Ship Navigation Assistance For Polar Waters By Providing Information On Sea Ice Drift And Deformation Zones Using TerraSAR-X Data

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Sea ice is subject to permanent changes. It arises as seawater freezes, and is drifted and deformed by winds and ocean currents, waves and temperature fluctuations. Within hours, leads of open water can be closed by drifting ice. If the drifting continues, pushing sections of sea ice together, floes are piled up forming an uneven surface, or pushed upright into pressure ridges. In other places, closed covers of sea ice can break, forming leads of open water. Hence, this can be either a severe hazard or a welcome opportunity for ships in polar waters.

Synthetic Aperture Radar (SAR) satellites make different structures within the sea ice visible. With their active radar antenna, they provide image data of the oceans and frozen waters through clouds and darkness. Since decades, national ice services utilize SAR images to create sea ice maps, which in turn are used for ship routing in polar waters. To further support the navigation in ice-infested waters, we established an operational data processing chain at the DLR ground segment. This allows to acquire and process SAR images of the German satellite mission TerraSAR-X along the planned ship course, as demonstrated in Figure 1, and provide them to navigators on board in near real time [1, 2]. The processing chain has been used in several research campaigns, amongst others the one-year-long MOSAiC expedition of *RV Polarstern*. It has been found that the support with these tailor-made, up-to-date TerraSAR-X data can help optimizing routes. To further support ship navigation, we aim to provide L2 products such as sea ice drift information automatically derived from subsequent SAR acquisitions.

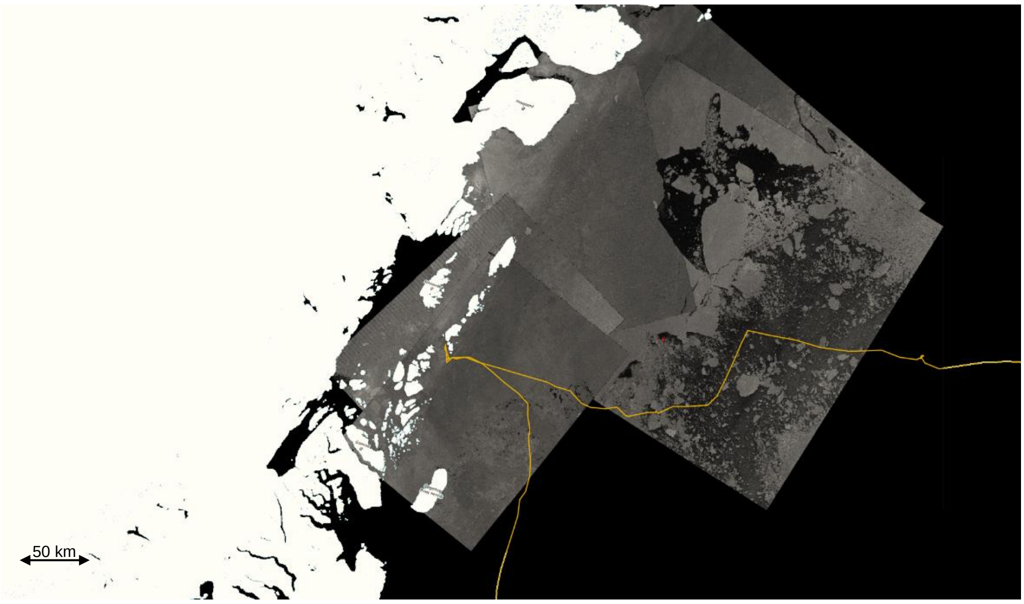

Figure 1: Ship navigation support during RV Polarstern expedition PS131 at east coast of Greenland through TerraSAR-X data supply along the planned ship route. Yellow: Ship track

In this contribution, we explore the capabilities of a new software processor that is intended to derive high resolution sea ice drift vector fields from subsequent SAR images, exemplarily shown in Figure 2. We quantize the accuracy of drift estimation using buoy data, and analyze the influence of different SAR parameters (i.e. incidence angle, heading, orbit direction), as well as different sea ice and metrological conditions. The drift vector estimation is based on the well-known phase correlation technique executed hierarchically in a multiscale Gaussian image pyramid. Phase correlation has first been applied in [3] for image pattern matching, and used for SAR based sea ice motion tracking in [4, 5]. We showed first experimental results of the general approach combining TerraSAR-X ScanSAR and RADARSAT-2 ScanSAR Wide acquisitions in [2] and [6] and first quantification of its accuracy using drift buoy data for validation in [7]. In the study presented here, we introduce a new iterative approach which fragments image patches in the last resolution level of the image pyramid in order to better represent sea ice drift at borders of different ice sheets. Inspired by the consistency check in [5], we re-estimate drift vectors iteratively in each resolution level until an update of zero indicates the best match is found, which results in increased accuracy.

Figure 2 exemplarily shows two drift vector fields derived from subsequent TerraSAR-X acquisitions taken on 25th, 26th, and 27th January 2020 during a storm event in Central Arctic. The drift vector fields show a quite homogeneous sea ice motion south- and eastwards, which supports the high reliability of the approach. Convergence and divergence zones become visible at the color jumps in the drift velocity map. Knowledge about the location and distribution of convergence and divergence zones as well as sheering zones helps for ship navigation in polar waters; in particular, convergence zones imply strong ice resistance difficult to pass even for icebreakers.

The sea ice drift retrieval presented here is part of the software suite SAINT developed at the DLR Maritime Safety and Security Lab Bremen. SAINT is integrated in the operational processing chain at the DLR ground segment in Neustrelitz and provides L2 products to maritime users, e.g. ship or iceberg detection. For reaching near real time requirements, we use parallel processing and hardware implementation on FPGAs.

References

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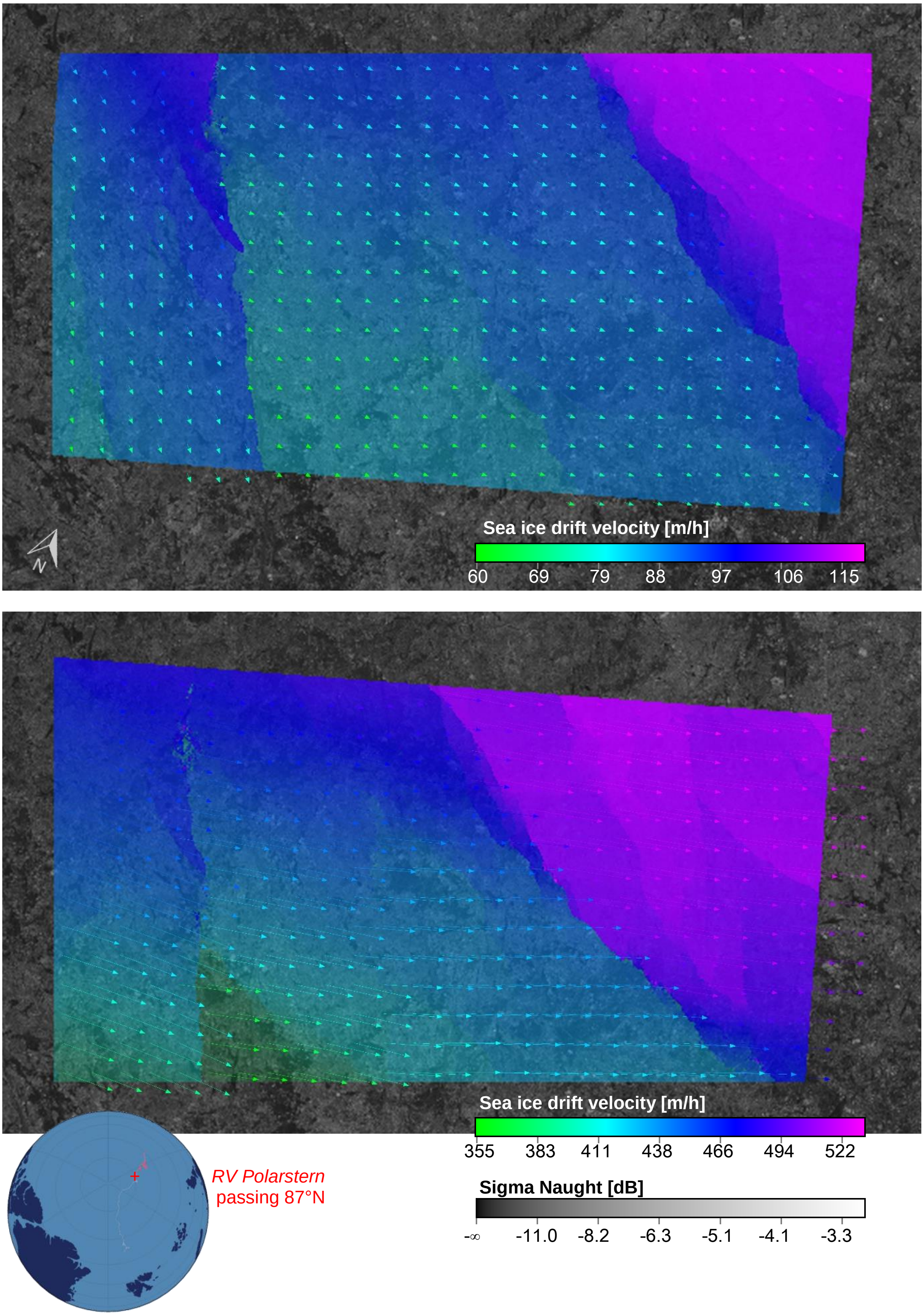

Figure 2: Examples for sea ice drift retrieval from TerraSAR-X data taken during MOSAiC expedition facing a storm event in late January 2020 in Arctic Ocean at 87°N. The background shows TerraSAR-X HH data from 2020/01/26 03:58 UTC (top) and 2020/01/27 03:41 UTC (bottom) in grey scale, calibrated to sigma naught. Overlaid colors represent retrieved sea ice drift velocity in 264 m resolution and arrows illustrate sea ice drift vectors (5 km spacing). The upper drift field is generated from TerraSAR-X acquisitions taken on 2020/01/25 and 2020/01/26, the lower from 2020/01/26 and 2020/01/27. Convergence and divergence zones become visible at the color jumps in the drift velocity map.