Response to referee 2: Estimation of Degree of Sea Ice Ridging Based on Dual-Polarized C-band SAR Data by Alexandru Gegiuc et al.

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Summary. This paper examines radar backscatter and texture parameters derived from Radarsat2 dual polarization imagery to determine ridge density in the Baltic Sea. A classification algorithm is described that derives several levels of ridge density, a useful parameter for shipping. Helicopter electromagnetic induction and manually derived ice charts are used for comparisons. The paper described the concept, approach and methods adequately and was satisfactorily written, albeit some grammatical editing is needed.
Many parts of the text have been edited to increase the readability, including some grammatical and spelling errors.

My primary suggestions are the following:

1) A final summary/set of conclusions of the basic findings is needed to be added. The discussion speaks in generalities about the need differences in the ice charts for both icebreakers and non-ice breakers in the Baltic plus shipping issues elsewhere in the Arctic.
The Discussion and Conclusions section has been partly rewritten, taking into account the remarks of both the reviewers. Please, see the edited section included in our response to the Reviewer 1.

It seems like a key result is that the results are much better in March than January and February. Please include a statement as to why you think this is the case.

"The major reason for the success of the classification in March is the better discrimination between the ridged ice and level ice in March than in the previous months as noted earlier in Section 4.2. The better discrimination property between ridging ice categories affects the final results in two ways. First, the segment boundaries of the dual-pol SAR imagery follow better the boundaries of the DIR classes in March (see Fig. 11). Secondly, the segmentwise feature vectors show more variability between different ridging categories in midwinter. The combination of these two factors determine the accuracy of the final classification.

We studied the success of the segmentation by examining how large fraction of the segments contained practically just one ridging category. i.e. the area of some ridging category covered over 90 % of the segment area. The results were that in January 93 % of the SAR imagery belonged to such segments, in February 80 % and in March 86 %. The high fraction of well defined segments in January is easy to understand because most of the ice was level ice (72 % of the area), and just three ridging categories appeared (the heavily

ridged area covered less than 1 %). In February the fraction of level ice has decreased to 55% of the total area, all four ice categories were present and the total area of well defined segments decreased to 80 %. In March the level ice area covered 59 % of the total area and the area of the well defined segments was 86 %. Hence there was better the segmentation accuracy in March than in February. In that month the total area of correctly classified ridging categories was 81 %, five percent points less than the total area of the well defined segments. In February the total area of correctly classified ridging categories was just 63 % which means 17 percent points less than the total area of the well defined segments. This analysis suggests that the main separating factor contributing to the classification accuracy was due to the more versatile feature vectors in March."

We added the above paragraphs inside the quotation marks at the end of Section 4.3.

Also these differences in interpretation of the ice charts for the two types of ships seems important enough to include earlier in the paper, as it impacts final comparison results.

We agree. We have mentioned this issue in the Introduction section as follows:

"In this paper we propose a method to automatize the DIR estimation process based on th RS-2 dual-polarized (HH/HV) SAR data acquired under cold conditions and using the FIS ice charts as reference data. The results are then evaluated together with the ice analysts. We don't expect a perfect match between the automatic chart and the manual one. The polygons in the manual charts typically suppress certain amount of variation for the small-scale features and merge them into one DIR category. Here we aim to produce a more detailed DIR chart, which follows closely the SAR texture features of sea ice ridges, edges, cracks and leads. This allows the icebreakers and the non-icebreaker vessels to benefit from it in advance route planning and optimization. Ultimately, the goal is to facilitate independent sea ice navigation of non-icebreaker ships, where a finer scale DIR map can offer more sea ice passages with lower degrees of ice ridging, instead of a large polygon which either allows or denies the navigation in a specific area."

2) I suggest a final section be added in Section 4 that describes value of each polarization, with the HV of seemingly little to marginal value except as was pointed out perhaps in March, and the other texture parameters, in terms of what were the most important parameters in deriving ridge statistics. Could the algorithm be successful with fewer parameters? What parameters were really needed to identify ridges?? I am suggesting a further evaluation of Figure 4 basically.

The first correction we made was the addition of the following paragraph at the end of the Section 3.2. to justify, partly intuitively, why we have chosen the computed features.

"Most of the features have a rather straightforward interpretation. Entropy describes how uniformly the HH/HV values are distributed.

Edge density is a measure for edge fragments present in the segment which fragments we assume to be related to ridging. Coefficient of variation (CV) describes how fast the standard deviation increases with the mean. We expect that in the ridged areas CV is larger than in the homogeneous areas. Kurtosis Kurtosis describes the peakness of the σ^o distribution. With the aid of the spatial autocorrelation we can quantify how structured the ice field in question is in the SAR imagery. We expect that more structural elements appear in the ridged ice than in the level ice where the spatial σ^o variation is more random."

Our procedure to compute the importance of the feature is explained in Section 3.3.2. It is based on the out-of-bag (OOB) samples of the data. We also considered how well different feature combinations classified the data. To clarify the nature of the importance of the feature based on the OOB data we added the following to the added subsection 4.4 (i.e. Importance of features) in the Results section:

"The selection the eight features in Section 3.3.2 was based on their importance value. The features consisted of six HH-polarization based segment-wise features (see Section 3.2) and the segment-wise σ^o_{HV} as well as the IC value extracted from the FIS ice chart. Their importance order when the training data covered the whole test period is presented in the Table 1. If the training data of just one month was used the importance order of features varied slightly. The importance of one specific feature is relative in the sense that it changes when the combination of the used features changes, i.e. the importance of one feature depends on which other features are included. The feature IC remained however the most influential feature in every case. This is comprehensible because when IC was between 80 % and 90 %, the ice area in question represented almost always the level ice category (DIR 1) and the corresponding feature vector was easy to classify correctly. The rather low importance value of σ^o_{HV} is probably due to the relative narrow range of the σ^o_{HV} values.

To gain more insight into how the eight selected features affected the classification accuracy, we studied the possibility of the feature reduction using the March data as benchmark. The March data was selected because the diversity of ridging categories was largest then (see Table 7). We eliminated systematically one by one the selected features and reclassified the March test data using the remaining features. In none of the cases the classification accuracy improved with fewer features. For several removed features (E_{HH}, AC_{HH},K_{HH}, σ^o_{HV}) the classification accuracy decreased with just a few percent points ($1-3$ %). The removal of the ED_{HH} feature did not practically affect the accuracy at all. A significant misclassification rate increase was observed by the reduction of the σ^o_{HH} (-6%), $CV_{HH]}$ (-8%) and IC (-12%). In every case the relative importance of the retained features changed. Hence the importance of the features present in Table 1 is true only in the context of this specific feature combination.

To see more clearly that the features included in the feature vector complement each other and make the classification more robust, we classified the March data using only three basic features (f_3 =

$(IC, \sigma^o_{HH}, \sigma^o_{HV})$). The overall accuracy was just 64%. Then we added the feature CV_{HH} to f_3 because CV_{HH} caused a significant drop in the accuracy. The accuracy remained low, only 68 %. Our conclusion of the performed analysis is that the information provided by the whole feature set is needed for a good description of ridged ice field in the SAR imagery. If already a reduction of one feature decreases the classification accuracy, the reduction of two or more features would degrade the classification further. The only feature which is perhaps unnecessary is ED_{HH}. It was also the most heuristic one (see Section 3.2). Because it does not decrease the classification accuracy, we have kept it in the selected feature combination. We also experimented by replacing the HH-polarization based features with their HV-polarization counterparts. This lead in all of the studied cases to the degradation of the classification accuracy."

These indicates that all of the features (perhaps except ED_{HH}) are needed in a successful classification.

Detailed comments.

1. Page 13, line 14 mentions green in Figure 5 which I assume should be red/pink.

We agree. We have replaced "green" with "pink".

Line 15 left off Figure number, which I assume to be 5.

We agree. Corrected.

2. Page 13, line 25. to SW I assume this means towards the SW.

Yes, we have corrected the text.

3. Page 13, lines 30-31. The sentence In areas with IC $80 - 90$ % the amount of open water is rather high... I think they may mean that in a relatively high ice concentration area, the relatively low amount of open water can still have a strong impact on the overall backscatter, particularly during high winds. Please rewrite.

Corrected to the form:

"In areas with ice concentration varying from 80 % to 90 %, the amount of open water area can impact on the backscattering statistics significantly, particularly during high winds."

4. Page 14. Line 8. A question mark appears in text without any apparent meaning.

The reference was missing. Now it has been added. The sentence was corrected to:

For thin ice rather high σ^o_{HH} (over -18 dB) have also been observed (Mäkynen et al., 2004).

References

Mäkynen, M., Hallikainen, M.: Investigation of C- and X-band backscattering signatures of the Baltic Sea ice., Int. J. Remote Sens., 25, 2061–2086, 2004.