The authors detail a SAR image sea ice-water classification technique for use during melting conditions in the Fram Strait region. The input data are dual-polarization (HH + HV) Sentinel-1 EW mode scenes which are widely available over marine regions and open access. Their method for pre-processing of the HV channel of the Sentinel-1 SAR data seems to work very well, enabling its inclusion in the classifier. A good classification accuracy of ~90% is achieved, and the results are used to examine sea ice concentration evolution in the summer months over the 2015-2020 period. Since C-band SAR images are commonly used for ice mapping and charting, the results are potentially extendable to other missions as well. The potential to use a SAR based sea ice concentration algorithm during the summer months, and in a marginal ice zone, when/where passive microwave data is less reliable, is also noteworthy.

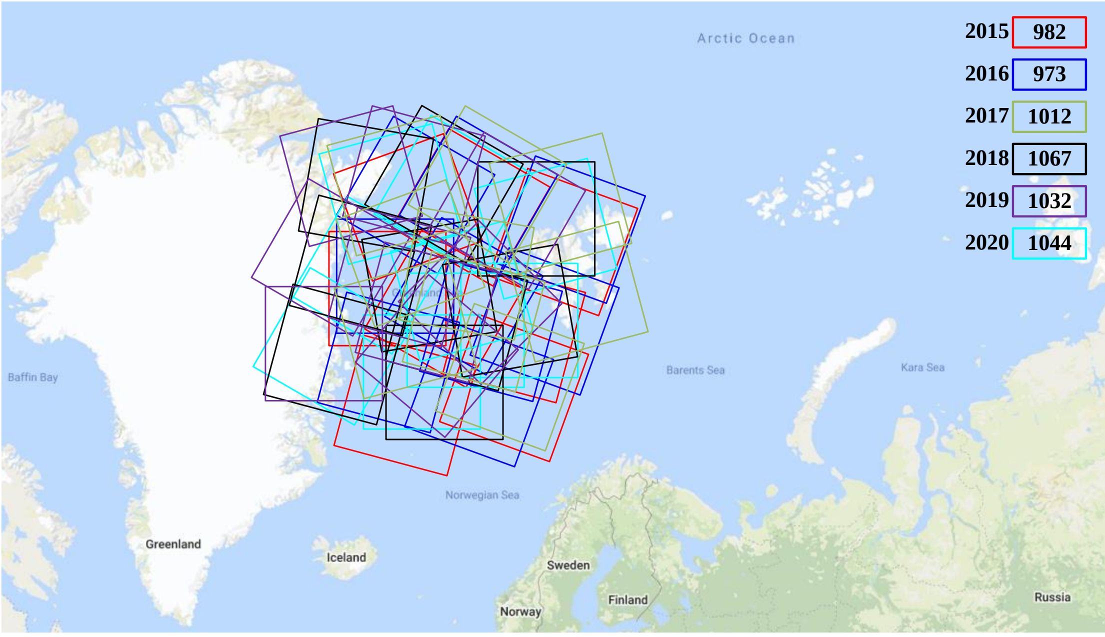
We are grateful to the reviewer for the constructive comments on our manuscript (tc-2021-85) entitled "Sea ice and water classification on dual-polarized Sentinel-1 imagery during melting season". We have addressed all the comments. Our point-by-point responses are attached below in blue, while the original Reviewers' comments are in black. Thank you again for the valuable comments on our manuscript. We will go through it and revise the certain parts of the manuscript following the reviewer's suggestions.

1. The paper is hard to follow, especially given that there is a lot of repetition in the text and figures, and some concepts and ; acronyms defined more than once. The input data to classification result is shown in Fig. 2 and Fig. 5; the SAR processing to remove noise is shown in Figs. 2, 3, and 4. Training sample selection is detailed in Sections 3.2. and 4.2. CRF and MSTA-CRF are defined on Page 3 then defined again on Page 6 (etc.). The selection of reference incidence of 23° doesn't need to be introduced on Page 8 then again on Page 13. The authors should describe their methodology in terms of input data, pre-processing, training, classification, and validation, and make it shorter in length. Everything on Page 17 and later could be included in Results and Discussion.

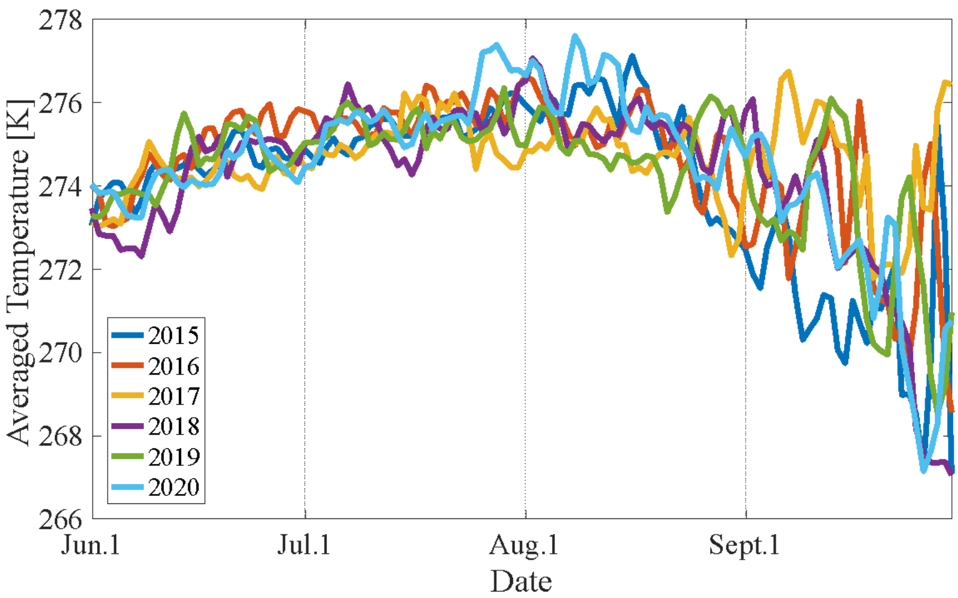
Response: We have tried to rewrite it according to your suggestions.

2. It is unclear what input data is actually used. Fig. 1 shows some scene extents though it is difficult to tell whether they are arbitrarily chosen or what they are supposed to represent. Later in the paper there is mention of 488 images, or one image each day from June to September over the period of 2015-2018. Provide more detail on what Sentinel-1 data are used (without listing them).

Response: We provide a new figure 1 in the revised manuscript. The different colors of the rectangles indicate the SAR images acquired in different years. Even this figure cannot show all the images used for classification, therefore, the number of images used for each year is given on the top right of the figure.



3. The images are described as pertaining to melting conditions. More justification for this should be provided since it is insufficient to assume that all images between June and September are in melting conditions at this latitude.



Response: You are right. Not all the area is melting in this latitude. We not only can solve the problem in the melting season, but also get good results in other situations.

We downloaded the hourly averaged ERA5 2-meter temperature from ECMWF website with spatial resolution of 0.25°. Then we illustrate the daily averaged temperature of Fram Strait in Figure 2. It is clear to see that the temperature starts to increase from the beginning of June, and reaches its top at the beginning of

August, then it starts to decrease and finally drops below 268K at the end of September. Except for the year 2015, when the surface temperature dropped below 273K at the beginning of September, in the years 2016-2020 the surface temperature drops below 273K in the middle of September. Surface temperatures above 273K mean that the sea ice is still in melting condition. As a result, we select the Sentinel-1 SAR data from June to September each year and define this time span as the melting period of Fram Strait.

4. If there is a Sentinel-1 image from each day in the Fram Strait, images that correspond more closely to the MET Norway ice charts should be used for selection of training data. Otherwise there is more chance for ice drift and changing ice/water conditions to introduce error into the training sample selection.

Response: This is correct. Training procedure will also make some influence on the classification result since the selection of training samples depends on the ice chart. But we do not have the detailed information of acquisition times of the datasets used for the ice charts. The maximum time difference would be 24 hours but as Sentinel-1 data is also used for the ice charts the actual time difference in many cases will be smaller.

The MET Norway ice charts are currently the only sea ice product that can be obtained with a temporal resolution of one day. The reference (Zakhvatkina, 2017) also uses the MET Norway ice chart products for training and verification of sea ice classification. Therefore, we chose the MET Norway ice charts in the paper for sample selection and validation. In order to improve the accuracy of sample selection, we have also combined the visual inspection to improve the accuracy of sample selection. Besides, we have also analyzed in the paper that due to the difference between the SAR data acquisition time and the MET Norway ice chart acquisition time, the drift and freeze-thaw changes of the sea ice also affect the classification accuracy

5. Does the inclusion of GLCM features in the SVM classifier improve its performance when compared to using just HH + HV data? The inclusion of GLCM features is described but it is unclear why, and on what basis the GLCM parameters, the kernel size, quantization level, and displacement were chosen

Response： The SVM classifier is used for two very different purposes in the manuscript. 1) It is part of our model. Here, we do not use the GLCM, only the HH+HV. We agree that the accuracy could potentially be improved by including GLCM but we did not test that. 2) The SVM is used as the comparison method (Zakhvatkina et al., 2017) for the classification accuracy, and it will be used as the comparison method in this manuscript. This SVM is used and implemented in the same way as described in Zakhvatkina et al. (2017)

In the paper about the SVM algorithm, Zakhvatkina et al.(2017) use Radarsat-2 data to achieve a good detection effect (~90%), but the classification accuracy is poor (~75%) in summer. In our manuscript, the SVM classifier is used to demonstrate the performance of our approach and we use the same configuration which was used by Zakhvatkina et al., where the GLCM features include mean value, standard deviation, energy, contrast, homogeneity, correlation and entropy with the 32 gray levels. The window size for GLCM calculation is 16*16 pixels, and the separated displacement is 8.

6. The main misclassification error, on a class-by-class basis, is given to be caused by the presence of melting water on fast ice, leading to misclassification of ice as open water. However it is unclear how this was determined. If it is assumed, then the authors should provide some justification for it (e.g. article reference).

Response: Sorry for the misunderstanding. Fast ice is defined in the MET Norway ice chart, but in figure 10, there is no fast ice, and we will remove it. The brightest is the “Very Close Drift Ice”, and there is no fast ice category in Figure 10.

The difference map in Figure 10(c) is mainly caused by the underestimation of the SIC compared with the MET Norway ice chart. As shown in Figure 10(a) and (b), the reason for the underestimation is that open drift ice (sea ice) is misclassified as very open drift ice (sea water). The averaged sea ice concentration of open drift ice in Table 2 is about 5.5 (calculated from 0 to 10), which means open drift ice also contains open water, especially the influence of sea ice surface melt water during the melting period, resulting in this underestimation.

7. Consistency in terminology is needed, e.g. “backscatter”, “backscatters”, “backscattering”, and “backscatter coefficient”; “incidence angle” and “incident angle”; “RS-2” and “RS2” etc.

Response: We have revised it.

Specific comments:

(Page = P, Line = L)

P1L23: “backscatters” should be “backscatter”

Response: corrected

P2L21: delete “value”

Response: corrected.

P2L23: should be “MAp-Guided”

Response: corrected.

P2L30: data “are” (plural)

Response: corrected.

P2L32: Backscatter is also affected by waves that form, e.g. by capillary action, not just waves propagating into the area.

Response: We reformulate the sentence as follows:

“Backscattering characteristics are determined by sea ice surface roughness and its dielectric properties. As these are different for ice and water, backscatter can be fully explored to separate different sea ice types and water. However, the backscattering can also can be affected by ocean waves, mainly by small scale capillary waves for open water areas like leads but also swell propagating into the ice area, which can cause ambiguities. Therefore, it is not enough to only rely on backscattering intensity for identifying the different ice types and water.”

P3L2: Delete “scatters of the”; also change “the mixture” to “a mixture” on the next line.

Response: corrected.

P3L7: “analysis” should be “classification”

Response: corrected.

P3L9: “Texture”

Response: corrected.

P3L14: Use of the term “usually” here creates ambiguity.

Response: corrected.

P3L31: “A statistical distribution ….”

Response: corrected.

P4L15-18: There is a lot of detail given about the classification method here. The focus should be on Fram Strait.

Response: rewritten.

Fig. 1.: Make a better map with the image detail provided.

Response: corrected.

P5L6: “mode”

P5L15: Very Open Drift

is defined as SIC<1 here, whereas in Table 2 it is shown as 1-4.

Response: We have corrected this. Very Open Drift is defined as SIC in the range 1-4.

P7L12: “sub-swaths”

Response: corrected.

P7L18-19: Delete sentence that starts “Preprocessing methods …”

Response: deleted.

P8L9-10: Delete the description “with SPAN being defined…” etc. since the equation is given. The equation doesn’t need to be in Fig. 4.

Response: deleted.

P10L3: Delete “e.g.” and correct “otherwise”

Response: corrected.

P10L32: “noise is based on…”

Response: corrected.

P12L8: Sentence beginning “It may have” is hard to understand. Perhaps break it up.

Response: corrected.

P13L28: The table isn’t really necessary since the analysis and its outcome is described well above it.

Response: deleted.

P15L31: “and Weibull distributions are not …”

Response: corrected.

P17L10: Delete “In the experiment”

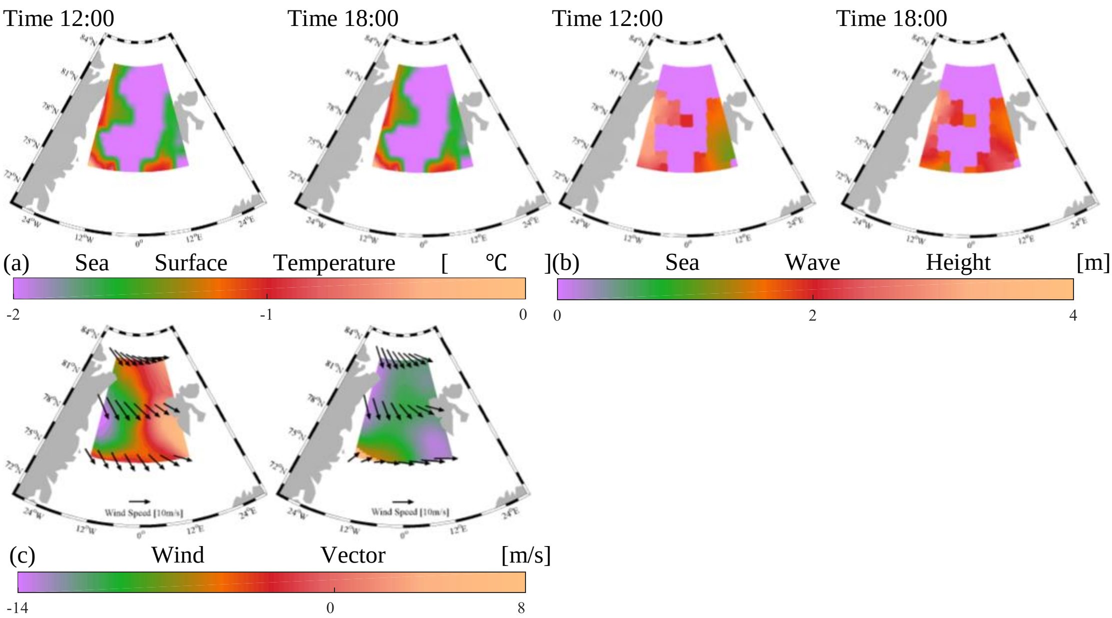
Response: deleted.

P18L12: Provide some detail about the temporal offset between the classification result and the ice chart.

Response: You are right that the evaluation of the classification could be affected by the temporal offset between SAR image and ice chart, but we do not have the detailed information. The MET Norway ice chart is a daily averaged product, but it is only provided from Monday to Friday.

In melting seasons, the drift speed of sea ice is accelerated and the ice condition may change a lot in a few hours. Due to the different acquisition times of the SAR image and the data used for the MET Norway sea ice charts, this may lead to uncertainty of the validation results. Figure 12 illustrates the daily average SST

(Sea Surface Temperature), SWH (Sea Wave Height) and wind speed of the Fram Strait using ECMWF ERA Interim data. It is clear to see that the ocean conditions have changed a lot within six hours. For the SAR image acquired on 16:23:33, 25 August, 2015 (Imaging in one minute), the SST remains stable from 12:00 to 18:00, While the V wind component was lower in the whole southern part of the Fram Strait at 12:00, at 18:00 high wind speed was in the eastern part. We can clearly see that sea ice shows a trend of drifting from west to east. The direction of the U wind component has reversed the sign, and the wind component has rotated by 90 degrees clockwise from 12:00 to 18:00. As a result, the SWH was lower in the northeast at 12:00 and became higher at 18:00. Moreover, the SWH of zero means that the data are missing, since SST is the lowest (-2℃), it indicates that these areas are mostly covered by sea ice.



P20L13: “MSTA”

Response: corrected .

P21L4: “from the same orbits”

Response: corrected .

P22L3: delete “has”
Response: corrected .