Publishable summary of MAIRES (263165) for period 01.01.2011 – 31.05.2012

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 (Fig. 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.

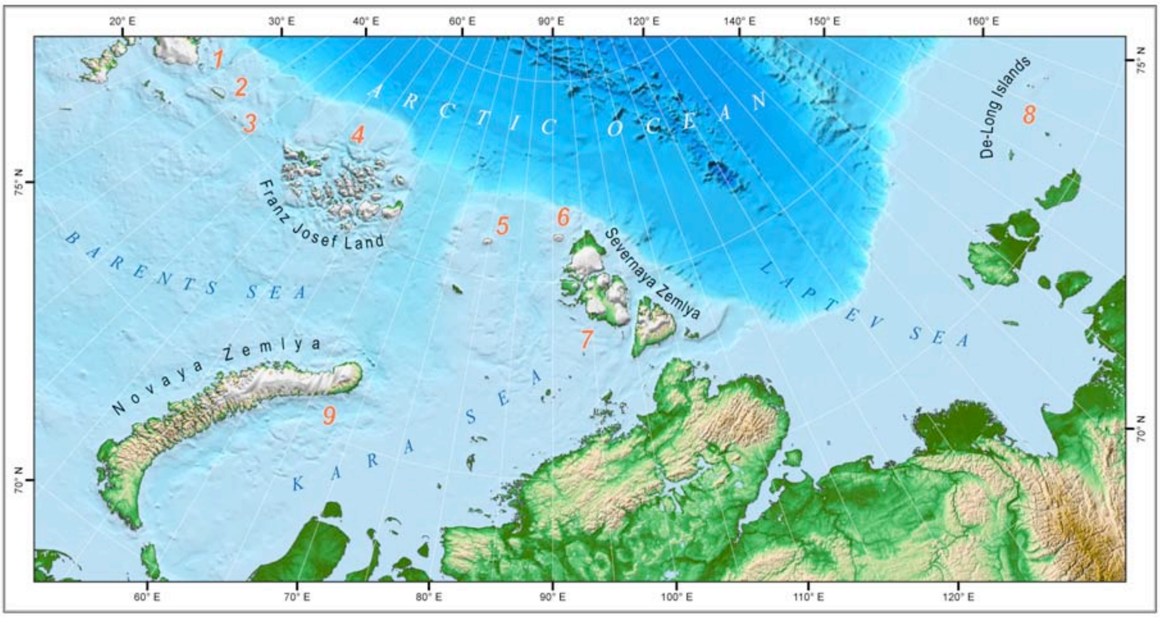

Figure 1. Map of the Russian Arctic region where MAIRES project conducts studies of land and sea ice. The northern part of the region is ice-covered year-round (dark blue area), while in winter most of the areas are ice-covered. The following glaciers are studies: 1 - Storöya (East Svalbard); 2 - Kvitöya; 3 – Victoria Island; 4 – Franz Josef Land archipelago; 5 – Ushakova Island; 6 – Schmidt Island, northernmost part of Severnaya Zemlya; 7 – Severnaya Zemlya archipelago; 8 – De Long Islands (including Bennett Island); 9 – Northern Island of Novaya Zemlya.

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.

WP3: Glacier studies

The processing method, the data flow, the results and their representation in glacier elevation change modeling in the Eurasian High Arctic have been described, as illustrated in Fig. 2. 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. 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 (Fig. 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.

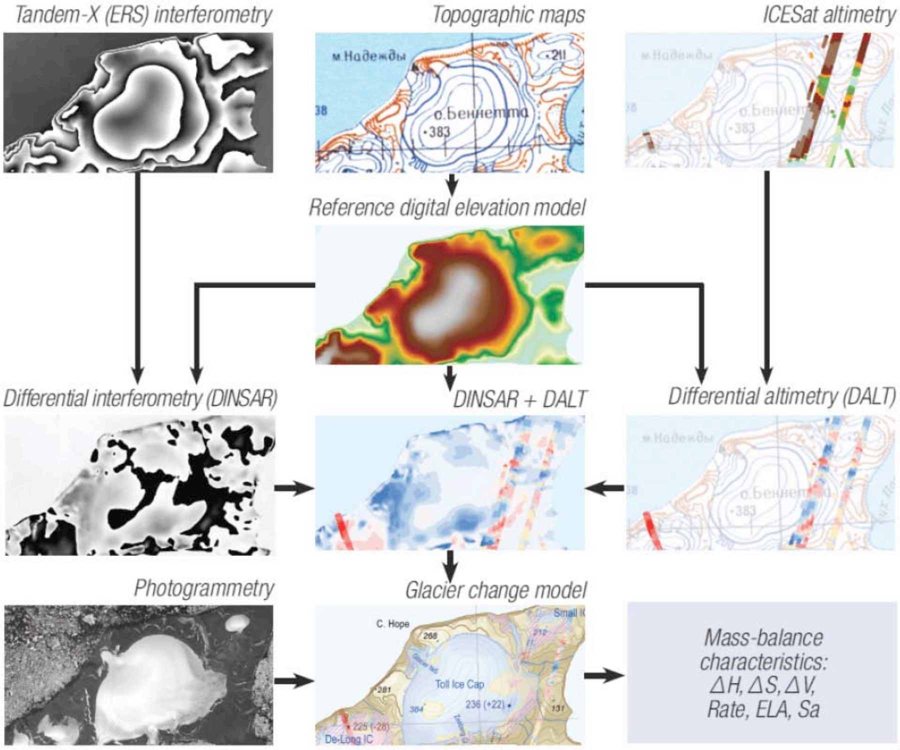

Figure 2. Basic procedures for glacier change modelling for Bennett Island.

WP4: Sea ice processes

The sea ice process studies have focussed on analysis of ice drift using data from several available sources, including large scale ice drift analysis from existing data sets available from Ifremer[2], NSIDC[3], EUMETSAT OSI-SAF[4] and atmospheric data sets from the last decades. Work has been done to analyse ice drift dynamics in response to various atmospheric wind systems. The ice drift and ice extent follow characteristic patterns that are determined by the large-scale atmospheric pressure and wind regimes. One characteristic pattern occurs when the North Atlantic Oscillation (NAO) index is negative in the winter months, which means that there a persistent low pressure in the North-Atlantic. This causes dominant south-westerly winds in the western Arctic region, resulting in highly dynamic and variable ice drift in the region. Under such condition, the eastern Arctic is a dominated by a high pressure with little wind and low variability of the ice drift pattern. The wind pattern and ice drift variability under this “West Arctic Cyclone” condition is shown in Fig. 3.

Sea ice drift analysis on regional scale has started using ENVISAT ASAR images collected in the area between the Fram Strait in west to Laptev Sea in east. The SAR database at NERSC has been built up with several thousand images for the period from 2004 to April 2012, when ENVISAT stopped. An automatic ice drift algorithm, based on correlation between sub-images, is presently used to retrieve ice drift vectors from SAR images and compare the results with other ice drift methods.

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[2] http://cersat.ifremer.fr/Data/Discovery/By-parameter/Sea-ice
[3] http://nsidc.org/data/sea_ice.html#SEA_ICE_MOTION
[4] http://saf.met.no/p/ice/index.html

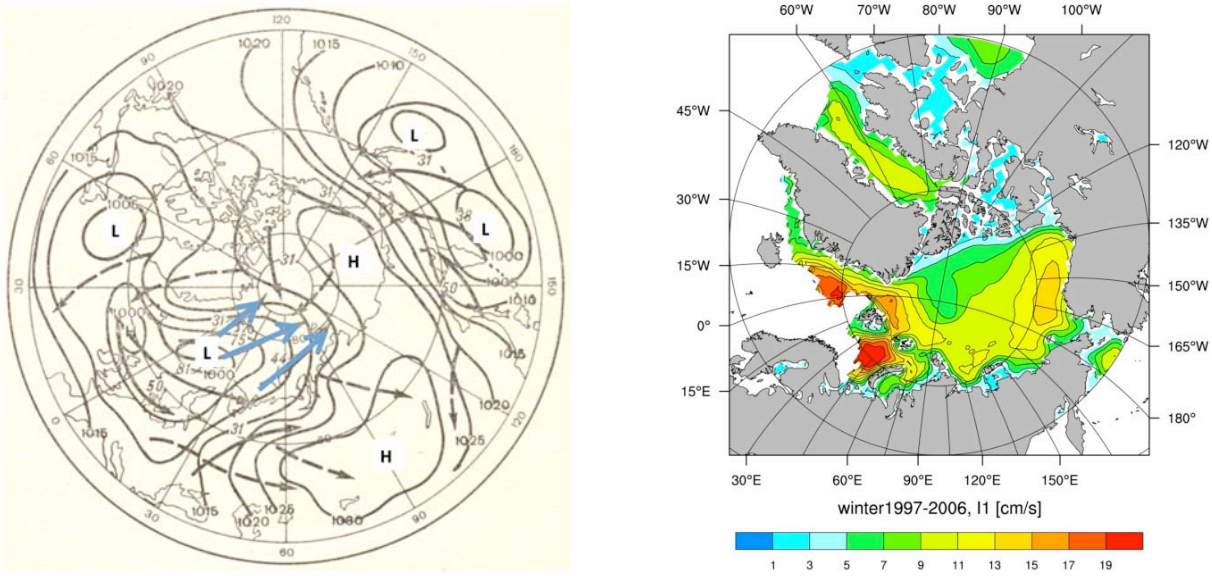

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Figure 3 (a) Air pressure and dominant wind pattern during the "West Arctic Cyclone" situation, where the blue arrows show the south-westerly winds from the North Atlantic into the Arctic; (b) map of ice drift variability (cm/sec) with high variability in the Barents Sea and Greenland Sea and low variability in other regions.

WP5: Iceberg detection

Satellite images to be used for detection of icebergs include optical images from Landsat, Terra ASTER, Monitor-E and Synthetic Aperture Radar (SAR) images from ENVISAT, RADARSAT, TerraSAR-X and Cosmo-SKYMED. Since most of the icebergs in the Barents-Kara Sea area are small, less than 100 m in horizontal extent, it is necessary to use high resolution. Pixels size for both optical and SAR images should be of order 10m. Optical images give more reliable identification of icebergs compared to SAR, because SAR has high-frequency speckle noise disturbing the iceberg detection. On the other hand, optical images are limited by cloud and darkness, and Russian Arctic region is cloud-covered most of the time. SAR can provide good data independent of cloud and light conditions, but iceberg observations are ambiguous and need to be confirmed by other observations. Iceberg detection depends also on the background conditions. Icebergs occur in (1) open water, (2) drifting sea ice, and (3) in fastice near coasts and in archipelagos. Examples of iceberg detection in optical images are shown in Fig. 4.

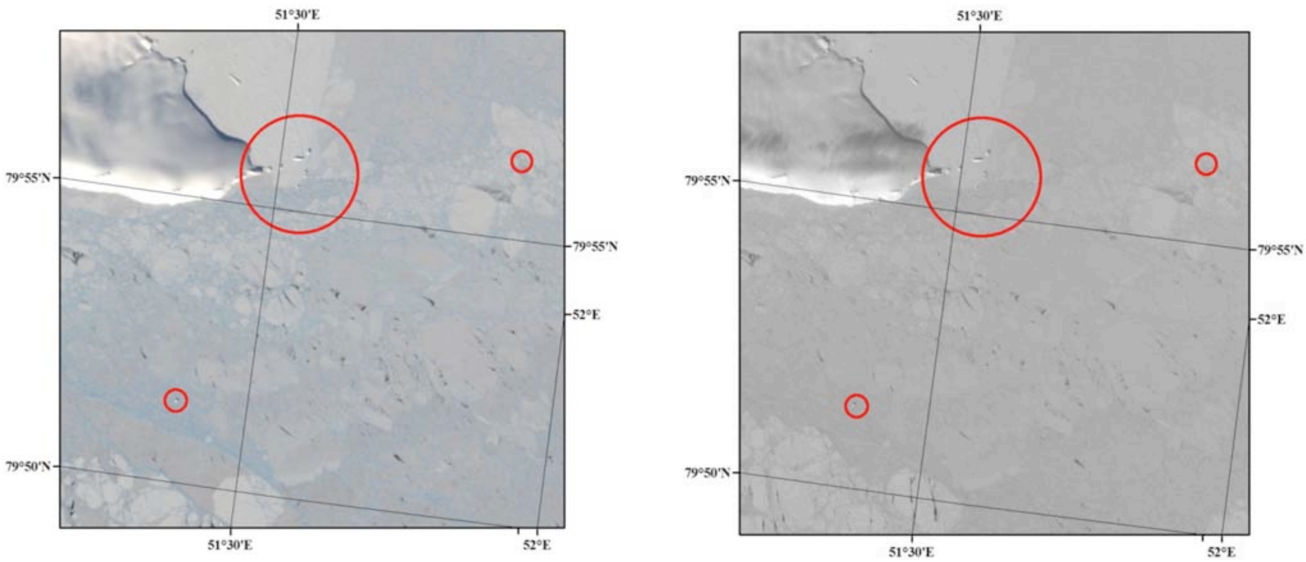

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Figure 4. (a) Landsat subimage from Franz Josef Land 05 April 2006, showing iceberg calving and spreading of icebergs into the drift ice; (b) Monitor-E subimage of the same area on 06 April, showing similar icebergs and sea ice as in (a).

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