BaLTIC SEA-ICE EXTENT AND CONCENTRATION CHANGES DURING WINTER 2011

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ABSTRACT:

The Baltic Sea is a brackish, mediterranean sea located in the middle latitudes of Europe. It is annually covered with ice. The ice covered areas during a typical winter are the Bothnian Bay, the Gulf of Finland and the Gulf of Riga. Sea-ice plays an important role in dynamic and thermodynamic processes and also has a strong impact on the heat budget of the sea. Also a large part of transport goes by sea, and there is a need to create ice charts to make the marine transport safe. Because of cloud cover in winter season and small amount of light in the northern part of the Baltic Sea, radar data are the most important remote sensing source of sea-ice information. The main goal of the following studies is classification of the Baltic sea-ice using radar data. The ENVISAT Advanced Synthetic Aperture Radar (ASAR) acquires data in 5 different modes. In the following studies ASAR Wide Swath Mode data were used. The Wide Swath Mode, using the ScanSAR technique provides medium resolution images (150 m) over a swath of 405 km, at HH or VV polarization. In following work data from 13th February, 24th February and 6th April 2011, representing three different sea-ice situations were chosen. Object-based Image Analysis (OBIA) methods and texture parameters were used to create sea-ice extent and sea-ice concentration charts.

1. INTRODUCTION

Sea-ice forms in the Baltic Sea annually and it covers a mean of 40% of the total Baltic Sea area during a typical winter (Granskog et al. 2006). The presence of sea-ice has a great economic consequences as timely information on sea-ice conditions is crucial for marine transportation, fisheries and other offshore operations. Furthermore sea-ice plays a very important role in the annual course of physical and ecological conditions in the basin and has a strong impact on the heat budget of the sea (Omstedt et al. 2004, Leppäranta and Myrberg 2009). Ice sheet is also the main habitat for many animals living in the Baltic Sea e.g. the ringed seal (*Pusa hispida botnica*) cannot breed without sea-ice cover (Brommer 2004, Meier 2005).

For this reason Baltic ice has been of great interest to both: people responsible for safety of marine traffic and climate scientists. Sea-ice services have been developed in all Baltic countries to publish ice charts, bulletins on ice conditions and sea-ice forecasts (WMO 2010). Also numerical sea-ice models have been developed. (Haapala and Leppäranta 1996, Vihma and Haapala 2009, Herman et al. 2011).

Ice charts published by the Finnish Ice Service (FIS) and the Swedish Meteorological and Hydrological Institute (SMHI) cover the whole Baltic Sea and are relatively accurate but they do not contain information about sea-ice floe distribution. This information might not be crucial for marine transportation purposes but it seems to be important in numerical modelling and forecasting of Baltic sea-ice cover (Herman 2010, Herman 2011). Sea-ice floe distribution might be also important in modelling of light distribution under a sea-ice cover (Frey et al. 2011).

Three types of satellite sensors may be used in Baltic Sea-ice monitoring: visual/infrared sensors, passive microwave radiometers and synthetic aperture radars (SAR). Because of the fact that the SAR data are cloud and daylight independent and their resolution is suitable for sea-ice observation they are the main source of the data in sea-ice studies (Karvonen 2004, Haas et al. 2005). In this work ENVISAT ASAR Wide Swath Mode (WSM) data were used.

During classification object-based image analysis (OBIA) methods were used. OBIA is not a common tool for sea-ice classification. Most of classification algorithms are based on Pulse-Coupled Neural Network or Markov Random Field Model (Hara et al. 1995, Karvonen 2004, Deng and Clausi 2005). However Brigham al. (2007) in their work used object-oriented methods to study sea-ice fragmentation using SAR imagery.

The objective of this paper is to show that object-based methods might be a good alternative for Baltic Sea-ice classification. Using object-based methods we would be able to study sea-ice floe distribution – parameter which have not been studied yet in the Baltic Sea.

2. METHODS

2.1 Study Area

The Baltic Sea is a semi-enclosed sea located in Europe between maritime temperate and continental sub-Arctic climate zones. It is a shallow and brackish water basin (Fig. 1).

During typical winter sea-ice forms in the Bothnian Bay, the Gulf of Finland and the Gulf of Riga. Annual ice extent is the largest between mid-February and mid-March (Leppäranta and Myrberg 2009).

2.2 Data

In the following studies ASAR Wide Swath Mode data were used. The ENVISAT Advanced Synthetic Aperture Radar (ASAR) acquires data in 5 different modes. The Wide Swath Mode, using the ScanSAR technique provides medium resolution images (150 m) over a swath of 405 km, at HH or VV polarization.

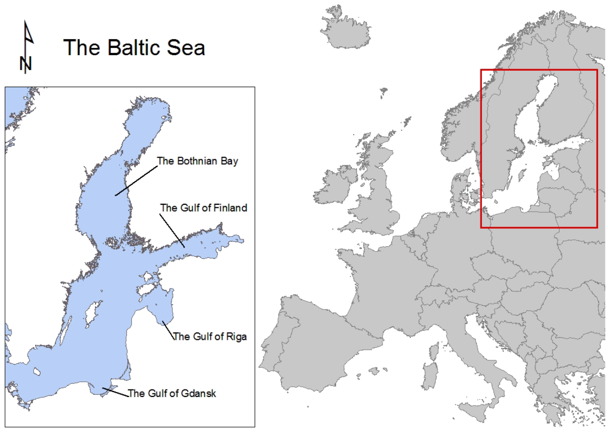


Figure 1. Location of the Baltic Sea

The data were recorded from 2nd February to 9th April 2011 and downloaded from ESA using EOLISA software. In this paper three scenes from 13th February, 24th February and 6th April are presented. As a validation data sea-ice charts published by SMHI were used.

2.3 Pre-processing of the data

SAR provides information about sea surface roughness and pre-processing is a very important step in analysing radar data. As a first step the data were georectified using GDAL (Geospatial Data Abstraction Library) to Lambert Azimuthal Equal Area (LAEA) projection modified for the Baltic Sea area. Next radiometric calibration to sigma nought was carried out based on calibrating formulas given by ESA (Rosich and Meadows 2004). As a speckle reduction filter Frost filter 3×3 and 5×5 were used (Frost et al. 1982). To detect edges filtration using Sobel filter was carried out (Sobel and Feldman 1968).

2.4 Image segmentation and classification

Image segmentation and classification were performed using eCognition Developer 8 (eCognition 2012). A multi-resolution segmentation on a few image object levels was carried out. Shape parameter was always set to 0.1, compactness parameter was changing from 0.1 to 0.5. First large objects containing water were created. After classification of water multi-resolution segmentation was carried out and new, smaller objects within a water area were created. Then misclassified objects were removed. The process was repeated until the classification was correct. Sea-ice was classified similarly.

The classification of sea-ice was based mainly on texture features defined by Haralick et al. (1973). They were GLCM Homogenity and GLCM Standard Deviation. In general, sea-ice was more heterogeneous than water but in some cases it might be easily misclassified. For this reason segmentation and classification was carried out on a few object levels.

3. Results and discussion

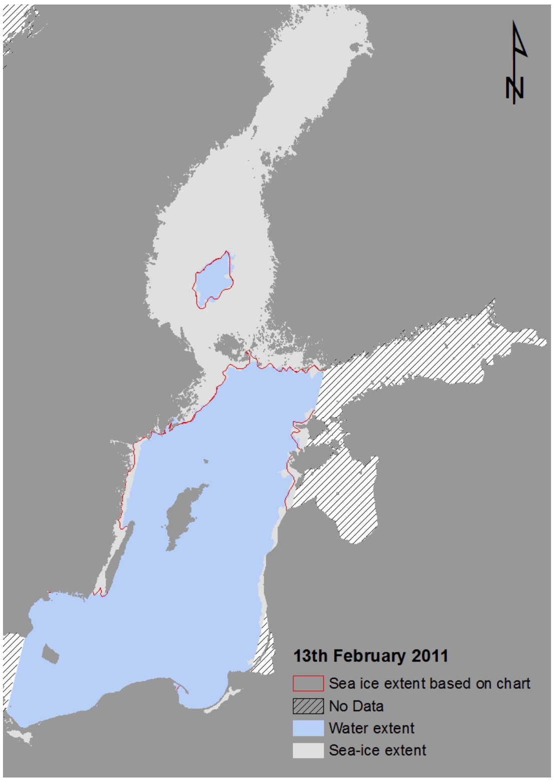
3.1 Sea-ice extent

Winter 2010/2011 was severe and most of the Baltic Sea areas which usually do not freeze, were ice-covered e.g. Gulf of Gdansk. In this paper three situations are presented: 13th February with fast ice cover in the northern part and many sea-ice floes surrounded with new ice in the southern part of the Bothnian Bay, 28th February is an example of situation where sea-ice cover is still growing and there is lots of newly formed dark ice. 6th April is an example of shrinking sea-ice cover. There is fast ice in the north and not so many sea-ice floes in general (Fig. 2).

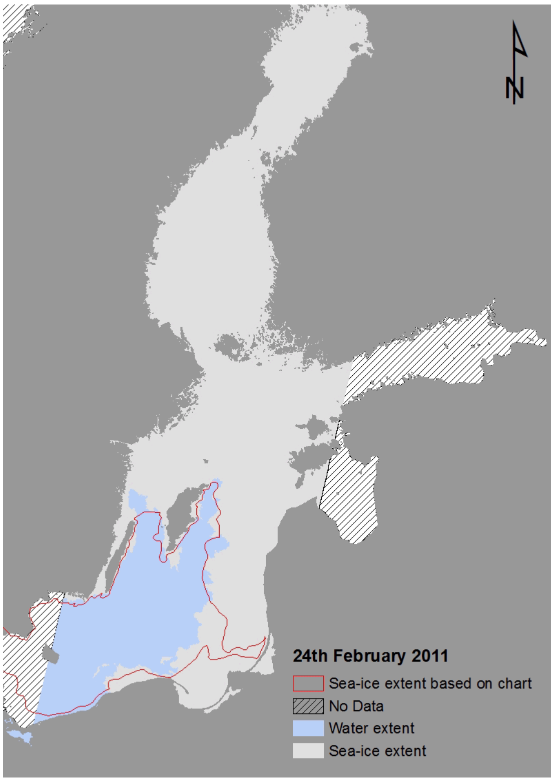
In those cases sea-ice was classified properly on 13th February, 24th February and 6th April with 99.33%, 97.76% and 97.89% based on properly classified area. Water was classified with 95.88%, 84.09% and 97.20% respectively. In general in incorrectly classified areas water more often tends to be classified as sea-ice rather than opposite. ASAR WSM data are not completely calibrated and are still influenced by incidence angle. Therefore any parameters based on mean pixel value cannot be used. Homogeneity seems to be the best parameter to separate sea-ice from water, but those two features might be easily mistaken if there is level new ice or very rough water e.g. Puck Bay (inner, western part of the Gulf of Gdansk) on 13th of February.

On 24th of February there was a lot of new ice which is also very homogenous. As a result only 84% of water was properly classified. The algorithm still needs to be improved to deal with those kind of situations. The best classification result was received on 6th of April where there was almost no new ice.

a)



b)



c)

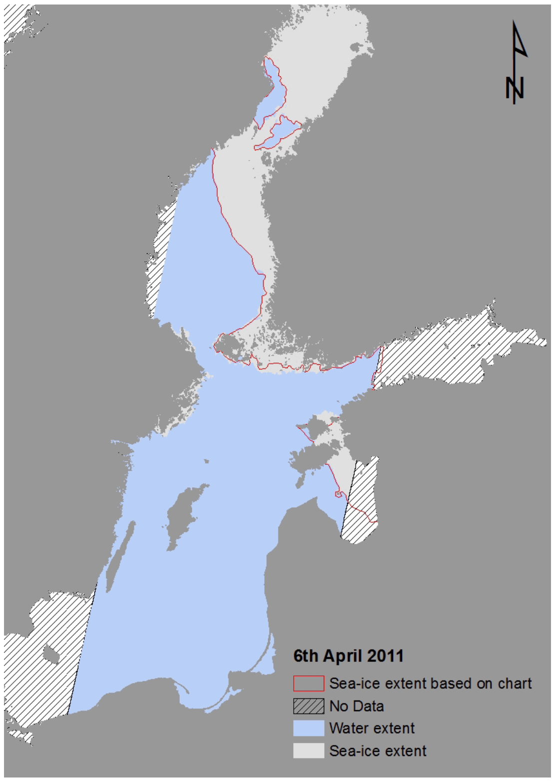


Figure 2. Sea-ice extent on the Baltic Sea on 13th February (a), 24th February (b) and 6th April 2011

Nevertheless results of OBIA classification tend to better reflect borders between sea-ice and water. SMHI sea-ice charts are more generalized.

3.2 Sea-ice classification

In this paper sea-ice classification is presented for 13th February 2011 (Fig. 3).

a)

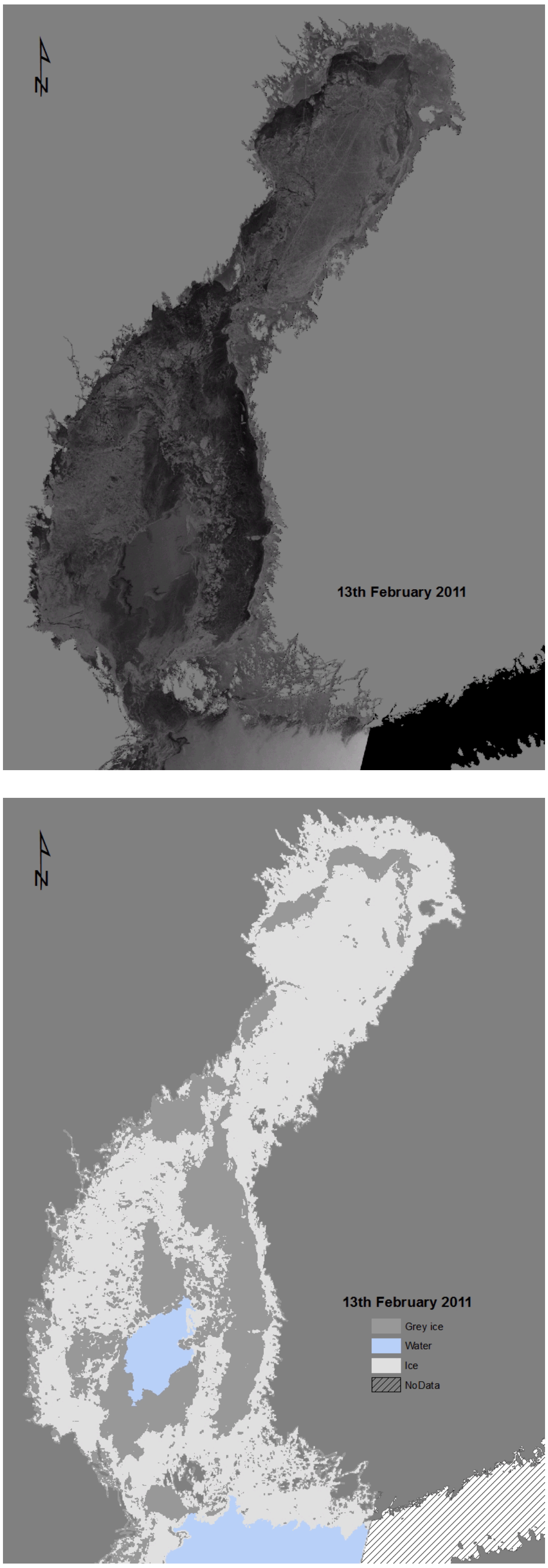


Figure 3. Raw (a) and classified (b) ASAR WSM data from 13th February 2011

First, the data were classified on different object levels to separate water, grey ice and ice. Again texture parameters were used.

In most cases grey ice is thin, newly formed ice. Also an ice without snow cover might be classified as a grey ice. New ice could have a very homogenous structure and in some cases can be easily mistaken with water. The results cannot be directly verified with sea-ice charts published by SMHI as the charts contain different ice classes (Fig. 4).

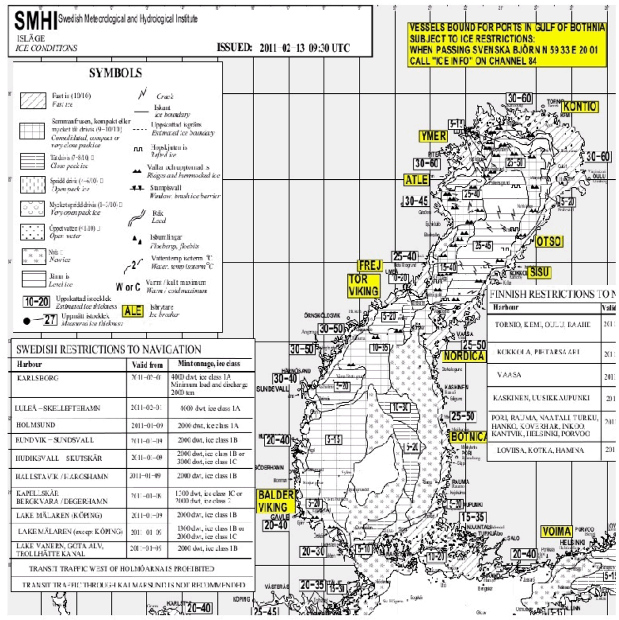


Figure 4. Sea-ice chart published by SMHI on 13th February 2011

Nevertheless, similarities can be clearly seen. Especially grey ice areas correspond with new ice areas on SMHI charts.

Comparing to other classification methods object-based methods enable us to separate single floes within the sea-ice pack. It could be seen in the area classified on the chart as close ice pack, that there are some regions with many small single floes and also a regions with a few big floes. We can also notice that fast ice, which is defined as 100% concentration ice, contain fractures. Classification of sea-ice based on OBIA methods gives a very detailed information about sea-ice cover.

3.3 Sea-ice concentration

Sea-ice concentration was calculated based on existence of sea-ice floes in both water and grey ice in pixel size 8×8 km (Fig. 5). Grey ice which is in most cases newly formed very flexible ice might be easily deformed and rafted if the weather conditions change rapidly. Therefore in calculating sea-ice concentration grey ice was counted as water. Areas with 100% water or 100% grey ice were separated. The results cannot be compared with generalized sea-ice chart, but general similarities can be clearly seen.

4. conclusions

In this paper classification of sea-ice extent and sea-ice concentration using OBIA are presented. The obtained results correspond with SMHI ice charts. What is more, OBIA classification tend to better reflect borders between sea-ice and water. Object based methods also enable us to separate single floes within the sea-ice pack. Studies of sea-ice floe distribution might be important in sea-ice forecasting or modelling of under-ice light distribution in sea-ice covered areas.

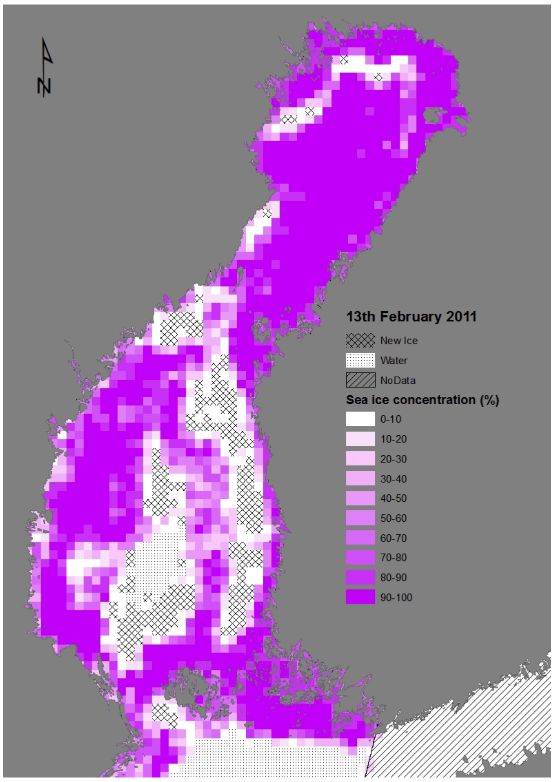


Figure 5. Sea-ice concentration on the Baltic Sea on 13th February 2011

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