Nansen Environmental and Remote Sensing Center

Technical Report no. 238

Kontrakt no. JOP.8.3.3.11.02.2

Norsk Romsenter

# ISOVERVÅKING MED SAR FOR KLIMA OG OPERASJONELLE TJENESTER

## FORBEREDENDE PROSJEKT UNDER SATHAV PROGRAMMET

*Stein Sandven*
*Kjell Kloster*
*Birgitte Furevik and*
*Torill Hamre*

**Nansen Environmental and Remote Sensing Center, Bergen, Norway,**

**May 2003**

**Nansen Environmental and Remote Sensing Center (NERSC)**
Edvard Griegsvei 3A
N-5059 Bergen, Norway
Phone: + 47 55 29 72 88
Fax: + 47 55 20 00 50
E-Mail: Stein.Sandven@nersc.no
http://www.nersc.no

| **TITLE** | **REPORT IDENTIFICATION** |
|---|---|
| Isovervåking med SAR for klima og operasjonelle tjenester<br>Forberedende prosjekt under SATHAV programmet | NERSC Technical Report no. 238 |
| **CLIENT**<br>Norsk Romsenter | **CONTRACT** No.<br>JOP.8.3.3.11.02.2 |
| **CLIENT REFERENCE**<br>Guro Dahle Strøm | **AVAILABILITY**<br>Open |
| **INVESTIGATORS**<br>Stein Sandven<br>Kjell Kloster<br>Birgitte Furevik<br>Torill Hamre | **AUTHORISATION**<br>Bergen, May 2003<br>Ola M. Johannessen |

Kort sammendrag på norsk

Prosjektet har vært en forberededelse til havisovervåking prosjektet under SatHav som skal starte opp i 2003. Tre hovedaktiviteter har inngått:

1) Planlegge bruk av “wideswath” SAR i polare havområder inkludert den marginale issone, og lage bruker scenarier og sampling strategier for hvordan SAR data skal anvendes til observasjon av spesifikke parametre som inngår i operasjonell iskartlegging. Aktiviteten har foregått i ært samarbeid med MI’s avdeling i Tromsø som har ansvar for den norske istjenesten.

2) Lage demoprodukter med “wideswath” SAR data. Ut fra eksisterende Radarsat wideswath data (og nye ENVISAT ASAR scener som ble tigjengelig fra januar 2003) er det laget et sett med demoprodukter fra SAR som skal brukes til isovervåking og andre overvåkingsoppgaver i de polare områdene. Eksempler er vist på høyoppløselig iskart, isfluks i Framstredet og isanalyser i Storfjorden hvor ASAR data brukes som input. Også høyoppløselig vindfelt fra ScanSAR er vist. Demoproduktene er laget i nært samarbeid med MI og NP.

3) Forberedlelse og utarbeidelse av ICEMON prosjektforslag under ESA GSE programmet. Prosjektforslaget ble aksptert av ESA og startet opp i februarf 3002. ICEMON er første fase i utvikling av operasjonelle tjenester for SAR produkter i polar områdene på europeisk skala hvor den norske aktiviteten beskrevet under punkt 1 og 2 skal danne grunnlaget. ICEMON skal integrere norsk og internasjonal kompetanse og ressurser slik at SAR-baserte produkter i kombinasjon med andre data og tjenester skal kunne tilbys til et bredt spektrum av brukere.

# Contents

# 1. INTRODUCTION

This report presents the results of three tasks carried out in the second half of 2002 and the first months of 2003 with the objective to prepare for operational use of SAR data in ice monitoring. The SATHAV programme has ice monitoring and forecasting as one of the main projects. SATHAV is a national programme to develop operational use of EO data in marine monitoring and forecasting[1].

Operational ice monitoring with EO data is also the core element in the ICEMON project[2], which is one of ten ESA GMES projects that will demonstrate operational services where EO data is part of the data sources. The ICEMON proposal was prepared in the autumn of 2002 with NERSC as coordinator. Contract negotiations with ESA took place in January – February 2003 and the project started in March 2003. Both ICEMON and SATHAV have similar objectives regarding ice monitoring where ICEMON has focus on the European dimension while SATHAV is a Norwegian programme.

# 2. PLAN FOR USE OF WIDESWATH SAR IN SEA ICE MONITORING

## 2.1 BRIEF DESCRIPTION OF THE PLANNED ICE MONITORING SERVICE

### Data provision

SAR data for ice monitoring in the Norwegian Arctic as well as the extended European sector of the Arctic, including Northern Sea Route, Greenland and Icelandic waters and the Baltic Sea, will primarily be downloaded and processed at KSAT. SAR acquisition in the extended region will be co-ordinated with Canadian and US coverage in the western part of the Arctic, and with Russian receiving stations in the eastern part. Use of SAR data will be co-ordinated with other EO data that provide large-scale maps of sea ice. Integrated sea ice products using data from passive microwave, infrared radiometer and scatterometer are from 2002 delivered by ***met.no*** which host the operational High Latitude Centre of the EUMETSAT Ocean & Sea Ice Satellite Application Facility (OSI SAF). Use of SAR data will supplement the OSI SAF products by providing higher-resolution information.

### Algorithms for retrieval of geophysical parameters.

Existing algorithms developed over the last decade will be implemented for operation use to retrieve ice parameters from SAR. Algorithms and derived products can be divided in to categories: near real time products for operational users (ice mosaics, ice edge location, ice drift, ice types, etc.) and offline climate-related products (thickness, fluxes in straits etc.) Ice drift and ice type classification will also be derived form scatterometer data with coarser resolution.

### Products development and testing for operational use

1 OSI-SAF sea ice products delivered by ***met.no***. Three operational products are available for the European sector of the Arctic Ocean: Ice concentration (%), Ice edge: probability of ice coverage, and Ice type: probability of multi-year/ first-year. The main users of the OSI SAF products are weather forecast centers, and the main intended use is input data to operational weather and ocean forecast models.

2 Sea ice products based on SAR data have been developed over the last 10 years, but has not yet been implemented in operational monitoring in Norway. Proposed products are
   - High-resolution ice maps for Svalbard area for operational users: fishing vessels, etc. Users who will receive the products: fishing vessels, commercial ships and other operation customers who need near-real time ice products.
   - Seasonal SAR ice classification in Storfjorden for monitoring polar bear habitats. The main user who will receive the products is the Environmental Management section of NPI

[1] SATHAV Programforslag, desember 2002,

[2] ICEMON: http:///www.nersc.no/ICEMON/

- Regional climate products from SAR: ice area flux in the Fram Strait and melt-freeze season in Storfjorden. Users: climate and sea ice modellers, NPI, DNV, Acsys/CliC.

All the SAR ice products will need to be validated and adapted to operational use. Examples of the proposed products are shown in chapter 3.

### Operational production and dissemination of products

For the Norwegian sector of the Arctic met.no, NERSC and KSAT will provide input to and generate the SAR ice products. Met.no's analysis system for meteorological and ice data in Tromsø will include SAR data in the daily production of ice charts. The OSI-SAF ice products are disseminated in near real time through the OSI SAF data distribution system (http://saf.met.no).. For users at sea, the C-STAR weather routing system provided by met.no will also be used to distribute met-ocean information to vessels as part of electronic charts. Dissemination to a wider range of users will be carried out for each of the service demonstrations

## 2.2 SAR SAMPLING SCHEME WITH 3 DAY REPEAT CYCLE

The Svalbard area, Fram Strait and Barents Sea is fully covered by wideswath SAR data from ENVISAT and RADARSAT every 3 days. The map in Fig.1 shows the descending and ascending orbits for the 3-day period (where the orbit numbers for 24 - 26.February 2003 are shown as an example). By exploiting the descending orbits (providing data between 0900 and 1200 GMT) as well as the ascending orbits (providing data between 1800 and 2100 GMT) it is possible to cover the ice areas twice per day. However, for the operational daily ice chart production by MI it is usually sufficient to obtain data once per day. In cases where there is need for more frequent data coverage, for example during critical operations when ships are working in the ice, data can be acquired and used twice per day.

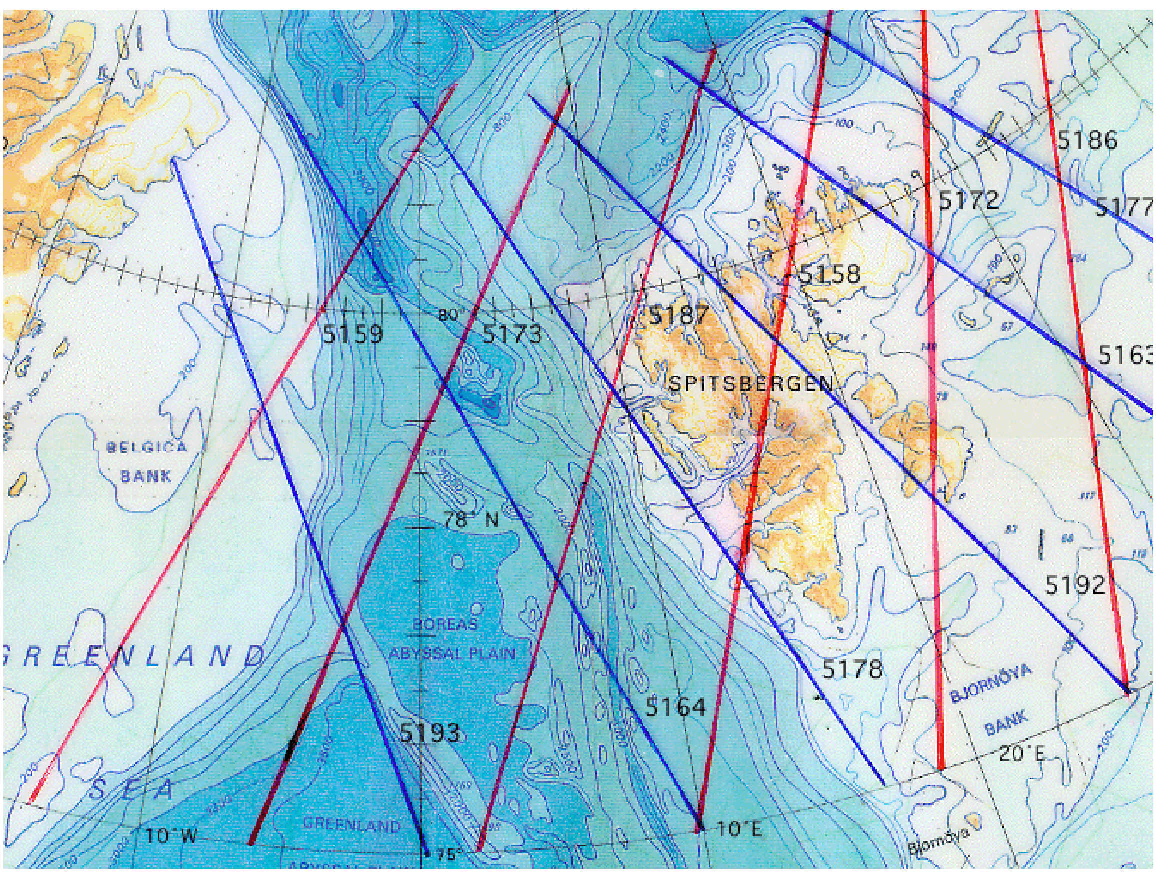


Fig. 1. ENVISAT ASAR orbits. The red lines are ASAR descending orbits (and the blue lines are the ascending orbits with orbit numbers for the period 24 – 26 February. The same pattern is repeated every 3 days and shifted slightly to the west.

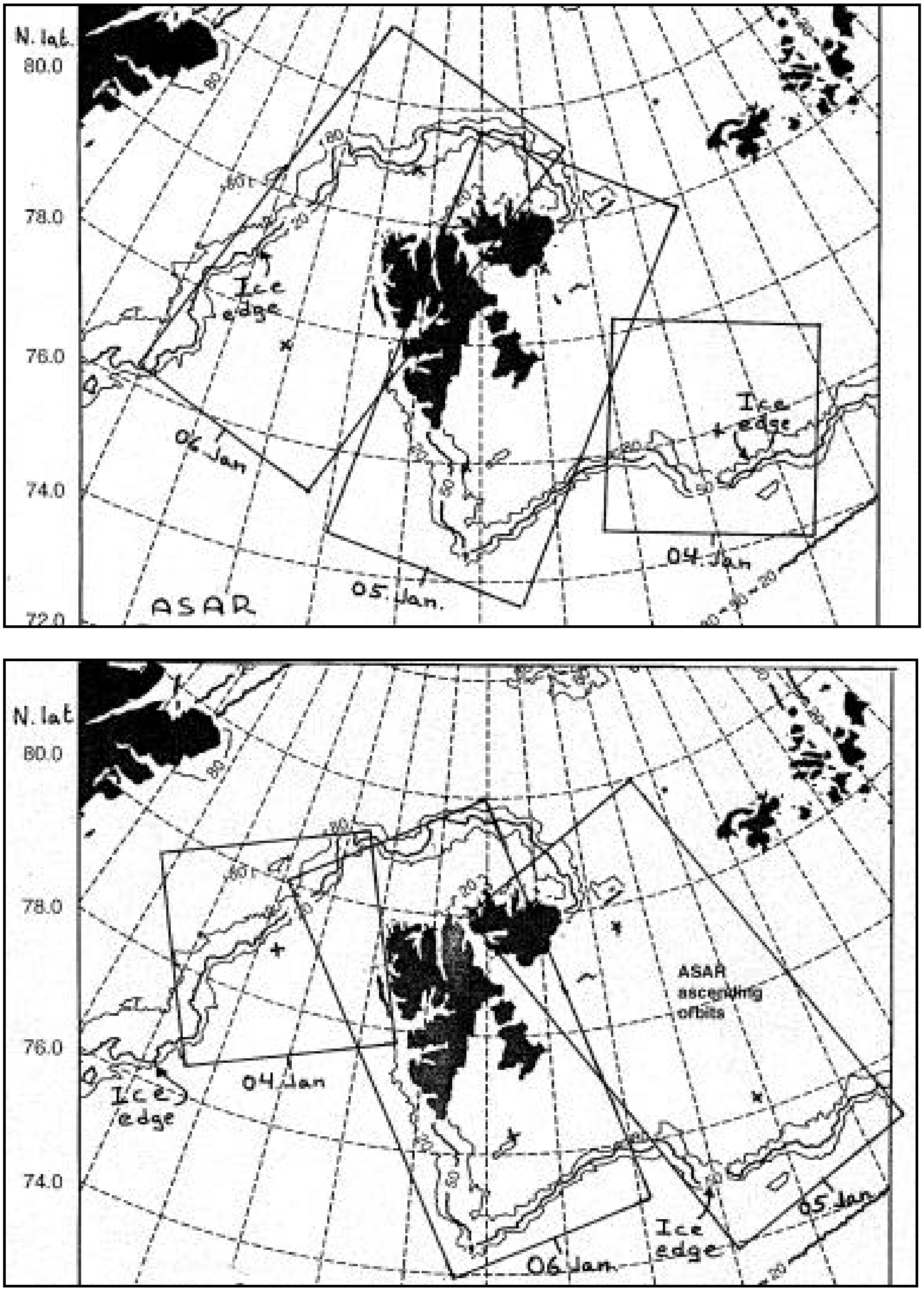



Figure 2.. Example of minimum ASAR coverage ( 4 – 6 January 2003) of the Fram Strait and Svalbard area using 5 scenes from descending orbits (upper fig.) or ascending orbits (lower fig.)

Optimal utilisation of the available SAR data is currently discussed with MI for the operational ice charting and with NP for monitoring of ice for climate and environmental indicators. Scenarios of the most important ice areas to be covered have been studied, as shown in Fig. 2. A minimum of 5 scenes every 3 days (10 scenes per week) will cover the most important areas around Svalbard. A more realistic requirement for wideswath SAR data, taking into account the whole area where MI produces ice maps, is of order 20 scenes per week, corresponding to about 1000 scenes per year.

## 2.3 ASAR MODE SELECTION

ASAR offers several modes of operation, and for ice monitoring we will combine the possibility to map large ice areas using the Wideswath mode with the possibility to map smaller areas with alternating polarisation in order to obtain maximum information from limited areas where more detailed information is required. There are 7 possible Single Beam modes of width 55 -100km, and one Wide Swath mode (ScanSAR) of width 405km with VV or HH polarization. Each Single Beam mode can be in either **Image** (VV or HH) or **Alternating Polarization** (VV/HH, VV/VH or HH/HV). The **Wide Swath** mode (VV or HH) combines several beams to generate a 405 km wide image. North of 81N, the Wide Swath of two successive descending orbits will overlap completely, providing full coverage every day. An overview of the ASAR modes is shown in Fig. 3.

**Image mode (VV or HH)** (single beam) | **Wideswath Mode (VV or HH)** (multiple beam) | **Alternating Pol. mode** (single beam)

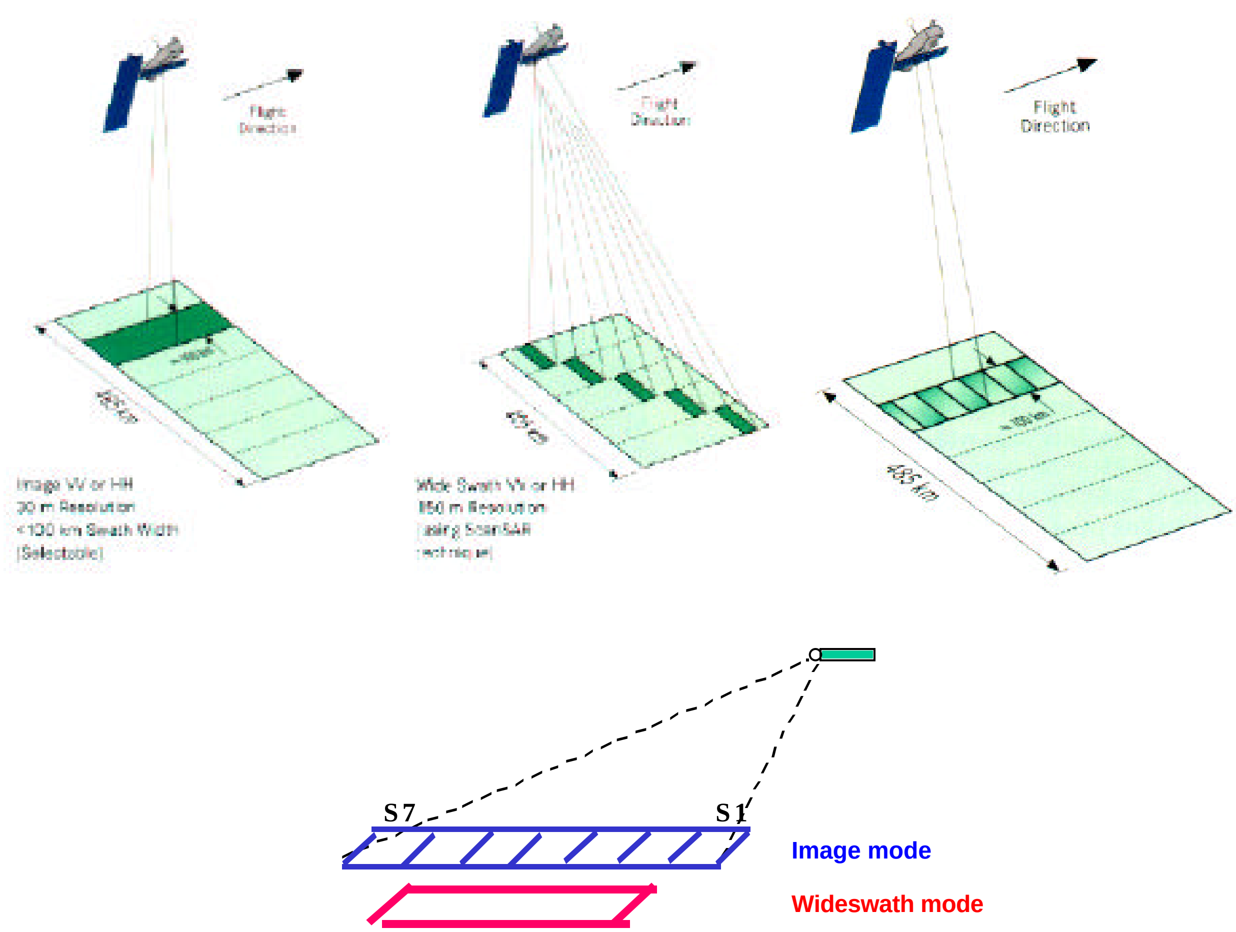



Figure 3. Illustration of the ASAR modes to be used in ice monitoring.

***Table 1. Technical specifications of ASAR Image Mode***

| Image Swath | Swath width (km) | Ground position from nadir (km) | Incidence angle range | Noise equiv. sigma Zero |
|---|---|---|---|---|
| S1 | 105 | 187 - 292 | 14.0 - 22.0 | - 20.4 |
| S2 | 105 | 242 - 347 | 19.2 - 26.7 | - 20.6 |
| S3 | 82 | 337 - 419 | 26.0 - 31.4 | - 20.6 |
| S4 | 88 | 412 - 500 | 31.0 - 36.3 | - 19.4 |
| S5 | 64 | 490 - 555 | 35.8 - 39.4 | - 20.2 |
| S6 | 70 | 550 - 620 | 39.1 - 42.8 | - 22.0 |
| S7 | 56 | 615 - 671 | 42.5 - 45.2 | - 21.9 |

The baseline mode to be used in ice monitoring will be Wideswath mode, supplemented by Image Mode and Alternating Polarisation when needed for specific monitoring requirements and for validation.

## 2.4 First validation activities for ASAR ice monitoring

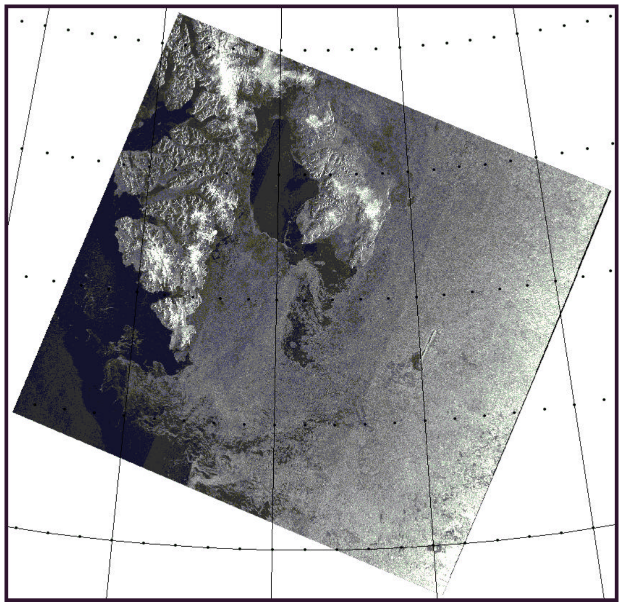
ASAR data from KSAT started to be produced in January 2003, and the first data set with systematic acquisitions was obtained in February - March in connection with the Polarstern expedition in the Svalbard area. The expedition provided the first validation data set for ASAR Wideswath and Alternating Polarisation images. Extensive in situ observations including use of helicopter and aircraft resulted in a unique data set which will primarily be used for CRYOSAT validation, but will also be important for ASAR validation. In April an expedition with Lance to Storfjorden provided another set of validation data were aerial photographs from helicopter were obtained in conjunction with ASAR data.

In similar manner as was done with ERS SAR data starting in 1991, it will be necessary to establish links between SAR backscatter (sigma-0) and SAR image texture and real ice characteristics, quantified by ice concentration, ice types and other properties such as surface roughness. All the experience gained for the ERS period will be used to retrieve ice information from ASAR. But ASAR with several modes and polarisations requires additional validation work in order to establish operational monitoring by use of wideswath SAR.

Further validation work is planned in cooperation with NP, using Lance, and MI where opportunity data from ships and aircraft will be collected over the next years. It will be necessary to obtain ASAR data in conjunction with the planned field activities in order to build up databases of ice data that can be used for validation. This will be integrated activities in the SATHAV and ICEMON projects.

# 3. DEMONSTRATION PRODUCTS FROM WIDESWEATH SAR

## 3.1 HIGH-RESOLUTION ICE CHARTS



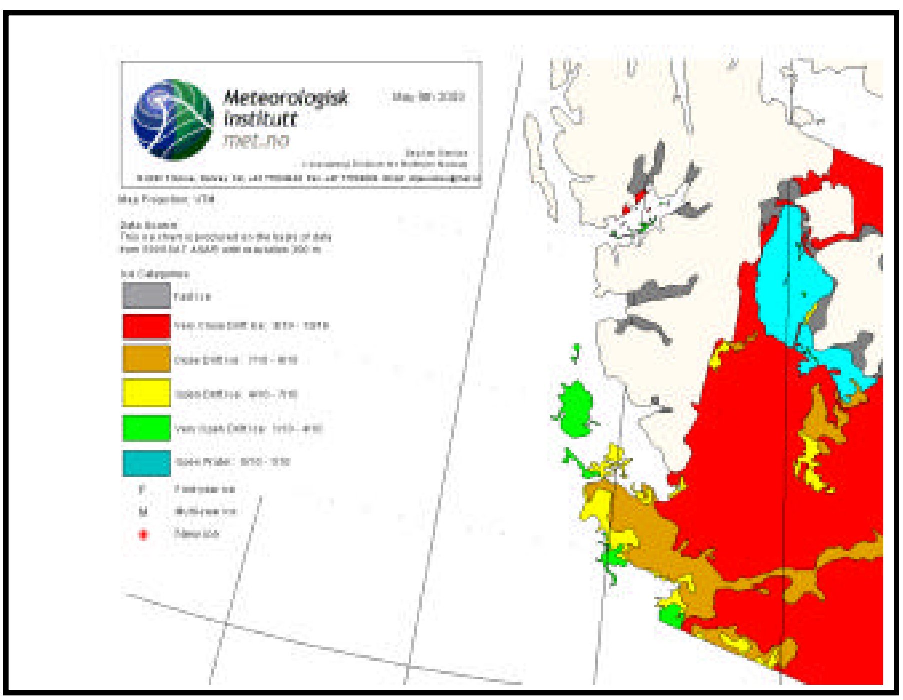



Figure 4. Example of ASAR wideswath image (upper fig) and results of ice analysis performed by met.no's ice charting system at VNN in Tromsø (lower fig.). Courtesey H. Tangen, met.no

### 3.2 Ice classification for environmental management in the Svalbard area

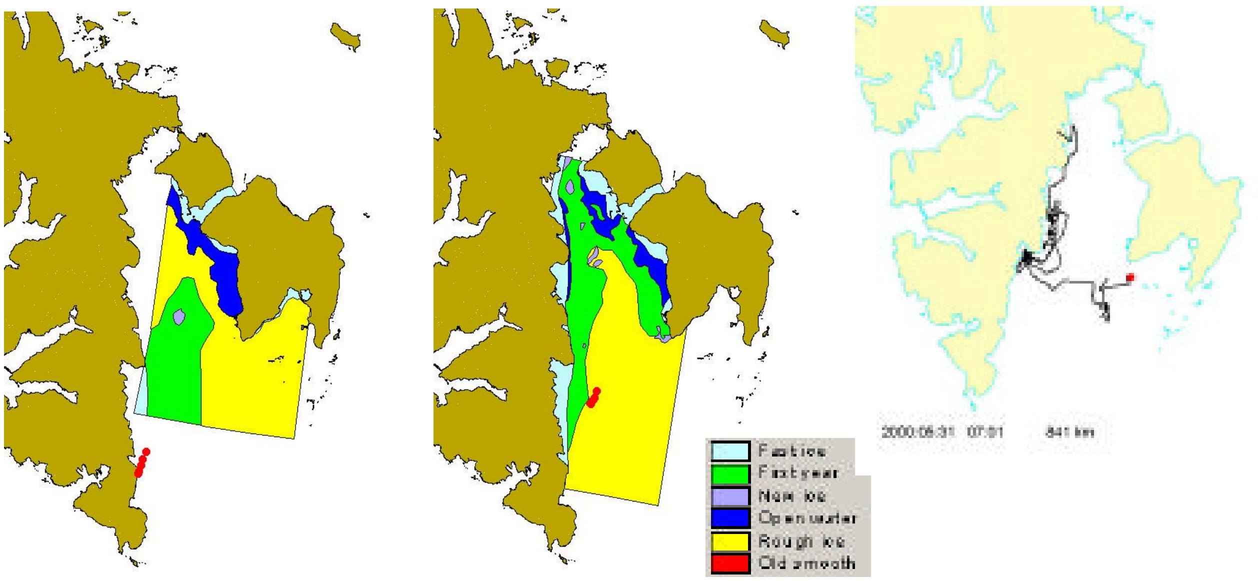



Figure 5. Example of ice type classification in support of NP's management of polar bears and seals (courtesy, H. Goodwin, NP)

### 3.3 Climate indicator 1: duration of ice season in Storfjorden

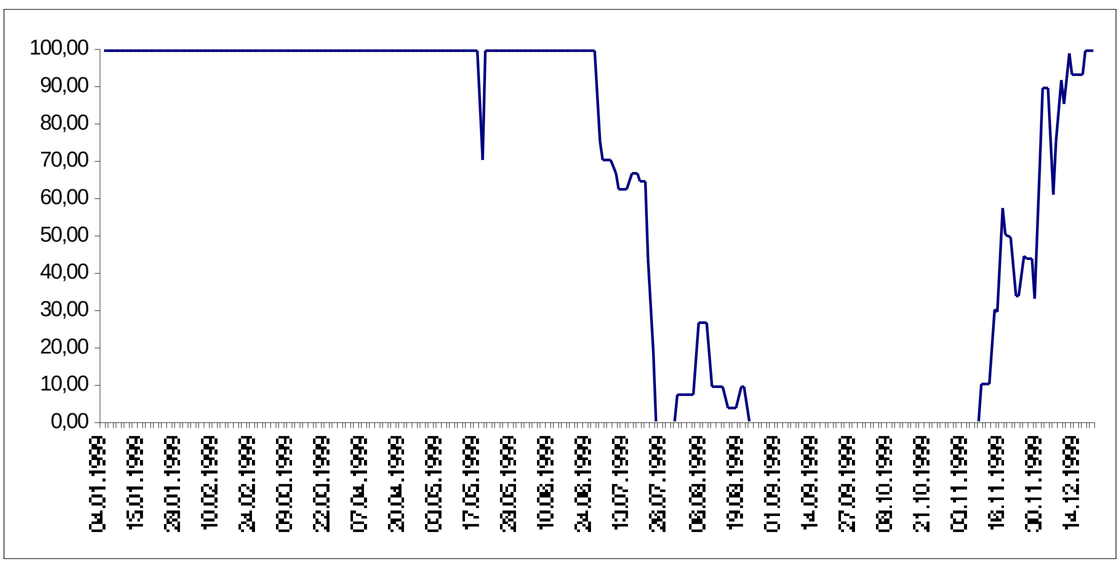



Figure 6. Duration of ice season in Storfjorden, represented by ice concentration as function of time of year (1999). The indicator needs regular observations throughout the ice season. Courtesey: H. Goddwin, NP

## 3.4 Climate indicator 2: ice area flux in the Fram Strait

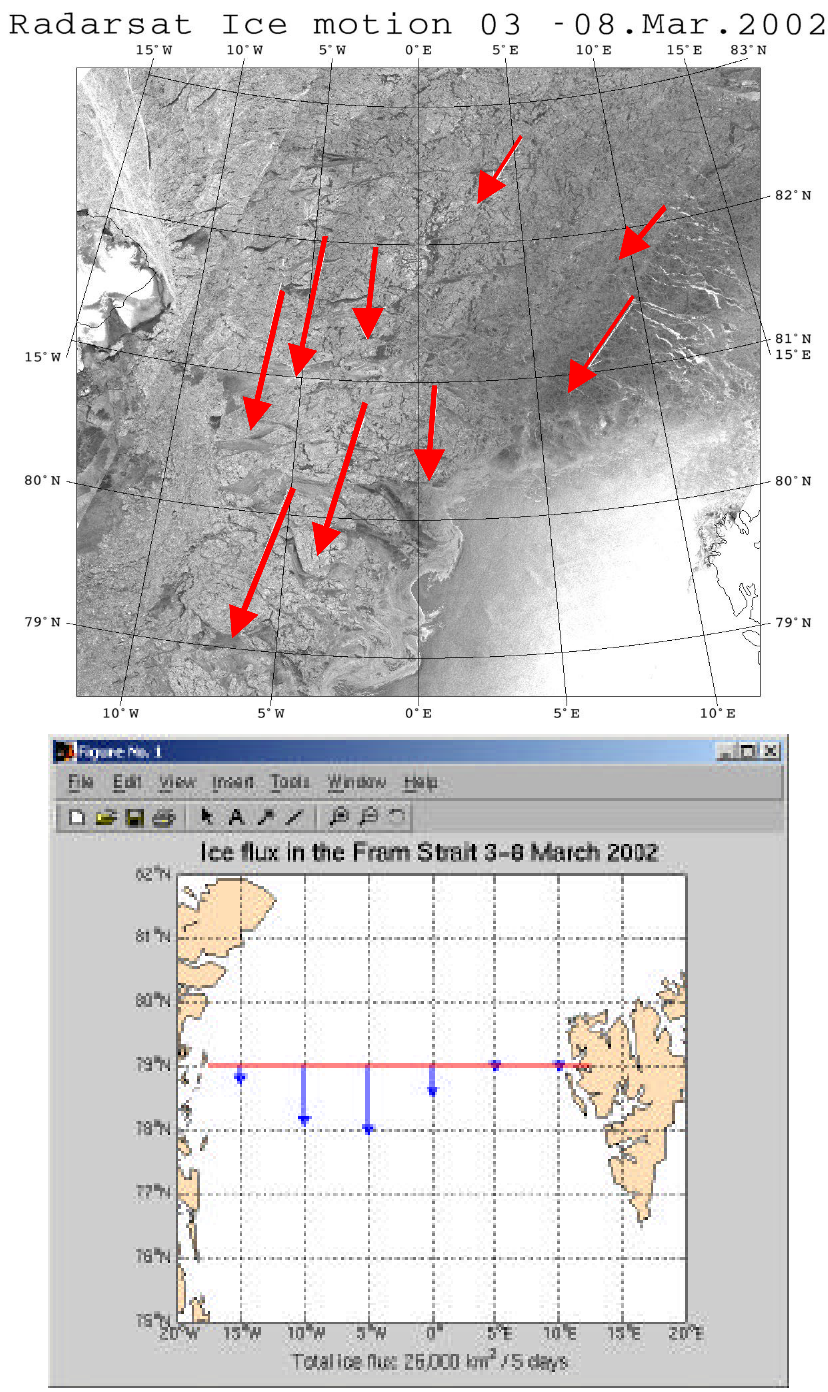



Figure 7. The upper firgure shows displacement vectors derived from two ScarSAR images obtained on 3 and 8 March 2002, and the lower figure shows estimation of the area flux across 79 in the Fram Strait in this 5 day period.

## 3.5 RESULTS OF ICE DRIFT ANALYSIS USING RADARSAT SCANSAR

### Introduction

Timer series of SAR images can be used to map ice drift independent of cloud and light conditions. In the Fram Strait, wideswath SAR images can cover the whole strait, allowing the total ice area flux to be mapped by SAR data, provided that images are obtained at regular intervals (for example every 3 – 6 days), and that ice features can be recognised in the sequence of SAR images.

When operating in ScanSAR mode or Global mode (400km swath), Envisat ASAR will have a potential coverage area that is similar to that of the Radarsat ScanSAR-B mode (450km swath). The orbit pattern is somewhat finer for Envisat, with descending pass separation at 79N (across the Fram Strait) of 15km, as compared to 22km for Radarsat.

### Acquisition of RADARSAT ScanSAR images in 2001 - 2002

Within each Radarsat repeat period of 24 days, data from four descending orbits, with repeat numbers 097, 168, 254 and 340, have been obtained from the archives of Alaska SAR Facility (ASF) for the period from November 2001 to August 2002. Table 2 gives an overview of the orbits where data were obtained.

***Table 2. Archived repeat orbits in the Fram Strait 01. Nov 2001 - 05.Aug. 2002.***

| Repeat no. | First date | Longitude of centerline at 80N | Last date | No of orbits |
|---|---|---|---|---|
| 097 | 03. Nov. 01. | 12.2W | 25.July 02 | 11 |
| 168 | 08. Nov. 01. | 0.5W | 30.July 02 | 12 |
| 254 | 14. Nov. 01. | 6.9W | 05.Aug. 02 | 12 |
| 340 | 20. Nov. 01. | 13.3W | 18.July 02 | 11 |

All the ScanSAR scenes available in the ASF archive were in the SCW-B mode that is approximately 450km wide and 500km long. All were on descending orbits. Using the received scenes in pairs for the ice displacement analysis, their overlap in width at 80N varies from a maximum of 430km (for the pair 340-097) down to a minimum of 230km (for the pair 097-168). This is quite acceptable for analysis. The length of the time intervals for the four available pairs 097-168, 168-254, 254-340 and 340-097 are 5, 6, 6 and 7days respectively. The sum of these intervals is the Radarsat repeat period of 24 days.

### Preprocessing of scenes

The ASF low-resolution (400m pixelsize) data has low speckle-noise (about 300 looks or ±0.25dB). The calibration equation for the backscatter coefficient, sigma0 is given by ASF as:

$$\text{Sigma-0(dB)} = 10 \cdot \log(0.000022 \cdot (DN \cdot DN - 11000 \cdot NR))$$

where DN is the data (or pixel-value). NR is a noise floor-value, it is range-dependent and vary between approx. 0.02 and 0.05, corresponding to a noise-equivalent sigma0 (NESZ) of -23dB and -19dB in near and far range respectively. Most of the scenes are displayed with a range of greytones between the pixelvalue of zero (black) and 80 (white). DN=80 correspond to a sigma-0 value of -8.8dB, which is higher than the backscatter for most ice types except rough ice. Gridding was made using the "gopgrid" program developed at NERSC, with use of the Radarsat orbit parameters and using as a reference point the scene center coordinates as given by the Leader-file Facility-related data-record.

## Analysis of ice motion

Ice displacement vectors are determined by a start and stop position of identified ice features and the time interval. The displacement vectors can be calculated by an ice motion algorithm as well as by manual analysis. Recognition of sea ice features for displacement is often difficult if the time interval is 7days between the scenes, because the ice drift velocity in this region is fairly high. Ice feature determination is also difficult near the ice edge more rapid changes than further into the ice. Also, the number of recognizable features significantly decreases in the summer compared to the winter and spring conditions.

In order to compute the Fram Strait ice area flux, ice displacement can be measured across a line between Nordostrundingen in NE-Greenland to the NW-tip of Svalbard. This is the shortest distance across the strait, with a length of nearly 400km. Results of ice displacement analysis from November 2001 – June 2002 are shown in Table 3, with average values for the western and the middle part of the line. The eastern third had no data because it was mostly icefree.

***Table 3. Ice displacement (km) across a line from 81°N, 10°W (Greenl) to 80°N,10°E (Svalb.).***

| Time interval 2001 -2002 | Western part 10W -3W | Eastern part 3W -10E | Edge position |
|---|---|---|---|
| 03. -08.Nov. | 100km/170° | 100km/180° | 05E |
| 08. -14.Nov. | 110km/180° | 110km/180° | 04E |
| 14. -20.Nov. | 080km/180° | 090km/195° | 04E |
| 20. -27.Nov. | 170km/190° | 160km/200° | 05E |
| 27/11 -02/12 | 070km/210° | 060km/210° | 04E |
| 02. -08.Dec. | 030km/030° | 030km/040° | 03E |
| 08. -14.Dec. | 080km/190° | 070km/190° | 02E |
| 14. -21.Dec. | 100km/170° | 090km/170° | 03E |
| 21. -26.Dec. | 100km/180° | 100km/180° | 03E |
| 26./12 - 01/01 | 080km/190° | 070km/210° | 03E |
| 01. -07.Jan. | 030km/190° | little ice | 00E |
| 07. -19.Jan. | No data | | |
| 19. -25.Jan. | 100km/200° | 090km/200° | 05E |
| 25. -31.Jan. | 090km/190° | 090km/210° | 04E |
| 31/01 -07/02 | 110km/210° | 150km/220° | 02E |
| 07. -12.Feb. | 040km/180° | 040km/200° | 02E |
| 12. -18.Feb. | 120km/200° | 100km/200° | 01W |
| 18. -24.Feb. | 180km/190° | 230km/190° | 02E |
| 24/02 -03/03 | 180km/180° | 140km/190° | 03E |
| 03. -08.Mar. | 110km/190° | 080km/180° | 03E |
| 08. -14.Mar. | 120km/170° | 070km/180° | 03E |
| 14. -20.Mar. | 120km/170° | 100km/180° | 05E |
| 20 -27.Mar. | 070km/160° | 070km/180° | 06E |
| 27/3 - 01/4 | 100km/180° | 080km/190° | 05E |
| 01. -07.Apr. | 100km/170° | 090km/180° | 06E |
| 07. -13.Apr. | 130km/180° | 110km/160° | >04E |
| 13. -20.Apr. | 050km/150° | 030km/150° | >05E |
| 20. -25.Apr. | 070km/180° | 060km/190° | 07E |
| 25/04 -010/5 | 120km/180° | 090km/200° | 05E |
| 01. -07.May | 100km/170° | 090km/180° | >04E |
| 07. -14.May | 070km/150° | 050km/150° | >05E |
| 14. -19.May | 060km/180° | 040km/190° | 05E |
| 19. -25.May | 060km/100° | 050km/110° | 05E |
| 25. -31.May | 070km/100° | 060km/120° | 05E |
| 31/05 - 070/6 | West edge at 05W | 030km/180° | 03E |
| 07. -12.June | Scattered ice. | 050km/200° | No clear edge. |

A larger ice displacement is generally found in the western part (off the Greenland coast at Nordostrundingen) relative to the middle part of the strait. Between 19 and 25.May, a large polynya formed at the NE-Greenland coast. Ice displacement direction in the Fram Strait is generally to the South except for 19 -31.May when it was to the East during the polynya opening. The displacement also generally increases from the pack-ice field in the north in toward the narrower Strait in the South. After mid-June, the ice field was very open, with only a few recognizable ice features and thus difficult to analyse for motion.

## Computation of ice area flux

From the displacements in Table 3, the ice area-flux across the defined line can be calculated. It is the sum of the products of the mean displacement, the ice-covered length of each part (130 km for a fully ice-covered west part), and the negative cosine of the drift direction. The mean ice edge position is used to determine the ice-covered length of the east part. The results are shown in Table 4

***Table 4. Southward ice flux over a line from 81N, 10W to 80N, 10E.***

| Time interval 2001 -2002 | Area-flux west of 3W | Area-flux east of 3W | Total flux (in 1000 km$^2$) |
|---|---|---|---|
| 03. -08.Nov. | 13 | 15 | 28 |
| 08. -14.Nov. | 14 | 14 | 28 |
| 14. -20.Nov. | 10 | 11 | 21 |
| 20. -27.Nov. | 22 | 23 | 45 |
| 27/11 -02/12 | 08 | 07 | 15 |
| 02. -08.Dec. | -4 | -2 | -6 |
| 08. -14.Dec. | 10 | 06 | 16 |
| 14. -21.Dec. | 13 | 10 | 23 |
| 21. -26.Dec. | 13 | 11 | 24 |
| 26/12 -01/01 | 10 | 07 | 17 |
| 01. -07.Jan. | 04 | 00 | 04 |
| 07. -19.Jan. | No data. | | |
| 19. -25.Jan. | 12 | 13 | 25 |
| 25. -31.Jan. | 12 | 10 | 22 |
| 31/01 -07/02 | 13 | 10 | 23 |
| 07. -12.Feb. | 05 | 03 | 08 |
| 12. -18.Feb. | 15 | 03 | 18 |
| 18. -24.Feb. | 23 | 20 | 43 |
| 24/02 -03/03 | 23 | 15 | 38 |
| 03 -08-Mar. | 14 | 09 | 23 |
| 08 -14-Mar. | 15 | 08 | 23 |
| 14 -20-Mar. | 15 | 15 | 30 |
| 20 -27-Mar. | 08 | 12 | 20 |
| 27/3 - 01/4 | 13 | 12 | 25 |
| 01. -07.Apr. | 13 | 15 | 28 |
| 07. -13.Apr. | 17 | 17 | 34 |
| 13. -20.Apr. | 06 | 04 | 10 |
| 20. -25.Apr. | 09 | 11 | 20 |
| 25/4 - 01/5 | 16 | 13 | 29 |
| 01. -07.May | 13 | 13 | 26 |
| 07. -14.May | 08 | 06 | 14 |
| 14. -19.May | 08 | 06 | 14 |
| 19. -25.May | 01 | 03 | 04 |
| 25. -31.May | 02 | 04 | 06 |
| 31/5 - 07/6 | 01 | 03 | 04 |
| 07. -12.June | - | | 02(?) |
| Total Sum (03.Nov.01 -12.Jun.02, except 07-19.Jan). = 704 000 km.$^2$ | | | |

The length of the time intervals in the table vary between 5 and 7 days. The highest flux value (20. -27.Nov.) is 45 000 km.$^2$ over 7 days, corresponding to a mean value of 6400 km.$^2$ /day. The mean daily ice flux value measured during the total period of 209 days is 3370 km.$^2$ /day.

## Data availability and accuracy of drift estimates

It is assumed that all the scenes in the ASF archive have been read down by KSAT according to a fixed schedule determined by a mutual agreement with the Radarsat operating center. The change to a larger (more south) coverage in mid-May 2002 for repeats 097 and 340 was given by a change in the Radarsat readdown schedule from Canada /US to TSS, but the reason behind this is not known. The shift was essential for including regular measurements also in the south part of the Strait.

The overlap in width (range direction) for the available scene pairs is quite acceptable. But for ice motion analysis, the time spacing should be shorter, preferably about 3 days. E.g. for the repeat-pair 168-254 the spacing is 6 days with an overlap in range of about 75%. By including also orbit repeat no. 211 into the schedule, two intervals of 3 days, each with 85% overlap would then be available. The number of recognizable features for mapping of the ice displacement would then be considerably increased, and also the short-term changes in ice motion would be better resolved.

The accuracy of the ice drift field depends on the accuracy of each drift vector and the density of vectors. The first factor is dependent on the scene center coordinates, found by comparison with shorelines to be within 2km of correct position. Each vector, being dependent on coordinates for two scenes, should then be well within 5km in accuracy. This is considered to be sufficient for the present analysis. For scenes with visible coastlines, increased accuracy up to about 1km is possible if more accuracy is required.

More important is the often sparse and /or uneven distribution of reliable displacement vectors. Therefore, interpolation can be necessary over distances of several hundred kilometers where no reliable vectors can be found. The error due to this can in extreme cases amount to several tens of km. A more detailed and time-consuming analysis may in some cases increase the vector density and decrease the interpolation distances, but the best solution will be to decrease the time interval between the pair of satellites scenes available.

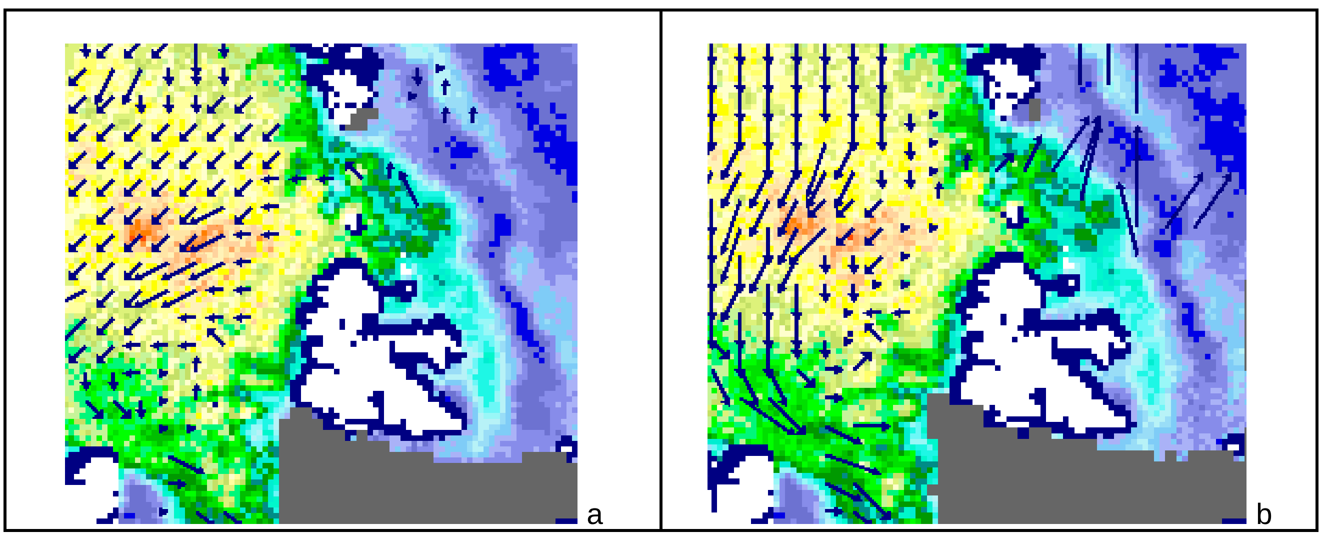



Figure 8. Ice products from scatterometer data provided by Ifremer in the ICEMON project, where yellow-green indicates multiyear ice and blue indicate firstyear ice. Arrows indicate ice drift. Image a is from 5 April 2003, and image b from 6 April 2003.

## Plan for further work

In the context of ICEMON and SATHAV, the ice area flux through the Fram Strait retrieved from SAR images will be further developed in co-operation with NP. Other ice drift data in the region can be used, either for comparison or for filling-in of coverage. Upward Looking Sonar (ULS) measurements are data to be used for validation of ice drift at the sites of the moorings. Ice thiockness data from the ULS will be used to improve the ice volume fluxes, which is a key climate indicator. Satellite microwave imagery of low resolution (e.g. the SSMI sensor on the DMSP satellite, the AMSR-sensor on the Aqua satellite and the Scatterometer on Quick-Scat satellite) can also be used to give some coarser ice drift vectors and ice type classification as shown in Fig. 8. All these sensors use algorithms for correlation between two successive images of the area.

The demonstration product produced by RADSARSAT images from November 2001 to August 2002 will be followed up by similar products derived from a sequence of ENVISAT ASAR data planned for the period 2003 – 2004.

When CRYOSAT ice thickness data becomes available, tentatively from 2005, synoptic ice thickness data for the whole Arctic will be available for the first time. These data will in combination with ice drift data provide improved estimates of the ice volume fluxes out of the Fram Strait.

### 3.6 High-resolution wind field in the Marginal Ice Zone

The SAR wind application developed at NERSC[3], based on ERS data, has now been modified for use with RADARSAT ScanSAR data. Used of Wideswath SAR from RADARSAT and ENVISAT allows mapping of wind in the whole Svalbard area, with possibility to map twice per day using both and descending passes. This means that SAR data has potential for operational use in monitoring of areas where high-resolution wind is required. In this section a short description of the calibration and wind retrieval processing steps for Radarsat wide swath images is presented, and one example of wind retrieval from ScanSAR data is presented.

## Calibration

Radarsat ScanSAR wide B is the only calibrated SAR mode on Radarsat-1. Since it is calibrated it can be used for wind retrieval. But the accuracy (±1 dB) is not as good as for ERS SAR (±0.5 dB). A calibration program can be downloaded from Alaska SAR facility (ASF) at http://www.asf.alaska.edu/apd/software/download.html

Calibration of the Wide B scene from Svalbard on 03 March 2002 06:42 UTC and using the conversion script (las2jpeg) gives the quicklook image as shown in Fig. 9.

## Wind retrieval

For ERS SAR there have been developed C-band transfer functions for wind speed retrieval. ERS SAR is VV polarised while Radarsat ScanSAR is HH polarised. So in order to use the CMOD functions for ScanSAR data a polarisation ratio is needed. Following the recommendations by Vachon and Dobson (2000)[4] the Kirchhoff polarisation ratio is here used together with the CMOD-IFR2 algorithm to create a hybrid model for ScanSAR HH images.

The wind speed retrieved from this Radarsat ScanSAR wide B image assuming a wind direction of 180deg (southerly wind) is shown in Fig. 10.

---

[3] The method is also summarized in NERSC technical report no. 213: Development of satellite remote sensing for marine monitoring and climate applications.

[4] P. W. Vachon and F. W. Dobson, 2000, Wind retrieval from RADARSAT SAR images: Selection of a suitable C-band HH polarisation wind retrieval model, *Canadian Journal of Remote Sensing*, Vol. 26, No. 4, August.

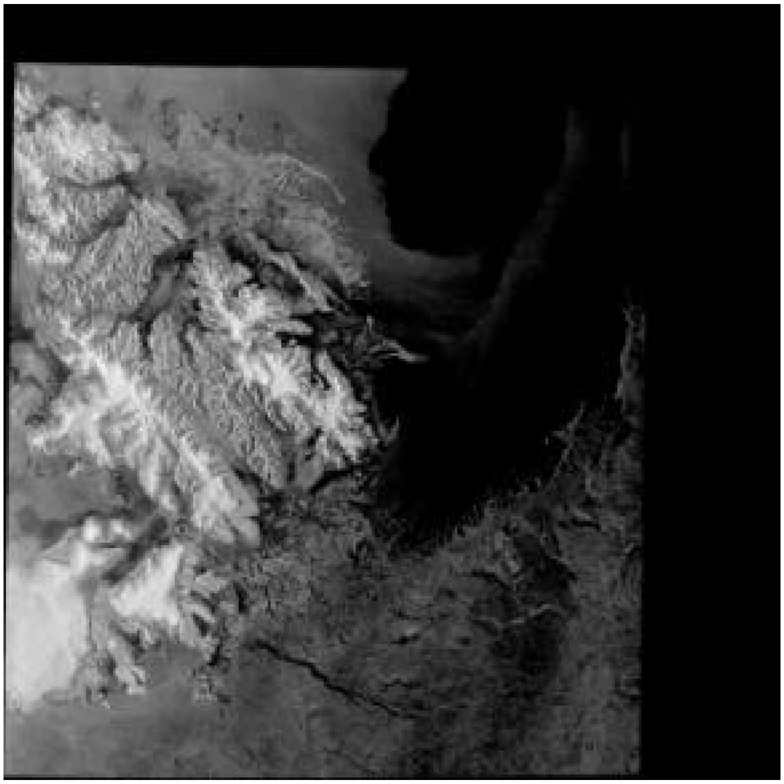


Figure 9. RADARSAT ScanSAR B image (not georeferenced) selected for the wind analysis 03 March 2002. The images is from a descending orbit (06:42 UTC) showing the Svalbard archipelago.

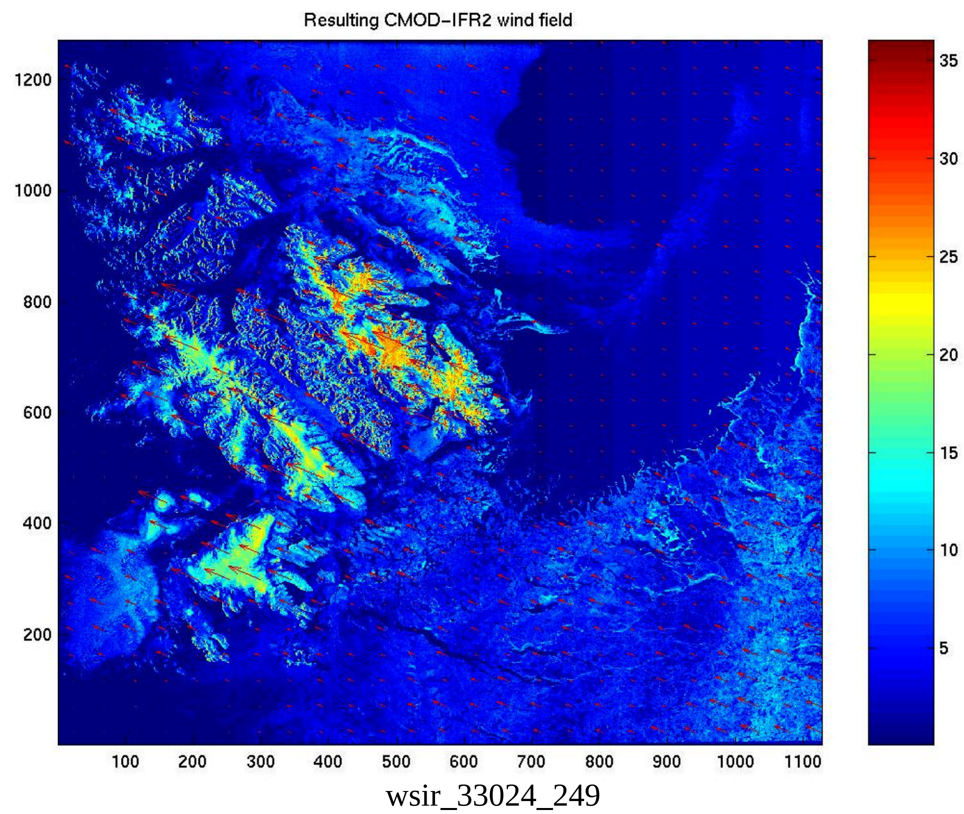



Figure 10. Wind speed retrieval, presented in m/s by the colour code, without masking land and ice-covered and before geo-referencing is applied.

Satellite flight direction is along the y-axis and antenna look direction is along the x-axis. There seems to be a lower threshold value at –25.5dB, which has taken effect in the upper right part of the image. The weak increase with range in the calculated wind speed is due to the constant backscatter value with increasing incidence angle.

## First result

In Fig. 11 the wind field has been geolocated and plotted on a map. The wind vectors over land and ice are artificial and should be removed before the products is ready. Future work will also be including image spectra for estimation of wind directions over the ScanSAR images. This example is not optimal for wind demonstration because most of the image is covered by land and sea ice. However, the example demonstrates the capability to map wind speed and direction in ice-free areas around Svalbard including the fjords. Further work is needed to identify sea ice and mask out sea ice areas before the wind products is complete. Examples of wind retrieval from ASAR data have not been produced because calibrated ASAR images are not yet available. We plane to adopt the wind algorithm to ASAR images and produce examples as soon as calibrated ASAR data are available.

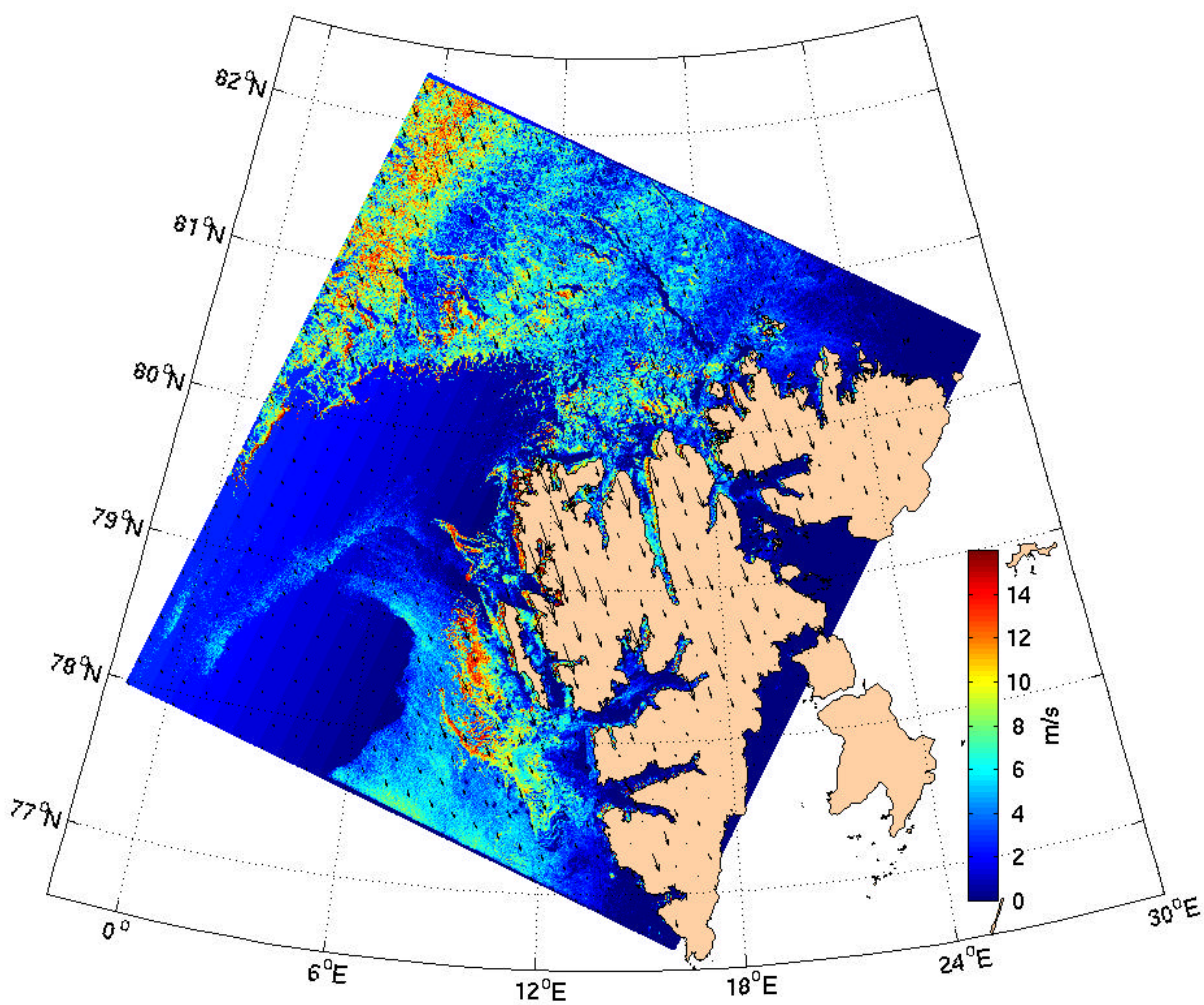



Figure 11. The first example of wind field retrieval from Radarsat Data in the Svalbard region. The area west of Westspitsbergen shows a realistic wind field, while the are area north of Svalbard is icecovered

# 4. PREPARATION OF ICEMON UNDER ESA GMES

Between June and November 2002 the ICEMON proposal was prepared with NERSC as co-ordinator and participation from 16 institutions in 8 countries. Full title of the proposal is "SAR ice monitoring for climate research, environmental management, resource exploitation and marine operation safety in polar regions", reflecting that SAR is a major data source in the project. Other data sources will also other EO data will be used. Modelling and in situ data will be incorporated over a period of 3 – 5 years.

## 4.1 OBJECTIVES OF ICEMON

The overall objective of ICEMON is to design and implement an integrated monitoring service for sea ice and related atmospheric and ocean processes in polar regions using satellite earth observation data in combination with in situ observations and modelling methods. The service shall support the following user segments:

1) climate and weather services at high latitudes
2) management of marine environment and resources in polar seas
3) safety of sea transportation, fisheries, and other marine operations

In the GMES consolidation phase (2003 – 2004) a network of services (service-portfolio) on sea ice and related processes of importance for the selected user segments will be identified and analysed with respect to cost-benefit. The user segments will be climate monitoring and modelling as well as weather forecasting services, ship traffic and environmental monitoring in regional ice-covered seas.

The main EO data will be SAR from ENVISAT and RADARSAT, supported by scatterometer products and other EO-data. The services will consist of near real time information for operational users and long-term information for climate monitoring including design criteria for marine structures. Demonstration of EO-derived sea ice products will be performed for the whole Arctic Ocean and in the surrounding regional seas. These demonstrations shall document that the proposed services are cost-effective and serve the public interests. ICEMON will demonstrate a prototype integrated met-ice-ocean service network to be fully implemented by 2008. The structure and contents of such integrated service system will be established during the consolidation phase. Partners from several European countries including Russia and Canada will carry out the consolidation study.

In the period 2004 – 2008, the sea ice service components will be integrated with atmospheric and ocean monitoring and forecasting services. By 2008 a fully operational met-ice-ocean service system for polar seas will be implemented. This requires that satellite products are used in combination with in situ data and models and that there are well-defined data providers and established service chains for the different data and modelling products. Ice thickness data from CryoSat will be included from 2005. In situ data from buoys and moorings will be incorporated to support the EO data. Integration with non-European services, such as Canadian services, is foreseen. The user segments will be expanded to include offshore industry, fisheries, climate modellers and others. Agencies that can take over the operational responsibility of the services will be identified. The satellite components of the global Arctic product can be operated by EUMETSAT, while regional operational ice centres can run services for the European regional seas. Focus of the services will be on Arctic regions, but also Antartica can be included if there is sufficient demand in this region.

## 4.2 THE GMES CARDINAL REQUIREMENTS

*What information is needed ?*

In high latitudes sea ice plays a very important role both for climate and marine operations. Monitoring and forecasting of sea ice and related meteorological and oceanographical parameters is of high priority to ensure safe operations with minimum risk for accidents and negative impact of human activities on the environment. Increased human activities in Arctic regions is expected in oil and gas exploration, especially in the Barents Sea and eastwards on the Russian continental shelf. Also global climate change is expected to be most dramatic in the Arctic regions where the sea ice cover is very sensitive to such changes. There is no service in Europe that provides SAR data and derived products from the whole Arctic region. Such service, proposed in ICEMON, would provide new and valuable information products for climate and weather at high latitudes as well as to regional met-ice-ocean services. Several policy issues and international conventions are particularly concerned with marine environment and operations at high latitudes.

***What services can be provided ?***

Satellite EO data are particular useful in polar marine regions because other observing systems are scarce and very expensive to operate. Large scale observations of sea ice extent and concentration with coarse resolution passive microwave sensors and visual/IR images have been done for many years. With the introduction of high-resolution SAR images, which are independent of clouds and light conditions, it is now possible to observe the Arctic sea ice cover in much better resolution. This allows determination and quantification of many important sea ice processes (freezing, melting, convergence, deformation, ridging, divergence, leads, polynyas, etc.) to the benefit of marine operators as well as in climate monitoring. Precursor SAR ice monitoring services have been demonstrated in several Arctic regions and operation monitoring is established in areas such as the Baltic Sea. SAR ice monitoring for the whole has been demonstrated by R. Kwok, showing unique resulyts on ice convergence, divergence, freezing, ice thickness distribution and seasonal ice growth. Hindcast analysis of these data in combination with ice modelling results can provide new insight into ice processes in the Arctic. In ICEMON the plan is to design and implement a monitoring service for all ice areas in the Northern hemisphere, using SAR in combination with other EO- and in situ data both for climate and operational monitoring. From 2005 CryoSat ice thickness data will become part of the service.

***What are the benefits for European Citizens ?***

4) better understanding of key climate processes at high latitudes and their impact on climate change

5) contribution to better management of environment, prevention/control of marine pollution and conservation of Arctic ecosystems

6) safer sea transportation and offshore operations in polar regions including improved design criteria for vessels and marine constructions in polar regions

***Do the benefits justify the costs ?***

- Satellite data from many sensors have already proven to be cost-effective for data collection in high latitudes where other observing systems are scare and expensive to operate. Use of SAR in combination with scatterometer and other existing and new EO data can enhance the observing capability for sea ice and related parameters significantly and contribute to safer and more economic sea transport and marine operations

- Large-scale ice parameters at coarse resolution are derived from passive microwave data, scatterometer data and IR-optical data are delivered for the whole Arctic region at low cost. The benefit of such low coast data products is significant for climate monitoring. However, higher resolution information can best be achieved by use of SAR images and derived products.

- Use of SAR data in operational ice monitoring is established as a cost-effective method to obtain regional ice information in several countries, but the data are poorly exploited in other applications such as global monitoring of climate process, management of resources, etc.

- Spaceborne observation systems including SAR and other sensors represent a major investment for the countries involved and better utilization of these data can be obtained with a minor additional investment for the benefit of a wider user community

- With more systematic acquisition of SAR data in larger parts of the Arctic Ocean and surrounding seas, the benefits of the SAR data can be significantly enhanced by offering a wider range of SAR-derived products to a larger group of users

- Increased human activities in polar regions (i.e. fisheries, oil and gas exploitation, sea transportation in the Northern Sea Route) with risks of accidents and damage to a very vulnerable environment require improved monitoring and forecasting systems, where use of SAR-based service will be cost-effective compared to other observing systems
- The sparseness of non-space observing systems and the high cost of operating such systems in Arctic regions (i.e aircraft, icebreakers, helicopters, buoy systems, etc.) enhance the importance of satellite observing systems in these regions.

## 4.3 SERVICE PORTEFOLIO PROPOSED

**1) Data provision:** SAR data for the European sector of the Arctic, including the Baltic Sea, will be downloaded and processed at KSAT in Norway. SAR acqusition in this region will be co-ordinated with Canadian and US coverage in the western hemisphere of the Arctic. Scatterometer data for global sea ice mapping is produced and disseminated by Ifremer.

**2) Algorihms for retrieval of geophysical parameters.** Existing algorithms developed over the last decade will be implemented for operation use to retrieve ice parameters from SAR. Algorithms and derived products can be divided in to categories: in near real time products for operational users (ice mosaics, ice edge location ice drift, ice types, etc.) and offline climate-related products (thickness, divergence, convergence, etc.) which can be used in combination with in situ data from buoys and moorings to quantify climate parameters such as ice volume fluxes and seasonal volume changes. Ice drift and ice type classification will also be derived form scatterometer data with coarser resolution.

**3) Operational production and dissemination of products**. For the European sector of the Arctic it will be met.no in Norway as part of the EUMETSAST OSI-SAF that will generate the SAR products. For the Baltic Sea, the Northern Sea Route, Greenland, Canadian waters, etc. it will be the responsibility of the national ice services to produce and disseminate products to the users. Dissemination systems will be implemented where different providers operate in a network of services where different met-ice-ocean products can be accessed via a single entry system. Different end-user systems, including ship-mounted systems, can be interfaced to the service network

**4) Climate data acquisition and hindcast analysis.** The climate analysis of ICEMON products in combination with other climate data and model simulations will be done through programmes such as ACSYS/CliC, ASOF and others to provide estimates of parameters such as seasonal sea ice volume and its fluxes through the Fram Straits and other straits. With Cryosat, spaceborne ice thickness data will be provided as part of these climatological data sets.

**4) A group of end users** will be involved in the project through the Core User Group to receive and evaluate the products to be demonstrated in the project. The end-users represent climate modellers, weather services, environmental monitoring, sea transportation, certification and classification of vessels and marine structures. Evaluation of the ICEMON prototype products by end users will used in the implementation of the fully operational service

**5) Cost-benefit analyses** will be performed to establish the affordability of the various service elements before implementation starts.

**6) A research team** will support the operational service with updated algorithms, validation data and new observing methods that can be implemented for operational use in the future. For climate studies research efforts will also be needed to analyse and disseminate the data for a wider user community.

**7) Service network for regional and global monitoring**. The concept of integrated service network is illustrated in Fig. 12 and 13, showing how the existing national ice services can operate in a global network.

## 4.4 The concept of global integrated service system

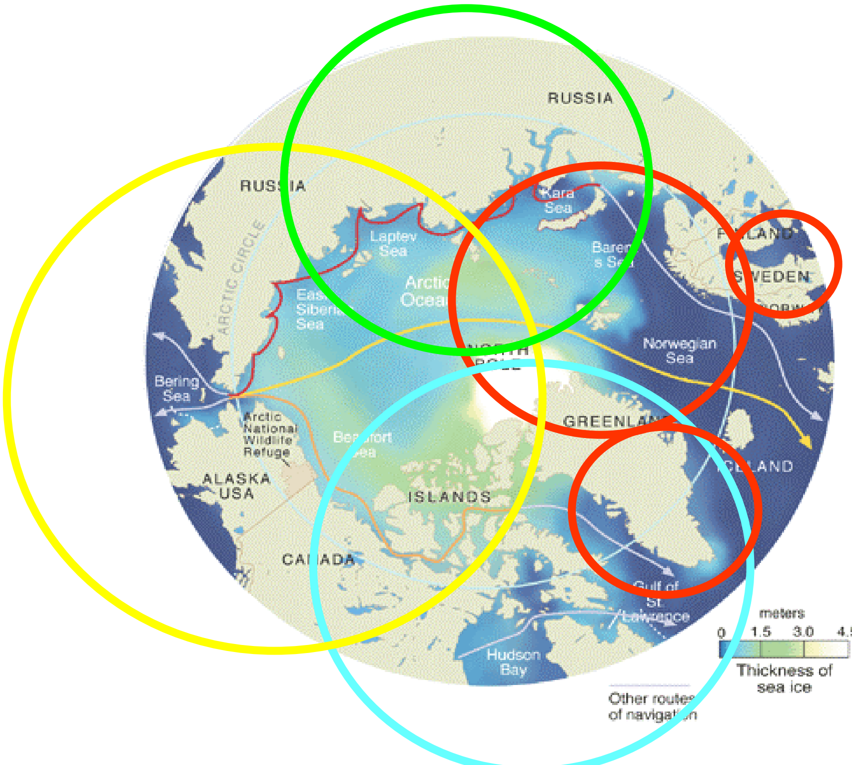



Figure 12. The circles indicates roughly where different national ice services have responsibility for monitoring of sea ice in the Northern Hemisphere

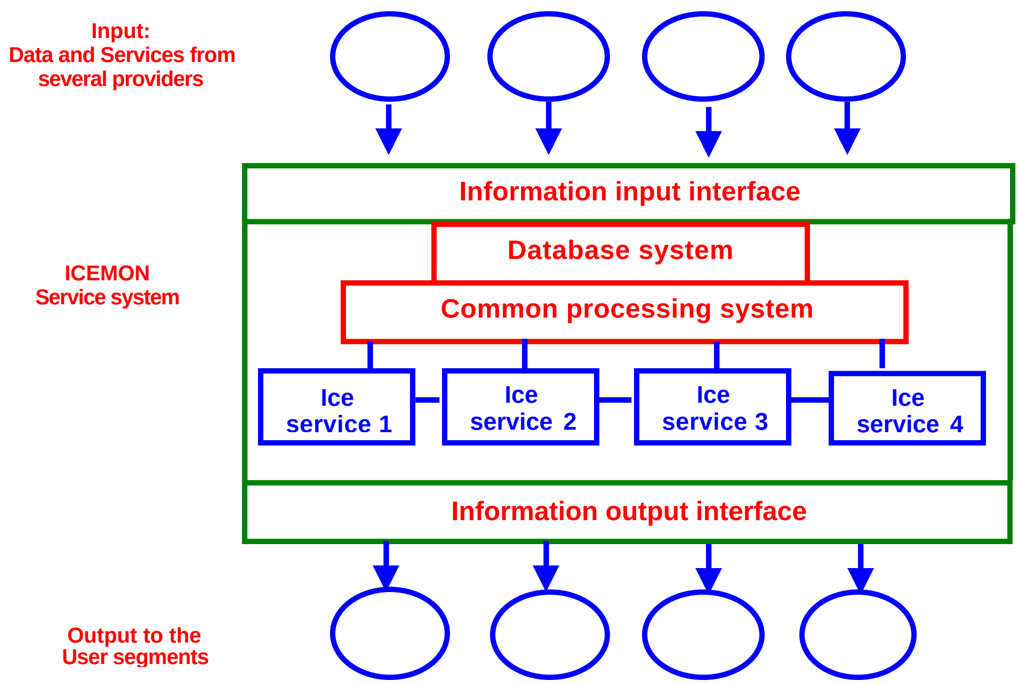



Figure 13. Proposed architecture for the ICEMON service network

## 4.5 TEAM COMPOSITION

### Core User group

***Finnish Maritime Administration (FMA)*** is representing the sea traffic user group in the Baltic Sea. FMA is a government agency responsible for the operations and safety of navigation in Finland. This includes the icebreaker service supporting all ship traffic in the winter season, The FMA issues decisions within its scope of authority, and participates in the drafting of maritime legislation. It also cooperates with the Ministry of Transport and Communications in the implementation of international agreements and EU legislation on the national level.
***Det norske Veritas (DNV)*** is an autonomous and independent foundation established in 1864 with the objective of safeguarding life, property and the environment. DNV's activity is primarily directed at four markets or business areas: maritime, offshore (oil and gas), process and general industries. DNV has classification and certification of ships and offshore structures as one of its prime objectives. The DNV organisation comprises 300 offices in 100 countries, with a staff of 5500.
***The Rossby Center of Climate Research*** represents the climate modelling community as user of ice information and will provide recommendations for sea ice products that are needed to improve and validate climate models in the Arctic. The Rossby Centre was established as a separate research unit for regional climate modelling, at Swedish Meteorological and Hydrological Institute in 1997.

***Norwegian Polar Institute's management division (NPI)*** represents the users of sea ice information for environmental monitoring in Arctic sub-regions, in particular the Svalbard area and the Barents Sea. NPI is responsible for environmental management and counselling, environmental data collection and dissemination, and topographic and thematic mapping. The mandate of NPI is to be the strategic adviser of the Norwegian government regarding polar environmental issues and to be responsible for the Ministry for the Environment's need for co-ordination of production, storage, and presentation of polar environmental data

In addition, two important user organisation from Russia will be involved***, the Northern Sea Route Administration*** (with overall responsibility for ship traffic in the Russian Arctic) and ***Murmansk Shipping Company's icebreaker fleet*** (the main operator of icebreakers and ice-going cargo vessles in the this region).
Users in Canada are represented the ***Canadian Ice Service (CIS***). The role of CIS in ICEMON is to establish links between European and Canadian user groups, service providers, system developers and research partners. In the GMES implementation phase (2004 – 2008) it is envisaged that joint European - Canadian EO-based monitoring .services can be established for the Northern climate and environment

### Operational Service providers

***Norwegian Meteorological Institute (met.no)*** is the operational service provider for operational met-ice-ocean services in Norwegian polar waters. The ***met.no*** department in Tromsø is operating the National Sea Ice Service which performs operational daily snow and sea ice mapping of the areas between Norway and Greenland. In the EUMETSAT Ocean & Sea Ice Satellite Application Facility, O&SI SAF, ***met.no*** department in Tromsø is hosting the operational High Latitude Centre responsible for the daily sea ice products. The SAR-based ice products from ICEMON will be distributed to users via the O&SI SAF. ***met.no's*** department in Bergen is running the Maritime Forecasting Centre, MFC. MFC has for more than three decades been involved in weather and sea state forecasting for the North Sea, Norwegian Sea and adjacent areas. Ice products from ICEMON will be distributed to offshore users via MFC's C-Star, which is an electronic sea chart systems with weather and sea state information included.
***Kongsberg Satellite Services (KSAT),*** formerly known as Tromsø Satellite Station, is a commercial Norwegian enterprise that provides operational applications based on space technology. KSAT is a world-leading provider of near real-time satellite radar data for near real-time ice monitoring and marine oil spill detection services. Through agreements with Radarsat International Inc. (Canada) and the European Space Agency, KSAT has the rights to distribute SAR data and derived services from the Radarsat, ERS and ENVISAT satellites.

***The Finnish Institute of Marine Research (FIMR)*** is a government research organisation for marine sciences established in 1918. The Institute carries out both basic and applied research in various fields in physical (including sea ice), chemical and biological oceanography, and maintain services for marine, harbour and route planners and other users. The operational Finnish Ice Service was founded in 1915 and in 1918 it become part of the FIMR. The Service, which is organised to collect, combine, analyse and distribute the Baltic Sea ice information, will be the main producer and distributor of SAR ice products.

***The Swedish Meteorological and Hydrological Institute (SMHI),*** is a governmental institute under the auspices of the Swedish Ministry of the Environment. SMHI comprises expertise within the fields of meteorology, climatology, hydrology and oceanography. The Marine Forecasting Department (MFD) at SMHI has the national responsibility for the monitoring and forecasting of sea ice in the Baltic Sea. MFD will be the main producer and distributor of sea ice products where SAR is included. The national ice services in the Baltic Sea has a regional co-operation that includes exchange of ice data, joint ordering and purchase of SAR data, co-ordinated icebreaker operations, and common ice information system used onboard the icebreakers.

***Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)*** is the only French organisation with an overall maritime research and monitoring purpose. It operates under the joint auspices of the Ministries of Education, Research and Technology, Fisheries and Amenities, Transport and Housing. In the framework of its activities in Observation and monitoring of the sea, IFREMER operates, since 1991, the " Centre ERS d'Archivage et de Traitement" (CERSAT) which is the French processing and archiving facility (Fpaf) for the ERS mission, in close collaboration with the scientific teams of the Laboratoire d'Océanographie Spatiale. CERSAT has progressively evolved to a multi-satellite/multi-sensor data processing/geophysical product provider and data distribution center. The laboratory has acquired an eleven year experience in Ocean and Sea ice data processing. It has developed specific scatterometer based geophysical products related to Ocean Winds and Sea ice monitoring using successively the ERS AMI-Wind, NSCAT and SeaWinds on QuikSCAT. Validated data and geophysical products are available through the Ifremer web site.

## System developers

***Kongsberg Spacetec AS (KSPT)*** is a 100% subsidiary of Kongsberg Gruppen ASA, the largest Norwegian defence and space company. KSPT is one of the leading producers of receiving stations for data from meteorological and Earth observation satellites. KSPT has nearly 20 years experience in designing and developing data acquisition and processing systems for satellites, and are capable of supporting several missions simultaneously. Ground systems have been delivered world wide. Work has been done for ESA for ERS and ENVISAT. KSPT will have a main role in the software implementation of the SAR Ice Processor in ICEMON

***Vexcel UK*** was established in February 2001 in Newbury, United Kingdom, with the goal of developing oceanographic and cryospheric applications of earth observation from satellites. The company has several contracts in the field of sea ice remote sensing. Current collaborators include the UK Met Office / Hadley Centre, Goddard Institute of Space Studies and Qinetiq, and current and recent customers include Canadian Government, ESA, Naval Research Laboratories and NASA. Vexcel UK's main role will be to design the SAR Ice Processor based on existing algorithms developed in Europe, USA and Canada.

***The Technical Research Centre of Finland (VTT)*** is a contract research organisation involved in many international R&D projects. With its more than 3000 employees, VTT provides a wide range of technology and applied research services for its clients, private companies, institutions and the public sector. VTT has developed ice information systems for distribution and analysis of SAR and other data in the ice centres as well as on icebreakers. VTT has also developed a prototype broker that will be the node in a distributed service system as proposed for ICEMON.

## Research partners

***Alfred Wegener Institute for Polar and Marine Research (AWI).*** is a multidisciplinary scientific institution engaged in topics of scientific and public interest. AWI is the german national polar research institution and as such promotes and carries out polar and marine science to further our understanding of the variability and functions of the global environment and of the Earth System based on observations, modelling and applications. AWI carries out cutting edge science by focussing on an interdisciplinary research approach together with national and international partners to whom it also provides polar infrastructure and logistics. It develops new approaches, tools and methods and applies these to research topics of both basic and applied interest. AWI will contribute to the provision of sea-ice data and to the development of new data products. AWI is regularly operating in ice covered waters, and AW is a leading institution particularly with in-situ studies of sea-ice. Some of these observations like ULS and EM ice thickness soundings could easily be transformed into routine monitoring programs, long-term provided funding could be achieved. At AWI, there are strong efforts to combine field and remote sensing data as well as model results to develop new algorithms for the retrieval of geophysical parameters as well as to better understand the polar climate system.

The Nansen Environmental and Remote Sensing Center (NERSC) was founded in 1986 as an independent non-profit research institute affiliated with the University of Bergen. NERSC performs interdisciplinary basic and applied research with focus on the marine and polar regions. NERSC has over the last decade co-ordinated a large number of projects for ESA and EU in remote sensing and modelling of the marine environment as well as in global climate modelling. Since the launch of ERS-1 in 1991, NERSC has performed a number of development, demonstration and application projects related to SAR ice monitoring. Through the sister institute in St.Petersburg, NERSC has built up a significant project portfolio in Russia, over ten where sea ice monitoring and modelling are key activities. NERSC was instrumental in establishing the ICEWATCH project (1995- 1999), which was the first joint project between ESA and Russian Space Agency in earth observation. This project led to the building of the first SAR receiving and processing station for ERS data in Russia. This station can potentially be part of ICEMON service network. A memorandum of understanding is established between European Commission, European Space Agency, and the Russian Aviation and Space Agency, Rosaviakosmos (see appendix). Several Russian institutions will be involved in the ICEMON proposal because the Russian Arctic is a very important areas for sea ice monitoring. In addition to co-ordinating ICEMON, NERSC will contribute to SAR ice algorithm implementation and testing/valiidation of sea ice products in sea ice and climate models.

***The Department of Space and Climate Physics, including the Centre for Polar Observation and Modelling, at University College London (UCL/CPOM)*** has more than 20 years experience in the use of space-borne data to determine changes in the mass balance of the land and marine ice masses. The team has played a direct role in the specification of ESA processing schemes for the ERS, ENVISAT and CRYOSAT radar altimeters over the polar regions. Currently funded ESA, EU, national projects are focused on the derivation, validation and exploitation of sea ice thickness measurements from these missions.

## Expert consultants

ControlWare, based in Brussels, is a small independent consultancy and business development company with a very strong background in the market, business and socio-economic aspects of space derived activities. ControlWare will be responsible for conducting the Cost Benefit Analysis of the ICEMON project. Birgitte Holt Andersen, director of ControlWare, worked for more than 6 years as European Commission staff at the Space Application Institute of the Joint Research Center in Ispra where she was responsible for a number of market, business development and socio-economic initiatives and projects in the framework of the CEO Programme. This background is very apprroppriate for conducting cost Benefit Analysis i ICEMON.

## Members of the Service Strategy Group

1. Pentti Malkki, general director of the Finnish Institute of Marine Research.
2. Bruce Ramsey, chief scientist Canadian Ice Service
3. Ola M.Johannessen, director of the Nansen Environmental and Remote Sensing Center

### 4.6 CONTRACT NEGOTIATION AND PROJECT START

ICEMON contract negotiaton with ESA took place from January to March 2003 and work started already in February with the first ASAR sea ice monitoring demonstration in the Svalbard area. Norwegian Meteorological Institute is project manager while NERSC is coordinator of the project. The activities by the Norwegian partners in ICEMON, especially NERSC, met.no and NP, will be closely co-ordinated with the SATHAV project.

The project can be followed on the web-sites

http://www.nersc.no/ICEMON
and
http://icemon.met.no