Sea Ice Downstream Services for Arctic and Antarctic Users and Stakeholders

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Abstract

The overall objective of SIDARUS is to develop and implement a set of sea ice downstream services in the area of 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 (Johannessen et al., 2007). In Antarctic, ice discharge from several ice shelves is a significant climate indicator, leading to enhanced iceberg population in the Southern Ocean. SIDARUS will develop, validate and demonstrate five sea ice services using satellites as the major source of data. The services include (1) high-resolution sea ice and iceberg mapping by SAR, (2) sea ice albedo from optical sensors, (3) sea ice thickness from satellite radar altimeter and passive microwave data, (4) ARGOS tracking of marine mammals combined with sea ice maps, and (5) ice forecasting based on numerical models and satellite data. In addition to analysis of satellite earth observation 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. Sea ice information is needed by a wide range of users including marine transportation operators and regulators, operational meteorology and sea ice services, search and rescue organizations, defence and security agencies, resource developers (oil, gas, timber, minerals, fish), policy-makers in the polar regions, marine engineers, residents in ice-affected regions, and environmental institutions working with sea ice habitat protection. Data products with large or unknown accuracy are of limited values for most users. It is therefore of high priority that data

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

products from past, present and future satellites are validated for quality control and error estimation. SIDARUS will be implemented by a consortium of six partners all with long experience in observation of sea ice and icebergs and implementation of operational services.

Work programme and methodology

Sea ice monitoring and other metocean services (meteorology, oceanography and sea ice) in many countries are presently providing large- and regional-scale ice charts and forecasting for the Arctic and Antarctic seas. Through ongoing projects such as MyOcean[2] and PolarView[3], deliver satellite- and model-based products for a wide range of users. Many of the ice and ocean services in the Arctic are available through the Arctic ROOS portal (http://arctic-roos.org). There are, however, many users such as offshore industry and Arctic-Antarctic shipping that require more specific data and services on sea ice and icebergs to support ice operations and ice navigation (Fig. 1). For climate research and prediction, there is a set of essential climate variables (ECVs) where satellites can provide important data (GCOS; 2010[4]). In addition to ice area and ice drift, which are already monitored by existing GMES services, data on sea ice thickness, leads/polynyas, surface albedo, and snow cover are needed, but these variables are not included in the services delivered by MyOcean or other GMES projects. SIDARUS will therefore extend the sea ice service products including high-resolution sea ice data to support operators on regional and local scale as well as large scale information for climate monitoring.

a b

Figure 1 (a) Minimum sea ice extent in the Arctic i September 2010 (white area) showing that sailing through the Northern Sea Route as well as the Northwest Passage was possible; (b) Russian nuclear icebreaker operating in sea ice in the Northern Sea Route.©NERSC

[2] MyOcean general web site: http://www.myocean.eu.org/. Arctic forecasting is available at http://topaz.nersc.no/
[3] http://www.polarview.org/
[4] http://www.wmo.int/pages/prog/gcos/index.php

The overall strategy of SIDARUS is to develop, validate and demonstrate five sea ice services using satellites as the major source of data. The services include (1) high-resolution sea ice and iceberg mapping by SAR, (2) sea ice albedo from optical sensors, (3) sea ice thickness from satellite radar altimeter and passive microwave data, (4) ARGOS tracking of marine mammals combined with sea ice maps, and (5) ice forecasting based on numerical models and satellite data. In addition to analysis of satellite earth observation data, the project will analyse in situ, airborne and under-ice data from previous and new field campaigns. These are essential data for validation of satellite retrievals. Data products with large or unknown accuracy are of limited values for most users. It is therefore of high priority that data products from past, present and future satellites are validated for quality control and error estimation. The project will be implemented over three years through 10 workpackages summarized in Table 1.

Table 1. Workpackages

Workpackage	Objectives and main activities
WP 1: User interaction and design of downstream services	To ensure that the products and services will respond to user requirements, a user group will be established. This group will have close interaction with the project partners, providing recommendations and feedback during development and validation of the products
WP 2: Field campaigns	Field experiments will be carried out in the Arctic using ice-going vessels, helicopters, autonomus underwater vehicles (AUV and submarine cruises to collect essential data for validation of the satellite retrievals
WP 3: Satellite data provision	Acquisition of the satellite data needed to develop the products will include SAR and optical images, radar altimeter data, passive microwave data and other data provided by the Marine Core Services
WP 4: Albedo and snow cover of sea ice	The objective is to develop improved parametrization of sea ice albedo based on optical satellite data, and provide an operational service to be used in sea ice and climate modelling
WP5: SAR analysis of sea ice and icebergs	Develop SAR-based sea ice classification order to map details of the ice cover (leads, polynyas, ice types, deformed ice) as well as iceberg detection methods
WP6: Sea ice thickness	Develop and validate ice thickness retrievals from satellite radar altimeter (CryoSat) and passive microwave data (SMOS), and analyze ice thickness data from field surveys for validation of the satellite retrievals.
WP7: Sea ice and iceberg forecasting	(1) Provide sea ice and ice forecasts for Barents Sea area from downscaling of MyOcean services; (2) Provide iceberg forecasting in the Antarctica by combining SAR detection and numerical ocean forecasting from MyOcean.
WP8: Data integration and validation	Integrate products from SIDARUS with MyOcean and other sea ice products, validate the SIDARUS products against field observations and present the results in a web portal.
WP9: Demonstration of services	Each of the five services developed in SIDARUS will be demonstrated to users during the third year
WP10: Dissemination and exploitation	Results of the product and service development will be exploited and implemented as services for specific user groups

Partnership

The consortium consists of operational service providers and research institutions with long experience in sea ice monitoring services and sea ice research. The consortium has complementary expertise representing high quality scientific and technological competence. The consortium has extensive experience in (a) satellite data analysis and retrieval of sea ice, snow cover and iceberg information, (b) operational satellite data services and (c) development of commercial services. The consortium has also experience in planning and implementation of field experiments for measurement of sea ice parameters, use of helicopter surveys, use of multibeam sonar for under-ice platforms, sea ice and iceberg modeling and forecasting, data integration and joint analysis of sea ice data from multiple sources using GIS technology, and use of web technology to disseminate data and derived products. The consortium has extensive contacts with users of sea ice information both in Arctic and Antarctic.

Expected scientific and technological results

Sea ice classification and iceberg detection from SAR: SIDARUS will develop and demonstrate sea ice and iceberg retrieval methods for exploitation of Sentinel-1 data, where several SAR modes can be utilized. Sea ice classification of SAR images can be performed using a neural network algorithm. The algorithm uses backscatter and several textural characteristics (Fig. 2). Dual-polarized SAR images with 10 m resolution will be used to produce high-resolution maps with ice classes, ice edge, leads and ridges, as well as for iceberg detection. Available SAR data from ENVISAT, TerraSAR-X and RSAT-2 will be used during the project. Data from Sentinel-1 will also be tested if available during the project.

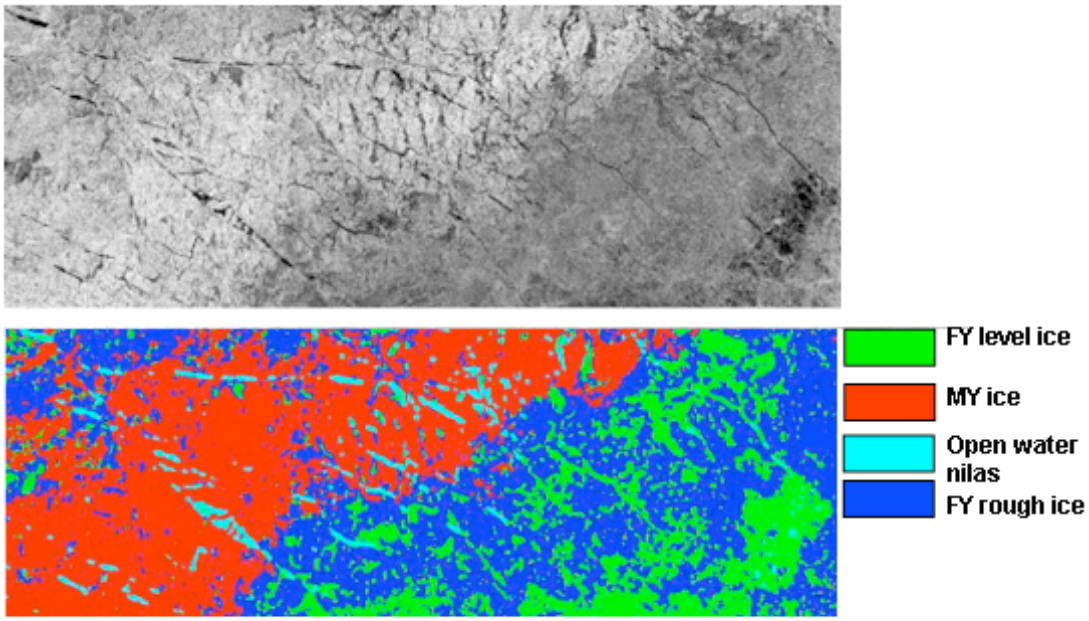

Figure 2. Classification of four ice types in ENVISAT ASAR image, taken on 18 January 2008 in the central Arctic ©NERSC.

Validation of the ice information retrieved form the SAR data will be done by use of Helicopter Electromagnetic surveys (HEM), in situ observations and under-ice measurements from field experiments. The high-resolution products will be provided in near-real time for areas required by the user groups both in Arctic and Antarctic.

Sea ice albedo product: SIDARUS will 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. Daily data may be of limited use due to cloud cover, therefore products will be generated from averaging over several days. Present data will come from MODIS, MERIS and AATSR, while future GMES services will come from the Multi Spectral Instrument (MSI) on Sentinel-2 and similar sensors. The main application of these data will be in atmosphere-ice-ocean models and in climate simulations. Data will be produced annually from 2003. The main users group is sea ice and climate modellers who need improved parametrization of albedo in their models.

Sea ice thickness products: SIDARUS will develop thickness retrieval of thin ice (< 0.5 m) based on 1.4 GHz passive microwave data from the recently launched ESA SMOS mission and the NASA AQUARIUS mission scheduled for launch in 2010. This will be supplementary to the retrievals from CryoSat which mainly map the thicker part of the ice cover. Both SMOS and CryoSat will provide large-scale low-resolution data on ice thickness. In order to validate the ice thickness provided by MyOcean models and satellite retrievals (from SMOS and CryoSat), profiles of submarine and AUV sonar data, HEM surveys and in situ data from field experiments will be employed. Future GMES services will use a combination of radar/laser altimeters for the thick ice and passive microwave L-band data for the thin ice, thus providing data on the average modal thickness at resolution scales of a few to tens of kilometres. Ice thickness data are needed by many users, ranging from climate modellers to ice navigators. In addition, higher resolution data on ridges and ice type distributions (as proxies for thickness) are particularly needed for operation of vessels and platforms in ice and as design parameters for constructions in ice. The strategy here will be to provide regional modal thicknesses from SMOS and CryoSat and thickness distributions (including ridge draft distributions) from specific mapping experiments (AUV/submarine) generalized by developing a relationship between ice type distributions and ice thickness distributions.

The only method available to measure both the full probability density function of ice thickness and the actual three-dimensional shape of the ice underside is sonic profiling from below, notably with 3-D multibeam sonar. Two-dimensional profiling of the ice underside using single-beam sonar has been done since 1958 from US submarines, and in Europe since 1971 using UK submarines. Analysis of UK and US submarine data collected over four decades has shown an enormous 43% decline in thickness from the 1970s to the late 1990s (i.e. Rothrock et al., 2008). In SIDARUS analysis, interpretation and databanking of all past upward sonar profiles of ice draft generated by UK submarines will be performed.

Ice Forecasting on regional scale: SIDARUS will implement a regional sea ice forecasting model in the Barents Sea with improved representation of sea ice dynamics in the marginal ice zone. This will be used to provide improved ice forecasting of the ice edge to support offshore and other operations in the Barents Sea. Furthermore, SIDARUS will combine observed iceberg detections and a regional Antarctic circumpolar model to provide forecast of icebergs. In the Arctic the organizations which have expressed a need to know about icebergs within the sea ice

zone, and which have signed up for potential services in this area, are shipping companies serving communities in East and West Greenland with both general cargo and vital oil products, who use ice-strengthened ships which can handle collisions with ice floes but not with icebergs; and defence agencies who are concerned with submarine and surface-ship operations in ice-covered waters. The main users involved will be sailing race organizations, which have already expressed a need and have been involved in precursor services. Other users such as shipping companies and scientific ship owners could be interested but the demand is less important.

Products for sea ice habitat conservation. SIDARUS will combine ARGOS position data from tagged animals with regional sea ice maps as well as with high-resolution ice classification maps from SAR, and ice thickness products. The merged products will be provided both in near real-time and as time series of archived data. The users will be environmental monitoring and wildlife protection institutions in Arctic and Antarctica.

Field campaigns to collect validation data. These will demonstrate the importance of using sea ice data from in situ, underwater and airborne platforms as a supplement to satellite data, to obtain data on sea ice thickness and ridges. Data from previous as well as campaigns to be carried out in 2011-2012 will be used.

User involvement. Sea ice information is needed by a wide range of users including marine transportation operators and regulators, operational meteorology and sea ice services, search and rescue organizations, defence and security agencies, resource developers (oil, gas, timber, minerals, fish), policy-makers in the polar regions, marine engineers, residents in ice-affected regions, and environmental institutions working with sea ice habitat protection. SIDARUS will establish a User Group with representatives from the sectors mentione above, and this group will be involved in design, development and validation of the products to be developed in the project.

The products will be developed through a set of case studies in different region regions in Arctic and Antarctic using data from previous field experiments as well as from new experiments conducted in SIDARUS. The products will be disseminated to identified users during demonstration periods. The results from SIDARUS will be exploited to build up observing and monitoring systems for the polar regions.

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