Response to the comments of reviewer #1 to

**Assessment of error in satellite derived lead fraction in Arctic**
by N. Ivanova, P. Rampal, and S. Bouillon

In the following we provide detailed answers (marked by “**A**”) to your comments (“**R**”) and describe what changes are done in the revised manuscript (“**Changes**”).

**R:** The manuscript presents a valuable contribution to sea ice remote sensing techniques, the chosen analysis methods are sound, and the authors discuss the most important limitations and open questions of their study. I can therefore recommend it’s publication in TC after some minor issues are resolved.

**A:** Thank you for such a positive response about our results, we value it greatly.

**Minor Issues:**

**R:** Both AMSR-E and SAR LF algorithms heavily rely on empirical tie-point or threshold values. How do you justify that one can be used as ground truth for validating the other?

**A:** This is a good point, and it should indeed be brought up more clearly in the revised version of the manuscript. We justify the use of the SAR-based method, firstly, by the combination of the fine resolution of this sensor (pixel spacing of original product: 75 m × 75 m, geometric resolution: 150 m ×150 m) and its capability to separate smooth surfaces such as open water or thin ice in leads (appear darker than the background) from the rough surfaces (surrounding thicker ice). In addition, leads have a characteristic shape: they are narrow elongated features. These three factors put together make it possible to visually recognize the leads. This allowed us to perform visual quality control of every pair SAR image – SAR lead fraction retrieval. An example is demonstrated in Fig. A1.1. Ambiguous images or images where many of leads were missed by the method were discarded.

However, even in the selected images there would still be some leads missed by the method presumably because the ice in them is thicker than the threshold allows. An example of lead fraction comparison is shown in the Fig. A1.1. Panel a) shows the original SAR image, panel b) shows the lead identification by the SAR-based method, where the red color corresponds to the identified leads, and the panel c) shows the SAR image overlaid by AMSR-E lead fraction original product (in %) with the color scale to the right. The features that are missed by SAR are relatively small, and are usually not captured by the coarse-resolution AMSR-E either (Fig A1.1-c). Please also note that the AMSR-E based method was found to identify only leads wider than 3 km (Röhrs et al., 2012), and such features were normally identified successfully by SAR in our study. In addition, we only performed the validation of AMSR-E lead fraction in locations where both datasets (SAR and AMSR-E) gave lead fraction > 0%, which excludes the cases of missed features in the reference SAR dataset.

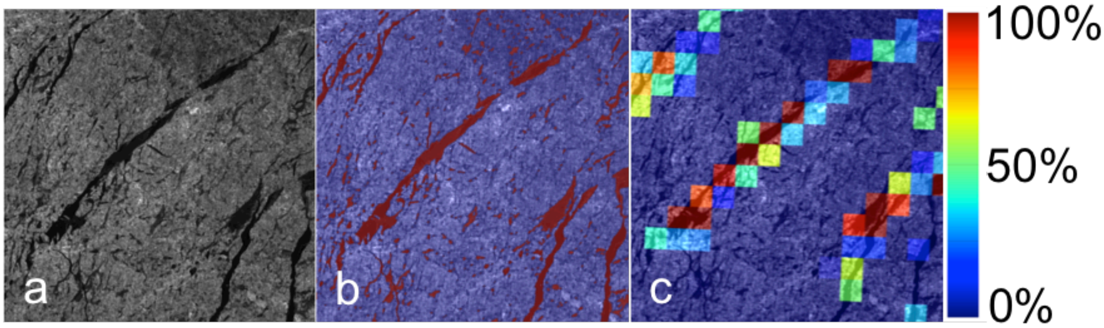


Figure A1.1. a) A subset of the original SAR image (backscatter) on the 8 March 2009, b) respective classified SAR-image (water/ice) with a) as background, c) AMSR-E lead fraction in % with a) as background.

**Changes:** The message provided above will be expressed more clearly in the revised manuscript.

**R:** Also, the data presented in Figure 4a raises the question if the SAR and AMSR-E LF algorithms measure the same quantity at all, or if both algorithms retrieve different sea ice properties.

**A**: This is a very relevant comment and a point that deserves to be discussed. First we would like to show one example that shows that SAR and AMSR-E LF algorithms measure similar quantity to some extent. And then we will discuss the possible differences in measured quantities.

To start, it should be mentioned that what we observed from comparison of SAR LF retrievals overlaid by AMSR-E LF product was that both identify the leads in the same locations. However, the amount of the lead area (lead fraction in percent) is a different story. Fig. A1.2 (left) shows similar scatterplot to Fig. 4 of the manuscript, except that it is only one-day example (8 March 2009 shown in the Fig. 8 of the manuscript).

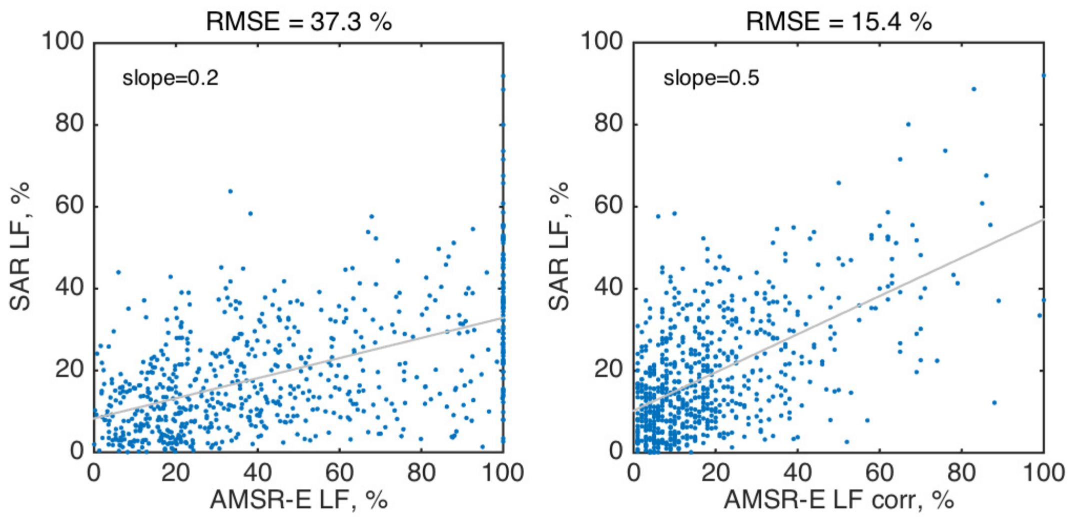


Figure A1.2. Left: scatterplot of SAR LF and AMSR-E LF using the original method of Rörs et al. (2012). Right: same but using the corrected AMSR-E method (new tie point).

The left panel of Fig. A1.2 compares the original AMSR-E lead fraction to that of the reference SAR dataset, while the right panel compares the AMSR-E lead fraction obtained with the new tie-point suggested in the study. The tie-point adjustment made the AMSR-E and SAR datasets agree significantly better: the RMSE improved from 37.3% to 15.4% (please note the numbers in the original manuscript are somewhat larger, this is a result of a mistake which is corrected now) and the slope of the regression line became closer to 1 (increased from 0.2 to 0.5). We believe this is an indirect indication of that the two methods do observe similar quantity.

However, as we mentioned in the beginning, this is the case only to some extent. The mechanisms that form the signal from an area with leads, represented by either open water or thin ice, are substantially different for SAR and AMSR-E. SAR is sensitive to roughness, while AMSR-E is sensitive to emitted brightness – these are two different physical parameters and they transfer into sea ice related quantities (thickness, type or concentration) in different ways. In addition, they have different resolution: 150 m ×150 m for SAR and 6 km × 4 km for AMSR-E (the footprint size of the 89 GHz channel).

What we can see from visual inspection of SAR retrievals (including comparison to MODIS) is that if SAR identifies a feature, it retrieves its limits correctly. This is natural because ice in leads stays relatively smooth for a while and therefore SAR is still capable of interpreting it as a lead (except some cases discussed in the manuscript, which were excluded from the comparison).

For AMSR-E the situation is different: a relatively large area of ~40 km$^2$ (the grid spacing of the final product is 6.25 km × 6.25 km) is included in each grid cell and within it neither the borders of the leads nor different surface types (nilas, new ice, open water, etc.) are resolved, but a total amount of open water + thin ice in percent found in the grid cell is retrieved. The signal is a sum of all the surfaces present in the grid cell. The signature of thin ice (new ice, nilas, and pancake ice), expressed by the ratio of brightness temperatures used in the method (and based on Eppler et al., 1992), is quite distinct from thicker ice, and therefore the method is capturing the leads in correct locations, but calculation of the areal fraction of lead in the grid cell is based purely on an empirical constant obtained using MODIS images. The upper tie point, corresponding to LF = 100%, is found by selecting the ASMR-E grid cells that contain 100% thin ice + open water according to MODIS image and similarly the lower tie point is found for the cases with no leads present in the footprint. But there will be certain variance around the tie points due to variance in the brightness temperature ratio caused by presence of different surface types within the category of "lead" defined by both several types of thin ice and open water (Fig. 1 in Rörs et al., 2012), and sometimes it will be a mix of them. For example, the anomaly of this ratio (relative to the surrounding thicker ice) will be quite different between nilas and new ice, and the value of the anomaly for open water is even further away. They are all indeed above the background value, but the amount of this difference would vary depending on what type of thin ice is there (or open water).

**Changes:** We will address the issue in the discussion.

**R:** The second half of the manuscript lacks good structure. For example, the adjustment of the ASMR-E LF retrieval is somehow hidden in the discussion part. I would recommend to dedicate an own sub-section to the determination of the new tie-points, and give recommendations on how the algorithm should be used in the future. This is an important result that must be easy to find for someone that skims through the paper.

**A**: The reason for presenting the AMSR-E-based method adjustment in the discussion section was that this adjustment was only a one-day case study, a test to demonstrate the possibility. We did not consider it as one of the main results of the paper because it was not completed on (and thus confirmed by) larger amount of data. It was rather a suggestion for future developments. However, we agree with the reviewer that it would be useful to make it more visible and easy to find.

**Changes:** The method adjustment will be moved to a new subsection with a title that will tell the reader that this is not final result. For example "future possibilities…", "suggestion…", "case study", etc.

**R:** page 6319 line 21: what do you mean by the phrase in parenthesis? Please reformulate this sentence and be clear what criteria the desired data set should meet, or which criteria is doesn't need to meet if that is important here.

**A**: We meant that our target is retrieving lead area (lead fraction) per grid cell as opposed to other studies that have already performed the validation of the lead locations and orientations in the AMSR-E dataset. They have shown that the AMSR-E product has leads in the correct places, but they have not looked at the amount of lead water/thin ice per grid cell as compared to other data sources quantitatively.

**Changes:** Will be clarified in the revised manuscript.

**R:** Equation 1: What is the scale of the median filter?
**A**: It is 5-by-5 pixels (p. 6322, l. 11)
**Changes:** "size of five pixels" will be changed to "5-by-5 pixels"

**R:** Is there a possibility that the SAR LF algorithm could oversee any leads?
**A:** please see our reply to the first item in the "Minor issues".

**R:** page 6330 line 8: Can you give a reference or other evidence for the power law behaviour?
**Changes:** The references that were meant here originally were Wernecke and Kaleschke (2015), and Marcq and Weiss (2012). However, this sentence (and other referring to the power law) will be removed from the revised manuscript because we do not find it justified connecting our reasoning to the distribution of lead width while addressing the lead fraction.

**Technical corrections:**

**R:** page 6317 line 14: instead of correlations, I think you mean a causal relation, or dependence.
**A:** Yes, this is correct. Thanks for notifying this. We will change the text to "causal relation".

**R:** A couple of articles ("The") are missing in the text.
**Changes:** The manuscript will be given to a native English-speaker for proofreading.

**R:** Change the title to “Error assessment of satellite derived lead fraction in the Arctic”
**Changes:** This is a good suggestion, we will do that.

**R:** Equation 1: If there is no vector cross product involved, use a simple dot instead of the cross.
**Changes:** Will be adjusted accordingly.

**R:** page6324, line 17: Remove “While”. It is not possible to form a sentence from to dependent clauses with no main sentence.
**Changes:** Will be adjusted accordingly.

**R:** page 6330 line 17: “define” is not suitable here. I would argue that you have determined the value for r100.
**Changes:** Will be adjusted accordingly.

**References:**
*(References listed in the manuscript are not duplicated here)*

Eppler, D., Farmer, L., Lohanick, A., Anderson, M., Cavalieri, D., Comiso, J., Gloersen, P., Garrity, C., Grenfell, T., Hallikainen, M., Maslanik, J., M¨atzler, C., Melloh, R., Rubinstein, I., and Swift, C.: Passive microwave signatures of sea ice, in: Microwave Remote Sensing of Sea Ice, edited by: Carsey, F. D., no. 68 in Geophysical Monograph, American Geophysical Union, 1992.