Improved Sea-ice Monitoring for the Baltic Sea: Project Overview and First Results

Leif E.B. Eriksson[(1)], Karin Borenäs[(2)], Wolfgang Dierking[(3)], Per Pemberton[(2)], Simon Griph[(1)], Henrik Lindh[(2)]

[(1)] Chalmers University of Technology, Department of Radio and Space Science, SE-41296 Göteborg, Sweden,
E-mail: leif.eriksson@chalmers.se
[(2)] Swedish Meteorological and Hydrological Institute, Sven Källfelts gata 15, SE-42671 Västra Frölunda, Sweden
E-mail: karin.borenas@smhi.se
[(3)] Alfred Wegener Institute for Polar and Marine Research, Bussestrasse 24, D-27570 Bremerhaven, Germany
E-mail: Wolfgang.Dierking@awi.de

Abstract
In 2007 a field campaign was conducted in the Gulf of Bothnia. The aim was to collect validation data for an evaluation of the possibilities to use SAR data from the ALOS satellite for sea-ice monitoring. This paper gives an overview of the field campaign, collected data and the first results. A comparison between ScanSAR images from ALOS and Envisat indicate that the main ice features can be seen in both image types. An initial analysis also shows that the L-band backscatter from open water is less sensitive to wind in the cross-polarized than in the co-polarized channels.

Keywords: Baltic Sea, sea-ice, PALSAR, ASAR, infrared

1. INTRODUCTION

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 reliable information in the ice chart production, because it is timely received and independent of cloud cover and light conditions. Customers of SMHI ice products are ice breakers, ferries and ice classified ships, port authorities and ship brokers as well as the public domain. In addition, the SMHI operational forecasting model system needs daily information for assimilation. SAR data give input to the ice and sea surface temperature charts, which are the daily products used for model assimilation. The model is used for warnings, rescue and oil spill operations, but the model forecasts also provide information for various processes of interest for environmental tasks.

The SAR data that are used by the ice service today are almost exclusively ScanSAR images acquired by the satellites Radarsat and Envisat. These satellites provide data at C-band frequencies and with one polarization. Note that the Envisat Advanced SAR (ASAR) allows simultaneous acquisition of two polarizations, but not in the ScanSAR mode. However, recently there has been a rapid increase in the number of satellites with SAR systems available for non-military applications. In January 2006 the Japanese Aerospace Exploration Agency (JAXA) launched the Advanced Land Observing Satellite (ALOS), which is carrying the Phased Array type 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, almost at the same time as the second COSMO-SkyMed satellite will be put in orbit, and more spaceborne SAR systems are expected to become operational within the next years. With these satellites, SAR data will be available at three different frequencies with multiple polarization channels, increased resolutions and shorter revisit intervals.

In January 2007 a project focused on the possibilities to use data from these new satellites for sea ice monitoring started in Sweden. This project has three objectives:

- 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,
- 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, and
- give recommendations on how data from the new satellites can be incorporated in the operational services provided by SMHI.

The project is focused 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 and no icebergs.

2. AVAILABLE DATA

2.1. Field data

A region in the Gulf of Bothnia, close to the city of Umeå in Northern Sweden, was selected as test area for the validation campaign. Contacts were established with the Umeå Marine Science Centre that became the base for the field work. The campaign was named “Bothnia Ice SAR experiment 2007” (BothnIS 2007) and in the period from 2007-02-13 to 2007-04-04 several field trips were conducted. Field trips were coordinated with satellite passes of Envisat and ALOS. In this region the ice season normally runs from mid January to mid April. Unfortunately, the winter 2007 had an unusually short period with ice cover, and only few ice ridges formed in the studied region. This limited the number of useful satellite images.

In order to collect information about location and structure of the ice edge, new ice, melt ponds and ice ridges it was necessary to collect observations from large areas. For this reason the main part of the field campaign was focused on observations from helicopter. Camera equipment both for the visual and thermal infrared regime was used. The infrared camera is expected to give valuable information for the identification of wet snow, melt ponds and open water. An infrared camera (FLIR Thermo Vision A40M) with wide angle lens was rented and used together with a Nikon D200 with a 14 mm wide angle lens (see Fig. 1). Examples of photos from the two cameras are given in Fig.2. The helicopter flight path was logged with GPS.

Figure 1. Photos were taken either with a Nikon D200 digital camera (bottom left) or a FLIR A40M infrared camera (bottom right) through a hole in the hull of the helicopter. Photos: Henrik Lindh, Leif Eriksson.

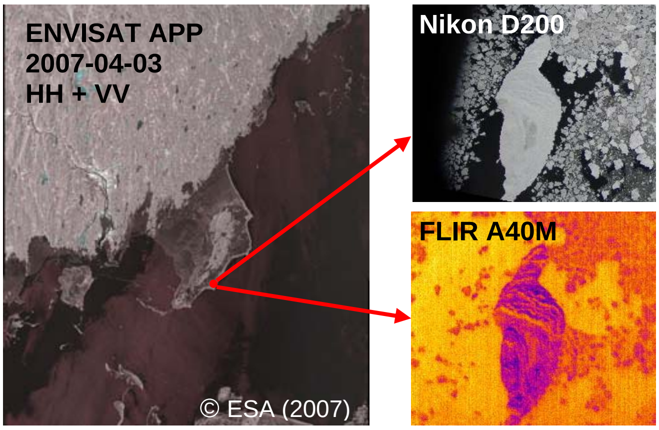

Figure 2. This Envisat image (left) shows the remaining sea ice around Holmöarna east of Umeå. On the same day a helicopter flight was performed and photos were taken with the Nikon D200 and FLIR A40M cameras. Examples of an ice flow at the ice edge are given on the right side. Note that there is a 90 minute time difference between the visual and infrared photos.

The helicopter observations were complemented with observations from land and on the ice. A temperature profiler, developed at SMHI during the IRIS (Ice Ridging Information for Decision Making in Shipping Operations) project, was recording the vertical temperature distribution of the water-ice-snow-air system during the first half of the field campaign. Available time series of ice and snow thickness from nearby stations were included in the validation data. Information from local weather stations was also collected for the data analysis.

2.2. Satellite data

Through proposals to three announcements of opportunity, the project has access to a limited amount of SAR scenes from ALOS, Envisat, TerraSAR-X and Radarsat-2. A proposal for data from COSMO-SkyMed is under evaluation. During the first year of the project, only data from ALOS PALSAR and Envisat ASAR were available. The ordered ASAR scenes were delivered during spring 2007, but one important PALSAR scene acquired on 2007-03-22 was not available in the ESA archives until December and another one from 2007-03-17 could not be processed. It is anticipated that these data can be included in the analysis during 2008.

PALSAR data are acquired according to an observation strategy that is designed to allow temporally and spatially consistent global-scale monitoring [1]. Following this strategy, PALSAR data were acquired in fine beam single polarization (HH) mode with a look angle of 34.3º (FBS34.3) during the three first weeks of the validation campaign (until 2007-03-06). After that, fully polarimetric data were acquired with a look angle of 21.5º (PLR21.5). These data were acquired for ascending orbits (evening passes), while during the whole campaign, ScanSAR data

(WB1) at HH polarization were acquired for descending orbits (morning passes). For Envisat the plan was to order ASAR data in alternating polarization mode (APP), to allow a comparison between L-band and C-band at different polarizations. However, the operational ice services in Finland and Sweden order ASAR ScanSAR data (WSM) on a regular basis, which lead to some ordering conflicts during the first half of the campaign. For this reason the first APP data were not acquired until 2007-03-15.

3. FIRST RESULTS

The analysis has so far been limited to occasions when both PALSAR and ASAR data were available within a two-day period. High resolution data (PALSAR FBS34.3 or PLR21.5 and ASAR APP) from both satellites are so far only available from 2007-04-03, which was close to the end of the ice season. As can be seen in the ASAR image in Fig.2, most of the sea-ice was already gone.

One of the problems that have been identified for the current ice monitoring system is that wind can give rise to high backscatter from open water, which in some cases makes the differentiation between ice and water difficult. It has been suggested that the use of cross-polarized data could reduce this ambiguity. Fig. 3 display all polarization channels from PALSAR data acquired 2007-04-03. The co-polarized channels (HH and VV) show large variability in the backscatter from water, while the cross-polarized channels (HV and VH) do not seem to be influenced by wind.

As mentioned in the introduction, one of the objectives of the project is to investigate the possibilities to use PALSAR ScanSAR data as a complement and backup for ScanSAR data from Radarsat and Envisat. Fig. 4 shows the test area as seen by PALSAR on 2007-02-12 and by ASAR on the following day. Currently, the ScanSAR images that are the base for most ice charts are manually interpreted by experienced people at the ice service. A visual comparison between the images in Fig. 4 indicates that all important ice features that can be seen in the ASAR image can also be found in the PALSAR image.

4. DISCUSSION AND CONCLUSIONS

The initial analysis of data acquired during eight weeks in spring 2007 indicate that the quality and information content in PALSAR images are high enough to make them well suited for operational sea-ice monitoring. However, operational use will require near-real time data delivery, ideally within 12 hours after acquisition. Wind and currents can cause rapid changes in the ice conditions and an image that is older than 24 hours could in some cases be useless. The first tests with near-real time PALSAR data over the Baltic Sea will hopefully start in 2008.

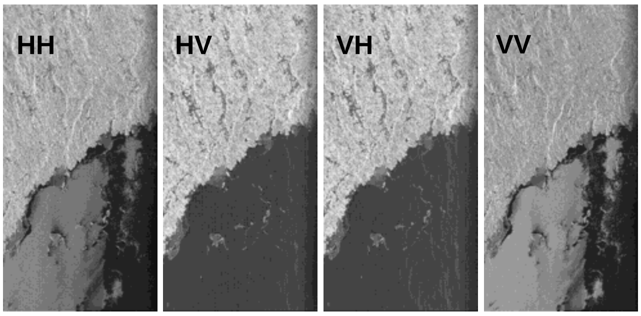

Figure 3. The four polarisation channels from a polarimetric (PLR21.5) ALOS PALSAR image acquired on 2007-04-03. Only small patches of ice remained in this area. In the HV and VH channels there is a clear contrast between ice and open water, but in the HH and VV channels the water signature shows strong variations caused by wind. © JAXA/METI (2007)

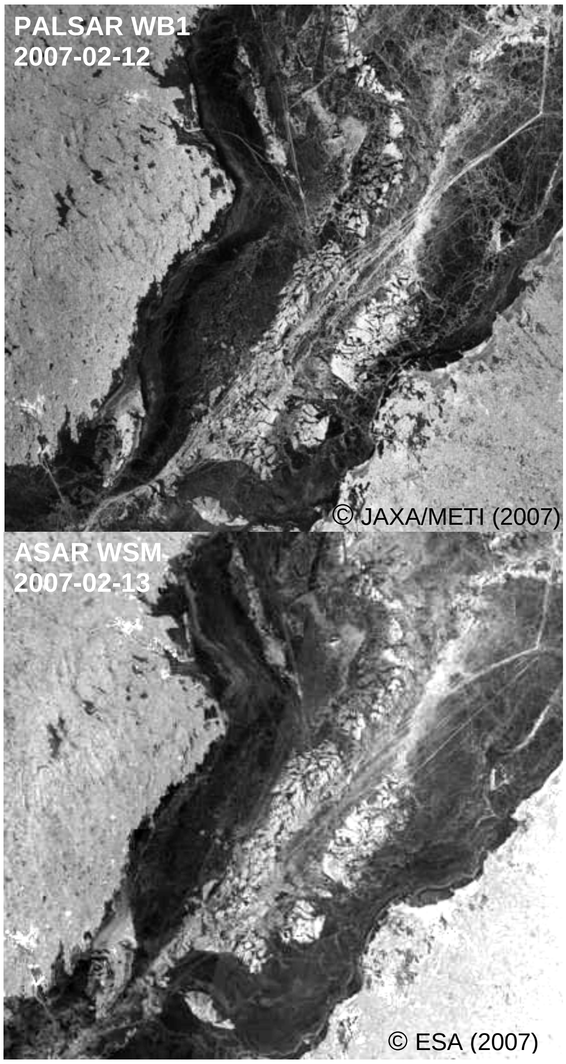

Figure 4. A visual comparison between sections of two ScanSAR images from PALSAR and ASAR shows that the main ice features from the C-band image are visible also in the L-band image.

Although the spatial coverage of the polarimetric PALSAR images is not sufficient for operational ice monitoring, the data analysis has proved that backscatter from one of the cross-polarized channels can reduce the variability over open water. This indicates that a cross-polarized ScanSAR channel could be a valuable complement on a future L-band SAR satellite.

The intention is that the project should continue in 2008 and 2009. This will include a more thorough evaluation of PALSAR and ASAR data, but will also allow inclusion of C-band data from Radarsat-2 and X-band data from TerraSAR-X and hopefully also COSMO-SkyMed.

Acknowledgements

This work was funded by the Swedish National Space Board (dnr 158/06), the Swedish Meteorological and Hydrological Institute and the Swedish Maritime Administration. Data were provided by the European Space Agency within the framework of the ALOS Data European Node Category-1 Proposal titled ‘Improved sea-ice monitoring for the Baltic Sea’ (AOALO.3562). The Umeå Marine Science Centre is acknowledged for logistical support during the field campaign.

References

[1] Å. Rosenqvist, M. Shimada, N. Ito, and M. Watanabe, "ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment," *IEEE Transaction on Geoscience and Remote Sensing*, vol. 45, pp. 3307-3316, 2007.