AN ANALYSIS OF THE RELIABILITY OF SEA ICE DRIFT PRODUCTS CALCULATED FROM SAR DATA

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ABSTRACT

Sea ice drift can be derived from a sequence of SAR images using a multiscale motion tracking approach. We examine the reliability of the resulting ice velocity field with the help of image texture analysis and consistency checks. SAR images acquired at different polarizations show different features of sea ice, and we examine the suitability of like- and cross-polarized data for sea ice motion tracking.

Key words: sea ice; drift; SAR; reliability; remote sensing.

1. INTRODUCTION

The motion of sea ice is not only of interest for ships navigating arctic or antarctic waters, but is also important for analyses of parameters describing the interaction between ocean, sea ice and atmosphere, such as heat exchange or salinity transport. Sea ice drift can be quantified by applying a motion tracking algorithm to a pair of spatially overlapping SAR images which were acquired at some temporal separation. For the present work, we have selected SAR data from two different regions: 1) the Ronne polynia in the Weddel Sea, Antarctica; and 2) the Fram Strait, between Greenland and Svalbard. Due to their very dynamic ice situations, both regions are interesting test sites for an evaluation of our drift retrieval algorithm.

Due to the scarcity of in-situ measurements of ice drift, it is a challenging task to validate the derived displacement field. Without using external data, the reliability of the result can be estimated using a consistency check called backmatching, but this is computationally expensive. Another approach estimates a set of parameters characterizing image intensity pattern quality that can be directly calculated during algorithm runtime. This method significantly reduces the computational load of the drift field reliability estimate.

In the following, we analyze the reliability of sea ice displacement maps generated from SAR data and introduce a method to estimate the accuracy of displacement vectors using statistical methods and texture analysis. In this way, we can assess the reliability of the ice drift maps when there is no reference data available. Furthermore, we evaluate the possibility to combine SAR data of different polarizations to improve the quality of the resulting drift field.

2. SEA ICE MOTION DETECTION

We determine sea ice motion using a pattern-based multiscale cascaded motion tracking approach described by [5] and [2]. Sea ice motion is detected by calculating a normalized cross-correlation coefficient with a prepending phase correlation as a pattern similarity measure. This is done, repeatedly, on different spatial scales represented by an image pyramid. The initial low-resolution motion field is gradually refined by multiple passes through the pyramid. While this approach generates a numerically stable result, it makes a direct quantification of the uncertainty of the derived motion field difficult.

3. QUALITY OF THE DISPLACEMENT FIELD

The normalized cross-correlation coefficient by itself is not a good indicator of the quality of the derived motion vectors [3], but there are several possible ways to evaluate the reliability of sea ice motion fields calculated from SAR data in the absence of in-situ measurements:

1. A comparison with visually determined drift vectors can indicate the reliability of the motion detection algorithm, but is biased towards regions where patterns are easy to identify for the human eye. This method is suitable for evaluation purposes only.

2. A consistency check can identify numerically unstable regions by running the algorithm in forward and backward direction over an image pair. This doubles the computational load of the algorithm. To obtain a quantity that is indicative of the reliability of

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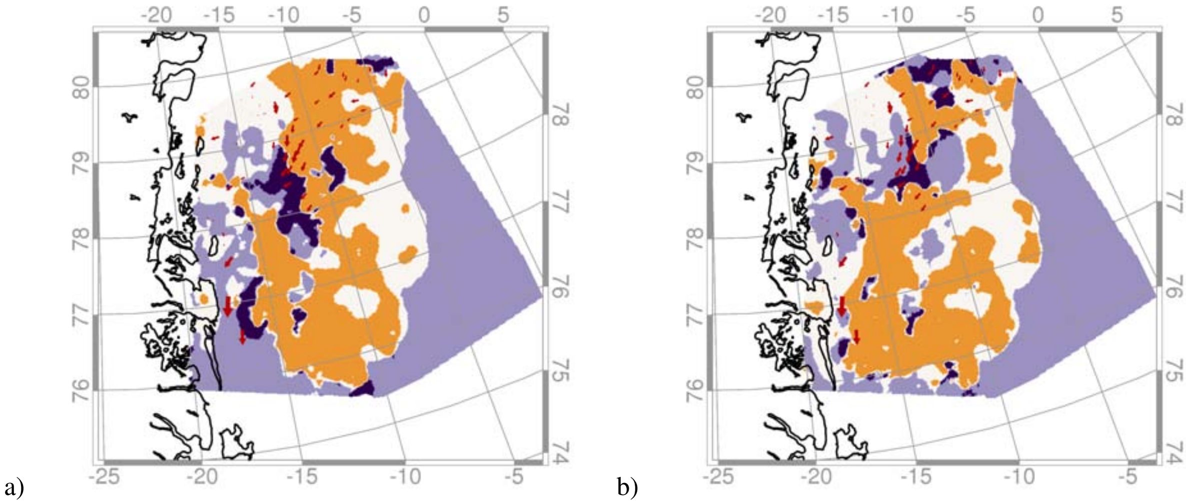

Figure 1. Comparison between texture analysis and backmatching. ● A_s; ○ $A_{cfa} - A_s$; ● $A_{bm} - A_s$; ● *regions considered unreliable by both methods. a) HH polarization. b) HV polarization. Red arrows are visually determined motion vectors. Radarsat-2 images acquired on 2012/09/16.*

the motion field, the difference between both runs is normalized by the drift velocity.

3. An analysis of the image texture can indicate regions where the pattern matching is likely to fail due to low pattern quality. This test can be conducted at runtime and does not significantly increase computation time. We combine different texture parameters to cover different aspects of pattern quality. Parameters are calculated at each pass of the pattern matching algorithm. Once the calculated value exceeds a threshold, a flag is set. Those flags are accumulated over the entire image processing chain. If a certain number of flags is exceeded for a motion vector, it is considered unreliable. For a detailed discussion of the parameters contributing to the texture analysis, see [1].

We can compare the areas marked as reliable from both the backmatching A_{bm} and the texture analysis A_{cfa} by calculating ratios between them and their intersecting area $A_s = A_{bm} \cap A_{cfa}$. This comparison shows overall good agreement, but it can be noted that the reliable area obtained by texture analysis is systematically larger than the shared area (Fig. 1). This is due to the fact that texture analysis fails to exclude highly dynamic regions, where patterns are very well developed but change too fast to be trackable by the algorithm. This effect can be observed in Fig. 1, where large parts of the ice margin zone is classified as reliable by texture analysis, but marked as unreliable by backmatching.

4. POLARIZATION EFFECTS

In [4], it was noted that under certain conditions, HV polarized images are better suited for motion tracking. An analysis of the reliability of the motion field derived from HH polarized Radarsat-2 data recorded over Fram strait (Fig. 1 a) and from the HV channel of the same scenes (Fig. 1 b) shows some differences. Quantiatively, the reliable area from the HV polarized data is slightly smaller. There are differences in the spatial distribution of reliable motion vectors, caused by a combination of ice conditions and radar polarization which in some cases enhances or lowers the contrast in the images and hence influences pattern matching. Based on the reliable re-

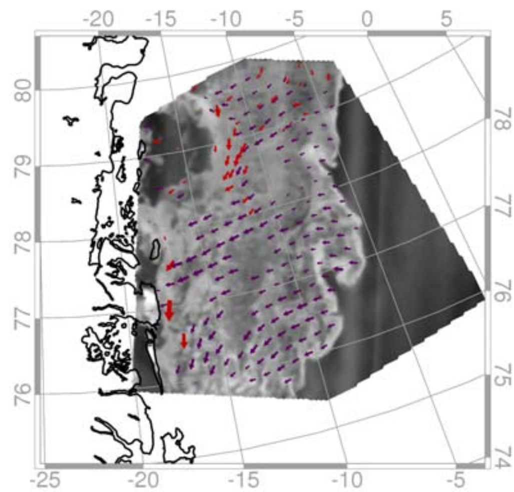

Figure 2. Motion field derived from a combination of HH- and HV-polarized data from Radarsat-2. Purple arrows are the calculated motion field, red arrows are visually determined motion vectors. Radarsat-2 images acquired on 2012/09/16.

gions defined above, we can combine results from both polarizations. Motion vectors from regions where both polarizations give valid results can be simply averaged. Including results calculated from both HH and HV polarization (Fig. 2) increases the number of reliable motion vectors by 36% in our example.

5. CONCLUSIONS

We analyzed the reliability of sea ice motion fields derived from SAR data using different quality indicators: a consisteny check (backmatching) and an approach based on image texture analysis. A comparison with visually determined motion vectors shows that the texture-based method works well, but tends to overestimate the area marked as reliable if the ice situation is very dynamic. For such conditions it would be adviseable to use backmatching to indicate the reliability of the derived motion field.

Using the quality indicators, we can combine motion fields calculated from different polarizations and significantly increase the number of reliable vectors in our results.

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