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Improved sea-ice monitoring for the Baltic Sea, 2007

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FOREWORD

In this report no 64, the Winter Navigation Research Board presents the result from a project to improve the sea ice monitoring for the Baltic Sea using satellite information and with different polarizations.

The Winter Navigation Research Board warmly thanks Mr Leif Eriksson for this report.

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Final report

for the project

Improved sea-ice monitoring for the Baltic Sea

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Background and objectives

Background

At the Swedish Ice Service of the Swedish Meteorological and Hydrological Institute (SMHI), Synthetic Aperture Radar (SAR) has been in use for ice mapping since the mid-1990's. Ice coverage, ice concentration and ridges are some of the parameters obtained from the imagery. SAR data provide high accuracy information in the ice map production, since the data is timely received and independent of cloud cover. Customers of SMHI ice products are ice breakers, ferries and ice classified ships, port authorities and ship brokers as well as the public domain.

The SMHI operational forecasting model system HIROMB needs daily information for assimilation. SAR data give input to the ice and SST maps, which are the daily products used for model assimilation. The model is used for warnings, rescue and oil spill operations. In addition, the model forecasts provide information for various processes of interest for environmental tasks. Current research involves the development of 10-day ice forecasts forced by ECMWF atmospheric forecasts.

The level of heat transfer between the ocean and the atmosphere is highly dependent on the ice cover. Sea ice acts as an insulating layer that reduces the heat transfer, but the level of insulation depends on the thickness of the ice. A more accurate determination of the ice concentration and ice type should therefore give improved estimates of this important parameter. The maximum extent of sea ice is also used as a climate indicator. Long term change in the ice extent has been suggested as a sign of climate change. These are two reasons why sea ice is of interest, e.g. for the "Global Monitoring of Environment and Security" (GMES) initiative of the European Union (EU) and the European Space Agency (ESA).

Recently three new SAR-satellites have been launched and a fourth will be launched before the end of the year. These satellites provide more options regarding frequency bands and polarisation. In January 2006 the Japanese Aerospace Exploration Agency (JAXA) launched the Advanced Land Observing Satellite (ALOS), which is carrying the Phased Array L-band Synthetic Aperture Radar (PALSAR). In June 2007 two satellites with X-band SAR were launched, COSMO-SkyMed from Italy and TerraSAR-X from Germany. After a series of delays the Canadian C-band satellite Radarsat-2 is now planned for launch in December 2007. New and better information from the satellite scenes are anticipated, which will improve the estimates of ice variables. These improvements will be beneficial for the operational activities as well as for climate change assessments.

Objectives

The project has been focussed on sea ice in the Gulf of Bothnia, which is an area with a high level of winter traffic. The conditions in the Gulf of Bothnia are special because the water salinity is very low and due to the geographical location there is no multi-year ice or icebergs.

This project had three objectives. To:

1. evaluate how multi-polarisation SAR data from L-band (ALOS), C-band (ENVISAT and RADARSAT-2) and X-band (TerraSAR-X and COSMO-SkyMed) can improve determination of sea ice concentration, classification of ice types and detection of ice ridges,
2. investigate the possibilities to use PALSAR ScanSAR data as a complement and backup for the RADARSAT and Envisat ScanSAR data that currently is used for operational sea-ice monitoring,
3. give recommendations on how data from the new satellites can be incorporated in the operational services provided SMHI.

The original proposal aimed for a two-year project, but funding was only approved for the first year. 2007 was intended as a start-up year when new equipment, methods and algorithms were tested, initial data analysis was performed and contacts were established. These goals have been achieved, but for thorough evaluation, validation and documentation, including feedback from end-users and writing of publications, one year is not enough. For this reason an application for a two-year extension of the project was submitted to the Swedish National Space Board in August 2007. The official decision will be taken in December, but according to an advance notification the proposal will most likely be accepted.

Important events and activities

In December 2006 the project “Improved sea ice monitoring for the Baltic Sea” was approved as a user project by the Swedish National Space Board and got funding for one year. The project started in January 2007 and during the following months a validation campaign was conducted in the Gulf of Bothnia outside Umeå. Contacts were established with “Umeå Marina Forskningscentrum” that became the base for our field work. The campaign was given the name “Bothnia Ice SAR experiment 2007” (BothnIS 2007) and included several field trips that were coordinated with satellite passes of Envisat and ALOS (see Table 1). The main focus was on collection of observations (visual and thermal IR) from helicopter. New and old equipment was tested and the field data are currently being evaluated together with the satellite images.

The first SAR data from Envisat were delivered by ESA during the spring 2007. The first ALOS data were received in August through the ALOS Data European Node (ADEN) at ESA, but some important images are still missing (see Table 1). TIF versions of the Envisat and Radarsat ScanSAR images that the Finnish Institute for Marine Research (FIMR) delivered to the Swedish Ice Service at SMHI were also available for the project members.

The project was presented at “The First Joint PI Symposium of ALOS Data Nodes for ALOS Science Program in Kyoto” (November 19-23) and the first results will be presented at the ESA SEASAR workshop in Frascati in January 2008.

The following list shows the main events and activities since the project start in January:

- Kick-off meeting
- Planning of field campaign
- Ordering of satellite images
- Purchasing of instruments and equipment, rental of IR-camera
- Field campaign
- Follow-up of the field campaign and compilation of field data
- Adjustment of processing chain for new satellite data
- Processing and geocoding of data
- Preliminary analysis of satellite images
- Start of master thesis; analysis of images taken from helicopter
- Organizing North-European sea ice workshop
- Meetings with the end-users
- Compilation of results and project documentation
- Project presentation at international symposium

Table 1. Satellite acquisitions and field work.

Week	ALOS	ALOS	ALOS	ENVISAT	ENVISAT	Helicopter Flight days	Field work
	FBS34.3	PLR21.5	WS1	APP	WSM		
7	14/2		12/2		13/2 + 14/2 + 15/2 + 18/2		13/2-15/2
8	19/2		19/2		20/2 + 21/2 + 23/2		
9	3/3		1/3	Cancelled	26/2 + 27/2 + 1/3?	Not available	27/2-1/3
10		10/3	6/3 + 11/3	Cancelled		Not available	
11		17/3	16/3 + 18/3	15/3	12/3 + 17/3 + 18/3	14/3 + 16/3 + 18/3	12/3-18/3
12		22/3	23/3 + 25/3	23/3	20/3 + 25/3	22/3 + 23/3	19/3-23/3
13			28/3 + 30/3	27/3	28/3 + 31/3		
14		3/4	4/4 + 6/4	3/4		3/4	2/4-4/4

Delivered
Not in ESA archive
In archive, not ordered
Ordered, not delivered
Not in JAXA or ESA archive

Description of field work:

Week 7: Establish field camp, discussions with helicopter operator (Lapplandsflyg), field observations, deployment of temp grid
Week 9: Tests of all instruments, field observations
Week 11: Camera fixtures tested on helicopter, test flight, regular flights, ice drift buoy deployed
Week 12: Helicopter flights, field observations
Week 14: Helicopter flights, packing, transportation

Results

With respect to the three project objectives listed above the current status is as follows:

1. The evaluation of multi-polarisation SAR data from L-band (ALOS) and C-band (ENVISAT) has started (see Fig. 1 and Fig. 2). A comparison of the capabilities for determination of sea ice concentration and classification of ice types can be performed, but for detection of ice ridges the ice conditions during 2007 were not favourable. X-band (TerraSAR-X and COSMO-SkyMed) data will not be available until 2008.
2. The evaluation of possibilities to use PALSAR ScanSAR data as a complement and backup for RADARSAT and Envisat ScanSAR data has started and show promising results (see Fig. 3).
3. Recommendations on how data from the new satellites can be incorporated in operational services will not be given until data from at least one more ice season have been analysed.

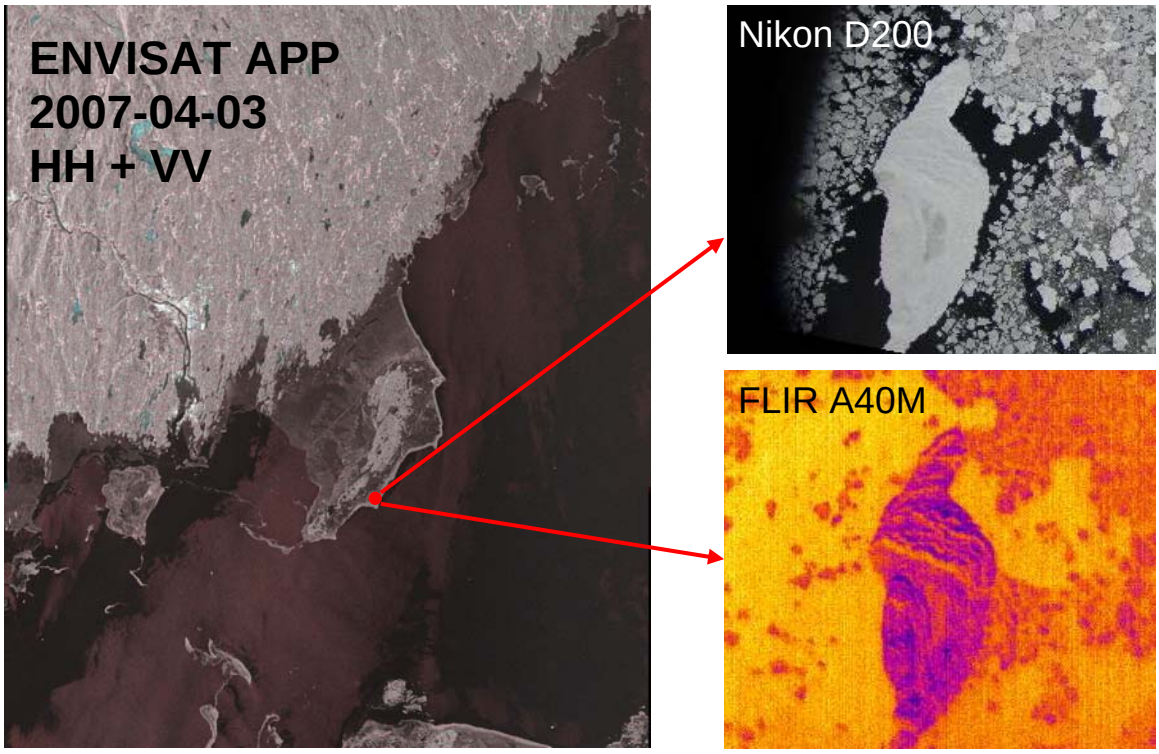

Figure 1. The Envisat image shows the remaining sea ice around Holmöarna east of Umeå. On the same day a helicopter flight was performed and photos were taken with the Nikon D200 and FLIR A40M cameras. Examples of an ice flow at the ice edge are given on the right side. Note that there is a 90 minute time difference between the visual and infrared photos.

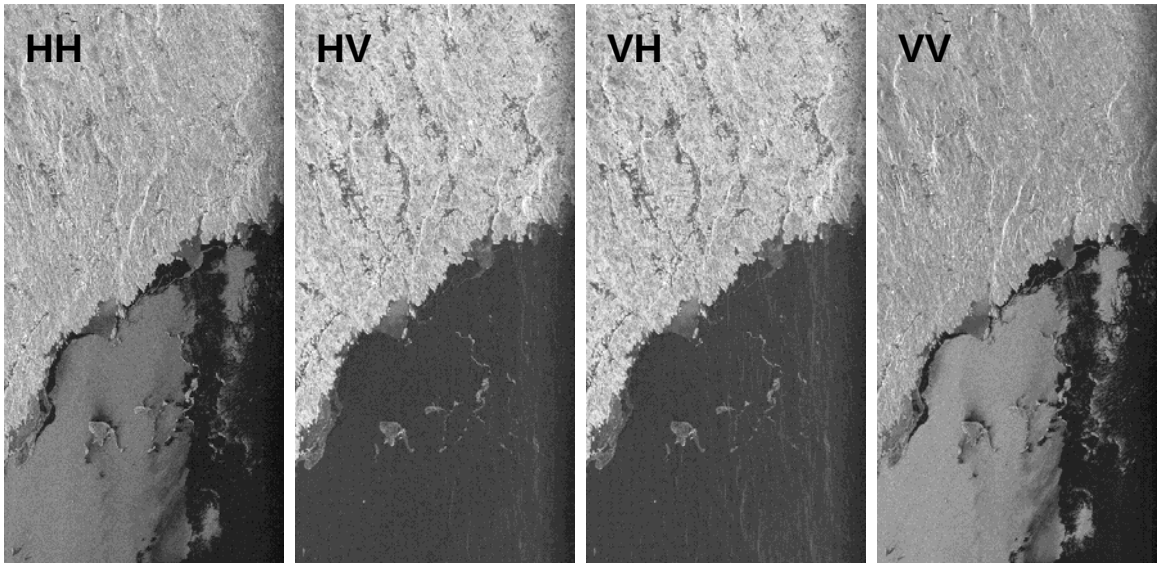

Figure 2. The four polarisation channels from a polarimetric (PLR21.5) ALOS PALSAR image acquired 2007-04-03. Only small patches of ice remain in this area. In the HV and VH channels there is a clear contrast between ice and open water, but in the HH and VV channels the water signature show strong variations caused by wind.

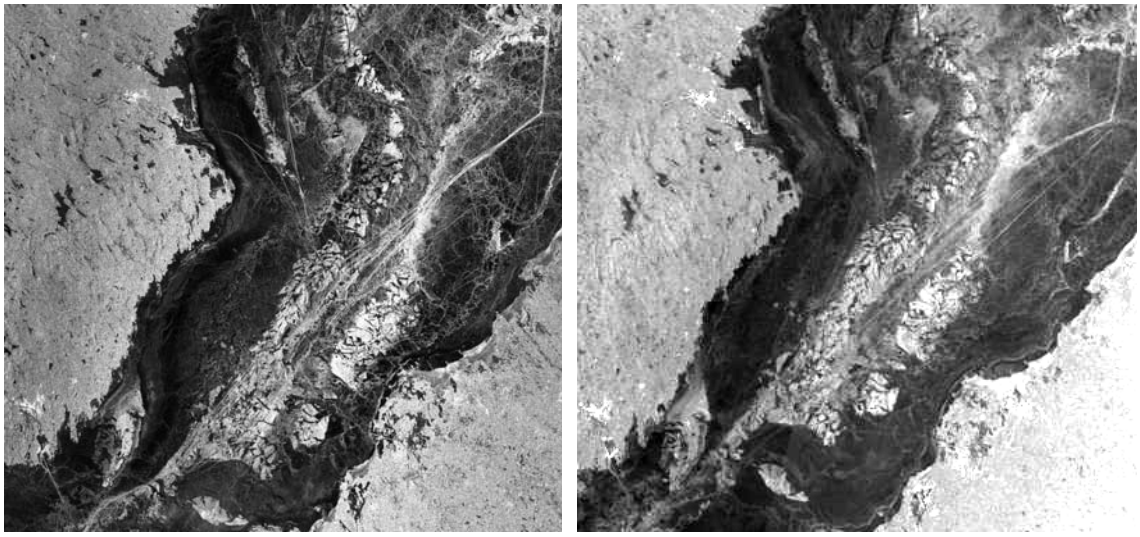
Figure 3. On the left side a section of an ALOS WB1 image from 2007-02-12 and on the right side the same area from an Envisat WSM image from 2007-02-13. A visual comparison shows that the main ice features from the Envisat image are visible also in the ALOS image.

So far the analysis of the L-band SAR data has been limited by the fact that important PALSAR images are still missing, in particular the polarimetric (PLR21.5) PALSAR images from 2007-03-17 (order cancelled by ESA due to software problem) and 2007-03-22 (not yet available in the ESA archive). These two images are important because validation data from helicopter and Envisat images were acquired within one day of the PALSAR acquisitions (see Table 1). Both images are present in the JAXA archive, so we have good hope that they will eventually be available for analysis.

The winter 2007 had an unusually short period with ice cover, with hardly any ice ridges, in the studied region. This limited the number of useful satellite images. Continued observations over the next two years should give a time series that make it possible to draw statistically sound conclusions. Continued observations are also necessary to capture weather conditions that are known to make interpretation of satellite images difficult. Without these data it is not possible to evaluate if the new satellites can reduce the uncertainties.

Due to delayed launches of TerraSAR-X and Radarsat-2, data were only available from Envisat and ALOS. This reduced the available frequency bands to C- and L-band. With recent launches of TerraSAR-X and COSMO-SkyMed, X-band data can be added in 2008. Radarsat-2 will allow combination of polarisations in a way that is not possible with Radarsat and Envisat. It is not likely that Radarsat-2 data will be available for the spring 2008, but data will be included in 2009.

Experiences and reflections

+ The helicopter measurements gave valuable and high quality results over a large area.
+ It is important to have access to a functional base station and good logistics.
+ It pays off to invest time in planning field measurements together with local actors (UMF and Lapplandsflyg).
+ During the ice period it is normally low activity for the helicopter companies. This gives good access and flexibility when it comes to planning validation flights. However, because of the expected low activity, the whole helicopter company was closed during two weeks in the middle of the ice season when they instead visited an annual helicopter fair in the USA. This lead to a delay of our first helicopter flight.

- It took longer time than expected to get the satellite images from ESA, especially the ALOS PALSAR images for which the ESA archiving system does not seem to be fully operational yet.
- Even though equipment was specifically selected to allow inter-connection, it was still difficult to connect everything as planned. The infrared camera required a fire-wire connection, but the available laptops did not have a fire-wire interface. This was solved with an additional fire-wire card. The Nikon camera should be possible to connect to a GPS from Garmin or Magellan, but the connecting cable could not be delivered from Nikon until after the last field campaign, and when it arrived it was not compatible with our new GPS (Magellan had changed connection from RS232 to USB).
- Our old processing chain required a digital elevation model for the geocoding of satellite images. This works fine for land applications, but not for images over the sea. This will be solved by using already geocoded ScanSAR images instead of digital elevation models as input to the processing chain.

End-user plans

The expected resulting algorithms for classification of the above mentioned sea ice types will be implemented in the daily routines of the Swedish Ice Service. It is foreseen that this will improve the accuracy of the operational ice charts. A simplified process with less emphasis on manual interpretation might also lead to ice charts becoming available to the public sooner than at present.

An optimized utilization of SAR imagery acquired at different frequencies/polarizations/spatial resolutions should also lead to a more detailed knowledge of e.g. the location of areas with heavy ridged ice. This will be highly useful for the data assimilation into the HIROMB forecast model, eventually producing more accurate ice forecasts which will benefit the icebreaking authorities in the Baltic as well as the large number of merchant vessels transiting the Baltic waters.

Since 1961 ice charts and estimations of ice concentration have been archived at SMHI. These archived data build a long time series and contain information about changes in ice conditions that are highly relevant for local climate studies. In order to capture the maximum ice extent it is important that the time series has a high temporal resolution. SMHI continue to compile these data and the results from this project will hopefully improve the accuracy of future additions to the time series. It is expected that these results will contribute to GMES efforts to detect climate change and monitor its effects.