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Interactive comment on "A lead-width distribution for Antarctic sea ice: a case study for the Weddell Sea with high resolution Sentinel-2 images" *by* Marek Muchow et al.

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Answer to Anonymous Referee 2

We thank the editor Dr. Jenny Hutchings and the two anonymous referees for the helpful comments and their efforts reviewing the paper. Please find point-by-point answers to the comments below. The answers to the other referee and the editors note are separate comments.

Anonymous Referee 2

While the study provides interesting statistics about leads in the Weddell Sea, it does

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Discussion paper

not offer details about the uncertainties implied in the data or the methodology (i.e. setting the thresholds). The subject is certainly timely and will have immediate implications, given the impacts of climate change on the polar regions, but I think with such as short manuscript it suits more a letter-style paper. I am not sure if TC allows this.
By including the suggestions by the referees, the paper will be more detailed and longer than before. Thus, we want to continue to handle the manuscript as a full paper and not change it into a letter.

The manuscript is fairly well written though I found some sentence structure can be improved, e.g. "we noticed that on products with wide leads ...." or "The goal of the classification is to get thresholds...". A better word would be "to identify thresholds". The "amount of lead" should be "the number of leads", and so on. I am not including more details but the authors and the site editor(s) can adjust the style.
Thank you, we will check the overall style of the manuscript.

MAJOR ISSUES:

The title suggests that results of lead distribution apply to the Antarctic ice cover. I don't think this would true. The authors concentrate on the Weddell Sea as a case study. There are two features in this region that make it unique, the dominant old ice and the gyre (Weddell Sea gyre). That should make the leads in this area unique. Perhaps a better title should specify Weddell Sea only.
The title should imply that this is the first lead-width distribution for an area (the Weddell Sea) of the Antarctic sea ice, therefore the label case study. Since both reviews highlighted a lack of explanation of the reasoning for the study area, we will specify that topic more through the paper.

The authors admit that in presence of snow, the reflectance measurement will not an indicator of the underlying ice cover. I don't see how they addressed this problem. Please clarify.
We assume that nilas has no or only a really thin snow cover, since snow would

brighten the appearance of the surface. Additionally, snow has an insulating effect and therefore inhibits the heat exchange for an example which would reduce the "lead effect" of an area where nilas is covered with snow. This is also the reason, why the names of our surface categories do not indicate any age of the ice or thickness of the ice, since – as you stated – the ice in the category "sea ice covered with snow" can be really different. But since we use the thresholds from the classification only for measuring lead widths, we are confident in the thresholds.

While leads are mostly covered with open water or thin ice, they also serve as a path for broken thick ice. The authors set thresholds on reflectance to identify the surface of the lead, OW, nilas, grey ice, etc. If I understand it correctly, the authors calculate the lead statistics for each type separately (Fig. 5 shows OW and nilas), but a lead may have all types of ice plus OW. What if the lead in your data is composed of the five ice types you referred to? Would that be included in the lead statistics? The answer is still not clear to me after reading the entire manuscript.
We only investigate leads with open water or leads with nilas and open water. The other surface categories are not used for the lead-width estimation. Also, the nilas threshold contains areas covered with nilas and open water. This then covers for example also the case of a lead, where one area starts to refreeze while the other part is still open. Thus, in that case we measure the whole lead width. We decided to omit leads that are covered by brighter (thicker) ice, since this has been common practice in many other studies (e.g. Marcq and Weiss (2016) and Lüpkes et al. (2008)) and thus makes our results more comparable.

Lüpkes, Christof, et al. "Influence of leads in sea ice on the temperature of the atmospheric boundary layer during polar night." Geophysical Research Letters 35.3 (2008).

The authors use Reflectance to set thresholds to identify surface types. However, Reflectance is angular-dependent measurement, therefore it is not a property of the surface. Albedo is a property of the surface because it is the integration of the angular reflectance. The comparison between albedo and reflectance on page 6 lines 24-26

cannot be used to confirm the reflectance thresholds. To proceeds with the reflectance in this study, all leads must be viewed with the same angle from the different satellite orbits.
This is an appropriate simplification because it is not practical to restrict the observed reflection angle. The reflectance anisotropy could in principle be estimated using many observations over rather static scenes. However, we do not expect a significant influence of a potential anisotropy on the resulting lead with distribution. We estimated the thresholds with images from January to April of 2017. Thus, the data for fitting the Gaussian curves includes several sun and look angles. Before estimating the thresholds we compared the TOA reflectance values for the the surface types within the each products and found no significant difference, but nevertheless used nine products for the classification for a larger data base.

MINOR ISSUES:

INTRODUCTION: There are many more references that can be used to review the work on lead width geometry and width distributions. The authors should check and quote more than the 2 references used here. Moreover, the Introduction jumps too much between different themes. I would recommend the authors to re-write while grouping themes in separate paragraphs.
Thank you for the suggestion, we will rewrite the Introduction accordingly.

P 1 L18: leads may not always form in linear shape.
We will replace "thus" by "often" to also include other possible shapes.

P2 L1: what is "coupled climate models"?
"coupled climate models" commonly refers to models consisting at least of an ocean or land and an atmosphere component which are coupled to each other.

P2 L15: "Reiser et al. (2020) introduced a retrieval algorithm for lead fraction in the Antarctic, but these studies indicate that knowing about lead-width distributions is beneficial when estimating heat transfer". It is not clear how this can be a conclusion from

a lead identification study. For one thing, it can only be a conclusion from a heat flux study but more importantly is a logical conclusion. It does not need a study.
The mention of Reiser et al. (2020) was supposed to highlight that there are lead-fraction products available, also for the Southern Ocean, but that the lead width is still missing. And that other studies (the ones named before) have indicated, that the lead width is important. We will clarify that part.

P2 L28: "To narrow down the effect of the fitting methods, we applied ...". Please change the sentence as the purpose of applying the two methods is not clear. *Will be revised.*

P3 L4:"The determined thresholds for leads covered with open water .." Threshold on what?Reflectance? *Yes, the threshold is a TOA reflectance threshold.*

P3 L5: the sentence "Two threshold are applied to identify .." is not understood. Please rephrase. *Will be revised.*

Figure 1: I find some of marked frames of the satellite images odd (with 3 or 5 sides instead of 4). Why is that? Also, in the caption, instead of "with shelf ice" it is better to use "including shelf ice border measured with..." then specify the satellite radar sensor
The form of the products is due to the differences of the satellite swath and the processing grid of the ESA which results in areas without a satellite measurement in the image (as explained and shown in Figure 3 with the missing corner in the bottom right corner in the upper image). We decided to use the "real image outlines" for the map to show the product size.

DATA:

P3 L10: attach the spatial resolution to the band.
The resolution of each band is not directly indicated, because it is irregularly distributed, and we only use the 10 m resolution of Band 4. See: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial

P3 L11: please include the spectral band for channel 4 (665 nm). *Will be changed.*

Also, in Line 12, provide a reference to support your statement - that it is best for thin detection. I am not sure about the reason. Please specify.
We manually compared Band 2 – 4 and 8 with each other in areas, where we expected thin ice in leads. After visual inspection we and decided to use Band 4. We will specify this in the text.

P3 L13: which Landsat? When I read this statement, I expect to see use of the coincident SPOT and LANDSAT data to support your finding. But they are mentioned here only to refer to their future use. Using these data will add value to the manuscript.
This information is a citation from Drusch et al. (2012), but at least Landsat 8 crosses the Equator every day at 10 a.m., while Sentinel-2 crosses the Equator at 10:30 am. The scope of the study was only to use Sentinel-2, this statement is just an outlook and will be moved to the end of the manuscript – according to the suggestion by reviewer 1

Table A1: why A1? It is not in an appendix? I would recommend inserting in the main text at the end of Section 2.
We decided to put the table in the appendix due to its size, but we are also fine with placing it directly into Section 2.

METHODS:

The use of n=2 and n-3 in Equation 1 for light-grey ice and dark-grey ice is not clear to me. I see clearly the use of n=1 for the other types in Figure 2. I don't think there is something wrong here. It is just my failure to understand. Please re-phrase.
The n indicates the number of Gaussian curves which were combined to one function for fitting the histograms. By using n>1 we can account for multiple maxima within a distribution. We will re-phrase that sentence.

Also, according to my information, what you call dark-grey and light-grey ice, should be grey ice (10-15 cm thick) and grey-white ice (15-30 cm thick). These are nomenclature

set by WMO and used in operational ice centers. You can refer to the document that defines ice types, published by the Canadian Ice service: MANICE (2005), "Manual of Standard Procedures for Observing and Reporting Ice Conditions", Canadian Ice Service – Environment Canada, ISBN 0-660-62858-9, Catalogue No. EN56-175/2005. *Since we only have information about the brightness of the ice and not of the thickness, we created our own terminology to indicate the brightness of the ice. However, we like your suggestion of using the WMO standard nomenclature. We will add a short explanation indicating that our terminology does not refer to ice thickness but rather optical properties.*

Figure 3: in the caption "The upper border of every image is 50 km wide". This is not the swath. Please clarify what you mean by upper border.
We mean that the width of the figure corresponds to 50 km, thus we will change the text to "The area shown in the figure has a width of 50 km."

This figure shows the OW in the lead. What about other ice cover, nilas, grey ice, etc.?
Figure 3 is used to illustrate the lead detection algorithm desribed in Section 3.2. The figure on the right shows the leads for the nilas and open water threshold. With that, the binary image for both applied thresholds are shown. The other surface types are not used for lead-width measurements, which is why we did not show them initially. We agree that it would be beneficial to also show an example of the classification described in Section 3.1 showing all 5 surface types.

RESULTS

P6 L21: the sentence "the TOA reflectance is only measured passively in the absence of clouds ..." is not clear. Please rephrase. *Will be changed.*

P7 L5: Nilas threshold cover also open water? Why? There is overlap between nilas and OW, but the threshold does not cover both.
The nilas threshold covers both. We realized that this is not clear in the manuscript. We will change that with renaming the thresholds in a more clear way.

P7 L6-21: it would be better to expand on the difference between lead statistics in the Arctic and Antarctic in a separate sub-section. Most of the lead studies in the Arctic are conducted in the Beaufort Sea area. Some organized presentation should show the differences in the results, with related reasons if possible, and then comparison with findings from the Weddell Sea area.
We will restructure the discussion and give additional detailed about the differences.

CONCLUSION

Before you mention about the method, you should mention the data used in the study.
Will be revised.

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