MULTI-RESOLUTION SAR DATA ANALYSIS FOR AUTOMATED RERTIEVAL OF SEA ICE AND ICEBERG PARAMETERS

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ABSTRACT

Multi-resolution SAR datasets (ENVISAT, TerraSAR-X, TanDEM-X) were used for ice parameters retrieval using automated algorithms within a prototype of system of multisource data fusion. It has been demonstrated that two SAR sensors with multiple frequencies and resolution lead to a better understanding of ice conditions including ice edge, concentration, floe statistics, and other ice features such as icebergs. Time series of ENVISAT Wide Swath data with low resolution were used to monitor the dynamic changes in ice, to detect ice edge, and to estimate ice concentration. High resolution TerraSAR-X/TanDEM-X constellation data were used to generate an interferogram for improved detection and estimation of size and geometry of ice floes and icebergs. Each individual floe has its own fringes interferometric pattern which can be used for calculating floe statistics. The iceberg interferogram was used for detecting iceberg in sea ice as well as for extracting iceberg topography.

1. INTRODUCTION

Sea ice monitoring is an important field of scientific research and relevant to operational applications including marine transportation, search and rescue operations and oil and gas exploration and development. The outputs of sea ice monitoring may include various parameters such as ice edge, ice thickness, ice classification, iceberg detection, and ice statistics. Depending on the application, this service must be provided in Near-Real-Time. Environmental services of different countries typically produce ice charts with low temporal and spatial resolution. In this case, detailed ice parameters can be extracted from high resolution data to achieve required coverage and revisit using multiple Synthetic Aperture Radar (SAR) sensors.

This work examines the suitability of multi-resolution SAR data (ENVISAT, TerraSAR-X, and TanDEM-X) for ice parameters retrieval using automated (and semi-automated) algorithms within a system of multisource data fusion.

Time series of ENVISAT Wide Swath data with low resolution can be used to monitor the dynamic changes in ice, to detect ice edge, and to estimate ice concentration. High resolution TerraSAR-X/TanDEM-X constellation data can be used for improved ice observation (e.g. estimating size and geometry of ice floes and icebergs).

In many cases, processing large volumes of data can be automized to help analysts extract ice parameters. Perspectives of implementing automated algorithms operated by expert system within a prototype of system of multisource data fusion were discussed at the symposium.

2. ICE PARAMETERS

2.1. Ice chart

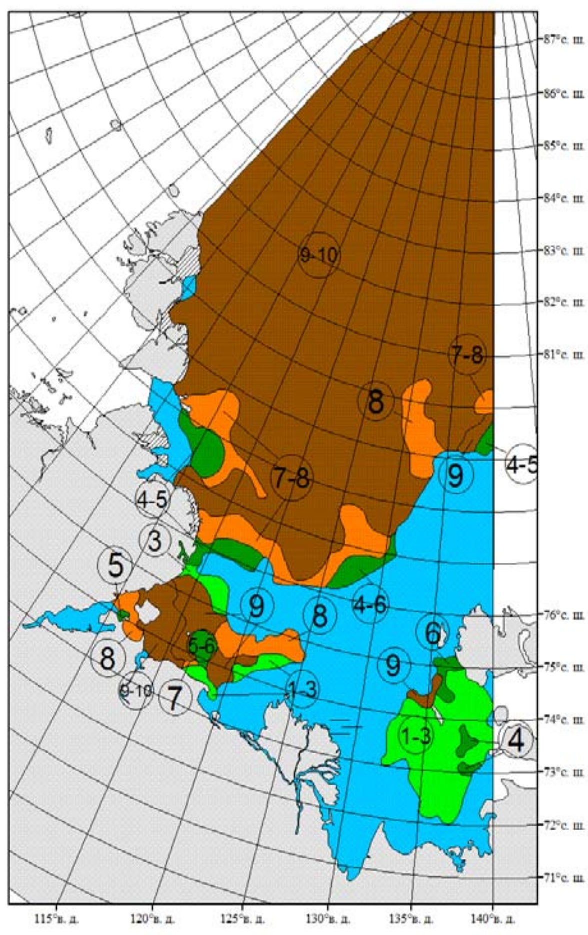

Figure 1. Ice chart for the Laptev Sea [1]

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Results acquired over the Laptev Sea and the Kara Sea, used as study areas, were demonstrated at the symposium. The Arctic and Antarctic Research Institute [1] produces ice charts (maps) of the Arctic ice and freezing seas from the satellite data (visible, infrared range, radar images), ships, and research stations. In summer the charts are prepared monthly with the spatial scale 1:5000000. The ice chart for August 2010 represents the distribution of generalised ice concentration (Fig.1). During winter the chart also includes information about ice age (nilas, young, first-year and multi-year ice).

Ice charts with more detailed information are also produced by the Russian State Research Center "Planeta." In addition to ice concentration, these charts contain information about size of ice floes, thickness, ridging and other ice parameters [2]. The temporal frequency of ice charts depends on cloud conditions because the chars are primary based on data acquired by optical satellites and radiometer.

2.2. Low Resolution Data

Time series of C-band Envisat ASAR images of Wide Swath mode (150m by 150m resolution) HH polarization between August 24, 2010 and August 28, 2010 were acquired. These images were pre-processed (geocoded and land-masked), and the analyst, working with the developed prototype of multisource data fusion system, was able to identify areas of interest in sea ice. Analysis can be performed relying on the ice backscatter coefficient and textural information, which depends on multiple SAR parameters (incidence angle, polarization). Texture can significantly vary depending on the season, ice type, and ice surface.

The ice parameters retrieved from ENVISAT data using automated algorithms were ice edge and ice concentration. Ice edge can be effectively detected (Fig. 2) using image processing techniques based on textural parameters (entropy and correlation) in combination with morphological operators.

After classification of open water and sea ice, the ice concentration for pack and land fast ice can be estimated as a percentage of ice cover in a window of M by N pixels. Over the Laptev Sea the ice concentration was higher than 85% on August 26, 2010. This result is consistent with ice concentration estimated from AMRS-E data.

Time series ENVISAT data allows monitoring dynamic changes in ice. In addition, the low resolution data with large area of coverage may assist with planning acquisition of high resolution data. However, the high level of ocean clutter and the presence of ocean features, such as, currents and eddies in ENVISAT data limit efficiency of the automated algorithms.

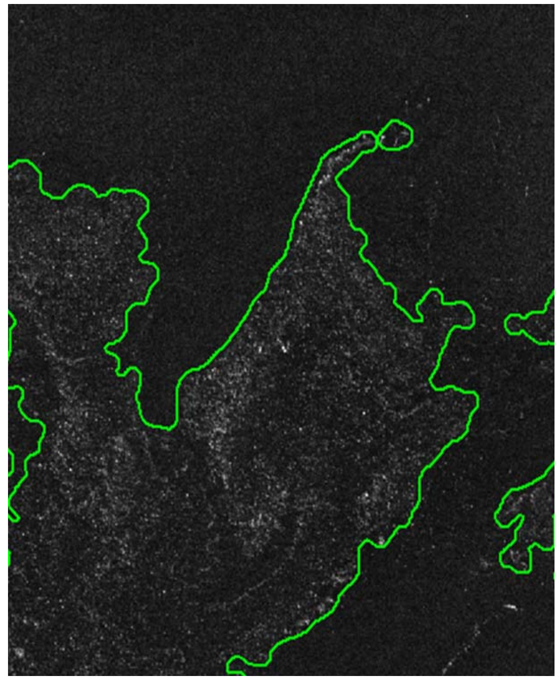

Figure 2. Ice edge automatically detected in Envisat image

2.3. High Resolution Interferometric Data

The unique TerraSAR-X/TanDEM-X constellation operates in monostatic mode and allows along track interferometric measurements with short time difference (2.6 sec). Three pairs of SAR X-band images of the TanDEM-X constellation acquired between August 16, 2010 and August 27, 2010 were used to monitor the area under study with sea ice. Each image of Strip Map mode HH polarization Single Look Slant Range Complex with resolution 1.2 m [slant range] and 3.3 m [azimuth] covers 30 km by 50 km. This dataset was used to detect and estimate size and geometry of ice floes and icebergs using SAR interferometry. A window of the magnitude image of TerraSAR-X, containing sea ice, is shown in Fig. 3 (a). Using only magnitude information it is difficult to differentiate sea ice from open water due to the high level of sea clutter. At the same time, the interferometric coherence between the SAR pair (image is shown in Fig. 3 (b)) indicates open water as dark tones.

The interferogram of sea ice depends on two factors: (i) ice thickness, related to the surface elevation [3], and (ii) ice dynamic [4]. As the result, each individual floe has its own fringe pattern (Fig. 3 (c)). Utilising this pattern it is possible to accurately delineate individual ice floes as well as areas of pack ice. This is challenging relying only on magnitude or coherence images, whereas the coherence can be used to separate open water from sea ice.

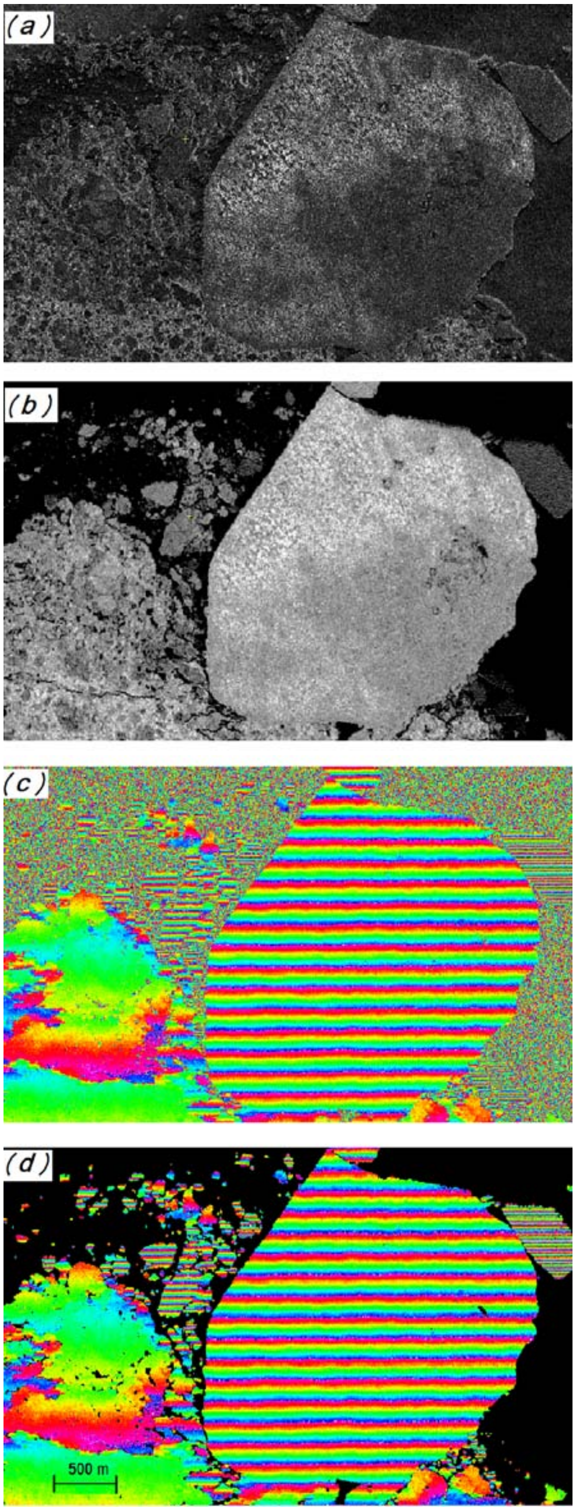

Figure 3. Images of sea ice generated from TerraSAR-X/TanDEM-X constellation data: (a) Magnitude; (b) Interferometric coherence; (c) Interferogram; (d) Fusion of (b) and (c).

Fusion of coherence image and interferogram (Fig. 3 (d)) makes it easy to observe each small floe for automated calculating of ice statistics.

Presently, the processing interferometric data can take more than two hours to extract and analyse interferogram.

3. ICEBERG PARAMETERS

Detection of icebergs buried in sea ice is a challenging problem [5] but it is an important for operational applications when all extreme features have to be monitored [6].

It was presented at the symposium that an iceberg in sea ice exhibits interferogram which can be easily detected.

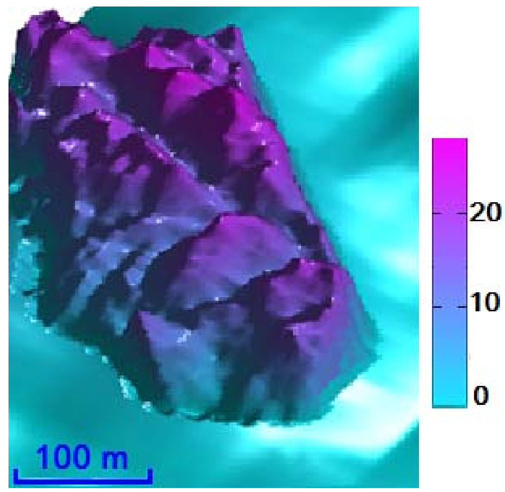

Figure 4. Digital elevation model of iceberg extracted from interferometric TanDEM-X data

A digital elevation model (DEM) of an iceberg (Fig. 4) was extracted using the interferometric method. The DEM makes it possible to estimate the freeboard and to analyse iceberg topography. This, in turn may allow one to estimate the draft of icebergs (underwater portion), and ultimately the mass.

In addition to the interferometric method of DEM extraction, there are techniques which make it possible to estimate elevation parameters by analysing a single SAR image. Freeboard and surface topography of icebergs were reconstructed using heights extracted from (i) shadows and (ii) shape from shading techniques [7]. The resulting DEM, generated using the shape from shading method, was compared with the interferometric DEM by calculating statistics of DEMs difference. The comparison on a large iceberg (the length greater than 120 m) has demonstrated a good correlation between DEMs [8].

4. CONCLUSIONS AND PERSPECTIVES

It has been demonstrated that several SAR sensors with multiple frequencies and resolutions lead to a better understanding of ice conditions, including floe sizes, ice edge, and extreme ice features, such as, icebergs. In addition, low resolution sensor data can assist with planning acquisition of data from high resolution sensors.

Interesting results were found using the high resolution interferometric TanDEM-X data. First, individual ice floes can be automatically detected and mapped fusing the coherence image and interferogram. Second, digital elevation model of icebergs can be extracted using the interferometric method. This can be used for accurate estimation of iceberg parameters, including freeboard and surface topography.

Future efforts will focus on validating the developed algorithms with the ground truth data from planned field campaigns.

5. ACKNOWLEDGEMENTS

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