

America may provide more information of the impact of surface elevation.

The validation is based on a too limited set of in-situ data, part of it is discarded because of cloud contamination (SnowEX17). The text truly dedicated to the algorithm performance evaluation is also relatively short and seems unfinished, most of text is about the difficulty to perform the validation, which in the end does not contribute to give confidence in the retrieval algorithm. The conclusion about the algorithm performance therefore lacks of support. There are also several technical issues (see below in the detail comments) in particular one on the RMSE definition. The lack of datasets is a common problem, but not to the extent depicted by the authors. The main example is for the snow grain size. The manuscript cites Kokhanovsky et al. 2019 which pursues a very similar objective as the present manuscript but uses OLCI, (on Sentinel 3 as well as SLSTR) to estimate grain size and SSA (not the grain shape). For the validation these authors used an extensive dataset with 100s of SSA field measurements in Greenland and in Antarctica. These data can be either retrieved from the graphs or in principle obtained from the authors, and should be used here to complete the validation (or even replace the 3 SnowEx measurements). Moreover, the performance between the SLSTR and OLCI algorithms could be analyzed at these in-situ points. At last, the authors "emphasize that the results presented in this section is considered as preliminary" (L373). They indeed propose to include Mosaic data in their analysis in the future. My concern is whether it is worthwhile for the community to publish "preliminary results" in two papers. My suggestion is indeed to wait for complete results and include Mosaic dataset.
Response: We have contacted the MOSAiC team and we will have to wait for quite long for the processing of the data, however, as we mentioned above, thanks for all snow scientists who are willing to share the valuable dataset, we have collected enough campaign data for an extended validation.

We also add the comparison over Greenland with the retrieval from OLCI (Kokhanvosky et al., 2019) in the revised version. However, SSA retrieved in Kokhanvosky et al. (2019) used the simple relationship between SGS and SSA, that is $SSA = \frac{3}{\rho \times SGS}$, ρ is the bulk ice density. Even the SGS is perfectly retrieved, the calculation using this simple "conversion" may provide 20% error, and the SSA-albedo relationships limits the accuracy of SSA retrievals from albedo when the grain shape is unknown (Picard et al., 2009). We believe that our work is a new attempt to provide the information we are lacking now, that is we retrieved an "effective particle shape" and SGS, and provide unique relationship between SSA and SGS.
For instance, in the case of convex faceted particles such as droxtal, solid column, and plate, the calculation of total area is straightforward and based on the Cauchy's surface

area formula:

$$A = 4A_p. \qquad (1)$$

Taking into account that for selected SPS, one can find corresponding V and A_p in database given by Yang et al., (2013), we have the following results for SSA of such particles:

$$SSA = \frac{4A_p}{\rho V}. \qquad (2)$$

In this case a solid column includes two equal cavities in the form of a hexagonal pyramid and cannot be considered as convex particle. The aspect ratio of hollow column with the height, d, of hexagonal pyramid is given according to Yang et al., (2013) as:

$$\frac{2a}{L} = \begin{cases} 0.7, & L < 100\mu m \\ \frac{6.96}{\sqrt{L}}, & L \geq 100\mu m \end{cases}, \quad d = 0.25L. \qquad (3)$$

The volume of such hollow column is given by

$$V = V_c - 2V_p, \qquad (4)$$

where the volume of solid column, V_c, and a hexagonal pyramid, V_p, are,

$$V_c = \frac{3\sqrt{3}}{2}a^2 L, \qquad (5)$$

$$V_p = \frac{\sqrt{3}}{2}a^2 d. \qquad (6)$$

Thus, the volume, V, is

$$V = \frac{\sqrt{3}}{2}a^2(3L - 2d). \qquad (7)$$

Employing the relationship between d and L given by Eq (A4) and excluding a, we have

$$V = \frac{2.5\sqrt{3}}{2}a^2 L \begin{cases} m_0 m_1^2 L^3, & L < 100\mu m \\ m_0 m_2^2 L^2, & L \geq 100\mu m \end{cases}, \qquad (8)$$

where $m = \frac{2.5}{\sqrt{3}/2}$, $m_1 = \frac{0.7}{2}$, and $m = \frac{6.96}{2}$. For a selected volume, V, the length, L, is calculated as follows:

$$L = \begin{cases} [V / m_0 / m_1^2]^{\frac{1}{3}}, & V < V_{100} \\ [V / m_0 / m_2^2]^{\frac{1}{2}}, & V \geq V_{100} \end{cases}, \quad (9)$$

where $V_{100} = m_0 m_2^2 100^2$.

Let us now calculate the area of each triangle side of the pyramid

$$S_t = \frac{a}{2}\sqrt{d^2 + \frac{3a^2}{4}}. \quad (10)$$

The area of lateral surface of two pyramids is

$$S_p = 3a\sqrt{4d^2 + 3a^2}. \quad (11)$$

And the total surface area of hollow column is given by

$$S = 6aL + 3a\sqrt{4d^2 + 3a^2}, \quad (12)$$

where a and d should be expressed via L according to Eq. (3).
Having obtained the total area, one can calculate specific surface area

$$SSA = \frac{S}{\rho V}, \quad (13)$$

For each pre-defined effective shape, such a solid derivation is provided in part 1.

Then the key issue becomes can we use the Yang shapes (effective particle shape) to re-produce the real snow properties, which is also raised in the next comment, and our answer is yes and please see detailed explanations and corresponding figure in the next comment.

The issue with respect to the definition of RMSE, is clearly explained in the specific comments later as well.

Picard, G., Arnaud, L., Domine, F. and Fily, M., Determining snow specific surface area from near-infrared reflectance measurements: numerical study of the influence of grain shape, Cold regions and science and technology, 56, 10-17,2009

The grain shape is a big issue of this study. It is claimed to be a major advantage compared to other algorithms (e.g. L617) but the demonstration is missing. First because it is difficult if not impossible to validate. I acknowledge that snow shape is a difficult topic. However as for the validation of the grain size, the choices of the authors are limiting the ability to perform the validation. The algorithm assumes and retrieves geometrical shapes that are representative of precipitating crystals, not of snow on the ground although the algorithm is supposed to be used for snow on the ground. A first consequence is that the algorithm can not perform well, because the phase function of such shapes does not apply to snow on the ground (expect for fresh snow). Snow on the ground is usually more rounded and irregular than crystals in the atmosphere. The second consequence (and the main one) is the difficulty to perform the validation. Data recorded by snow practitioners and scientists in the field usually follows the international classification of seasonal snow on the ground (Fierz et al. 2009, not cited in the manuscript) which has some shortcomings but is widely used. Since the algorithm does not use these "standard" shapes, it is inherently impossible to perform a fair comparison with external data. It follows a third consequence about the usefulness of the shape information retrieved by the algorithm. I'm wondering how useful is this retrieved "grain shape" for snow community since it does match with its standards. I suggest that to solve this major issue, ideally by adapting the shapes used by the algorithm, and if not possible at least by establishing a link between the different shape systems. Even if imperfect and highly uncertain, this link will benefit to the whole clarity of the paper and will help to shorten the validation section (see comments below). They should also explain why retrieving the shape is useful for the algorithm. The algorithm uses a first guess grain size from another algorithm but no comparison is given. I would expect the authors to demonstrate that taking into account the grain shape has an effective positive impact on the SSA or grain size estimates. This would be very useful for the snow remote sensing community to know if such an approach is fruitful.

Response: We agree that it is not possible for an apple-to-apple validation for the snow grain shape, as we discussed with Dr. Ghislain Picard by emails. Dr. Ghislain Picard also mentioned the way without an assumption of grain shape, that is to use an assumption of stochastic medium, consisting of irregular ice grains and air bubbles, however, in this manner, there is also parameters which cannot be validated. In particular, this is the mean photon path length. It is worth to notice that, all manners, for the retrieval of snow properties from satellite, needs to make some assumption, which is fundamentally needed for a specific retrieval algorithm (Langlois et al., 2020). We extend our introduction part to make a clearer statement in the revised version.

For the widely used ART model (the one used in the retrieval of OLCI in Kokhanovsky et al., 2019), even though the users do not highlight the issues linked to snow particle shape, these issues exist. (1) The original ART model (Zege et al., 2004; Kokhanovsky and Zege et al., 2005) is derived based on the assumption of second-generation fractal for ice crystal shape. (2) In the updated ART model (Kokhnaovsky et al 2018), g and B parameters are introduced. The g parameter depends on both size and shape. The B parameter depends strongly on the shape (Libois et al., 2014). Even one can state that the g and B parameters can be fitted to real observations, several issues linked to the assumption of particle shape occur (1) the accuracy of use single g parameter to describe the complicated particle phase function needs to be checked; (2) ART model is designed for medium with weakly absorption properties, thus it cannot be used for certain particle size/shape, especially for long wavelength, e.g. 1.6 µm. So, we cannot really avoid making certain (explicit or hidden) assumptions of SPS if it is not iteratively retrieved in the algorithm, like in our case.

To “demonstrate that taking into account the grain shape has an effective positive impact on the SSA or grain size estimates”, the mathematical derivation (see example above) is included in part 1 and corresponding sensitivity study is also performed, in the revised version.

The question with respect to if the recent development from Yang can be used for the description of snow properties, such as the snow phase function, this has been confirmed by recent publications (e.g Saito et al., 2019; Pohl et al., 2020; Mei et al., 2021) and private communication with Prof. Ping Yang’s group. We have included a detailed explanation in Part 1 and we will make a short summery of this issue in Part 2 as well. Additionally, we have compared the model from Yang with real surface BRDF measurements, including ground-based measurements, aircraft measurements and satellite observations, all shows that Yang shapes can provide good accuracy to simulate snow directional reflectance (Mei et al., 2021), which is the fundamental basis of our retrieval algorithm. Fig. 2 shows an example of how Yang database can re-produce the NASA Cloud Absorption Radiometer (CAR) instrument observed snow BRDF at the flight height of 200 meter, we will include some of our latest investigation in the revised version as well.

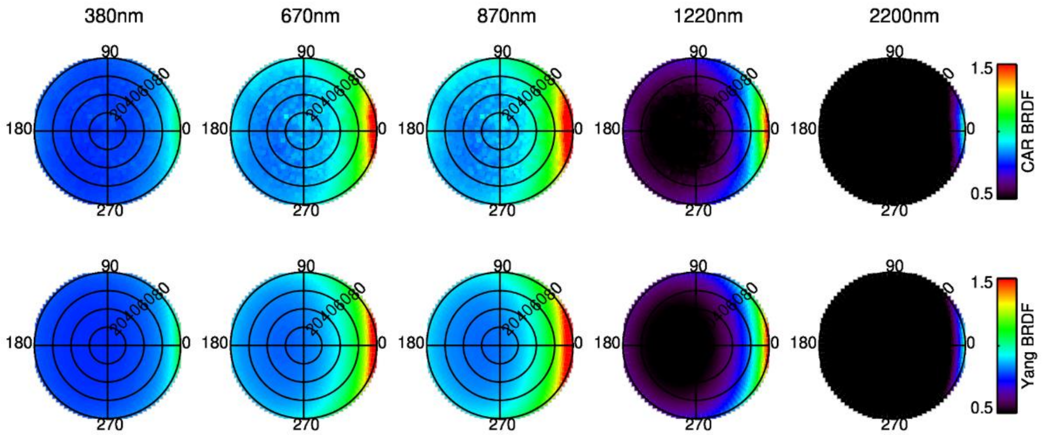


Fig 2 Comparison of NASA CAR instrument observed snow BRDF (upper) and Yang shape simulated snow BRDF (lower) for different wavelengths.

In short, the Yang et al. database can be used to describe the ice crystal local optical properties of snow.

With respect to the classification referring to Fierz et al. (2009), as clearly stated in the document, “we expanded and clarified where necessary but did not include those most recent developments that are not fully agreed upon by the whole community." And as far as I understand, the classification is a work to provide "the creation and maintenance of a common language", no local optical properties are available for the proposed names/classifications. And what we need is the local optical properties for an "effective particle shape" for the RTM calculations. We will emphasize that we should not over-interpret the shape we retrieved in the revised version.

However, we will include certain suggestion of the linkage between Yang's shape and the shapes proposed in Fierz et al. (2009), as suggested by Dr. Ghislain Picard. We are currently harmonizing this issue with Yang's group.

Fierz et al. (2009)		Yang et al (2013)
Precipitation Particles		Aggregate of 8 columns
Machine Made snow		Droxtal
Decomposing and Fragmented precipitation particles		Hollow bullet rosettes
Rounded Grains		Hollow column
Faceted Crystals	?	Plate
Depth Hoar		Aggregate of 5 plates
Surface Hoar		Aggregate of 10 plates
Melt Forms		Solid bullet rosettes
Ice Formations		Column

We believe that the only way to check the accuracy of a retrieval algorithm is comparison with independent ground-based measurements for parameters such as SGS and SSA, so in our revised version, with such a large validation samples, we will have a comprehensive understanding of the accuracy of XBAER algorithm.

Fierz, C., Armstrong, R.L., Durand, Y., Etchevers, P., Greene, E., McClung, D.M., Nishimura, K., Satyawali, P.K. and Sokratov, S.A. 2009. The International Classification for Seasonal Snow on the Ground. IHP-VII Technical Documents in Hydrology N°83, IACS Contribution N°1, UNESCO-IHP, Paris.

Langlois, A., Royer, A., Montpetit, B., Roy, A., and Durocher, M.: Presenting Snow Grain Size and Shape Distributions in Northern Canada Using a New Photographic Device Allowing 2D and 3D Representation of Snow Grains. Frontiers in Earth Science, 7. doi:10.3389/feart.2019.00347,2020

Mei et al., A new snow bidirectional reflectance distribution function (BRDF) model

in the spectral region between UV and SWIR, in preparation, 2021

the benefits to split the study in two parts is not clear. The paper (part 2) presents the validation of an algorithm that is not described, which raise several questions and make it be difficult to read without reading the other paper (part 1). For the review, I didn't read the part 1 (I just browsed it) to be in the same position as a normal reader. I found that reading part 2 was difficult with many open questions about the algorithm and was sometimes annoying because of a few elusive statements referring to the part 1 without providing information. E.g. "The similarities and differences of the required snow parameters and their accuracy between the snow remote sensing community and other communities (e.g. field-measurement community) are detailed discussed in part 1 of the companion paper (Mei et al., 2020), thus we will not summery again in this paper. ". The length of this part 2 is normal and the information density is relatively low. For the comfort of the reader, I suggest to shorten or remove some sections (e.g. the first results section on Greenland), and merge with the part 1. Only if extending the validation as proposed above with a complete dataset and with Mosaic data, it would be justified to make two papers.
Response: We believe that with comments from reviewers of both part 1 and pat 2, for the revised versions, it is better to keep the two parts separated. The reasons are below:

Besides changes/updates on the current content, the reviewers of Part 1 suggest two more valuable sensitive study, which will further extend the length of the paper. In particular, the new sensitivity study includes

(1) Impact of spectral response of the two channels at 0.55 µm and 1.6 µm

In the revised version, one more section to investigate the impact of spectral response of the two channels at 0.55 µm and 1.6 µm is included. The following figure shows the spectral response functions for 0.55 µm (left) and 1.6 µm (right). Using these spectral response functions, we will perform the forward simulation with SCIATRAN model, to get TOA reflectance at 0.55 and 1.6 µm. After that, the retrieval using the XBAER algorithm will be performed. Since in the XBAER algorithm, we did not take the spectral response functions into account, thus this investigation shows the impact of the spectral response function on the retrieval results.

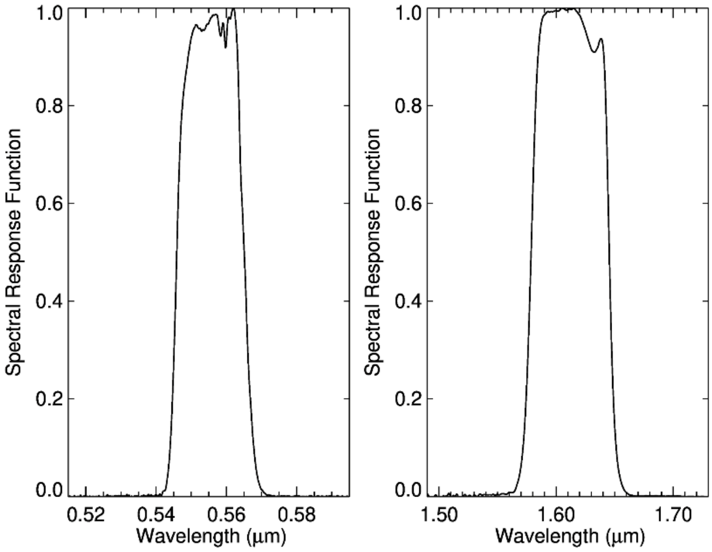


Fig. 3 Spectral response function of 0.55 (left) and 1.6 (right) µm of the SLSTR instrument

(2) The impact of snow profiles and mixture of different snow shapes

In order to assess the impacts of snowpack vertical inhomogeneity and the habit mixture on the accuracy of the retrieval algorithm, we add a new section in the revised version. The forward simulation of TOA reflectance at 0.55 and 1.6 µm will be performed using the vertical profile of grain size, particle size distribution, and habit mixture as presented in the following figure. The snow grain size profile was obtained during the SnowEx17 campaign (panel (a)). The particle size distribution of the ice crystal and the habit mixture are provided by Satio et al (2019) (see panel (b) and (c)). Then the retrieval will be performed assuming that the snowpack is vertically homogeneous and consisting of mono-disperse snow particles of single shape, and the retrieval accuracy will be assessed.

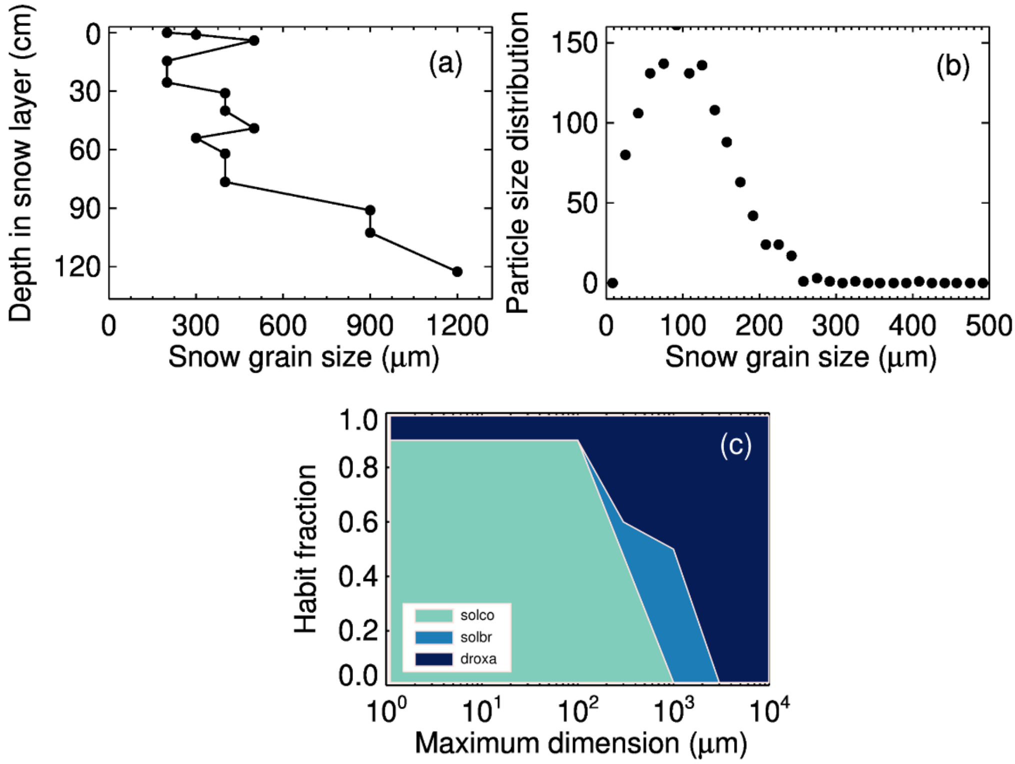


Fig. 4 Snow properties used for simulations to investigate the impacts of snow profiles and mixture of different snow shapes on XBAER retrieval (a) snow grain size profile observed during SnowEx17 (b) particle size distribution of snow grain size (c) ratio of snow particle shape. (b) and (c) are suggested by Saito et al (2019)

Saito, M., P. Yang, N. G. Loeb, and S. Kato: A novel parameterization of snow albedo based on a two-layer snow model with a mixture of grain habits, J. Atmos. Sci., 76, 1419–1436, 2019.

And at the meantime, as we mentioned, the validation is also largely extended using almost all available campaign data during 2016 -2020. We believe this extension will satisfy Dr. Ghislain Picard.

We think we always need to make a balance between the overlap content of such companion papers. We have also made a search on snow-topic-related journals, companion papers occur not so often in ground-based community, but very often in the satellite community. For a new retrieval algorithm, a comprehensively theoretical sensitivity study is essentially needed before the retrieval and evaluation of the retrieval results. We will, of course, harmonize again of the overlap content between these two parts. We will make a short summery of the content from part 1, if needed in part2, rather than use “see part 1”.

So, in short, we update both parts, by adding new investigations/validations. And we believe that keep them separated is an optimal way, taking both the content and the length into account.

Detailed comments:

L63. What is the definition of "grain size" used here ?

Response: grain size (effective radius) is defined as $3V/(4A_p)$, where V and A_p are the volume and average projected area, respectively.

L 69: correct "detailed discussed"
Response: Done

L70: "summery" → "summary"
Response: Done

L91-L92: I'm not sure to understand "to be with good quality"
Response: "to be with good quality" refers to "the retrieved plane albedo was compared with the measured spectral albedo and a good agreement was obtained with ±10%", stated in the cited paper. We update some details in the revised version.

L98-L99. Please add a reference / name for the operational product.
Response: The product is named as SGSP, which, together with the reference, is included in the revised paper.

L104 I'm not sure to understand "to partly taking snow irregular ".
Response: We removed this sentence in the revised version.

L118: "Details of these issues have been discussed in Part 1 of the companion paper.". Please remove and add a proper reference. Or just remove.
Response: We made a short summary of relevant content from part 1 to part 2.

L120-122: This sentence is strange, "no publication. . . especially using" seems contradictory.
Response: We have updated this sentence in the revision.

L 124-126. I don't understand the sentence. What is an "optimal complex shape". The part 1 paper seems to use very geometrical/simple shapes and the goal of the retrieval algorithm is to retrieve SPS. How does this apply to this sentence ? Also, what do you mean by the e.g. TOA ?

Response: "optimal complex shape" is the shape for which the difference between simulated and measured reflectance is minimal. That means, we need to pick up 1 "optimal complex shape" from the 9 "candidate shapes".

TOA, as we mentioned in the manuscript, is the Top Of the Atmosphere, the TOA reflectance or radiance is the quantity observed by satellite, which is used later for our retrieval.

We believe the word "complex" is misleading and we deleted this word in the revised version.

L147-149. I suggest to move this statements to the conclusion.

Response: Done

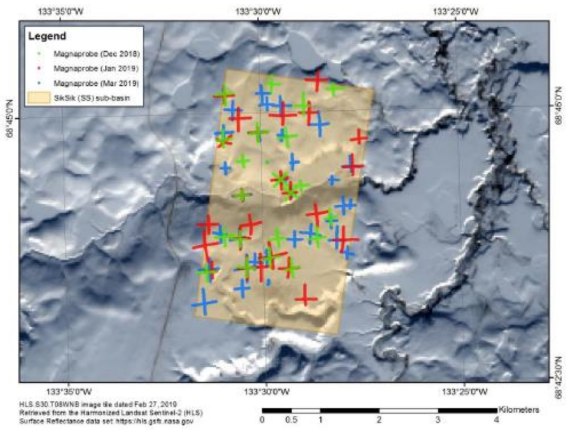
L150. I suggest to remove this statement or merge the two papers.

Response: We included a short summary in part 2 of "the three points we mentioned in Part 1".

L152 – L162. I suggest to move this paragraph to the discussion because it is a typical analysis of the uncertainties of the results/validation. The representativeness issue is a general problem, that affects any in-situ vs remote sensing comparison. Why the SPS would be particular? This also concerns SGS and SSA.

Response: According to our previous experience with non-experts or even experts for the discussion of the comparison between ground-based measurement and satellite retrievals, it is worth to put some general description as we are doing now, in the very beginning of the paper. The "scale issue" can be more than a "general" problem because this fully depends on your retrieval parameters, especially on the "inhomogeneity" of your retrieval parameters.

We had a long discussion with Dr. Joshua King, and we include an investigation of this issue using the observations over tundra basin. The measurements over tundra basin provides the possibility for such an investigation.



Campaign Totals
Snow pits: 80
Snow depths: 21946
SnowMicroPen: 1444

	Static	Roving	Total	$\overline{AT}$ [°C]	Crew [#]
November	6	16	22	-20.0	3
January	6	19	26	-28.4	4
March	6	26	32	-8.3	5

Fig. 4 Information of measurements over tundra basin (provided by Dr. Joshua King)

L170. Remove double “show”.
Response: Done

L215. I suggest to remove SnowEx17 grain shape from the table because it is mis-leading even with the warning in the legend caption. Instead it is possible to list these grain type in the caption and/or in the main text. Note that the grain type measured by SnowEx17 are not specific to this campaign but refer to the international classification (Fierz et al. 2009).
Response: We think the information of SnowEx17 in this table help the readers for a better understanding of the analysis later. We would like to keep it in Table 1. And we update this table by adding possible suggestions of the linkage between Yang shape and the shapes proposed in Fierz et al. (2009). We are currently discussing it with Prof. Ping Yang’s group.

L253 have→are
Response: Done

L276. Could you give a definition of spherical albedo and Lambertian surface albedo ?
Response: The Lambertian surface albedo is defined as the ratio of reflected to incident flux.
The spherical albedo is the fraction of the incident solar radiation diffusely reflected over all directions (albedo of an entire planet).
We include some explanation in the revised version.

L281. Could you indicate the resolution of MERRA ?

Response: MERRA resolution is 1°×1°

L282. Our → a

Response: Done

L339-355. The comparison is very qualitative and referring to generic and broad "classification" of "polar snow" does not bring significant information for this validation, especially because not all the existing references about snow grain shape and size have been taken into account. It must be taken into account that July is warm with a large proportion of the ice-sheet subject to melt, which unequivocally leads to rounded coarse grains very quickly.

Response: We largely extend the validation, as we mentioned above. Some measurements will include more information of the shape information, for instance, the aspect ratio of the ice crystal particle. We also highlight that the reader should not over-interpret the retrieved shape.

The impact of temperature on shape is included in the revised version.

Because the validation can not be done with information that are not available, I suggest to convince the reader that the results are plausible using cross-analyzed external data: use MERRA to separate where the snow is fresh and for which the present discussion in these lines apply fairly well.

Response: We include the cross-validation in the extended validation. And a post-processing to remove "ice and dirty snow" is also be introduced in the additional runs.

Where snow is fresh use successive image to show that SGS increases (and SSA decreases) as predicted by metamorphism (as you suggest, July is interesting for the most rapid metamorphism). use passive microwave (or MERRA or SLSTR thermal channels) to separate where melt is active and where the grains are very likely to be rounded. - use the images next 28 July 2017 to demonstrate that the blue shape for instance in NW Greenland are not due to clouds/aerosols. (I've made this comment before reading the discussion, see further comments below).

Response: We include the above suggestion with respect to the explanation into the revised version.

I also suggest to mask out areas in the ablation zone with ice and dirty snow, as the algorithm does not work in these cases. This should be emphasized.

Response: We include post-processing to remove "ice and dirty snow" in our additional runs.

Fig 3. adding a scatterplot with relevant statistics (R^2, RMSE, bias, . . .) is common

for a more quantitative validation. In particular, it would be useful to compute the same statistics with the first guess to really show the benefit of the algorithm.
Response: Scattering plot with relevant statistics is used in the extended validation. We also include these parameters from the first guess in our revised version.

L371. The previous section was titled "Results" but was also a comparison (and validation to some extent). Why not a unique Result section that includes both comparison?
Response: Done

L372. I suggest to remove "validate".
Response: Done

L373. ground-based/aircraft → ground-based and aircraft
Response: Done

L377- 379. I'd remove this introductory sentence that starts by concluding that the algorithm is good although the actual goal of the present sessions is to perform the validation.
Response: Done

L 385. "time and location" or "times and locations".
Response: times and location

L394. Why the rows are not sorted chronologically as in next figure ? What is the order? Has the gray shade in the last row a meaning ?
Response: We have sorted chronologically as in next figure in revised version. We have removed the gray shade in the revised version.

L398. This is the second "Fig 4". Review numbering. +Please add a scale to the maps.
Response: We have harmonized the figure number and put the scale on the maps in the revised version.

L406. How does this perform in the case of thin clouds ?
Response: There will be risk of remaining cloud contamination in the retrieval.

Fig 4 and Fig 5. I don't understand why two figures ? If I understand well, Fig 4 is a zoom of Fig 5 ? They should be merged in a single composition using the same symbology / graphic style.
Response: We have merged Fig. 4 and 5 in to one figure in the revised version.

L412-413. “is not correctly avoided”. This is a bit confusing. The next sentence is clearer to me but seems to be in contradiction with Table 3 indicating “cloud contaminated snow” for this date (which seems accurate based on Fig 4).
Response: We have updated the order and explanations of Table 3. The sample of 9 Feb. (partly cloudy) is not detected by the cloud screening while the sample of 11 Feb. has been detected, however, to check the impact of cloud contamination, we have manually “removed” the cloud screening for sample 11 Feb.

L388 indicates that the comment in Table 3 is obtained with the algorithm. Please clarify.
Response: Done

L413. Give → gives.
Response: Done

L421. Add a ref to the study.
Response: Done

L442. “Our → a” or “our calculations with”
Response: Done

L444. Fig 1 → fig 1 with a lowercase as it is referring to another paper. Add the ref.
Response: Done

L451-452. “cloud effective radius” → “cloud ice crystal effective radius”. SGS and “ice crystal size” are used interchangeably in the paper which is sometimes (and especially here) confusing.
Response: We harmonized the names in the revised version.

L464. “”This is similar to the issue in field measurements.” what do you mean ?
Response: For the field measurement of SSA, certain shape assumption is also used, and the assumption may not exact occur as well.

Leppanen, L., Kontu, A., Vehvilainen, J., Lemmetyinen, J. and Pullianinen, Comparison of traditional and optical grain-size field measurements with SNOWPACK simulation in a taiga snowpack, Journal of Glaciology, 61, 151-162, 2015
Langlois, A., Royer, A., Montpetit, B., Roy, A., and Durocher, M.: Presenting Snow Grain Size and Shape Distributions in Northern Canada Using a New Photographic Device Allowing 2D and 3D Representation of Snow Grains. Frontiers in Earth Science, 7. doi:10.3389/feart.2019.00347,2020

L465. “ (e.g.,the measurement of SSA),”. This is generally not true. Do you refer to a precise device and processing?
Response: Yes, this depends on the device and how the measurements are obtained, we include this explanation in the revised version.

L466-470. I’d suggest to define in the method section (Table 2) the most-likely correspondence between Yang’s shapes and the snow type defined in the international classification (that used in SnowEx) so it is possible here and in the Section 4 in the results section to assess the algorithm performance in a more rigorous way.
Response: Firstly, we try to make possible linkage between Yang shapes and the “international classification”. Secondly, other campaigns (such as campaign performed in China) provide some information with respect to the aspect ratio of particles, which is used to quantify the “accuracy” of shape as well. But again, we would like to highlight that we should not over interpret the retrieved “effective particle shape”.

L473. “A previous publication” or cite more than one
Response: Done

L474 are → is
Response: Done

L479 “is ‘facet’ while XBAER says ‘droxtal’ both tend to be roundish”. Facets according to Fierz et al. 2009 is not rounded. If the retrieval algorithm SPS can not distinguish rounded grains from faceted grains because both are droxtal, how useful it this for field practitioners ? This asks an important question that is not addressed in the introduction: why and for what usage to retrieve SPS from satellite ?
Response: We try to make a linkage between Yang’s shape and shapes defined in Fierz et al. (2009). And we will highlight that we should not over-interpret the retrieved SPS in the revised version. The retrieved SPS is an “effective shape”, which provides the best agreement between radiative transfer simulations and satellite observations.
As we mentioned above, SGS and SPS are the two fundamental inputs for the RTM calculations in XBAER algorithm.
Additionally, with the extended comparison, we will focus more on the validation of SGS and SSA, in the revised version. The comparison of SPS will be reduced.

L483. I do not agree. It is also believed that grains get rounded due to sublimation in blowing snow (Domine, 2009). This probably depends on the conditions, on the actual

grains available on the surface, and the strength and duration of the saltation/reptation process.
Response: We have updated this statement in the revised version.

L493-496. Please indicate the number of points of each comparison (n=...) and the statistical significance of the results. By "difference" do you mean "rms difference" or "difference of the average" ?
Response: Number of points will be included in the extended validation.

"difference" means "difference of the average"

L548. Here it would be particularly interesting to see how good the first guess predictor of SGS. I'm really interested by knowing if the algorithm sophistication is worthwhile.
Response: We include a small validation/analysis of the accuracy of the first guess.

L533. I'm not sure to understand how the RMSE is calculated. The RMSE includes both systematic and random errors, and here given the difference of the mean, the RMSE should be at least 165 – 138 = 17 microns while the text indicate 12 microns. Please check also "lower grain sizes".
Response: The definition of RMSE is calculated for two groups (satellite retrievals and corresponding SnowEx measurements), not for one group. The understanding reviewer mentioned above is to calculate RMSE for a single group, which indicates the "scattering properties" of this group of data. In our manuscript, RMSE is calculated as following:

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{n=N}(SSA_n^{XBAER} - SSA_n^{SMART})^2},$$

where N is the number of samples, SSA_n^{XBAER} and SSA_n^{SMART} are the SSA of sample n obtained from XBAER and SMART retrievals.

L550. The same question applies for SSA, with a difference in the mean of 3 m2/kg, it is not possible that the RMSE is 2 m2/kg.
Response: See above

Fig 8. This figure is interesting but should be used earlier in the validation to infer the errors of estimations. I see the following possible artifacts: - The presence of undetected clouds in the NW Greenland. - The dramatic grain size decrease after 28 July in Eastern Greenland (analysis around L588) is very suspicious and stronger evidences are needed to prove that it would be related to a massive drift event, and not to a retrieval artifact. In particular it would be necessary to demonstrate that the wind sustained over 6m/s for a sufficient long period of time to really bring sufficient quantities of small grains over the considerable distance. - Why grain shape changes so fast between a Droxtal to a column in central Greenland ? Wind is able to drift fresh snow, but in the absence of recent snowfall, if snow was already Droxtal at the surface, wind can not transform it into more elongated crystals. Faceting of grains at such a pace is suspicious. - The Western side is also affected by the grain size change. The shape change is also marked and different from that observed in the Eastern side. Why this is not discussed?

Response: We have included more explanations for Fig.8, especially with the information of wind from ECMWF. The possible reason of blow of fresh snow due to wind or ice crystal change due to temperature are further analyzed.

L590. The weblink does not point to any data. A figure should be added in the supplementary with direction and wind speed.

Response: We have included the wind information from ECMWF in the revised version.