Publishable summary of MAIRES (263165) for period 01.06.2012 – 31.05.2013

Summary description of project context and objectives

Satellite Earth Observation (EO) data provides unique opportunities to studying Arctic climate processes and in particular changes in the cryosphere. There have never been more polar orbiting satellites in operation, providing EO data for environmental monitoring on global and regional scale. Use of EO data is necessary in several climate-related scientific disciplines, providing methods for environmental monitoring, support to marine operations, resource management and contribution to education. The user requirements for land and sea ice information in the Arctic region is growing as a result of climate change and its impact on the environment and human activities. The expected growth in ship traffic, oil and gas exploration, fisheries and tourism in the coming years will increase the risk of accidents affecting the environment, health, safety and economy of this unique and vulnerable region. The EU has started developing the Arctic policy[1] with the environmental protection and sustainable use of resources considered as issues of the highest priority (EU Communication, 2008).

The objectives of MAIRES are

- to establish cooperation between ongoing GMES projects and Russian actors in the area of Arctic ice observation from space;
- to develop a method for precise overall modelling of glacier elevation changes by use of differential interferometry and altimetry data;
- to test and validate sea ice drift data derived from SAR images in combination with other ice satellite derived ice drift data
- to develop iceberg detection methods using a combination of high-resolution SAR and optical images;
- to document inter-annual and decadal changes in land and sea ice variables based on the EO-products developed in the project;
- to disseminate EO-based products for/of monitoring land and sea ice to users and stakeholders.

To achieve these objectives, a number of satellite-based products from European and Russian data are used supported by US and Canadian data. For landice studies, the following data are used: SAR from for interferometry, IceSat lidar altimetry, CryoSat-2 radar altimetry, GOCE gravity field data, high-resolution optical mages and Russian digital elevation data and topographic maps. For sea ice and icebergs, the main data sources are SAR from ENVISAT, RadarSat and TerraSAR, optical images from Landsat, MODIS, and several Russian satellites, passive microwave data for regional sea ice studies as well as in situ data for ice drift and ice thickness.

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

WP1: User requirements and case study definition

In the first six months of the project the consortium reviewed user requirements for land and sea ice data with emphasis on Russian Arctic regions (Figure 1). The study area contains sea ice, icebergs and many glaciers that are well covered by satellite data over the last decades. Access to data from satellites, both from ESA, Russian Space Agency and other space agencies have been established, providing overview of data that can be used in the project. Furthermore, a set of case studies for land ice, sea ice and icebergs to be conducted in the project were planned. The case studies were identified based on previous and ongoing research work in the area and on availability of satellite data over several years. The user requirements for providing more data on the cryosphere in this area are growing because of shipping, offshore operations, and the general interest in climate change data. However, the possibility to provide new climate related products depends on the spatial and temporal coverage of satellite data. This topic has been investigated in WP2.

The user requirements have been reviewed from literature, other previous and ongoing projects and through direct contact with some users. A key document describing the requirements for cryospheric observations from space is the IGOS Cryosphere Theme report published in 2007 (http://igos-cryosphere.org.).

[1] More information about Arctic policy is found at http://ec.europa.eu/maritimeaffairs/arctic_overview_en.html#

Observational requirements for climate research are also defined by GCOS (Global Climate Observing System) in a series of documents (http://www.wmo.int/pages/prog/gcos/index.ph). At present, the ESA CCI programme runs a series of projects where the climate observation requirements are analyzed in detail (http://www.esa-cci.org/). The results of this analysis will be used in the project. For sea ice and icebergs, there are also many requirements from operational users such as Arctic shipping, offshore industry, weather and ice services, due to the growing human activities in the western Russian Arctic.
A user workshop was organized by NIERSC in St. Petersburg on 12 April 2013. The workshop was attended by 15 participants representing different institute in Russia

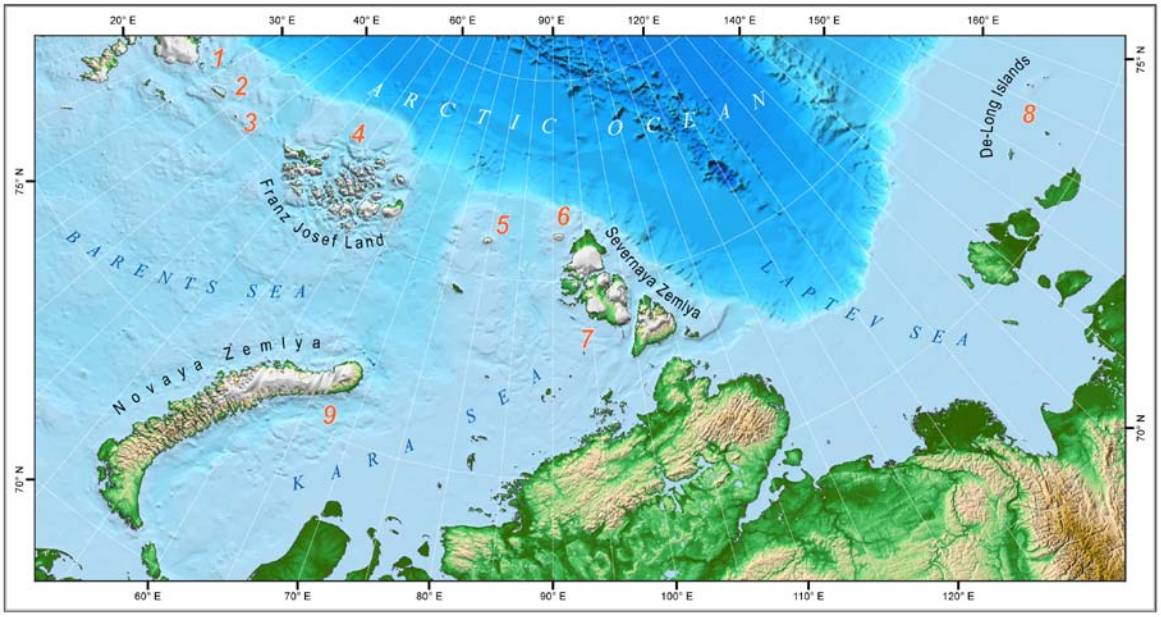


Figure 1 Map of the Russian Arctic region where MAIRES project conducts studies of land and sea ice. The northern part of the region is ice-covered year-round (dark blue area), while in winter most of the areas are ice-covered. The following glaciers are studies

WP2: Data acquisition
In the first months of the project, a data procurement plan was made for land ice, sea ice and icebergs, describing the types of data needed, time periods and areas of data coverage, access to data and quantities of data planned for use in the project. A main effort has also been to establish systems for browsing, downloading and archiving satellite data for the study areas, based on data from ESA, RKA and other agencies. Data are collected and stored on several websites where ENVISAT ASAR, Radarsat Wideswath SAR, Landsat, ASTER, and others are available and can be used for the project. Data from Russian satellites are extracted by NTSOMZ and provided on a dedicated website. These websites makes it possible to search for time series of data covering the same area over several years and at for different seasons. A specific task has been to find collocated data from Russian and European satellites as well as in situ data, which can be used to improve the research of land and sea ice processes. In order to manage these data, NERSC has established a database with web interface (Figure 2), which makes uses for the above web sites and facilitate for users to find data to be used in the case studies of the project. This work started in the first period and has continued in the second period. The database updated automatically when data are available on the server used to get this data.

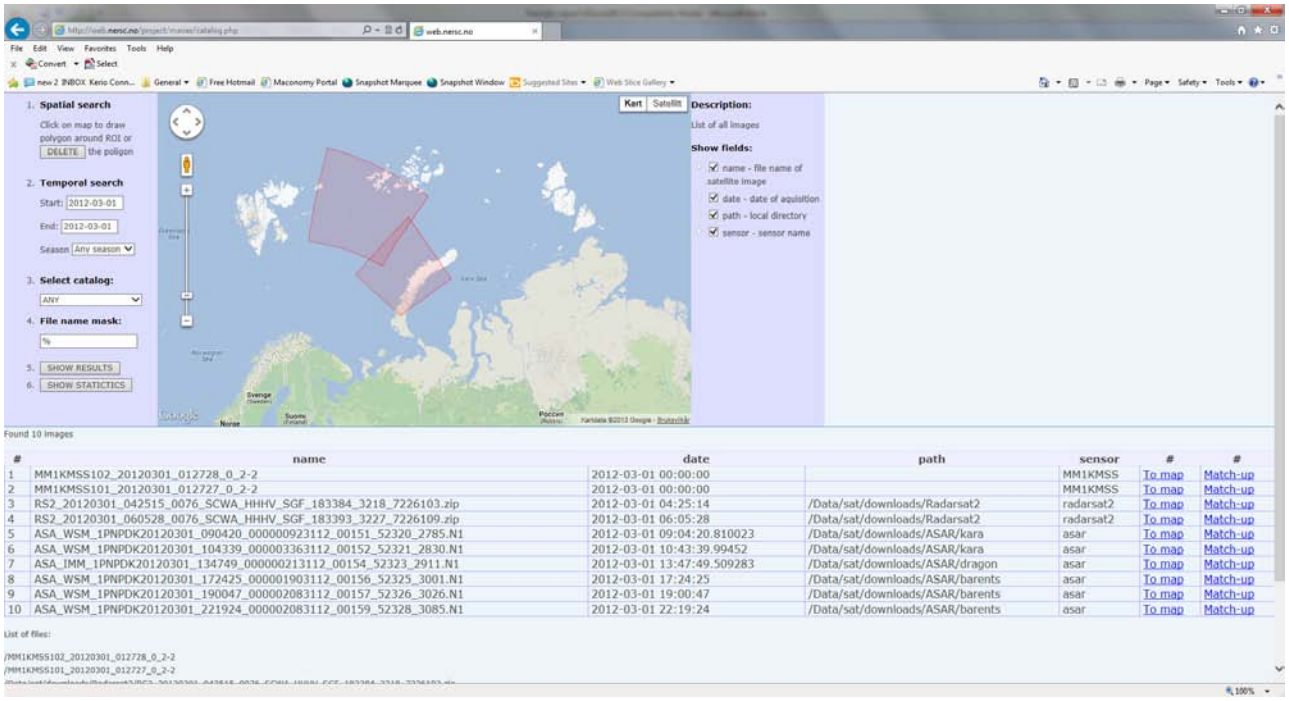


Figure 2 database web interface http://web.nersc.no/project/maires/catalog.php

WP3: Glacier studies

The processing method, the data flow, the results and their representation in glacier elevation changed modeling in the Eurasian High Arctic have been described, as illustrated in Figure 3 and 4. The glacier elevation changes in the Barents-Kara-Laptev region over the past 60 years has been analyzed by means of joint geometric processing of altimetric, interferometric and reference elevation data. The INSARAL algorithm for mapping glacier state and change at a macroregional scale with the aid of satellite differential interferometry and altimetry has been developed to generate the specified change models within the constraints of time schedule and cost.

A new series of 50-m glacier change models for the Eurasia's northernmost ice caps were generated and represented in the UTM projection available at http://dib.joanneum.at/MAIRES/index.php?page=products. A total of 28 satellite maps representing glacier elevation changes, ice land processes, mass-balance and geopotential characteristics in the Eurasian High Arctic at 1:100 000, 1:200 000 and 1:500 000 scales in UTM projection (Zones 35N – 57N, WGS 84, CI = 25-100 m, 50-m grid, 60-year reference period: 1950s – 2010s). The maps contain glacial borders, ice divides, ice coasts, top heights, elevation change values, areas of retreat / advance, multi-year equilibrium line, accumulation and ablation area, outlets, frontal velocities, strain rate, other mass balance characteristics and gravity anomalies with magnitudes.

The resultant models of glacier changes allowed a precise measurement of glacier changes in linear, areal and volumetric terms to be performed in semi-automatic mode. The research revealed the reduction of glacier area and general lowering of the glacier surface on most ice caps. Several new islets were discovered due to the glacial retreat in northern parts of Franz Josef Land and Severnaya Zemlya (Figure 1). The cumulative mass budget in the study region remained negative while individual rates of volume change varied from -0.07 km3/a to +0.03 km3/a. Positive values of average mass balance with the maximum accumulation signal of approximately 1.0 m/a were determined on Ushakova, Schmidt and other small island glaciers. The multi-year equilibrium line altitude (ELA) measured was systematically lower than that published by other investigators.

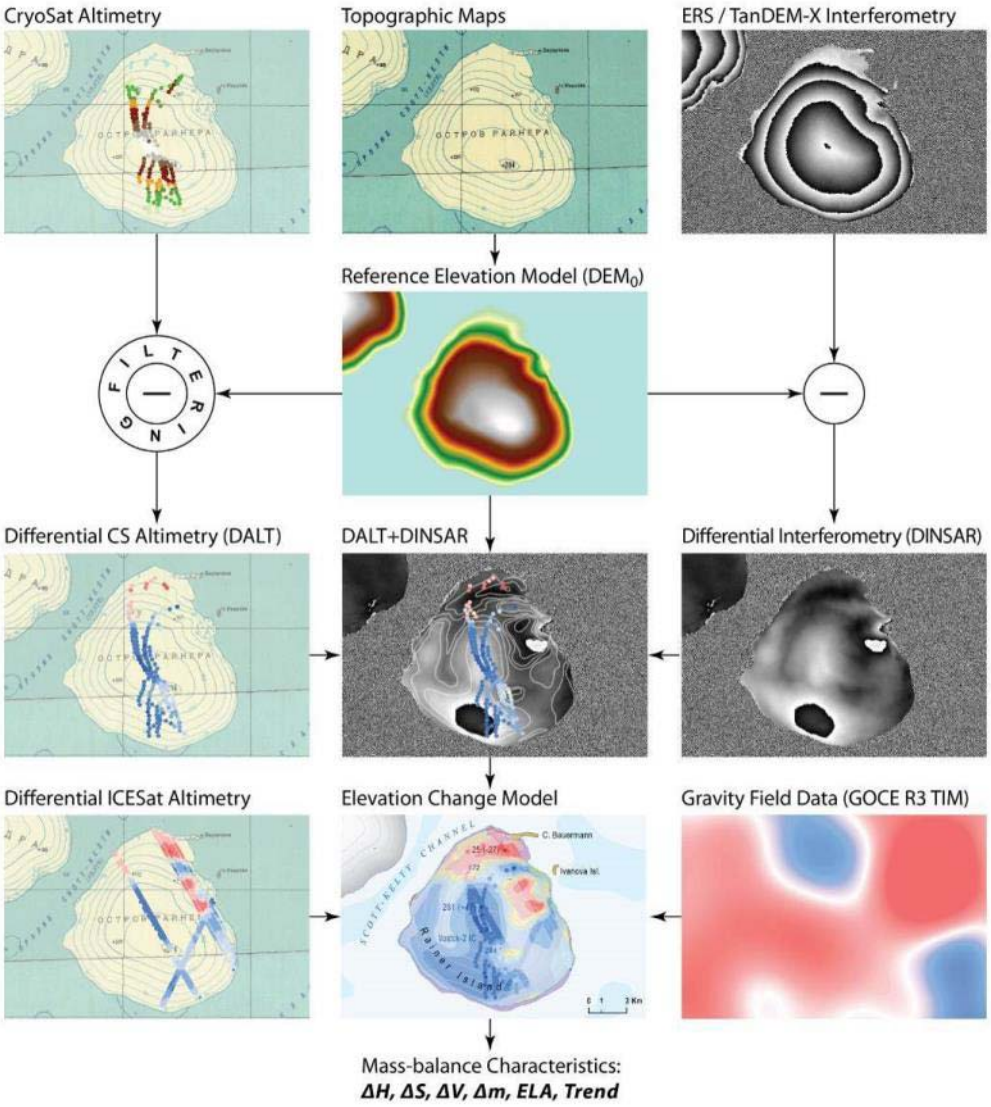


Figure 3. Basic procedures for glacier change modelling for Bennett Island.

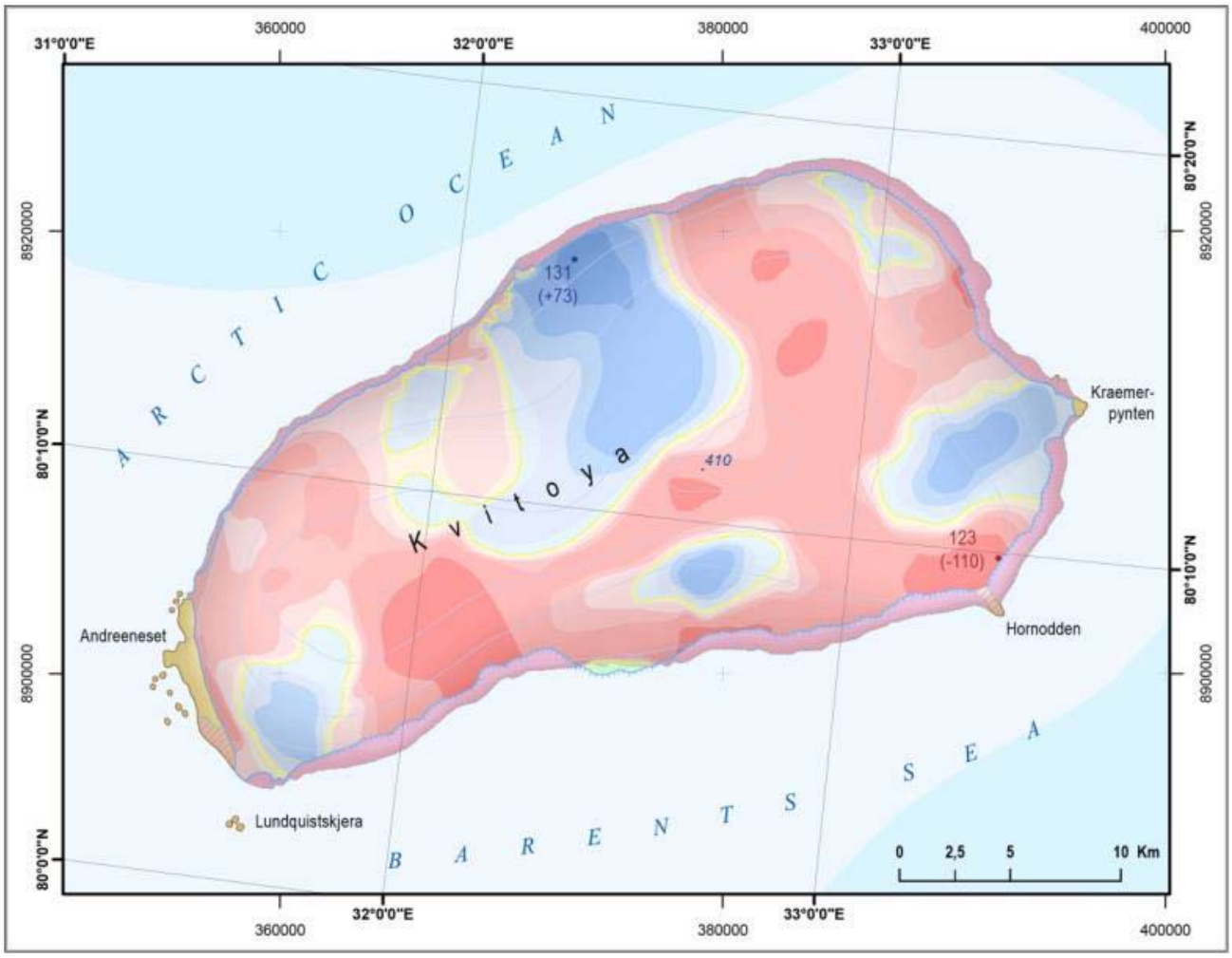


Figure 4 Elevation change of Kvitøya: red is decreasing, blue is increasing elevation.

WP4: Sea ice processes

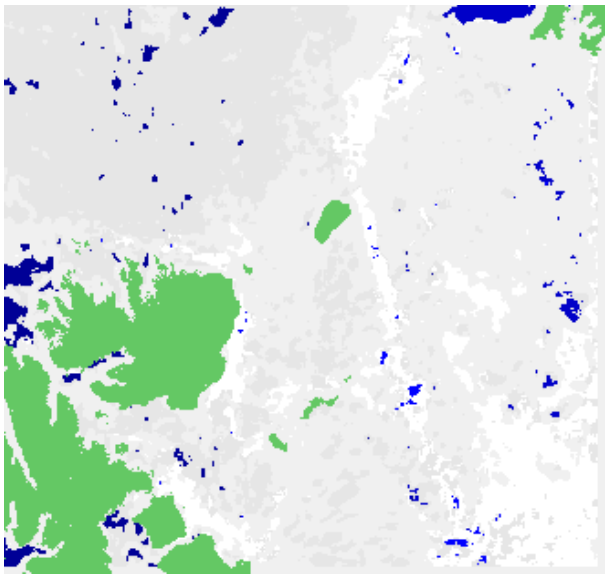
A method of sea ice \ open water retrieval was developed and demonstrates for exploitation of RADARSAT-2 data, where several SAR modes can be used. Dual-polarized SAR images with 50 m resolution are used to produce high-resolution maps with ice edge, leads and open water areas (later also with ice classes) Figure 5. Available SAR data from RADARSAT-2 are used during the project. Validation of the ice information retrieved from the SAR data is done using Met.no ice charts, in situ observations and visual sea ice expert's analysis. The high-resolution products are provided in near-real time for areas required by the user (e.g. Fram Strait and Arctic Basin).

Validation: Comparison Norwegian Meteorological Institute (Met.no) ice charts and OW/sea ice SVMs classification. MET.no sea ice type data were ranged into 2 classes: OW and sea ice. SVMs classification: sea ice as sea ice; OW – OWcalm + OW rough. Met.NO ice charts are used as “apriory” (correct) classification and we find the accuracy of SVMs classification agreement with MET.no data. Figures below: a) calibrated RADARSAT-2 image, HH-polarization; b) SVM classification result from MIRES catalog; d) Norwegian Meteorological Institute (Met.no) ice charts; c) the differences between MET.no data and our classification (MET.no - icetypes).

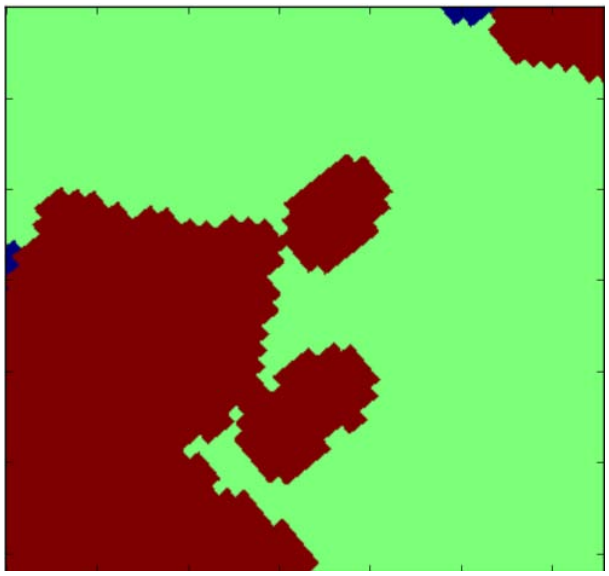
Figure 5 RADARSAT-2 image, HH-polarization, 4 April 2013

Sea ice accuracy = 0.985	OW error = 0.0023	ICE error = 0.013

a) MET.no data



b) NERSC classification result



c) MET.no ice chart

d) Difference: METn0 – NERSC

Figure colors:
dark blue (1) →seaIce
light blue (2)→ OW
orange (3)→ land mask

dark blue (1) → OW on METno, seaIce - our
light blue (2)→ no difference (zero)
green (3)→ Sea Ice – METno, OW - our
orange (4)→ land mask

A new approach of automatic sea ice drift retrieval has been tested over the Fram Strait region Figure 6 & 7. The method based on original implementation of feature-based tracking technique and allows retrieving more valid ice drift vectors compared to cross-correlation approach. We have started test calculations for winter and summer months from ASAR and Radarsat2 data. A geo-spatial database of in-situ data was prepared (IAPB dataset for 1979-2012) for validation. SAR images generated by NANSAT system.

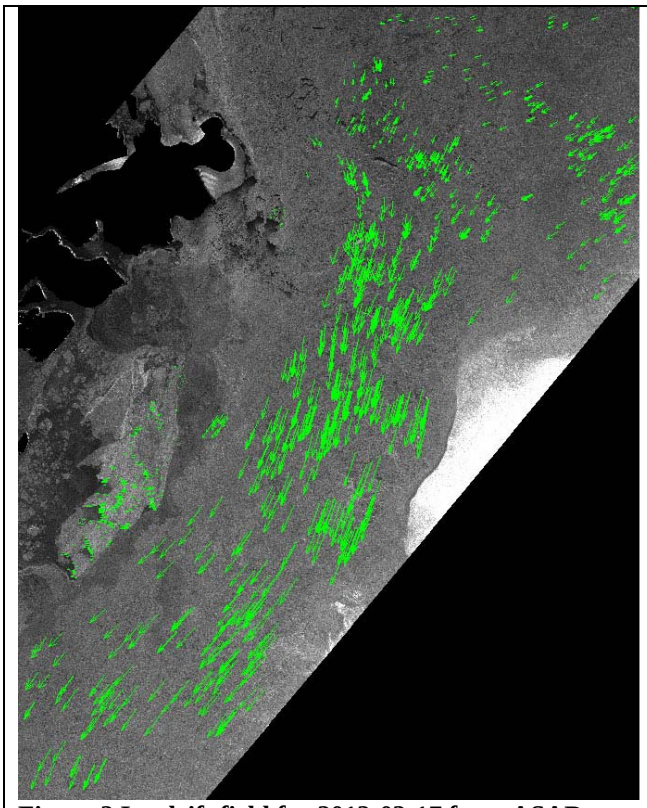


Figure 2 Ice drift field for 2012-03-17 from ASAR imagery

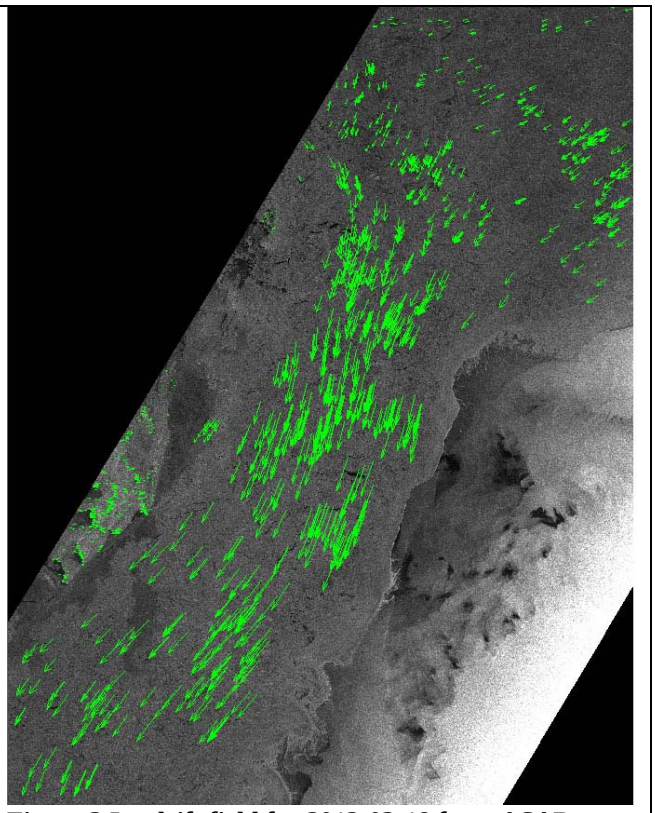


Figure 3 Ice drift field for 2012-03-18 from ASAR imagery

WP5: Iceberg detection

Iceberg identification among open water, fast ice and drifting ice using visible Landsat, "Monitor-E", ASTER , MODIS images and synthetic aperture radar (SAR) images was studied (figure 8). The possibility of identification of icebergs in satellite images of different types is estimated, and features for iceberg detection in these images are determined. Several examples of satellite image analysis and maps are presented (Figure 9). The technological schemes of combined use of different types of satellite information depending on ice and hydrometeorological conditions are proposed. The perspectives of development of iceberg detection methodology are outlined and some maps were prepared

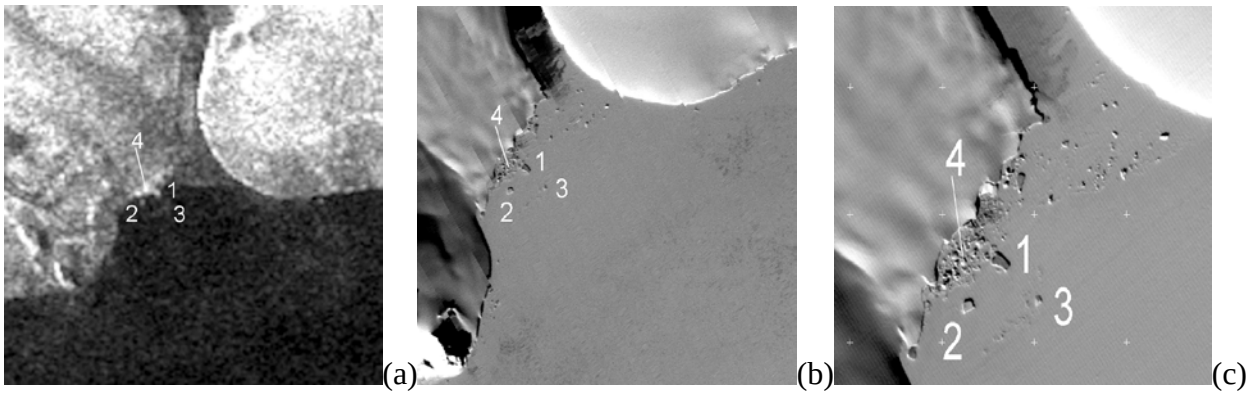


Figure 8 Images of icebergs in fast ice of FJL. a) ENVISAT ASAR subimage for April 5, 2006, b) Landsat subimage for April 14, 2006, c) "Monitor-E" subimage for April 7, 2006.

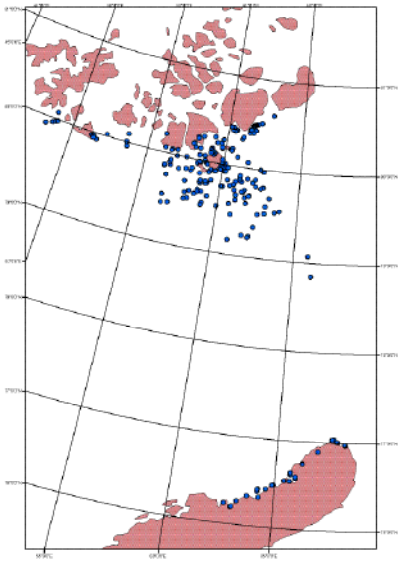


Figure 9 and map of iceberg distribution to the south of FJL, composed from ENVISAT ASAR image for September 15, 2006 (b).

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)

Landice: obtain new data and scientific results on changes of Arctic glaciers by use of several new satellite observing techniques

Sea ice and icebergs: improve the monitoring methods by use of satellite data and quantify changes in sea ice and iceberg conditions in the Barents and Kara Sea regions in the last decades

The address of the project public website: http://maires.nersc.no