Publishable summary of work in year 1

A summary description of project context and objectives

The objective of SIDARUS is to develop new sea ice data products from satellite, airborne and underwater platforms as well as ice forecasting from models in order to improve sea ice monitoring services. In addition to analysis of satellite and airborne data, the project will analyze in situ, airborne and under-ice data from previous and new field campaigns. These are essential data for validation of satellite retrievals of sea ice parameters such ice concentration, ice thickness and ice type classification. The data sets and products will be demonstrated to users working in climate research, marine safety and environmental monitoring. SIDARUS will extend the present GMES marine services[1] with new satellite-derived sea ice products, ice forecasting from regional models and validation of sea ice products using non-satellite data. The demand for improved sea ice information in the Arctic and Antarctic by many user groups is growing as a result of climate change and its impact on environment and human activities. The presently observed reduction of the Arctic sea ice extent, in particular during the summer months and an increasing demand for natural resources are key mechanisms driving human activities in these areas. In Antarctic, ice discharge from several ice shelves is a significant climate indicator, leading to enhanced iceberg population in the Southern Ocean.

Description of the work performed since the beginning of the project and the main results achieved so far

The user requirements for sea ice monitoring and forecasting services have been reviewed and a user group for the products and services to be developed in SIDARUS has been established. The user group include representatives for each of the five application areas where products will be developed: (1) High-resolution sea ice and iceberg mapping by SAR to support marine transportation, offshore operations, and ice-weather forecasting services in polar regions. (2) Sea ice albedo from optical sensors to support sea ice modelling and climate research, (3) Sea ice thickness from satellite data, airborne surveys and other observing platforms providing data for climate research and operational users. (4) ARGOS tracking of marine mammals combined with sea ice maps to support environmental management, wildlife protection. (5) Ice forecasting based on numerical models and satellite data for marine safety.

The plan for products and services have been presented to users through user survey, meetings, brochure, website and presentations at conferences. A service level agreement document and validation plan for the products have been prepared.

Sea ice data from field campaigns are important for validation of the satellite retrievals as well as to provide ice data that are difficult to obtained from satellites. This is specially the case for ice thickness. The field data used in the project includes airborne electromagnetic measurements of ice thickness and ridges (EM-bird), underwater ice draft measurements from multibeam sonars mounted on submarines and AUVs. Also other field measurements of sea ice parameters are used to validate ice thickness, ice types and ridges/leads that are derived from satellite radar altimeter, passive microwave data and SAR/optical data. Data from many previous field campaigns have been compiled and reported. In addition, new field

[1] http://www.gmes.info/pages-principales/services/marine-monitoring/

experiments were conducted in the Fram Strait and north of Svalbard in 2011 with support from SIDARUS.

Satellite data acquisition for the product development in the project has been planned and coordinated between the partners. One category of data are provided by GMES Marine Core Services through the MyOcean project. These data are mainly large-scale modelling fields that are needed for the regional models and some satellite sea ice products provided by the Sea Ice and Wind Thematic Assembly Center in MyOcean. The second category of data are high-resolution SAR and optical images needed for detailed sea ice and iceberg mapping. These data are used primarily during field campaigns and for the demonstration periods and areas planned in year 2 and 3. The Data Ware House (DWH) put in place in June 2011 by ESA is the mechanism used to request, archive and retrieve EO data under GMES. However, before this service was established, the partners had to obtain SAR and optical data from other projects. The third category of satellite data are ARGOS position data for marine mammals in ice covered areas. These data are the property of some of the users involved in the project. Access to these data will be obtained by signing an agreement with users who will provide test data sets for the project.

One activity is to develop a sea ice albedo parametrization based on optical satellite sensors with sufficient spectral resolution. The objective is the generation of operational products that will show sea ice albedo and meltpond fraction in the period from spring to autumn. During the first year, the theoretical background for this algorithm has been developed, and the first results from computer simulations have been performed.

For SAR studies of sea ice, the first report was compiled where a number of existing algorithms and analysis tools were reviewed. The purpose of the review is to identify algorithms that can be useful for development of SAR-based products. For example, sea ice concentration can be derived from sea ice type classification since the suggested methods include also the detection of open water areas. The conditions in and around leads and polynyas can be monitored using algorithms from sea ice classification, ice motion tracking and deformation mapping. In the SIDARUS project it is possible to combine algorithms that often are treated as separate fields of image analysis. The simultaneous application of different types of algorithms seems promising in a number of cases, e. g. for drift and deformation mapping by combining the results with a classification approach separating level and deformed ice. The results of sea ice classification with two different methods, a Neural Network method and a Bayesian method, have been submitted for publication and is presently under review.

The next step was to identify a Prototype toolbox that can be used for product development and services based on SAR data. A report was prepared where possible toolboxes to integrate SAR-based algorithms were described. The functional requirements of the toolbox were identified. The design and the implementation of the toolbox shall take into requirements related to software and processing systems that exist among the partners.

In studies of sea ice thickness, a report on data from previous UK submarine cruises has been prepared. The report presents all sea ice thickness measurements made with upward-looking single-beam sonars during Arctic cruises between 1976 and 2007. In addition, the yet unpublished complete study of the full draft distribution and the pressure ridge distribution of the last two cruises, in the winters of 2004 and 2007 was presented. Data from the two cruises were compared with those of earlier voyages in an attempt to establish how the Arctic Ocean sea ice cover has evolved in the past few decades. The results of the submarine measurements were compared with sea ice thickness determinations made with other techniques, such as satellite altimetry and airborne electromagnetic sounding

Work on ice forecasting in the Barents and Kara Seas has not started yet, but he modelling system has been established previously. In the next period the model system will be run and validated against available data.

Integration of data from different sources have started by demonstrating how ARGOS tracking data can be combined with sea ice data to show how marine mammals move around in the ice edge region over a period of several months. Also combination of high-resolution SAR and optical data for detailed mapping of ice types has been tested.

As part of the dissemination and exploitation activities, a public project website has been established (http://sidarus.nersc.no), a brochure, a project summary paper and a briefing document for policy makers have been prepared, the project has been presented at several conferences and workshops, and the first version of the dissemination and use plan has been made.

The expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far),

The results of the project are expected to have impact on climate research as well as marine operations and environmental protection in polar regions. The Arctic and Antactic is dominated by ice-covered oceans and coasts. The regions are exposed to climate change with significant impact on the cryosphere and the environment which depends on the presence of ice. In the Arctic the global warming is at roughly twice the global average rate, with a dramatic reduction in summer sea ice extent as one of the clearest indicators of this trend. Physical and biological processes are being transformed across the entire regions while climate feedback mechanisms in the Arctic's changing atmospheric and oceanic dynamics impact at global scales.
The Arctic regions offer vast areas of hydrocarbon resources that have just started to be exploited. The Arctic Ocean is surrounded by continental shelves, where in particular the huge Siberian shelf covering the eastern hemisphere, extending from the Barents Sea to the Chukchi Sea.

The ongoing changes in Arctic climate with increasing temperatures and decreasing sea ice cover have stimulated the interest for oil and gas exploration in several Arctic areas. A reduction of the sea ice area opens up the possibility to access new areas of the Arctic Ocean where hydrocarbon resources can be exploited and transported to the markets. The main Arctic areas where large-scale offshore exploration have started are: Sakhalin in Sea of Okhotsk, North Slope of Alaska, Cook Inlet, Grand Banks of Newfoundland, Barents Sea (Snøhvit field and the upcoming Shtokman field) and the Pechora Sea. All these areas have seasonal sea ice cover and some have icebergs that put severe constraints on design and operation of installations and on transport solutions. Even if the sea ice cover is decreasing and is expected to diminish further in the coming decades, the sea ice will still remain a dominant factor in most of the exploration areas in the winter season. In the summer months, however, less sea ice will provide access to offshore areas in Canada, Greenland and on the eastern Siberian shelf that were previously inaccessible due to sea ice.

Improved sea ice end iceberg monitoring and forecasting in the polar regions will have large socio-economic impact due to climate change combined with increased human activities

Figures

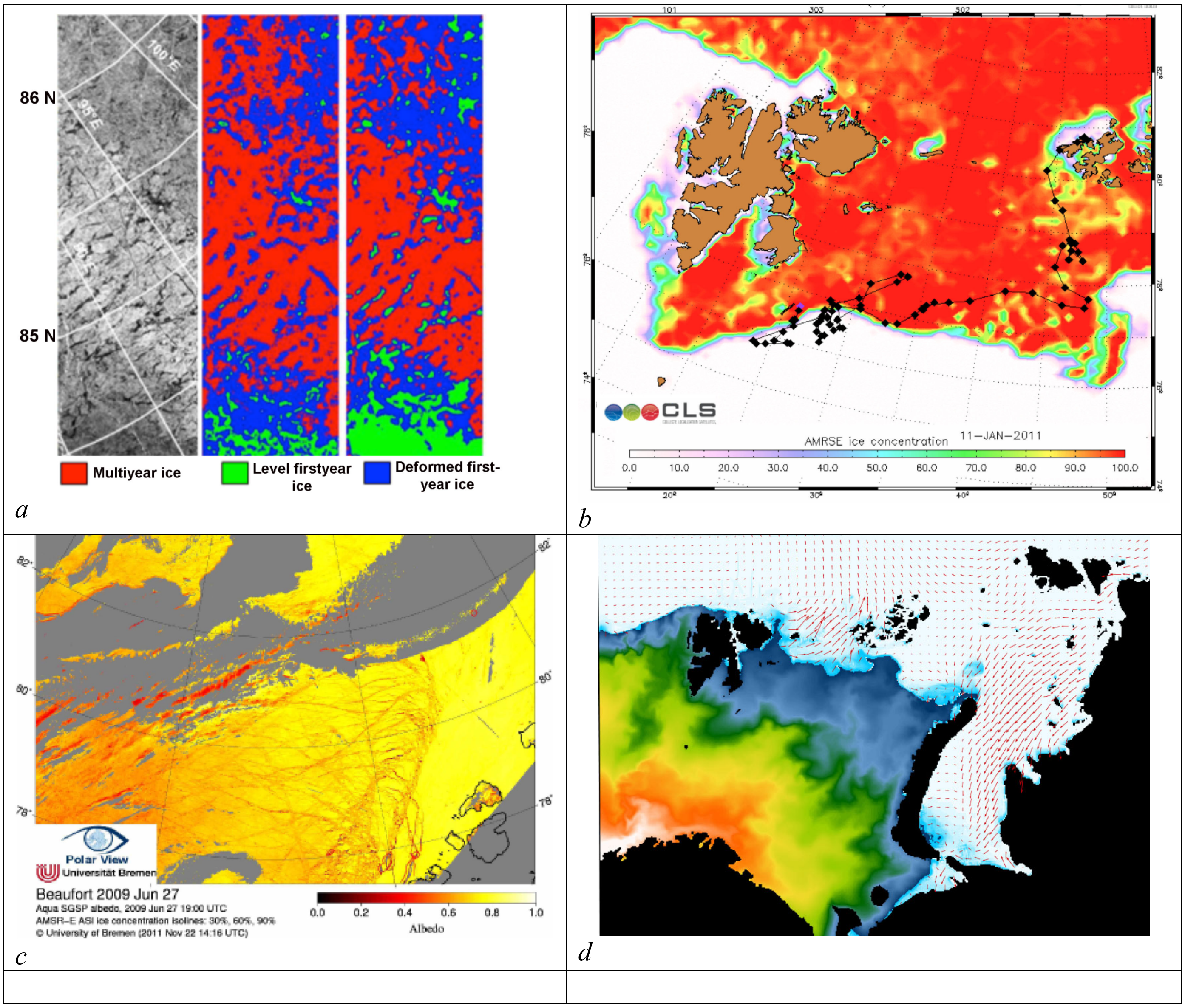

Figure 1. Examples of satellite sea ice products under development in SIDARUS:

- *(a)* SAR ice classification using a Neural Network algorithm (centre) and Bayesian abd a Bayesian algorithm (right) in the central Arctic.
- *(b)* Polarbear track from September 2010 to April 2011 for bear with Argos ID 103383 (black line) superimposed on an ice concentration map from 11 January 2011. The track starts on northern Franz Josef Land and ends near Hopen island.
- *(c)* Ice albedo retrieved from averaging of MODIS reflectance of three visible bands (1, 2, and 3). The grey areas are cloud-masked.
- *(d)* Ice-ocean model in the Barents Sea region using the 4 km HYCOM model forced at the boundary by the TOPAZ system, where colour code indicates SST and arrows show ice drift