Response to RC 1:
(The reviewer comments appear in black, the responses are in blue and the proposed changes to manuscript are in ***bold italics***.)

Summary

This paper compares different sea ice type products currently available to the community. The products are based on passive microwave data, scatterometer data (C or Ku band), or a combination of both. The products have been developed empirically via training data. The type fields are inter-compared and evaluated against a widely-used sea ice age product and SAR retrievals. The products perform better in mid-winter than in early or late winter when melt/re-freeze may occur. Ku-band scatterometer generally is better at type discrimination. Combination of passive microwave and scatterometer data can yield better performance at times, but not in all situations.

General comment

This is a fairly comprehensive review of the primary sea ice type products available. There are notable differences in how the products are assembled, the input source data, and their performance in different conditions. Thus, this paper is a valuable contribution to the community be providing such an assessment. The paper is quite thorough and overall it does a good job in presenting the inter-comparison and evaluation of the products.

Reply:

Thank you for the thorough review. Your comments and suggestions are highly appreciated. For better comparison and evaluation of the sea ice type products, we will revise the manuscript from the following two aspects:

1) The "Data" section will be re-structured. This section will include four sub-sections: "2.1 Microwave remote sensing", "2.2 Sea ice type products" and "2.3 Other data". In section 2.1, specifications of the sensors and the satellite data will be introduced in a chronological order, with subsections of passive/active microwave remote sensing data. In section 2.2, theory of SIT classification will be introduced at the beginning, followed with the overall description of the respective SIT products in terms of grid size, projection, availability period, a summary of the satellite data used and the algorithm with necessary details. In section 2.3, sea ice age product (with evaluations from previous studies) and the SAR images will be described accordingly.
2) A new section of "Methods" will be added, which includes "3.1 Estimation of MYI extent" and "3.2 Interpretation of SAR imagery". We will modify the computation of MYI extent in the revision for consistent griding, projection among all the SIT products. In section 3.1, Information such as co-locating/re-griding the data and calculation of the MYI extent will be introduced. In section 3.2, the theory and characteristics of sea ice classification in SAR images will be introduced with references from previous studies and examples from our study. In addition, we will interpret the entire SAR images, consult with ice experts regarding the results, convert the sea ice classification results from ice types polygons to grided ice classification results, and eventually give quantitative evaluation results.

Besides, case studies will be presented in the chronological order with more discussions referring to the physical background and the algorithms of SIT products. Figures will be modified for better presentation. A thorough edit of the language style and grammar will be conducted. And all the references and citations will be double-checked and corrected accordingly.

Specific comments are below, but one overall comment is on the SAR data used for evaluation. In general, SAR is going to be the best "truth" for comparison. It is high resolution, so it can delineated even individual floes often. And it is all-sky, so retrievals of type are available anywhere the sensor collects imagery. However, the challenge with SAR is interpreting the imagery. The authors interpret the SAR imagery and classify various locations as a given ice type, but they don't give a particular rationale or provide references for their classification basis. Often, expert ice analysts interpret SAR fields for operational ice charts. They have deep experience in understanding the imagery and properly defining features. It appears the authors here classify the imagery themselves. This is okay, but I would like to see more substantial justification for their classification.
Reply: Thank you for the advice. In the revision, we will add a new section regarding the theory of SAR interpretation. The theory and characteristics of sea ice classification in SAR images will be introduced in the section "3.2 visual interpretation of SAR imagery".

Another weakness with the SAR comparison is that it is just a few scenes in selected regions and selected periods. And even within the SAR scenes, a few specific locations are picked out as "pure types" for comparison. Ideally, a full SAR image would be classified and compared. I know automated SAR classification algorithms for sea ice are troublesome, so I can understand the approach taken, but it results is a fairly ad hoc and qualitative evaluation. Since this paper is otherwise quite comprehensive, I won't request more evaluation, but ideally (perhaps in a future paper), it would be good to get classified SAR images – perhaps from an expert ice analyst at an operational ice center – and conduct a more comprehensive and quantitative evaluation of the ice type products.
Reply: Thank you for the advice. In the revision, we will interpret the entire SAR images, consult with ice experts, convert the sea ice classification results from ice types polygons to grided ice classification results, and eventually give the quantitative evaluation results.

A final note is that there is a need for a thorough copy edit for English language style and grammar. The issues are mostly minor – in particular, there are numerous missing articles ("the", "a", "an") – but they are widespread throughout the manuscript. I don't bother to point them out individually as they are too numerous, but they need to be addressed before final publication.
Reply: Thank you for the advice. We will go through the manuscript and conduct a thorough edit for the language style and grammer.

Specific comments (by line number):
11: The authors definite "sea ice type" as "SIT" here. This is fine and it is used consistently throughout the manuscript. However, as a sea ice scientist, "SIT" means "sea ice thickness" to me. And particularly with numerous thickness products coming out from altimeters, "SIT" is becoming quite common in the community to denote thickness. I can understand wanting to use an abbreviation and "SIT" makes sense for ice type, and the context is clear throughout the manuscript. So, I can't say it needs to be changed, but it might be something for the authors to consider. For me, every time I saw it, "thickness" popped into my mind first until I recalibrated. I can't think of another good abbreviation myself, but one could just use "type" or "Type" as a short-hand, instead of "SIT".

Reply: Thank you for the comment. We now use "SITY" instead to represent "sea ice type". All the abbreviations in the manuscript will be modified accordingly.

28-30: I'm struck by the use of more than author listed and then "et al." in the citations – i.e., "Comiso, Parkinson, et al., 2008". Generally, if there are more than two authors, just the first author is listed followed by "et al." – i.e., it would be "Comiso et al., 2008". In looking at The Cryosphere guidance for citations, I don't see anything that indicates two authors should be listed, so I'm not sure of the rationale. This seems to be done throughout the manuscript. (If there are only two authors, you list both, e.g., if it were "Comiso and Parkingson, 2008".) Not a big deal and I assume the copy editing will decide the proper citation format. I just haven't seen this before and it struck me as odd.
Reply: Thank you for the advice. We will carefully check all the references and correct the citations in the revision.

31-32: Be careful about terminology. "Thin" and "Young" ice are standard stage of development classifications. I think here you mean "thinner and younger" for FYI, and then "thicker MYI". I'm also not sure what you mean by "firm" in relation to MYI?
Reply: Agree. The sentence will be modified to:
"The Arctic sea ice has been increasingly dominated by thinner and younger first-year ice (FYI) instead of thicker and older multiyear ice (MYI)."

57: "ergodic" is an obscure word – I was not familiar with it. Based on my understanding after looking it up, I'm not sure it is used properly here. Regardless, I think a simpler word is appropriated here or I wonder if it is needed at all – "combined use of both data" is clear to me.
Reply: Agree. The word "ergodic" is deleted. "combination use of both data" will be replaced with "combined use of data".

62-63: "While ice chart…" is a confusing sentence – not sure what it is say. I would suggest revising.
Reply: Thanks. The sentence will be modified to
"While ice chart is used as "ground truth" in some validation (Aaboe, Breivik, et al. 2016), some areas of MYI in the ice charts correspond to areas with MYI concentration of approximately 50% or greater"

72: Just one example of grammar/style issues: "…are detailed investigated." – It should be "are investigated in detail."
Reply: Done.

107-109: Is AMSR-E used in the product? The description indicates only AMSR2 is used. So, why describe AMSR-E characteristics? Why not just describe AMSR2 characteristics?
Reply: AMSR-E is used in Zhang-SIT from 2002 to 2011. In the revision, we will add a new section "2.1 Microwave remote sensing data", where the satellite data will be introduced in a chronological order meanwhile with same level of details. The microwave radiometer data will be introduced as two series of dataset: one includes SSM/I and SSMIS, the other means AMSR-E and AMSR2.

109: Maybe another grammar/style issue: "working" is okay, but typically when describing sensors or satellites, "operating" or "collecting data" are more common.

"working" seems a bit colloquial here.
Reply: Agree. "working" is replaced with "operating".

147: This goes for all products, but noting here because NSIDC products have specified references that should be used. For SIA, it is:
Tschudi, M., W. N. Meier, J. S. Stewart, C. Fowler, and J. Maslanik. 2019. EASE-Grid Sea Ice Age, Version 4. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/UTAV7490FEPB. [Date Accessed].
This should be cited in the manuscript text and listed in the references. I see that the dataset website is noted in the Acknowledgment section, but where a reference is provided, it should be included in the manuscript proper, including the dataset DOI. I know all datasets do not provide a formal citation and/or DOI – for example for OSI-SAF, their recommended citation is simply: "The type dataset shall be referred to as the Sea ice type product of the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF, osi-saf.eumetsat.int)." If that is all that is provided, that is fine, though I would also say that the product ID (OSI-403-d) and version (if provided) should be included. The other datasets used should be cited to the extent they properly can be.
Reply: Agree. References for all the datasets used in the manuscript will be updated accordingly.

185-186: I think the potential for MYI increase could be explained better here. In practice, overall Arctic MYI cannot increase over the winter – it can only decrease via advection out of the Arctic. "Temporary" increases can happen within products due to divergence – e.g., a 100% MYI pixel diverging into two pixels with 50% ice each; if the threshold for detection is <50%, there will now be two pixels. And regionally, MYI can increase, both due to divergence or due to advection into the region from neighboring regions.
Reply: Thank you for the advice. The sentence will be modified as below:
"However, it can temporarily or regionally increase due to ice divergence or advection from neighbouring regions (Kwok, Cunningham, et al. 1999)."

191: This is discussed a bit more later, but this left me hanging: "why such a dramatic peak in the first half of winter?" Maybe provide a brief explanation and then say it will be discussed further later in the paper.
Reply: Thanks for your suggestion. The following sentence will be added to give a brief explanation:
"…, which is due to misclassification of FYI as MYI in the peripheral seas of the Arctic and will be further discussed later in the paper."

204: I would use "to" instead of a "-" because it looks like a minus sign. Or use an "em-dash" or "en-dash" with spaces on each side.
Reply: Agree. "-" is replaced with "to" in the sentence.

219: Figure 5 is mentioned quite cursorily here, but I notice the behavior of several products in BS during 2016-2017. That sticks out compared to other years and regions. Why was the performance so different?
Reply: Thanks for the comment. Explanations for the performance will be added in the

revision. This sentence will be modified as below (Note that we modify the abbreviations of each region in the revision)
"Overall, the MYI extent in the CAO and ESL regions shows consistently negative trend, while that in the BCS region remains constant or is increasing. The former mainly results from the outflow of MYI to more southern areas…."

224-225: Okay, the KNMI-SIT increase is mainly in the BS and ESS regions. But why? In general, this paragraph (223-229) feels like it needs to drill down a bit more and give more detail/explanation.
Reply: Thank you for the advice. We will give more explanations in the revision.

259: Kind of the same thing here. Okay, you have an overestimation of MYI, but that doesn't specifically explain the abnormal increase in MYI during 2016-2017. Why was the MYI overestimated in the one year versus others.
Reply: Thanks for the advice. We will specify the reasons in the revision.

265: How are cases selected? Were they ad hoc? Random? Was it simply availability of imagery? Or was there some physical rationale to select the scenes? I understand in general wanting different regimes and different time periods, but why those specific images on those specific days at those specific regions? In other words, what "different conditions" were you selecting for here?
Reply: Thank you for the advice. The images were selected based on the availability, time, region and overall SIT distribution. We will include sentences to explain the rationale of selecting the scenes.

268-271: Following from my general comment above, how were characteristics of the SAR images used for visual interpretation. What is the basis? There are no references here to justify the classifications.
Reply: Thank you for the comment. We will add references to justify the rationale of the classification. More specifically, in the new section "3.2 Visual interpretation of SAR imagery", the theory and characteristics of sea ice classification in SAR images will be introduced.

273-278: This paragraph illuminates the previous comment. The text is very "squishy". You say things like "appears to be MYI", "more likely to be MYI", "which could be interpreted as newly generated FYI". This is very qualitative and seemingly tentative. I think maybe you just need to say why something "appears to be MYI" – what is in the SAR image that leads to that conclusion and what is the basis for that?
Reply: Thank you for the advice. We will modify the words in the revision. In addition, as mentioned in previous replies, the theory and characteristics of sea ice classification in SAR images will be introduced in the new section 3.2.

288-293: Same here. You have "could be identified as MYI", "are a typical feature of FYI".
Reply: Thanks. Such expressions will be modified in the revision similarly as we mentioned in the above replies.

299: I guess there is a thematic reason for the order – looking at early and late winter as "edge" cases, but it seems more logical to order these subsections chronologically: early winter, mid-winter, and then late winter.

Reply: Thank you. These cases will be presented in the chronological order as suggested.

315-319: Again, very qualitative.
Reply: Thanks. Quantitative results such as overall accuracy of the respective SIT products on each case will be added based on the visually interpreted results of each image.

391-446: I can see the logic of discussing the methods here – you are linking them to the performance assessed previously. However, to a large extent, this feels like it should go with the data product descriptions in Section 2.1. I guess moving this there would make that section rather long. But I kind of feel like I get to here and I finally understand how the type products are created – after all of the evaluation and comparison. I'll leave it to the authors to decide if this fits better in 2.1 or should stay here. Or maybe, put some description in 2.1 and then the relation to the product evaluation here.
Reply: Thank you for the thoughtful comments. In the revision, we will provide more details of the algorithm used in the respective SIT products in the section "2.2 sea ice type products" and put the description of satellite data to section 2.1 "Microwave remote sensing data".

400: "[55]"? Is this a numbered reference?
Reply: Yes, We will correct the citation in the revision.

434-436: Melt affects the performance in early and late winter. But melt also basically makes the algorithms ineffective in spring and summer. That is implied, but never really stated explicitly it seems.
Reply: Thank you for the advice. We will give more explicit statement in the beginning of the new section "2.2 sea ice type products".

Figure 5: Following up from above, I'm struck by the notable increase in many products in BS during 2016-2017. That is not noticeable in another region or year. There is some discussion, in relation to OSI-SAF in Figure 7, but the text doesn't really discuss this. I think this deserves some explanation in the text.
Reply: Thanks. We will add explanations in the text regarding the notable increase in BS.

Figure 5: What is the shaded green region that accompanies OSISAF? Maybe it is in the main text and I missed it, but regardless, it should also be included in the caption for the figure.
Reply: The upper and lower lines of shaded green region represents the MYI extent calculated under the assumptions of 1) regarding the "Amb" class as MYI, and 2) regarding the "Amb" class as FYI. We will add such information in the caption.

Figure 6-7: This is a style/aesthetics thing, but the beige/brown for the OW seems odd. Such a color is more commonly used for land, and definitely not for ocean. I would suggest considering a different OW color – just swapping the land color (light gray) for the ocean color, would be more logical to me. Of course, you want to make sure that the colors contrast and are clearly delineated. But a good solution other than beige/brown for OW seems possible.
Reply: We will change the colors as suggested in the revision.