Author's response

Comparing C- and L-band SAR images for sea ice motion estimation

Jonni Lehtiranta, Simo Siiriä, and Juha Karvonen

Finnish Meteorological Institute, Marine Research Programme, Helsinki, PB 503, 00101 Finland

Response to Anonymous Referee #1

The major criticism was about the “Validation of motion estimates” section, which compared the operational algorithm by Karvonen to the results of our study. We agree with the suggestion (3), that if we want to compare the performance of the tracking algorithm relative to a reference, we should manually generate a drift data set for the purpose.

Due to lack of time, this comparison is not in the revised manuscript now.

R1 (1): Why was it necessary to implement another algorithm instead of using the existing operational one?

The maximal cross-correlation algorithm was used in this study for several reasons. First, the operational algorithm has been tuned for C-band radar images and built to work in conjunction with open-water detection and ice type classification algorithms written for C-band images. Second, there was a desire to write a GPGPU program code, which speeds up the calculation and enables quick testing, many re-runs with a large set of images, and the development of computationally intensive algorithms. The author also wished to avoid problems, such as correlation wrap-around, that are specific to methods operating in the frequency domain. It was also feared that phase correlation, used in the operational algorithm, might be problematic for correlating images acquired using different frequency bands.

R1 (2): Why do the results of the two algorithms shown in Fig. 14 differ so much?

The results of the two algorithms, illustrated in fig. 14, differ so much for several reasons. First, the operational phase-correlation algorithm was run without the customary open-water information that was not available. The phase-correlation algorithm produces spurious results for open-water areas, roughly, south of 63 40’ N and west of 22 E. In the ice-covered area the phase-correlation algorithm also fails to find motion in certain locations, and produces southward movement mainly in the central area of the moving ice pack and on its southern edge. The

reason for this is not known.

The comparison between these two algorithms is left out of the revised manuscript.

Minor comments:

Abstract: By “seasonal sea ice inner structure” we mean volume scattering that happens below the ice surface. Due to the longer wavelength and bigger penetration depth, L-band SAR images contain significant information of the inner structure of sea ice. This is clarified in the revised manuscript.

Introduction: By “empirical data” we mean “observations”. The word has been changed.

The references we list for optical flow all do motion estimation for SAR images by some method of correlation for pixel blocks, except for Liu et al., 1997, which applies wavelet analysis to track edges of ice floes. The term “optical flow” encompasses several different approaches, and we are still unsure which of the references should be excluded.

Section 2.3 Performance: the section was rewritten to only explain what was done in this work, and hopefully do that in a clear manner.

”Displacement” and “motion” were used interchangeably in the discussion paper. The word ”motion” was chosen and is now used exclusively.

Page 2728, lines 14-16: The registration error did vary spatially, and an interpolation between land points was done. This is clarified in the revised manuscript.

Section 3: Images have been modified to contain visual hints about the features we write about.

Response to Dr. Lang

1. Readers may have difficulties to understand the structure of the paper in general and sections specifically. And an English edition (both structure and

grammar) is required to make the paper more fluent.

The grammar of our paper has been improved for the revised manuscript. The structure is hoped to be acceptable.

2. It is not convictive to make the conclusion that L-band images are preferable for motion estimation with only two L-band images available. If possible, I recommend considering more data for analysis.

We agree that no strong conclusions can be drawn based on the limited data set. Our feeling is, however, that the study of large image sets is best handled by a different methodology and left for another publication.

3. The sequence of figures is so disordered that must be adjusted.

The figure sequence is adjusted such that image numbering corresponds to the order they are discussed in the paper.

4. Both “Abstract” and “Conclusion” require a deeper discussion.

Both the abstract and the conclusion will be expanded with a deeper discussion.

Specific comments:

Image pairs mere hours apart will be useful for our purposes. Ice drift velocities of 20 - 30 cm/s are not uncommon. We use satellite images of 100 meter resolution, thus these velocities cause 7 - 11 pixel displacements during just one hour.

The image window size 16 x 16 pixels was chosen because it is near the smallest feasible sizes to do reliable matching by maximal cross-correlation. We chose a small window to minimize problems from ice deformation and coastlines that introduce discontinuities within image windows. A larger window, say 32 x 32 pixels, might improve the matching, but as we were only interested in the difference between C- and L-band images, the absolute performance of the method wasn’t critical.

The “peak margin” was calculated as a ratio of two cross-correlation coefficients, between the two highest cross-correlation peaks found in one cross-correlation. 15 % was chosen as it often seemed to be sufficient for accepting a result. The “regularity” criterion for accepting a motion vector was calculated by subtracting each motion vector from the median-filtered vector at that location. The idea was that if some motion vector differs considerably from the local median drift, it is probably erroneous. The section 2.3 will be rewritten for the revised manuscript to clarify these issues. Incidence angle correction was not done as it was not

deemed necessary for normalized cross-correlation using such a small image window. Speckle noise was not filtered out. A generic filtering would be easily done if deemed necessary. For the best result, filtering should be different for different instruments. These details are noted in the revised manuscript.

Page 14 line 15: “in Fig. 14” was a mistake. The reference has been removed, as it referenced a figure that was removed from the manuscript. Line 18: MCC is now explained at the first appearance of the concept. Section 4: the cross-correlation coefficients are small, but they suffice for the purposes of this paper.

Other changes in the manuscript

- Addition of a wind rose in fig. 2
- Many small clarifications in image captions