
CIRFA
UNIVERSITY OF TROMSØ
sfi
Centre for Research-based Innovation
2016
Annual Report
CIRFA – Centre for Integrated Remote Sensing and Forecasting for Arctic Operations

2016 IN REVIEW

2016 was the first year of full operation in CIRFA - Centre for Integrated Remote Sensing and Forecasting for Arctic Operations. The centre is now well established in SIVA Innovation Centre in Tromsø, and is considered to be already well set up to contribute with new knowledge and technologies in support of Arctic operations.

Administrative bodies: CIRFA has in place an Executive Board consisting of 7 representatives, 4 from industry and 3 from the research partners. The Dean of Faculty of Science and Technology, UiT-the Arctic University of Norway is chairing the Board. The Centre's "Scientific Advisory Board (SAB)" is constituted with 4 internationally acknowledged scientists, and towards the end of 2016, also the "Innovation Advisory Board" was appointed, and the technical committees had a first meeting.

Hiring: CIRFA had by the end of 2016 employed 8 PhD students and 2 Postdocs, fully financed by the Centre. The PhD projects cover basically the research program; remote sensing of ocean, sea ice, oil spill, iceberg detection, numerical modelling, and Arctic drone technologies. The PhDs come from Norway (5), Germany (1), Italy (1), and Hungary (1), 3 females and 5 males. The postdocs come from Norway (female) and France (male). The hiring is almost according to schedule.

Research: The research in CIRFA includes theoretical studies, algorithm development, and data collection and processing. The foundation for much of the research work is collocated measurements from satellites, drones, and ground-based instruments. In 2015 and 2016 CIRFA collaborated with several research institutions on acquiring data for the research projects of PhDs and Postdocs. Team members were involved the N-ICE campaign (i.e. the freeze-in of Lance, NPI), and NORSE-2015 (NOFO's oil on water experiment). We also participated in a field campaign in Ny-Ålesund (in collaboration with Norut, Fram Centre, and NTNU (AMOS)) and another campaign in the Fram Strait (in collaboration with the Norwegian Polar Institute). These collected data for sea ice classification, iceberg detection, and testing of drone technologies. In addition, drifters were deployed in Vestfjorden (in collaboration with MET.no and the Institute of Marine Research), which provide in-situ data related to WP1, ocean remote sensing, and WP5 drift modelling and prediction. For more details on CIRFA's research activities, see work package summaries, and more details on our web site http://cirfa.uit.no.

Publications: Several papers based on CIRFA activities have already been published in peer-reviewed scientific journals. It is noted that the article "Measurements and modelling of oil slick transport" (Jones et al., 2016) got the first page highlight in the October issue of JGR Oceans. CIRFA has also actively contributed at many international scientific conferences with oral presentations and posters (e.g. EUSAR 2016, IGARSS 2016).

Vision

CIRFA shall become an international leading research centre on integrated remote sensing and forecasting for the Arctic, providing:

- An attractive environment to scientists, young researchers and students
- Outstanding scientific contributions
- High-level research training for new researchers in the field
- CIRFA shall become a facilitator for collaboration between industry and academia on issues related to remote sensing of Arctic phenomena, providing
- Innovative integrated solutions to challenges in Arctic operations
- Scientific support to industry on issues related to remote sensing technology
- Decision support to policymakers and authorities

Outreach: CIRFA members has presented the centre at relevant political/industrial meeting places like Arctic Frontiers (Tromsø), Arctic Circle (Reykjavik), ONS 2016 (Stavanger), and Arctic Operations (Hammerfest).

CIRFA arrangements: CIRFA organized its first annual conference at Sommarøy Arctic Hotel in September 2016, with more than 60 participants from 15 different countries. More or less all partners were present, in addition representatives from collaborating institutions and companies. The first day included presentations of the research by WP leaders, PhDs and Postdocs. The second day was devoted to innovation, and was organized according to the "World Café" set up, with group discussions, plus a plenum summary. The SAB of CIRFA was present at the conference, and provided, after the conference, their comments and recommendations to the on-going research and activities.

In 2016, CIRFA also organized a first young scientist forum for PhDs and Postdocs, with focus on presentation skills.

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Contact information

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cirfa.uit.no

CIRFA – A CONTRIBUTION FOR INNOVATION AND BUSINESS DEVELOPMENT AT KSAT

Dr. Jan Petter Pedersen
Senior Vice-President,
Kongsberg Satellite Services, CIRFA
Board member

Kongsberg Satellite Services (KSAT) is a world leading provider of multi-mission satellite based services to global customers with operational requirements. Satellite radar data is the main source for near real-time detection of oil spills at sea, ship traffic monitoring, met-ocean information, and information about the sea ice edge and ice flows.

The oil spill detection is currently the most CIRFA relevant service, and KSAT is worldwide ranked first among all providers of this service. The focus on the global environment represents an increasing business potential for this service, both for commercial customers, like the offshore oil and gas industry, as well as for public customers including national authorities. There is currently an increasing competition among the service providers, and providing an innovative service, with more information than just a detected, potential oil spill at sea, is becoming more and more an important competitive criterion.

KSAT's ambition is to maintain the leading position as a multi-mission satellite service provider, but the company does not have any algorithm development activities in-house. New and improved methods and algorithms are acquired through cooperation in innovative research projects, including CIRFA. KSAT's activities in the market create knowledge about the customers' evolving requirements, as well as about new and more advanced satellite missions in coming years. This information is used to define research needs, which are fed back into the CIRFA work program. It is an important for KSAT that CIRFA provides new methods that can be operationally utilized, and not only result in scientific papers.

CIRFA's multi-disciplinary focus is important for KSAT with respect to its strategy of generating future services. As an example, CIRFA's activities on met-ocean and sea ice may be included into the oil spill service, both for improving the reliability of oil spill detection, and for extending the service information content, but they could also be used to extend KSAT's service portfolio through the establishment of new services.

KSAT is leading the integrated services work package in CIRFA, together with MET.no. This activity shall validate the results towards the market, and is hence a benchmark on KSAT's business gain resulting from the investment in CIRFA. KSAT has expectations that new and improved methods for information retrieval from multi-mission satellite data will be available from quite early on in the project. This will give opportunities to test and evaluate new products in close cooperation with customers, and subsequently decide on next steps towards preparing new services for the global market.

PARTNERS

Research partners:

UiT The Arctic University of Norway (UiT)
Northern Research Institute (Norut)
Northern Research Institute Narvik (Norut Narvik)
Norwegian Meteorological Institute (MET.no)
Norwegian Polar Institute (NPI)
Norwegian University of Science and Technology (NTNU)
Nansen Environmental and Remote Sensing Center (NERSC)

User partners:

Kongsberg Satellite Services
Kongsberg Spacetec
Statoil
ENI Norge
Aker BP
OMV Norge
Total E&P Norge
Aker Solutions
Multiconsult
Globesar
Aranica
Maritime Robotics

FOREWORD

Prof. Torbjørn Eltoft
CIRFA Centre Leader
UiT

As the full name of the centre indicates, a core activity in Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA) is the art of combining and extracting information from heterogeneous datasets. This process is also denoted data fusion, and is becoming more and more important as the number of satellite platforms increases, and remote sensing sensor technology is getting more advanced. The overall objective of integrated remote sensing is to produce enhanced information of the phenomenon under investigation compared to the knowledge achievable from individual sensors. Clever information retrieval algorithms, combined with methodologies on how to use the derived information in numerical forecast models, are important tools to support safe Arctic industrial operation.

The initial research projects of CIRFA address processing algorithms and information retrieval associated to met-ocean, sea ice, and oil spill remote sensing applications, as well as questions related to how remote sensing derived information can be imported into numerical models to improve forecasting. The latter process is referred to as data assimilation. These studies are all relying on having access to relevant satellite data, with validated ground truth information. Solid ground truth data for validation and calibration of satellite products, especially in the monitoring of Arctic areas, is in general a big challenge. In 2015 and 2016 CIRFA members collaborated with colleagues at centre partners or collaborating institutions on acquiring such data, and thanks to dedicated efforts, especially from our young scientists, CIRFA is currently having excellent datasets to support the work in all on-going projects. During dedicated field campaigns at and around Svalbard, we also have been able to collect some data sets combining drone based and ground based measurements with observations from satellites. These data sets are now being analysed in studies on sea ice characterization and iceberg detection.

Besides doing research and educating PhD candidates, CIRFA's third core mission is innovation. There is in general, a great need for integrated remote sensing information about the ocean, sea ice, and icebergs to support of Arctic operations. We are convinced that the tight collaboration between the research and industrial partners in CIRFA, will enable the identification of improved services and products that can remedy current shortcomings. It is also our strong belief, that the technology developed within our centre, could have great value to other sectors. CIRFA's innovation opportunities and technological relevance to other sectors are being considered by our Innovation Advisory Board, which is now in full operation.

Tromsø, March 2017,

Torbjørn Eltoft

OBJECTIVES

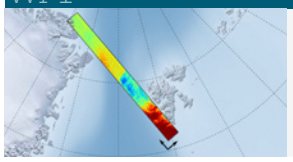
CIRFA shall create knowledge, methods and technologies, which are a prerequisite for environmentally safe industrial operations in the Arctic.

CIRFA will contribute to:

- Improved understanding of important geophysical processes in the Arctic
- Improved monitoring capabilities
- Improved assimilation methods and forecasting services

The research tasks are organised in seven work packages:

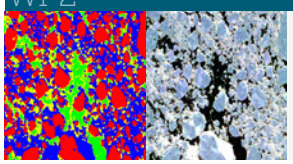
WP1



Ocean Remote Sensing

The objective of WP1 is to further develop the use of satellite technology to advance our understanding of the Arctic Ocean processes and dynamics, and contribute to better predictions.

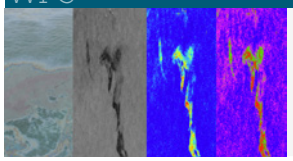
WP2



Sea Ice, Iceberg and Growler Remote Sensing

WP2 shall further develop remote sensing algorithms to enable mapping of Arctic sea ice conditions, estimation of sea ice velocity field, and improved detection and characterisation of icebergs.

WP3



Oil Spill Remote Sensing

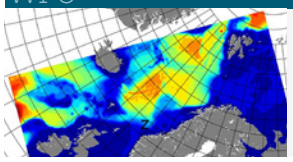
WP3 aims to develop accurate remote sensing information retrieval methods for reliable oil slick detection and characterization, and to improve modelling of oil behaviour and fate in sea ice covered waters..

WP4

RPAS Technology

In WP4 the focus will be on working a Remotely Piloted Aircraft Systems (RPAS) based sensor system. Icing, high winds and turbulence limit flight window at low altitude. We will look at new designs and technologies to maximize the operational window.

WP5



Drift Modelling and Prediction

The objectives of this work package are to assimilate observations collected within CIRFA into an ocean-ice forecast model, and to produce probabilistic ocean, sea ice and drift forecasts.

WP6

Data Collection and Field Work

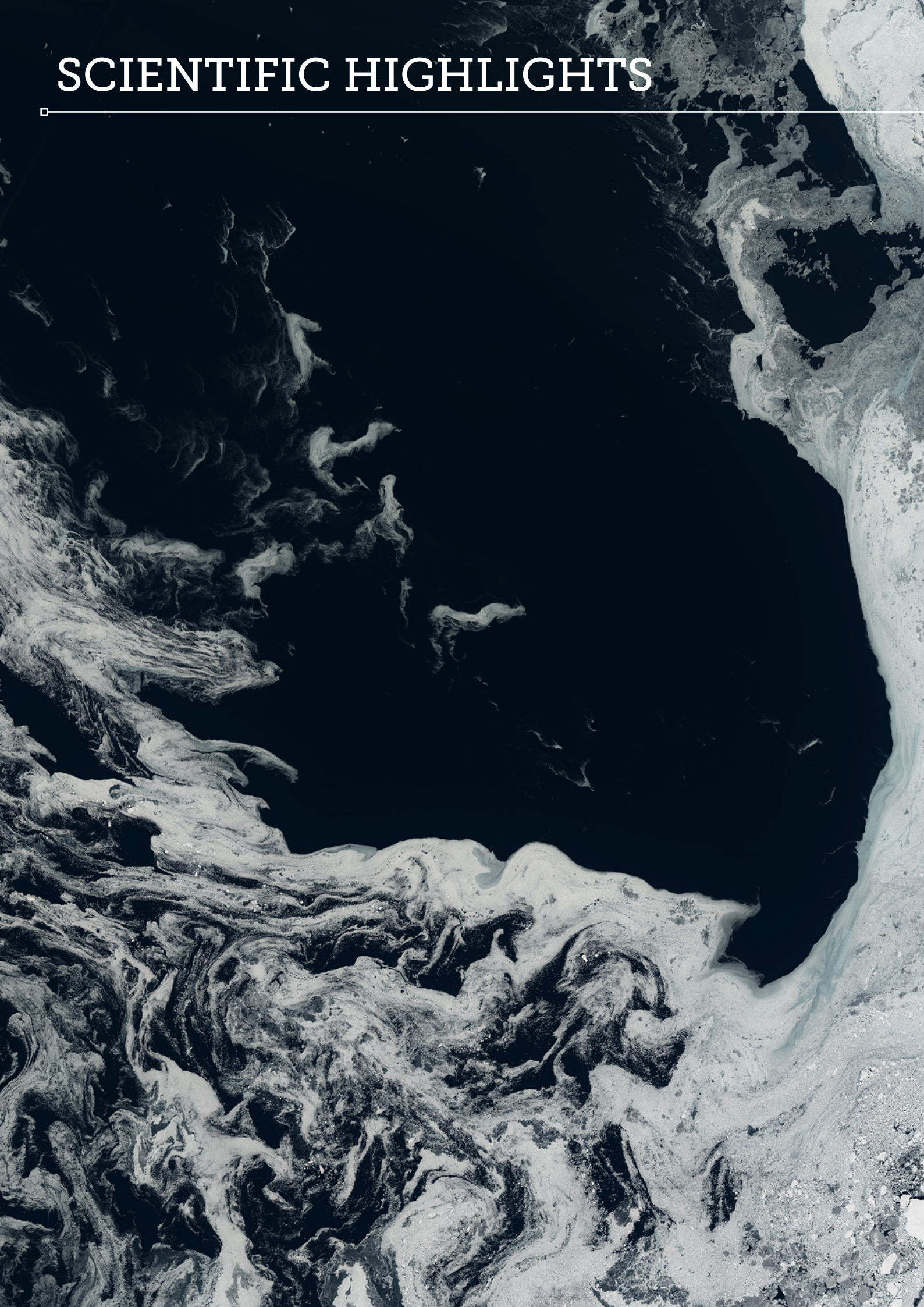
WP6 shall organize dedicated field campaigns on and over Arctic sea ice and ocean to combine accurate in-situ, RPAS, aircraft and helicopter observations, and satellite data, and improve validation shortcomings by seeking new and refined methods.

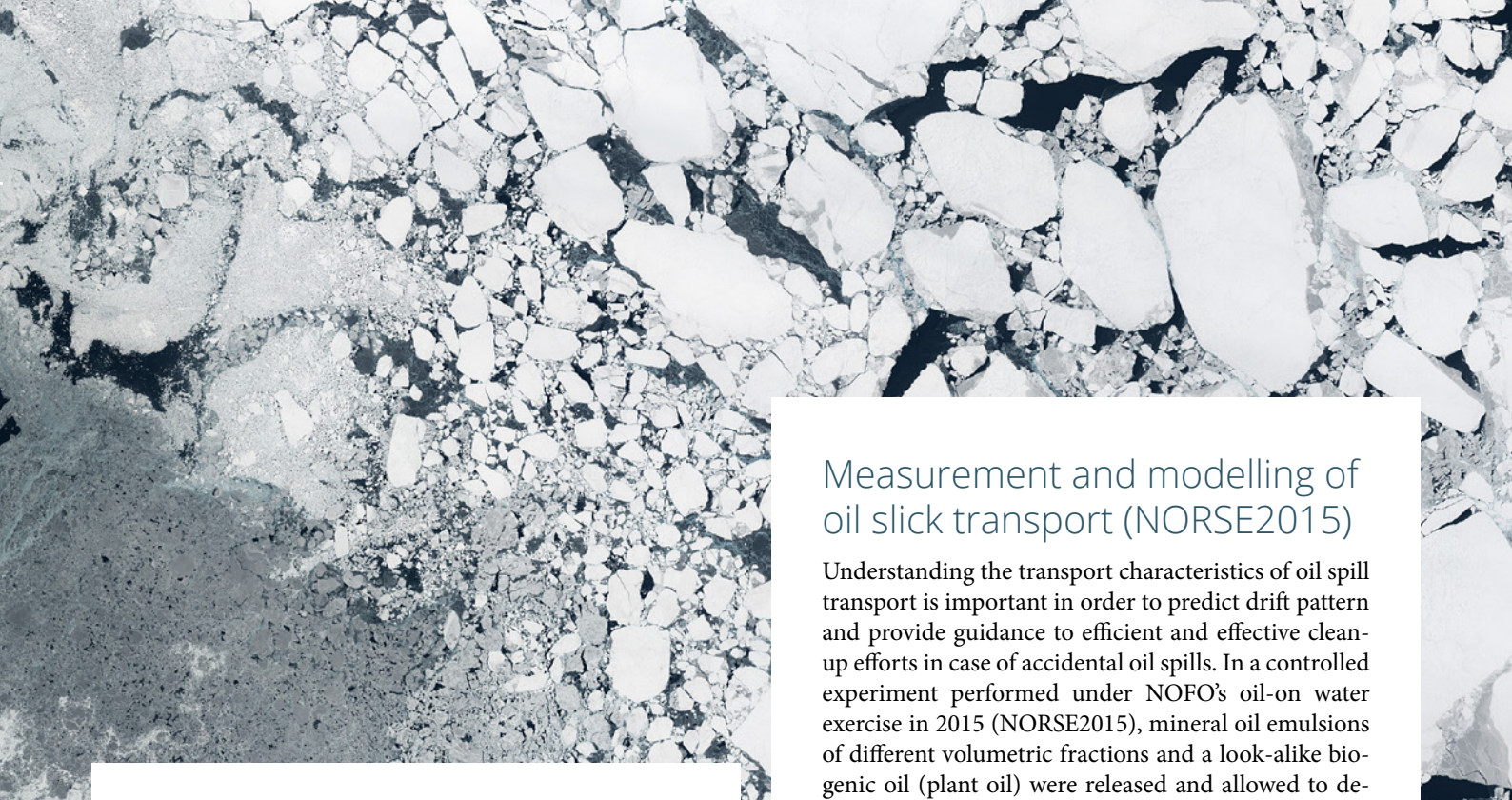
WP7

Pilot Service Demonstration

WP7 will demonstrate a pilot service system showing the provision of integrated environmental information to end-users involved in Arctic operations. The methodologies, tools and products developed in WPs 1–5 will be validated using data from WP6, and integrated into information products for the pilot service demonstrations.

SCIENTIFIC HIGHLIGHTS





Connection between phytoplankton bloom and sea ice characteristics

The sea ice monitoring studies performed within CIRFA also have high relevance to environmental and climate related research. This is demonstrated in another highlighted paper, now being published in Nature Scientific Reports. The paper has contributions from three CIRFA members. The paper links phytoplankton blooms to the observed lead fraction in sea ice cover, and the study was supported by a segmentation image made under WP2, subsequently labeled by the MET. no office in Tromsø. Read more in Assmy et al., 2017.

Improving the Doppler product from Sentinel 1

The instantaneous Doppler frequency parameter estimated from an oceanic SAR scene has contributions from geophysical components (wind, waves and currents), geometrical effects (orbit, attitude), and electronic mispointing of the antenna. In order to retrieve the small component, which carries the desired geophysical information, the non-geophysical Doppler terms need to be precisely estimated and removed. An important breakthrough in the calibration of ocean Doppler measurements from Sentinel-1 has been achieved by the WP 1 team using more than 30000 data sets acquired globally around the Earth, using a data driven (neural network) approach. The proposed method has the potential of solving the calibration problem of Sentinel 1, which has prevented the use of the Sentinel 1 ocean Doppler measurement product for ocean surface current retrieval. The methodology and results have been presented at several workshops at the European Space Agency.

Measurement and modelling of oil slick transport (NORSE2015)

Understanding the transport characteristics of oil spill transport is important in order to predict drift pattern and provide guidance to efficient and effective clean-up efforts in case of accidental oil spills. In a controlled experiment performed under NOFO's oil-on water exercise in 2015 (NORSE2015), mineral oil emulsions of different volumetric fractions and a look-alike biogenic oil (plant oil) were released and allowed to develop naturally. The slicks were imaged by JPL-NASA's L-band UAVSAR, which acquired a time serious of 22 radar images, which allowed for tracking of location, size and shape of the different slicks for about 8 hours. The measurements were combined with data from two pairs of drift buoys, released with the plant oil and the highest fraction emulsion oil. Modelling of oil slick transport was performed by the OpenOil drift model, which represents the oil by particles with individual positions and properties. The study provided new insight into transport characteristics of the oil slicks, and valuable data on how to adjust and constrain model parameters to correctly predict the true nature of oil slick development. Read more in Jones et al., 2016.

Imaging Arctic sea ice with co-incident X-band, C-band and L-band synthetic aperture radars (SARs)

Getting quantitative sea ice parameters from SAR images is challenging, due to the high sensitivity of radar images on radar parameters, imaging geometry and the meteorological conditions at the data actuations instants. This problem was expensively studied in a recently published paper in Journal of Geophysical Research, Oceans. By using multiple collocated satellite scenes at different wavelengths and polarizations, the study shows how new knowledge about the sea ice characteristics is gained by comparing spatially and temporally overlapping fully polarimetric X-band, C-band, and L-band SAR scenes with information about ice thickness and roughness derived from helicopter-borne electromagnetic induction soundings (HEM), as well as photographs taken systematically from the helicopter. Read more in Johansson et al., 2017.

WP1
OCEAN REMOTE SENSING

WPL: Adj. Prof. Harald Johnsen
Norut/UiT

Objectives and motivation:

Ocean surface is the complex boundary between two very dynamic and stochastic media, the ocean and the atmosphere.

Better forecasting of the ocean state and understanding of the physical processes going on at the ocean/atmosphere interface require combined capacity in remote sensing, numerical modelling, and in-situ observations. Synoptic maps made from space of ocean surface winds, waves and currents are core inputs to better characterization and parameterizations of oceanic mesoscale and sub-mesoscale dynamics, as well as important contributions to the understanding of ocean-atmosphere interaction and research on numerical modeling. The newly launched Sentinel satellites will greatly improve the capabilities of providing such high-resolution information from space due to the enhanced time and space coverage offered. This work package works on developing methodologies and algorithms to extract more accurate high-resolution sea state parameters from remote sensing observations over the oceans to improve modeling and forecasting.

Team:

Geir Engen
Senior Researcher, *Norut*

Tom Grydeland
Senior Researcher, *Norut*

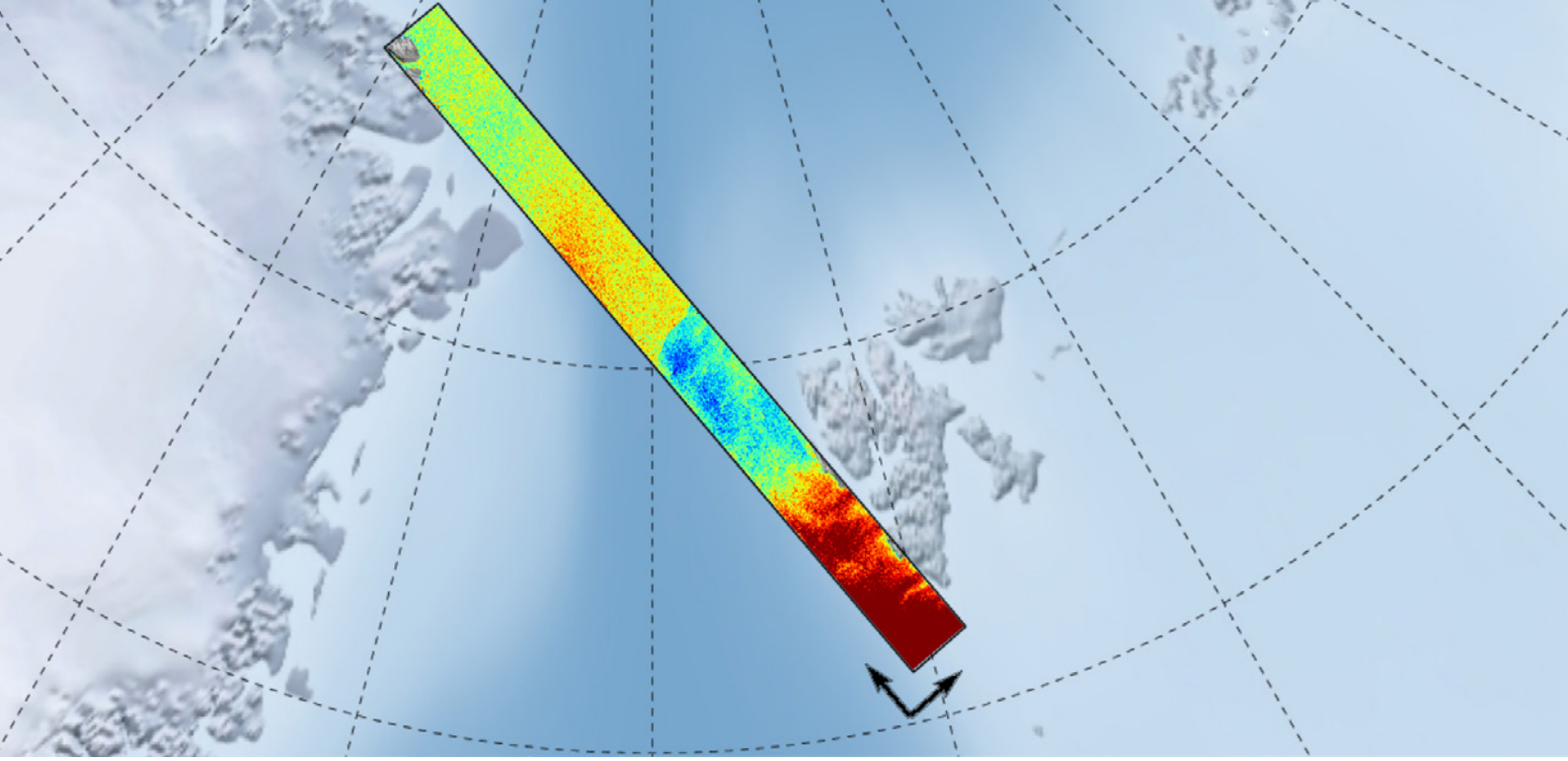
Vegard Nilsen
PhD Fellow, *Norut*

Katalin Blix
Associate PhD Fellow, *UiT*

Thomas Kræmer
Associate PhD Fellow, *UiT*

Key research tasks:

- Develop physical and statistical methodologies to improve the reliability of satellite-derived geophysical parameters.
- Develop algorithms, products and a processing system for providing ocean state parameters from satellite observations beyond what is achievable today.
- Provide short range forecasting of ocean state through coupling with high-resolution numerical models in collaboration with work package 5
- Perform extensive product calibration and validation analysis.



Achievements 2015-2016

The effort has been on developing a processing line for data from Sentinel-1 and Radarsat-2 satellites to perform calibration and validation of ocean state measurements. An important breakthrough in the calibration of ocean Doppler measurements from Sentinel-1 was achieved by the WP 1 team using more than 30000 data sets acquired globally around the Earth, using a data driven (neural network) approach. The proposed method has the potential of solving the calibration problem of Sentinel 1, which has prevented the use of the Sentinel 1 ocean Doppler measurement product for ocean surface current retrieval. The methodology and results have been presented at several workshops at the European Space Agency, who has acknowledged the achievements and encouraged us to continue the work.

As part of the work a stand-alone Sentinel 1 ocean wind speed retrieval algorithm was developed and validated against global model wind field from ECMWF. Example results are shown in Figure 1. Further R&D towards operationalization of this algorithm has started, and will have the potential of improving operational services on wind field information.

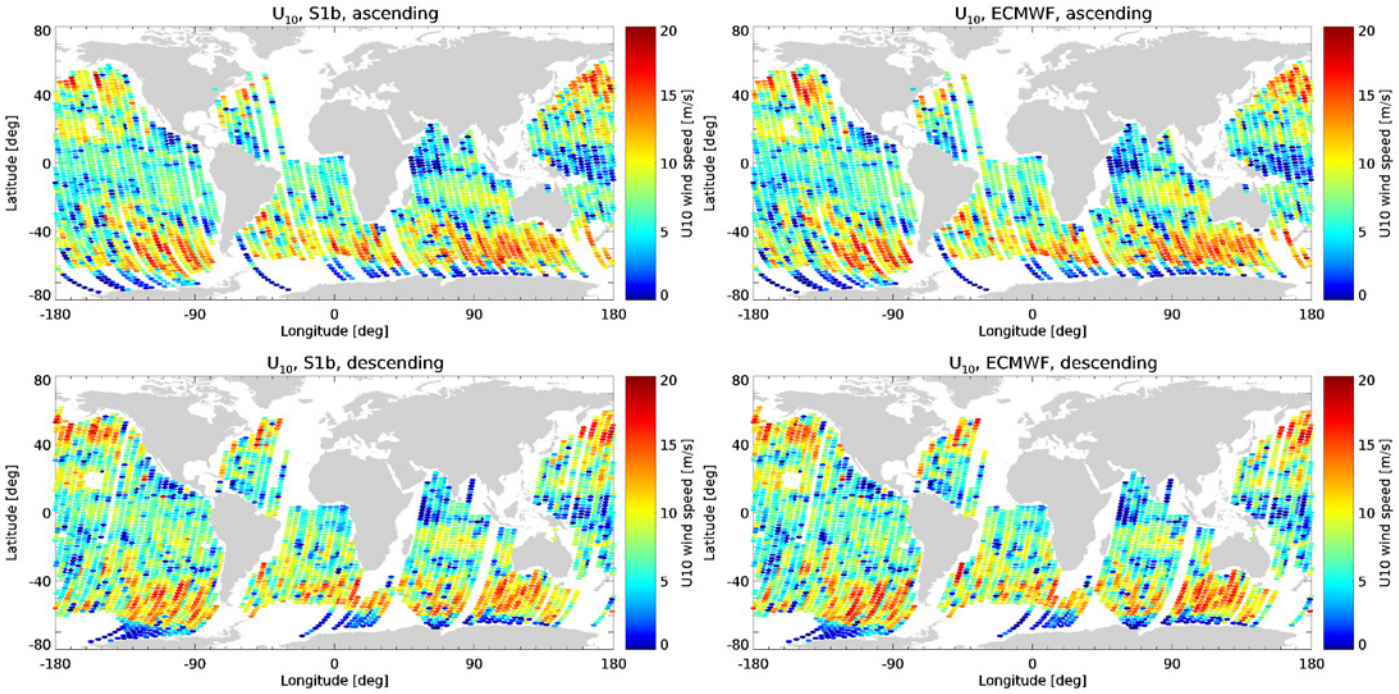


Figure a): Ocean surface wind speed derived from Sentinel-1B ascending and descending passes acquired between 25 and 31 October 2016. Figure b): Co-located model wind speeds from European Centre for Medium Weather Forecast (ECMWF) are shown for comparison.

WP2
MONITORING SEA ICE AND ICEBERGS

WPL: Adj. Prof. Wolfgang Dierking
AWI/UiT

Co-WPL: Assoc. Prof. Anthony Doulgeris
UiT

Team:

Johannes Lohse
PhD Fellow, *UiT*

Ingri Halland Soldal
PhD Fellow, *NERSC*

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Jakob Grahn
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Jean Negrel
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Anca Cristea
Associate Postdoctoral Researcher, *UiT*

Sebastian Gerland
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Wenhui Lang
Visiting Researcher, *Hefei Univ. of Tech., China*

Objectives and motivation:

Sea ice is a very dynamic medium. It varies in thickness from a few centimeters, typical for the stage of a thin, skin-like new ice cover to several meters for multi-year ice.

Different zones of ice may drift with different velocities due to spatial variations of the driving forces, while obstacles may limit the mobility of fractions of the ice cover. This causes the ice to break and pile up, forming various compression structures such as linear ice ridges or extended rubble fields that pose a hazard to maritime traffic. A systematic analysis and monitoring of Arctic ice conditions thus not only requires the separation of different ice types, but also the monitoring of varying ice motion. Icebergs are still a hazard to maritime operations both in the open ocean and in ice-covered waters. The detection and monitoring of the smaller icebergs (lengths of less than 100 meters) still remain a challenge. The objective of this work package is to further develop remote sensing methodologies and algorithms to enable detailed characterization and mapping of Arctic sea ice conditions, and to provide improved detection and characterization of icebergs and growlers. Data products generated will be thoroughly assessed on the basis of the developed procedures, field campaigns from ships or coastal test sites in the Arctic are planned to collect in-situ ice data while satellite images are taken. This also includes data taken with remotely-piloted aircraft systems (RPAS).

Key research tasks:

- Apply modern statistical methods and image processing techniques to develop robust and reliable procedures to classify and characterize sea ice.
- Develop improved methods for mapping and monitoring sea ice drift velocities.
- Investigate new, robust methods for iceberg and growler detection and characterization, including drift trajectory predictions.
- Optimize the developed procedures such that the new algorithms can be integrated into the workflow of the operational ice centers.

Achievements 2015-2016

The work has been focusing on the mapping of the temporally varying spatial distribution of ice types, the retrieval of ice drift velocity, and the detection and tracking of icebergs. In close collaboration with the Alfred Wegener Institute (with an AWI scientist employed as Professor II at CIRFA) and with colleagues from the Nansen Environmental and Remote Sensing Center (NERSC), algorithms are being developed to deduce different properties of the sea ice cover, to detect icebergs, and to retrieve sea ice movements. Important in this context are the joint activities of the Norwegian Polar Institute (NPI), NORUT, and CIRFA to gather micro and macro scale sea ice data in the field and use them for developing and validating the algorithms. In 2016, field data were collected in Fram Strait and in the area of Svalbard. The focus and design of new algorithms is being driven by the needs of the operational ice services and the requirements for improving and validating models for sea ice forecasts. This work on automatic sea ice segmentation algorithms is being done in close collaboration with Met Norway. Exchange of information and interactions with the other WPs remain an important component of the work in WP 2.

In April, a field campaign took place in Kongsfjorden, Svalbard, where the team acquired a variety of parameters, including ice thickness along transects and ice salinity and temperature. Geo-localised photographs were taken to identify the different thin ice types and to follow their evolution in time. Co-located satellite data has been analysed using in-house developed software with focus on the research questions: How well does the algorithm detect the ice edge? How well is smooth thinner and rough thicker ice separated? How severe is the influence of local variations of wind speed and direction on the segmentation of open water areas?

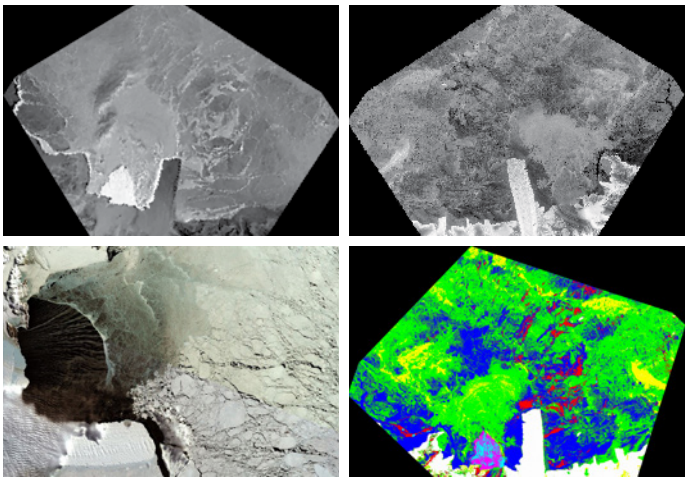

Figure: Ice type classification based on RS-2 images for 24 May (left panel) and 15 June (right panel) 2015. The segments were automatically calculated, and then manually identified by ice analysts. The thin ice classes (open water, new ice, and thin ice) were used to derive the lead fraction.

Research in WP 2 has also included studies on

- the classification potential of several polarimetric parameters that are calculated from polarimetric SAR images with the objective to establish a ranking (J. Lohse, A. Doulgeris),
- the implementation of different methods for detecting icebergs in satellite radar images with the motivation to analyze pros and cons of each method, and to find out under which conditions they can be optimally used (I. Soldal),
- and on incidence angle modeling in wide-swath radar imagery to allow for improved sea ice segmentation. Initial results are promising. (IAESTE student J. van Houtte, A. Doulgeris)

The optimal use of different sensor types is one of the major topics of CIRFA work and this was demonstrated in an investigation reported by Thomas Hollands from AWI and Wolfgang Dierking (CIRFA/AWI). They focused on a polynya in the Ross Sea (Antarctic) and integrated information on regional scales (several 100 km) with passive microwave radiometers, local scales (tens to hundreds of meters) with radar and thermal infrared sensors, and fine scales (meters) with optical sensors. The combination of sensors improved the interpretation and classification of the ice conditions around the polynya and can be seen in the example figure.

Another highlighted paper is now published (Assmy et al., January 2017) in Nature Scientific Reports and had contributions from three CIRFA members during 2016: Anthony Doulgeris from WP2, Sebastian Gerland from WP6, and Nick Hughes from WP7. The paper links phytoplankton blooms to the observed lead fraction in sea ice cover and a segmentation image made under WP2 that was subsequently labelled by the Met Office in Tromsø was used for the supporting material. Figure S4 is reproduced here to show the segmentation and labelled ice types.

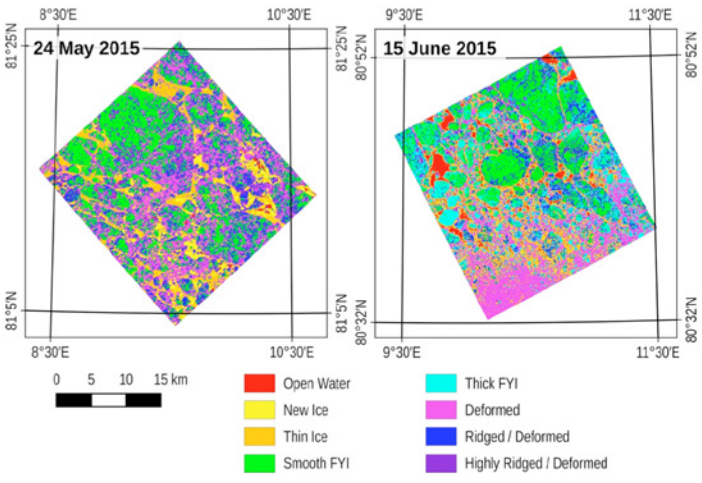

Figure: The polynya study in Terra Nova Bay / Ross Sea. (Top row) Low resolution Envisat AATSR (Advanced Along-track Scanning Radiometer) to the left and medium resolution ALOS PALSAR (L-band radar) to the right. (Bottom row) A high resolution optical Landsat 8 image (left) and a map showing results of an ice type classification: thin, consolidated ice in blue; nonconsolidated or thicker ice floes in green; newly formed ice in red; very rough ice in yellow; and the open water area of the polynya, which is partly covered by streaks of ice, appears pink and cyan.

WP3
OIL SPILL REMOTE SENSING

WPL: Prof. Camilla Brekke
UiT.

Co-WPL: Dr. Christian Petrich
Norut Narvik

Team:

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Marianne Myrnes
PhD Fellow, *UiT*

Stine Skrunes
Postdoctoral Researcher, *UiT*

Malin Johansson
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Megan O'Sadnick
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Cathleen Jones
Adj. Prof., Jet Propulsion Lab, *California Inst. of Tech./UiT*

Laurent Ferro-Famil
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Benjamin Holt
Visiting Researcher, *Jet Propulsion Lab, California Inst. of Tech.*

Fabrizio Argenti
Visiting Researcher, *Univ. Firenze*

Objectives and motivation:

In case of a major oil spill event, remote sensing will be instrumental in providing the authorities with both spatial information regarding distribution and qualitative properties of the spill guiding the clean-up operations.

To predict the spills transport is also important in a combat situation. Integration of remote sensing measurements and modelling efforts is essential in validating and improving drift models for oil spills. Remote sensing imagery from satellite is today applied in operational oil spill screening operations, where however false alarms are a major issue. There is also a need to establish proven methods for oil spill detection in ice-infested waters as oil & gas exploration, shipping, and tourism are expanding their activities into Arctic regions. To develop remote sensing techniques for sea ice conditions requires at first instance an understanding of the oil's interaction and migration within the sea ice medium, and secondly knowledge about the interaction between the remote sensing signal and the oil-ice layers. This work package aims to develop new techniques for solving the look-alikes ambiguity related to detection of oil on water, and to study methods for detecting and monitoring of oil in ice.

Key research tasks:

- Develop accurate remote sensing information retrieval techniques for reliable oil slick detection and characterization on open water.
- Improve the modelling of oil behaviour, transport and fate in open water and sea ice infested areas.
- Investigate the potential of remote sensing techniques for oil spill detection and characterization in sea ice-infested waters.

Achievements in 2015-2016:

In June 2015, CIRFA took part in a joint and carefully planned oil-on-water experiment conducted by UiT, Met Norway, and Jet Propulsion Laboratory (JPL)/ National Aeronautics and Space Administration (NASA) (NORSE2016 – NOrwegian Radar oil Spill Experiment 2015). The experiment was carried out during the Norwegian Clean Seas Association for Operating Companies (NOFO) annual equipment testing (oil-on-water exercise), and took place at the Frigg field. A time-series of synthetic aperture radar (SAR) data was collected from a NASA aircraft (Aerial Vehicle Synthetic Aperture Radar, UAVSAR), multiple SAR scenes were collected from various satellites, and meteorological and oceanographic auxiliary information were collected from a vessel that also released samples of oil simulating real spills on the ocean surface. This dedicated remote sensing experiment provided CIRFA with a highly valuable time-series of SAR measurements and buoy data. The main focus of the work in WP 3 in 2016 was on analysing these data sets with respect to oil slick detection, characterization, and modelling of the oil spills transport at sea.

In 2016, the first international journal articles and conference proceedings papers were published from this campaign. In particular, it should be noted that we got the front page of Journal of Geophysical Research; Oceans' October issue. The article conveys how new insight into the transport and behaviour of oil spills were gained and modelling were improved by combining remote sensing and modelling efforts.

Another major activity in WP 3 in 2016 has been the planning of the Oil-in-ice tank experiment 2017. In March-April 2017 an oil-in-ice experiment is planned to take place at The Hamburg Ship Model Basin (HSVA). CIRFA has joined forces with MOSIDEO (another RCN project) working out detailed plans for this experiment, which involves a whole suite of remote sensing instruments. Two different types of sea ice will be grown in the tank and multiple oil spill patches shall be created. The objective of the experiment is to investigate at what point in the process remote sensing techniques will be able to detect oil in sea ice, as well as to study the oil spill behaviour and distribution within the microstructure of the ice. Two new PhD students have been hired within CIRFA to work on the analysis of the data to be collected.

Front page of JGR; Oceans October 2016 issue. journal's web-site.

The polarimetric L-band SAR instrument on NASA's aircraft at Sola, Stavanger in June 2015. Photo: Camilla Brekke, UiT.

Laboratory study of crude oil rising through the pore space of sea ice in spring. Photo: Megan O'Sadnick, Norut Narvik

WP4
RPAS TECHNOLOGY

WPL: Assoc. Prof. Rune Storvold
Norut/NTNU

Co-WPL: Prof. Tor Arne Johansen
NTNU

Team:

Richard Hann
PhD Fellow, *NTNU*

Rolf-Ole Jenssen
PhD Fellow, *UiT*

Svein Jacobsen
Professor, *UiT/Norut*

Stian Andre Solbø
Senior Researcher, *Norut*

Agnar Sivertsen
Senior Researcher, *Norut*

Objectives and motivation:

Drifting sea-ice and icebergs may cause a threat to ships and installations in the high north, hence detailed knowledge of properties of sea ice and ice objects is critical for managing the operation in a safe and cost effective manner.

Both satellite based systems and RPAS (Remotely Piloted Aircraft Systems) have their strengths and weaknesses. Satellites have superior coverage and repeatability, but limitations when it comes to accurate fine spatial and temporal scale measurements of thickness distribution, drift, convergence and divergence. RPAS can achieve accurate high-resolution measurements, but have limited spatial coverage and range, and are weather sensitive. The systems needed by industrial operators in the Arctic should be robust and reliable, and the system should be able to handle disruption in service by individual components. This work package aims to develop robust and efficient RPAS and sensor technologies, that can handle the widest possible ranges of environmental conditions enabling high quality measurements of sea-ice and iceberg properties, as well as detecting and monitoring oil spills in ice affected areas.

Key research tasks:

- Develop platforms with improved take-off and landing capabilities, de-icing performance, wind tolerance, and fault tolerance.
- Improve communication links, robustness and bandwidth in Arctic RPAS operations.
- Develop RPAS sensors for sea ice characterization, ocean surface parameters measurements, and oil-in-ice detection.

Achievements in 2015-2016

In 2016, we installed and tested the Radionor MBR radio that gives 5 Mbps on the Cryowing Scout aircraft. This gives extended range communication out to about 50 km in radio line-of-sight. Further, a new onboard computer system is also set with several microcomputers allowing real time on-board image processing. This allows us to run the Norut developed EASYICE algorithm, which segments sea-ice and iceberg size distributions and fraction in real time. Improved timing on still imagery is achieved by using the camera flash synchronization signal achieving ground position accuracy on the instant geolocation to 2-5 meters. This also speeds up and increases accuracy of the SfM (structure from motion) 3D imagery processing.

In February, an icing tunnel experiment was conducted at the LeClerc Cox Icing tunnel in New York. Here, ice buildups on the leading edge of the wings at different temperatures, droplet concentrations, and size distributions were measured, as well as the amount of de-icing power used. This experiment was a joint effort with AMOS. In May, Richard Hann started his PhD study of the effects of icing on small UAS airfoils. 3D printed icing was used for verification of numerical simulations in wind tunnel experiments in September. Results will help optimizing de-icing systems based on aircraft tolerance for icing induced performance deterioration.

April 5-6 the ReCAMP (Remote Controlled and Autonomous Measurement Platforms) workshop, co-funded by Svalbard Science Forum, was held in Tromsø, with 67 participants from US and Europe representing both academia and industry. The workshop discussed challenges and solutions in operating unmanned systems in an arctic environment (www.asuf.no/recamp).

The WP 4 CIRFA team, in collaboration with Arctic EO (Arctic Earth Observation and Surveillance Technology), ARCEx (Research Centre for Arctic Petroleum Exploration) and AMOS (Centre for Autonomous Marine Operations and Systems) teams, performed a one-week field campaign in Ny-Ålesund April 13-20th. Here, co-located measurements from a ground-based radar system, optical RPAS sensors and satellite borne SAR were collected, focusing on sea ice characterization and iceberg and growler detection limitations. In addition, an initial field-test of the carbon coating de-icing system was performed, as well as an initial arctic field tests of NTNU's sensor feedback system for iceberg tracking.

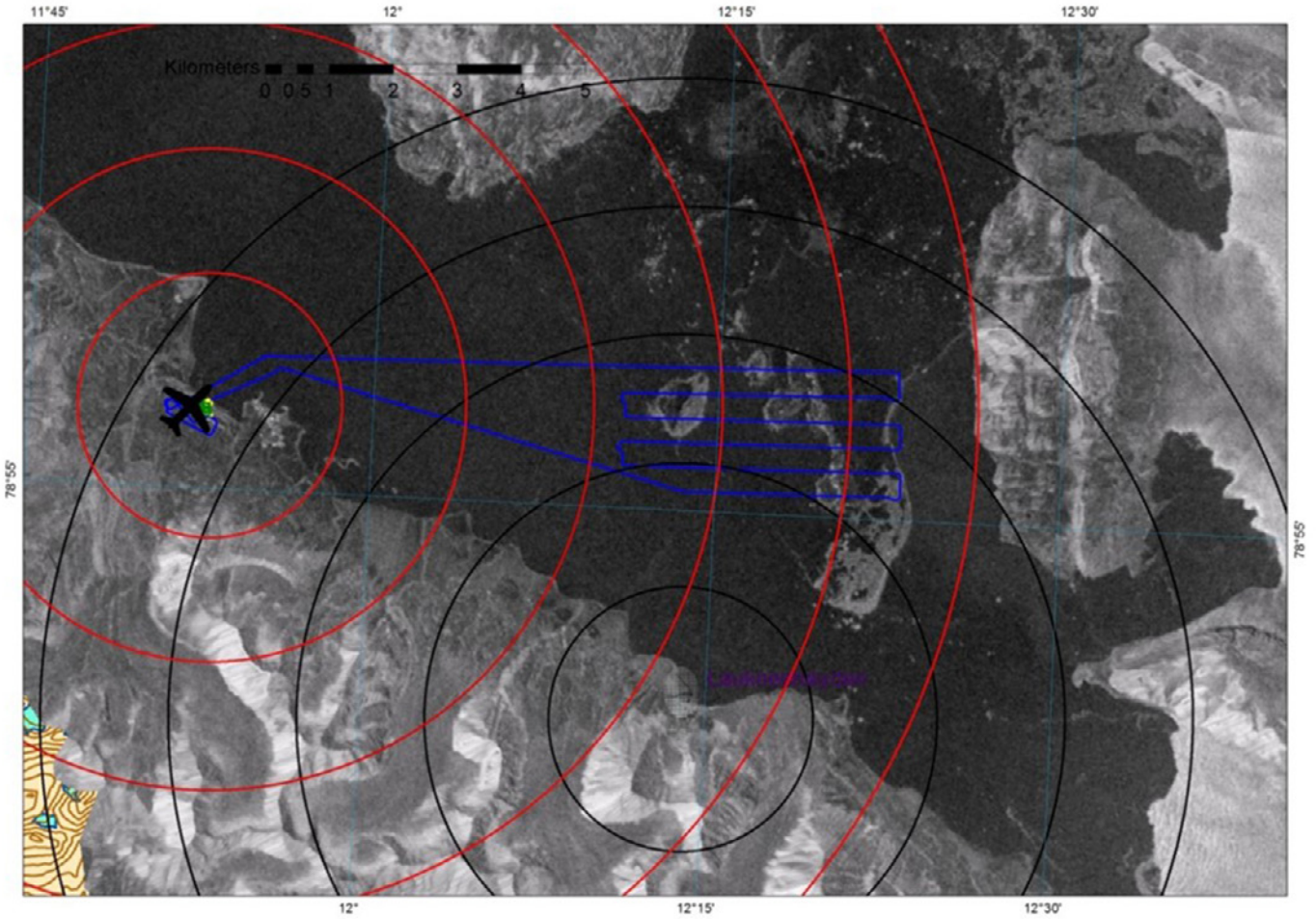


Figure: Example of flight path covering the sea-ice stations where NPI conducted in-situ measurements, simultaneously with a RadarSat-2 image acquisition and covered by the Norut GPRI radar. Hence coupling UAS based high resolution size and shape measurements with radar signatures.

WP5
DRIFT MODELLING AND PREDICTION

WPL: Dr. Kai H. Christensen
MET.no

Co-WPL: Prof. Rune Graversen
Norut/NTNU

Team:

Sindre Fritzner
PhD Fellow, *UiT*

Runa Skarbø
PhD Fellow, *UiT*

Patrick Stoll
Associate PhD Fellow, *UiT*

Keguang Wang
Researcher, *MET.no*

Knut-Frode Dagestad
Researcher, *MET.no*

Ann Kristin Sperrevik
Researcher, *MET.no*

Penelope Wagner
Researcher, *MET.no*

Objectives and motivation:

Ocean and ice forecasting at high latitudes, including the forecasting of drift of icebergs, oil-spills and other pollutants, is challenging due to a severe lack of observations of oceanic 'weather'.

Improved operational forecast systems will require increased amounts of high-resolution observations and the assimilation of such data into ocean and ice models. Also, because of the large observational uncertainties and the chaotic nature of the flow, the forecasts have to be probabilistic, i.e. presented as a range of possible outcomes based on an ensemble of slightly different model runs. Assimilation and ensemble forecasting are the central issues to be addressed within WP5. The work will utilize ocean-ice models and assimilation techniques already in use at MET Norway today, but substantial advances will need to be made. Central to this development is a so-called ensemble prediction system (EPS), in which several instances of the ocean and sea ice models are run simultaneously to assess the uncertainties in the forecasts. A dedicated high resolution ocean-sea ice modeling system is being configured for CIRFA related work. This regional modeling system will utilize the detailed observations that will be made available. It will be forced by a fully coupled surface wave/ atmospheric circulation model and nested into state-of-the-art basin scale ocean model.

Key research tasks:

- Develop, test, and utilize EPS-based ocean forecast system with variational data assimilation.
- Develop, test, and utilize EPS-based sea ice forecast system with Kalman filter data assimilation.
- Develop, test, and utilize EPS-based forecast system for Lagrangian drift (oil spills, icebergs, search and rescue).

Achievements in 2015-2016

Improved ocean data assimilation methodology was tested in the 4D-Var analysis scheme that is part of the ocean model ROMS. More specifically, the possibility to adjust not only the initial conditions, but also the lateral boundary conditions was shown to be important in a reanalysis of a period with dense surface and subsurface observations. This work is summarized in a submission to J. Geophys. Res. (Sperrevik et al., in revision, see Fig. 1). The main author Ann Kristin Sperrevik will join CIRFA/WP5 as a full-time postdoc from July 2017, focusing on the assimilation of radial velocities such as observed by coastal HF radar and SAR, and she will be working closely with WP1 researchers.

In OpenDrift, an improved scheme has been developed for modeling the vertical turbulent mixing of oil droplets which has been entrained due to breaking ocean waves. As there are large vertical gradients in horizontal transport in the upper meters of the ocean, this vertical transport has a large influence on the horizontal transport as well (Fig. 2).

The PhD student Sindre Fritzner has been working on sea ice data assimilation since January 2016. He works on assimilation of observations into the sea-ice part of the ROMS-CICE coupled model system. The ability of this ocean-ice coupled model system to produce skillful forecasts of sea ice and ocean currents is dependent on the initial model state being as close to reality as possible. This is accomplished by assimilation of observations obtained from for instance remote sensing. Currently, two different data assimilation systems is being in the sea-ice model CICE, the Ensemple Kalman Filter (EnKF) and the Combined Optimal Interpolation and Nudging (COIN).

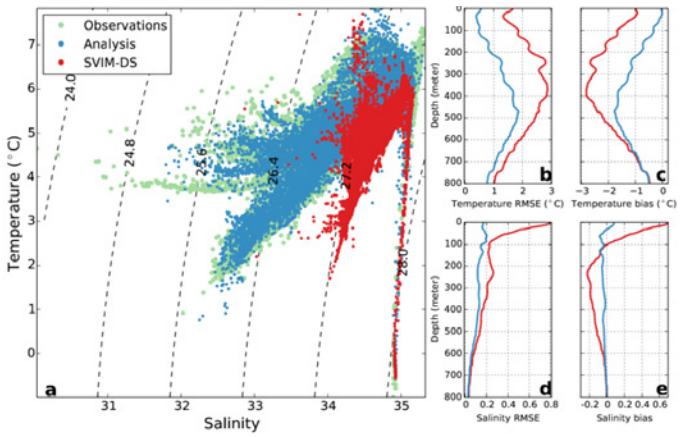


Figure: The TS-diagram on the left shows how the data assimilation (DA) scheme in the ocean model ROMS successfully draws the ocean model closer to the observations in a reanalysis of the circulation in the Lofoten-Vesterålen area (green – observations, blue – analysis after DA, red – control simulation without DA). The control run without DA cannot properly represent the coastal water masses, which results in unrealistic stratification and hence a reduced ability to correctly model the upper ocean velocities. The righthand-side plots show the temperature and salinity bias and RMSE values (blue – with DA, red – without DA). In regional models, and especially in in regions with strong currents, it is critical for the success of the DA procedure to be able to adjust the lateral boundary conditions, as has been done here.

Another PhD student, Runa A. Skarbø, focuses on operational use of information from SAR images, marine radar and other remote sensing technologies. Ice drift velocities, iceberg detection and tracking, and ice feature identification will be combined with drift prediction to assess the risks and scenarios for marine offshore operations in the Arctic. In 2016, Skarbø did research on ice drift prediction, resulting in a paper together with Dr. Renat Yulmetov on modelling iceberg drift in pack ice (Fig. 3). In addition, Skarbø participated in a six-week research cruise to the Arctic Ocean, where the scope was to collect valuable full-scale data from the Arctic.

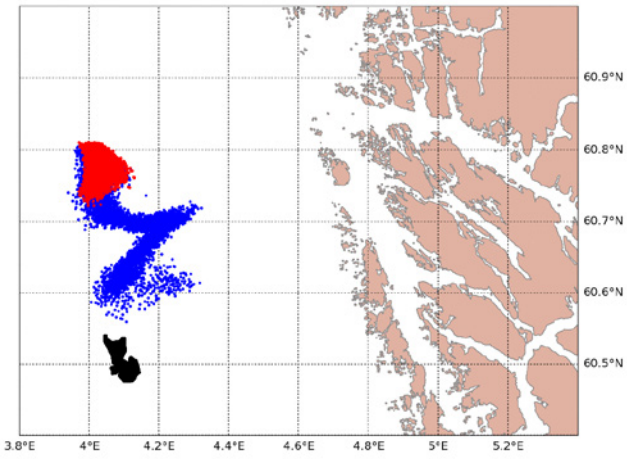


Figure: The map shows 12-hour transport simulations of the drift of an oil slick observed by satellite (black). The predicted drift is shown without (red) and with (blue) the improved turbulent mixing scheme that is now part of OpenDrift.

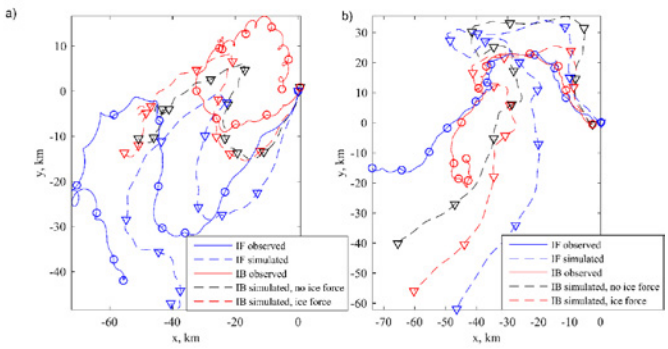


Figure: Drift trajectories of observed and modelled icebergs and ice floes. Panel (a) illustrates the larger iceberg, while Panel (b) illustrates the smaller one. Markers indicate every 24 hours. Simulations both including and excluding forcing from sea ice on the iceberg are shown.

WP6
DATA COLLECTION AND FIELDWORK

WPL: Dr. Sebastian Gerland
NPI

Co-WPL: Assoc. Prof. Rune Storvold
Norut/NTNU

Co-WPL: Assoc. Prof. Camilla Brekke
UiT

Team:

Jean Negrel
Postdoctoral Researcher, *NPI*

Objectives and motivation:

This work package is concerned with the design, organization and implementation of focused remote sensing validation measurement setups in connection with field campaigns, ensuring remote sensing coverage at relevant scales in space and time.

Partners centrally involved in this work package are the Norwegian Polar Institute, Norut, and UiT The Arctic University of Norway. WP 6 functions as a validation and calibration platform for remote sensing data, as well as organizing the collection of ground truth data for assessing the work conducted in other work packages. Aside new expeditions organized by CIRFA, also long-term monitoring data from land stations are used for calibration and validation purposes to support the remote sensing research. Examples of such auxiliary data sets obtained together with collaborating institutions, are archived data collected during previously conducted national and international campaigns, like N-ICE2015 (a half-year experiment where the research vessel "Lance" of the Norwegian Polar Institute was frozen into drifting ice in the Arctic Ocean north of Svalbard), annual campaigns of the Norwegian Polar Institute, NOFO's annual oil-on-water exercises, and future data takes from the planned Arctic MOSAiC drift in 2019-20 (www.mosaicobservatory.org).

Hence, the objective of WP 6 is to designing field campaigns in connection with satellite and RPAS measurements, and to carefully plan and conduct the measurements needed for calibration and validation of remote sensing products.

Key research tasks:

- Organize and implement dedicated field campaigns on Arctic sea ice, oceans, and oil spills to combine accurate direct measurements of surface properties, with data from remote operated aircrafts (RPAS or UAV), and satellites.
- Improve validation shortcomings by seeking and implementing new and refined measurement concepts and methods using new technologies and platforms.
- Provide quality ground-truth data from archives and new campaigns for assessing the theoretical work in other work packages.

Achievements in 2015-2016

Main the work within WP6 has so far been connected to two larger fieldwork/cruise campaigns. In early 2016, postdoctoral researcher Jean Negrel was employed at the Norwegian Polar Institute (NPI) and quickly got involved in fieldwork activities. The scientific fieldwork in Kongsfjorden was planned and prepared, including the scientific programme, logistics and practical preparations, before this fieldwork was successfully conducted in April. Data from sea ice, snow, and icebergs was collected, in combination with high-resolution quad pole satellite imagery, UAV surveys (Norut) and coastal radar monitoring (Norut/UiT). Parts of the fieldwork are also connected to other projects, specifically "Arctic EO", lead by Norut and funded by the Research Council of Norway, and "Mapping Sea Ice", led by the Norwegian Polar Institute and funded by the Fram Centre in the flagship programmed Fjords and Coasts. These links increase the networks and the capacities regarding field- and data collection work.

Data processing from the Kongsfjorden campaign included sea ice segmentation applied to some Radarsat-2 satellite images, using the SAR segmentation algorithm developed at UiT, and results were presented at the Annual CIRFA conference.

In late summer, fieldwork from RV Lance in Fram Strait was conducted successfully, with ice stations and helicopter surveys of sea ice. Jean Negrel and PhD student Johannes Lohse participated from CIRFA. Results of the analysis of these data and the data from Kongsfjorden were presented as posters at the AGU Fall Meeting (San Francisco, December 2016) and Arctic Frontiers (Tromsø, January 2017).

Fieldwork for 2017 is in the planning phase (Kongsfjorden, INTPART cruise to marginal ice zone), and support is given to the HSVA ice tank experiment planned for March 2017.

Ice measurements in Kongsfjorden in 2016. Photo: S. Gerland, NPI.

WP7
PILOT SERVICE DEMONSTRATION

WPL: Carles Debart
KSAT

Co-WPL: Dr. Nick Hughes
MET.no

Co-WPL: Dr. Jan Petter Pedersen
KSAT

Team:

Gudmundur Jøkulsson
Director Systems Development, *KSAT*

Thomas Kræmer
IT Engineer, *UiT*

Objectives and motivation:

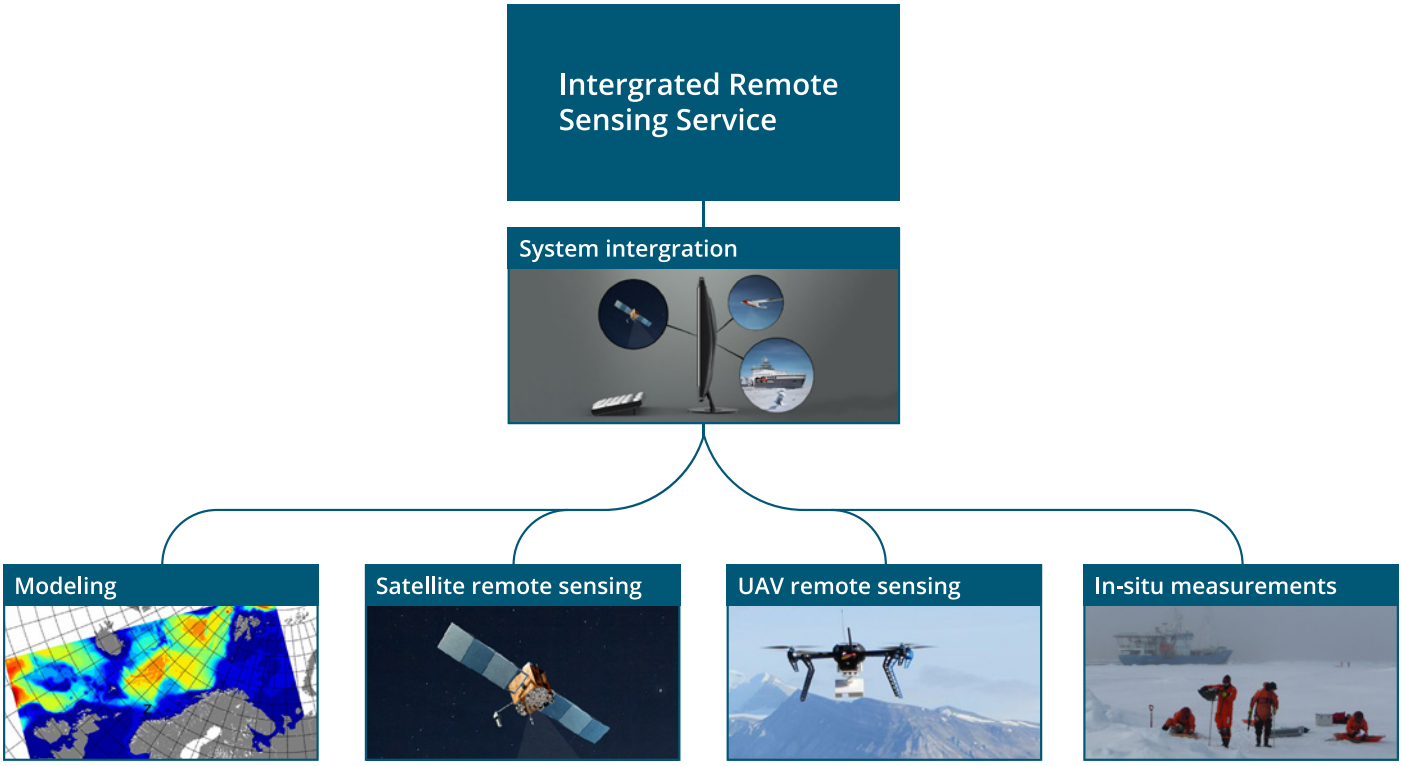
Satellite-based operational capabilities including oil spill detection, ship traffic monitoring and sea ice mapping have been demonstrated and developed into regular use.

However, there are still requirements for industrial maritime operations that have not been met. Oil and gas companies operating in the environmentally sensitive Arctic areas need monitoring technologies integrated into their day-to-day operations for operational decision support. In this work package, we will demonstrate a pilot service system showing the provision of integrated environmental information to end-users involved in Arctic operations.

The objective of this work package is to demonstrate the implementation of R&D results into some integrated pilot services to be delivered to end-users with operational needs. The service will be based on multi-sensor data acquired from various sensors and platforms, accessed via improved communication infrastructure and brought into analysis and decision though dedicated interfaces.

Key research tasks:

- Establish an infrastructure that allows the WP partners to access and perform processing on the project data in a technically efficient way close to the data storage.
- Integrate the R&D results from the other WPs into service demonstrations at KSAT and/or MET.NO to show the provision of integrated environmental information to end-users involved in Arctic operations
- Develop a visualization solution associated with the integrated pilot service demonstrations.



Achievements in 2015-2016

The activities related to WP7 in 2015 and 2016 have been focused on understanding the needs that the other WPs, and also a broader audience of researchers, have in terms of infrastructure and software framework needed to access and process data. So far the WP has primarily looked at satellite data, but will also consider data from other sources like meteorological stations or UAV platforms.

KSAT has performed and assessment on how data can be stored processed and easily delivered to the members of CIRFA.

This activity has taken the feedback from a pool of researchers and the PhD students working on CIRFA-related projects. The advised solution will be characterized by storing the available data, and enabling data processing in the "KSAT cloud", which will be preliminarily tested during a planned field exercise. The test should prove that the infrastructure can handle the data collection, storage and access, and produce appropriate results. Visualization of the results has also been considered necessary for this test, and the suggested first-step solution is to develop dedicated web application to handle this.

ARCTIC FIELD SUMMER SCHOOLS

Norway–Canada–USA Collaboration

CIRFA has received support to establish "Arctic Field Summer Schools", a project that will engage graduate students from Norway, USA and Canada in exploring science questions related to Arctic challenges through a series of summer schools.

The "Arctic Field Summer School" is funded by the Research Council of Norway (NFR) and Norwegian Centre for International Cooperation in Education (SIU), under the program International partnerships for excellent education and research (INTPART), grant agreement number 261786/H30. The project supports research and education collaboration among UiT The Arctic University of Norway, University of Alaska Fairbanks, USA and University of Calgary, Canada.

The first field-school of the project is organized by Assoc. Prof. Anthony Doulgeris at UiT The Arctic University of Norway and is planned for the period from 15 May to 2 June 2017. CIRFA partners Norut and NPI are also strongly involved in this field school.

During this first Norwegian field school, a group of 15 students will participate in a remote sensing and ship-based field work in Svalbard and Tromsø. The course is divided in two tightly related events, starting with a one-week field course on board R/V Lance to the marginal ice zone (MIZ) in and around Svalbard, where the participating students will receive introductory lectures and collect in-situ and remote sensing data to be analyzed in the subsequent session. The second week will take place at CIRFA. This part of the course will cover analysis of data collected in the field and additional archived data. The participating students will have to submit an individual report or an oral presentation at the end of the camp, and will earn credits for the participation based on an assessment of the work.

A second course will be organized at Barrow, Alaska, in 2018, on the topic of remote sensing and ground-based observations at coastal observatory flagship site, in a setting that has been a venue for advanced interdisciplinary education in the past. The final course will be a Capstone Synthesis Workshop in Calgary in 2019.

Photo: Thomas Kræmer, UiT

R/V Lance. Photo: NPI.

Skarbø checking the display cable connection between the radar operator station and her equipment, during the Arctic Ocean 2016 research cruise.

USE OF REMOTE SENSING FOR ARCTIC MARINE OPERATIONS

PhD Fellow Runa A. Skarbø bridges work of CIRFA and SFI SAMCoT (Sustainable Arctic Marine and Coastal Technology), hosted by the Norwegian University of Science and Technology (NTNU)

In her studies, Skarbø focuses on operational use of ice intelligence retrieved from remote sensing products such as synthetic aperture radar (SAR) images, marine radar and other remote sensing technologies. The ice information, i.e. ice drift velocity, iceberg detection and tracking and ice feature identification, will be combined with drift prediction, in order to assess the related risks and scenarios for marine offshore operations in the Arctic.

During 2016, Skarbø focused on finishing the course requirement part of her doctoral studies. Courses included SAR and remote sensing technology at UiT and Arctic offshore technology, both theory and field work, at UNIS. Furthermore, she did research on ice drift prediction, which resulted in a paper on modelling iceberg drift in pack ice together with Dr. Renat Yulmetov. Additionally, Skarbø participated in a six-week research cruise to the Arctic Ocean, along with SAMCoT WP5 doctoral students Hans-Martin Heyn and Jon Bjørnø. The scope of the PhD candidates' work during the research cruise was to collect valuable full-scale data from the Arctic and to gain experience from ships travelling in sea ice and icebreaking. The three PhD candidates plan to cooperate on joint research based on the data collected on this cruise.

Modelling iceberg drift in pack ice

Precise short-term modelling of iceberg drift is of high importance when operating in iceberg prone waters, in order to assess risk of and potential damages in a collision. However, most operational drift models consider forecasting in open water. Modelling iceberg drift in pack ice is challenging, mainly due to limited knowledge of additional resistance associated with the surrounding ice.

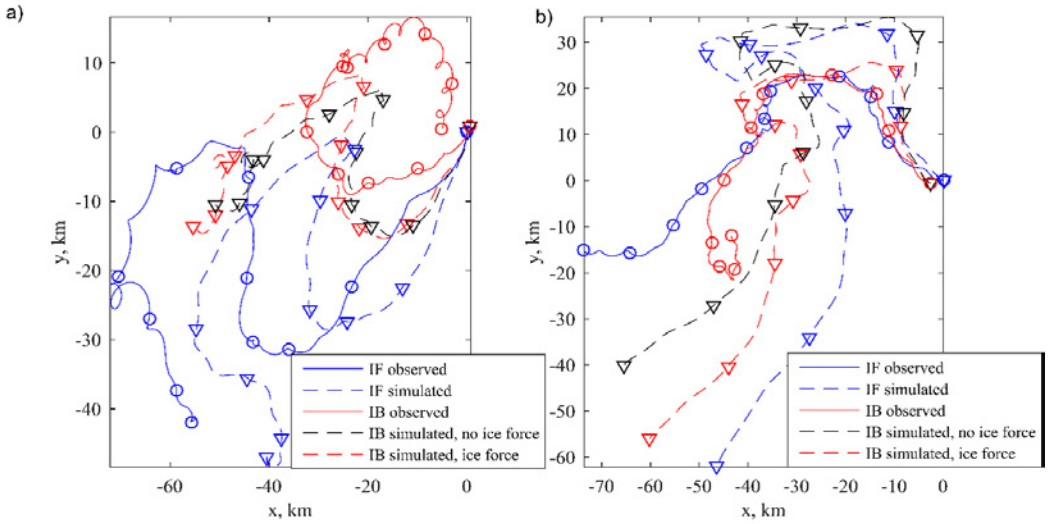


Figure: Drift trajectories of observed and modelled icebergs and ice floes. a) illustrates the larger iceberg, while b) illustrates the smaller one. Markers indicate every 24 hours. Simulations both including and excluding forcing from sea ice on the iceberg are shown.

An iceberg drift model was developed and tested using drift hindcasting with historical metocean data from the area and measured drift of two icebergs and ice floes. The icebergs and ice floes were GPS tracked off the east coast of Greenland in 2013. The icebergs were of vastly different size, the larger one having a mass of over 16 times more than the smaller one.

The model demonstrated an acceptable level of accuracy for short-term forecasting in the region, where knowledge about winds and ocean current profiles is insufficient. Furthermore, in comparing the performance with and without including forcing from sea ice, the results showed a significant effect of sea ice forcing on the smaller iceberg but only a small difference for the larger one.

The results of the study were published in a conference paper was presented at the IAHR ICE 2016 conference in Michigan, Illinois, USA.

Full-scale data collection - Arctic Ocean 2016

When the opportunity arose to join the Swedish-Canadian research cruise Arctic Ocean 2016, Skarbø had no doubt that she would like to join. First, the cruise would provide valuable full-scale data from the remote Arctic, and second, the six-week cruise would provide insight and experience from the Arctic, and in sea ice and operation of icebreakers.

Skarbø works on technology to detect movement in the ice field. Her co-supervisor, Dr. Øivind Kjerstad (NTNU/UNIS), has developed an algorithm for detecting and tracking the ice drift around the vessel using the marine radar. In her PhD work, Skarbø seeks to utilize Kjerstad's algorithm, combining the information retrieved from it with information from other sensors such as satellite SAR and/or cameras to get a complete overview of the ice drift conditions. During the Arctic Ocean 2016 research cruise, Skarbø collected data series of radar images while the ship was stationary. In addition, SAR products from Radarsat-2 along with ground truth from buoy drifters, meteorological data and rheological data from the ice was collected.

SAMCoT researchers Bjørnø, Skarbø and Heyn at the North Pole, 21 August 2016

Skarbø joined the Arctic Ocean 2016 research cruise along with two other SAMCoT participants, doctoral students Hans-Martin Heyn and Jon Bjørnø. Heyn measured ice-induced accelerations on the icebreaker's hull. Additionally, the whole cruise was documented using 180-degree front-looking and 360-degree camera systems. Thus, Skarbø and Heyn will work on comparing different sensors for use in ice action prediction on the background of the data collected from the research cruise.

IN-SITU MEASUREMENTS OF SEA ICE DURING THE FRAM STRAIT CRUISE 2016

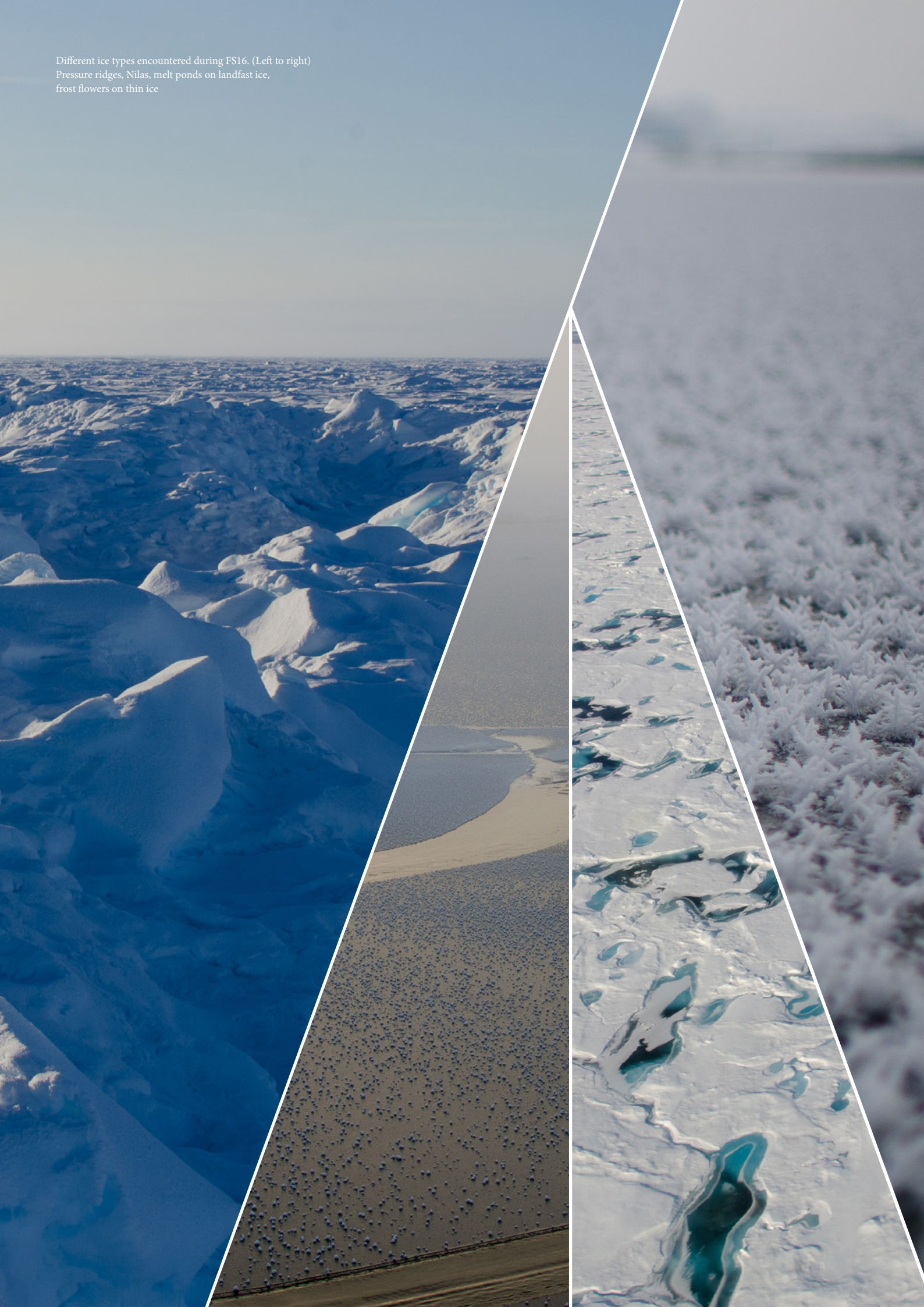
From August 25th until September 15th 2016, CIRFA post-doctoral scientist Jean Negrel (NPI) and CIRFA doctoral student Johannes Lohse (UiT) joined the yearly Fram Strait Cruise (FS16) of the Norwegian Polar Institute (NPI) on the research vessel RV Lance. The cruise is conducted by NPI every year in the late summer, and while the main objectives are oceanographic measurements in the Fram Strait between Svalbard and Greenland (i.e. recovery and redeployment of moorings as well as CTD measurements (conductivity, temperature, depth)), the cruise also offers a great opportunity for fieldwork on sea ice physics. This includes in-situ measurements on the sea ice itself as well as helicopter based ice thickness measurements and aerial photography. These field measurements make a crucial contribution to research in remote sensing of sea ice, as they provide the scientists with so-called "ground-truth" data. The ground-truth data is needed to check and validate results from remote sensing data analysis, such as ice drift velocity estimations or ice type classification.

RV Lance left from Longyearbyen, Svalbard, on August 25th and made its way across the entire Fram Strait and back within the three week cruise. Various sea ice types were encountered in the western part of the strait, where sea ice exits the Arctic in the East Greenland Current (EGC). Jean Negrel and Johannes Lohse were both members of the sea ice team on board Lance, which in total conducted 17 sea ice stations and 6 helicopter flights. Additionally a drift buoy was brought out on the landfast ice close to Greenland. While in the ice, regular sea ice observations were carried out from the bridge, logging parameters such as observed ice types, concentration and thickness.

The work during each ice station includes thickness measurements with an electromagnetic system (EM31), which are combined and calibrated with thickness measurements from drill holes. Furthermore, various cores are taken from the ice for temperature and salinity measurements as well as stratigraphic, biological and chemical analysis. Larger scale thickness measurements are carried out from the helicopter, also using an electromagnetic instrument (EM-bird), which is towed underneath the helicopter.

Various satellite data were acquired parallel to the field measurements. Because of the ice dynamics and the fast changes in ice cover over time, it is crucial to get as close overlap as possible between the in-situ measurements and the satellite acquisition. As the cruise plan can change quickly due to weather or ice conditions and is in practice adjusted on a daily basis, collaboration and communication with land parties from UiT and NPI is required to coordinate the booking and acquisition of suitable data. The acquired remote sensing images are now being used in various studies, including e.g. investigations on sea ice classification or ice edge detection.

Electromagnetic systems for ice thickness measurements. EM31 in sledge (left) and EM-bird underneath the helicopter (right).



Different ice types encountered during FS16. (Left to right)
Pressure ridges, Nilas, melt ponds on landfast ice,
frost flowers on thin ice

EVENTS

CIRFA PhD course in Radar Remote Sensing

The first CIRFA organized PhD course took place at UiT from January 25-29th, 2016 and had an excellent turnout from PhD students, Master's students, and researchers from the CIRFA partners. All in all 26 people were registered for the course in Radar Remote Sensing.

The objective of the course was to give the theoretical foundations of important aspects of radar remote sensing, and provide new students in the field a sufficient introductory understanding to explore specific applications in more detail.

Photo: V. Os, UiT & E.I. Hætta

First CIRFA Annual conference

On September 13-14, CIRFA partners and collaborating organizations gathered at Sommarøy Arctic Hotel to discuss research issues, come up with ideas for innovation projects, and to socialize in the calm and scenic environment. During the first day of the conference the whole spectrum of research questions already addressed by CIRFA were presented to the audience by work package leaders, PhD students and postdocs. The number of attendants was good, with more than 60 participants from 15 countries. The conference was organized in two sessions. The first day was allocated to science, and here the research within the different work packages were presented by the WP leaders. In addition, the PhD and Postdoc projects were presented as posters. The second day was devoted to innovation, and was organized according to the "World Café" set up, with group discussions, plus a plenum summary.

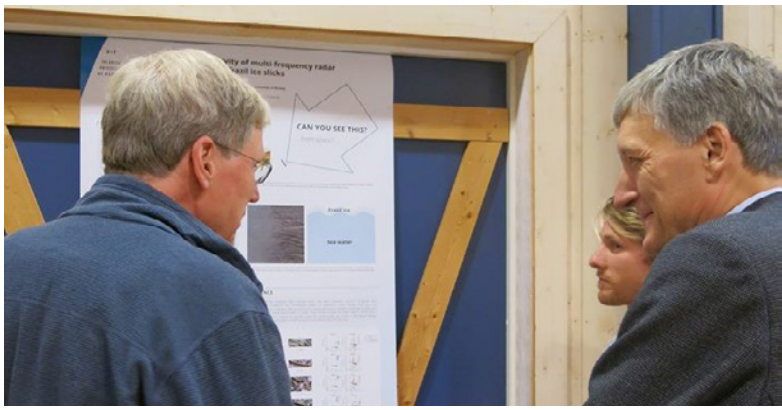


Photo: V. Os, UiT & E.I. Hætta

Young Scientist Forum

The CIRFA Young Scientist Forum (YSF) is an organization for the CIRFA and associated PhDs and PostDocs. The objective of the YSF is to exchange research, have workshops, courses and complementary skills training, and to gain a common CIRFA identity. The first YSF event took place on September 5, 2016 on the topic of communication and presentation skills.

Photo: R. Shadbakhsh.

CIRFA seminars

CIRFA has started up with regular science seminars in 2016. The seminars are meant to be a scientific forum, where students and researchers can present new results, but also get feedback and discussions on issues of relevance for their research. The seminars are announced on our website, and are open to all that are interested.

The topics addressed during the seminars in 2016 were:

- Very High Resolution Imaging of the Vertical Structure of Snowpack and Sea Ice, Prof. L. Ferro-Famil, University of Rennes 1, Rennes, France
- Newly formed sea ice in Arctic leads monitored by X-, C- and L- band SAR, by Postdoc Malin Johansson, UiT
- Quad-Polarimetric SAR for Detection and Characterization of Icebergs, by Postdoc Vahid Akbari, UiT
- The effect of imaging geometry on multipolarization SAR for oil spill observation, by Postdoc Stine Skrunes
- Numerical Simulation of Microwave Scattering From Sea Ice Based on Finite Element Method, by PhD fellow Xu Xu, UiT
- Fieldwork campaigns during the summer where CIRFA has participated, by Malin Johansson, Stine Skrunes, Martine Espeseth, UiT, and Anja Rösel and Jean Negrel, NPI
- Measurement and modeling of the transport and evolution of oil slicks on open water, by Adj. Prof. Cathleen Jones, Jet Propulsion Laboratory, California
- Research topics in the field of remote sensing at University of Florence, by Prof. Fabrizio Argenti, University of Florence

Cathleen Jones giving a talk on measurement and modelling of oil slicks.

Polar Researcher for a day

At the Science Days 2016 and the event "Den store kunnskapsjakten – Utforsk UiT", CIRFA had joined forces with the Research Center for Arctic Petroleum Exploration (ARCEx) for a joint stand at UiT in Tromsø. The researchers Katalin Blix, Johannes Lohse, Thomas Kræmer and Vahid Akbari had prepared several activities for school-children and families. The concept was "Be a Polar Researcher for a day". The children could learn about melting ice in Arctic waters by pouring salt on ice blocks and adding food coloring to see how the ice reacts to salinity. Another popular activity was to try on survival suits borrowed from the Norwegian Polar Institute and take selfies from the "Arctic".

The new generation of Polar Researchers.

ORGANISATION

Centre Board (CB)

The CB is CIRFA's main decision-making body. The CB consists of representatives from the user partners and research partners. The CB is in charge of the overall direction of the centre.

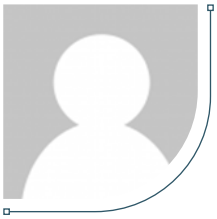
Morten Hald
Dean, Faculty of Science and Technology, UiT (Chair)

Nalan Koç
Norwegian Polar Institute

Kjell Arild Høgda
Northern Research Institute

Edmond Hansen
Multiconsult

Richard Hall
Statoil



Oddvar Ims
Eni Norge

Jan Petter Pedersen
Kongsberg Satellite Services

Scientific Advisory Board (SAB)

A SAB consisting of international experts with outstanding reputations in the relevant fields has been established to ensure excellence in research. The SAB will provide scientific input, review progress reports and provide support for networking and internationalizing of the centre's activities.

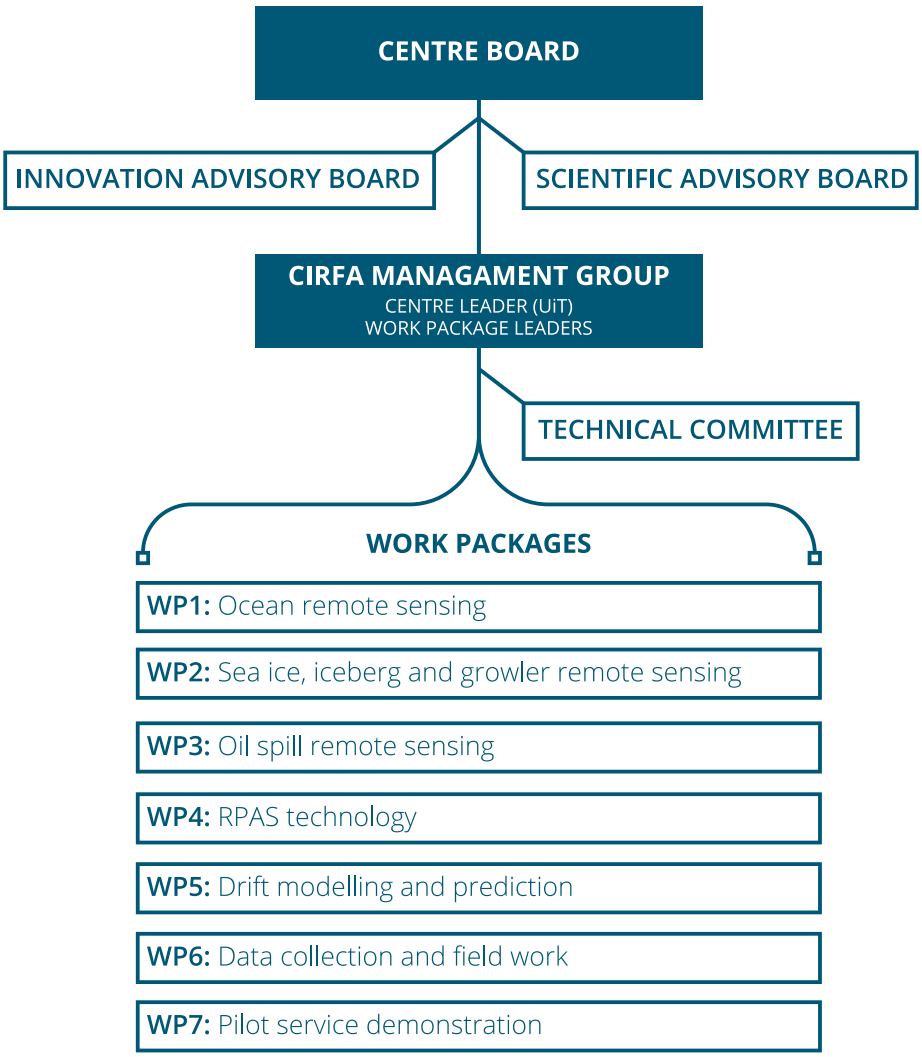
All four members of the SAB had their first introduction to CIRFA during the CIRFA conference in September 2016. The interaction with the SAB is crucial to ensure high quality in research. The SAB has already given important feedback and input to our strategic planning.

Assoc. Prof. Henning Skriver
Technical University of Denmark (DTU)

Prof. Emer. James Maslanik
University of Colorado in Boulder, Colorado, USA

Dr. Charlotte Hasager
Technical University of Denmark (DTU), Roskilde, Denmark

Prof. Dr. rer. nat. Irena Hajnsek
Swiss Federal Institute of Technology (ETH) Zürich, Switzerland



Innovation Advisory Board (IAB)

The IAB will have representatives from the industrial partners, plus external experts on innovation. The role of the IAB is to help bridge the gap between research and innovation in particular by giving input and ideas on technical developments, and discuss project progress with the Centre Leader and Work Package Leaders, evaluating project results for use and development by the user partners, identifying innovations with potential for commercial utilisation and giving recommendations for alternative routes for protection and technology transfer. The IAB its first constitutional meeting in December 2016.

Members:

Roald Johansen (Chair), *Total E&P Norge*
Caroline Dezecot, Statoil
Ove Stapnes, *Eni Norge*
Basile Bonnemaire, *Multiconsult*
Martin Skedsmo, *Norinnova*
Julien Moisan, *Innovation Norway*
Torbjørn Eltoft, CIRFA *Centre leader, UiT*
Jan Petter Pedersen, *Kongsberg Satellite Services*

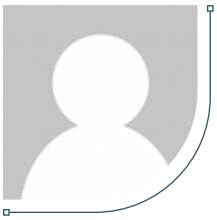
Technical Committees

The involvement as well as the valuable feedback from each of CIRFA's partners is important to make sure that the activities and results are relevant for the user partners as well as for the scientific community. The Technical Committee (TC) is an arena where technical staff from the user partners meet with scientific personnel from the research partners. Three TCs have been established based on the application domains of CIRFA:

- Ocean Remote Sensing,
- Sea Ice, Iceberg and Growler Remote Sensing, and
- Oil Spill Remote Sensing

The first TC meeting was held in December 2016, with specific focus on the collaboration between user partners and the CIRFA scientific staff.

CIRFA RESEARCH FELLOWS



Vegard Nilsen
PhD Fellow, *Norut*

Johannes Lohse
PhD Fellow, *UiT*

Ingri Halland Soldal
PhD Fellow, *NERSC*

Martine M. Espeseth
PhD Fellow, *UiT*

Alberto Arienzo
PhD Fellow, *UiT*

Marianne Myrnes
PhD Fellow, *UiT*

Richard Hann
PhD Fellow, *NTNU*

Rolf-Ole Jenssen
PhD Fellow, *UiT*

Sindre Fritzner
PhD Fellow, *UiT*

Runa Skarbø
PhD Fellow, *NTNU*

Jean Negrel
Postdoc, *NPI*

Stine Skrunes
Postdoc, *UiT*

Katalin Blix
Associate PhD Fellow, *UiT*

Xu Xu
Associate PhD Fellow, *UiT*

Temesgen G. Yitayew
Associate PhD Fellow, *UiT*

Jakob Grahn
Associate PhD Fellow, *UiT*

Patrick Stoll
Associate PhD Fellow, *UiT*

Vahid Akbari
Associate Postdoc, *UiT*

Malin Johansson
Associate Postdoc, *UiT*

Anca Cristea
Associate Postdoc, *UiT*

FINANCES

Costs per partner

Research partners:	
UiT the Arctic University of Norway	8 929
The Northern Research Institute	4 627
The Northern Research Institute Narvik	492
Norwegian University of Science and Technology	2 084
Norwegian Polar Institute	2 120
Norwegian Meteorological Institute	1 760
Nansen Environmental and Remote Sensing Center	600

Industry partners:	
Statoil	200
Eni Norge AS	100
Total E&P Norge	185
OMV Norge	57
Aker Solutions	192
Multiconsult	51
Kongsberg Satellite Services	180
Kongsberg Spacetec	195
Total	**21 773**

Funding sources

Research Council of Norway	8511
Research partners	7 417
Industry partners	5 843
Total	**21 773**

PUBLICATIONS

Peer reviewed publications

Brekke, C., Jones, C. E., Skrunes, S., Holt, B., Espeseth, M.M., Eltoft, T. (2016): *Cross-Correlation Between Polarization Channels in SAR Imagery Over Oceanographic Features,* IEEE Geoscience and Remote Sensing Letters, 13 (7), 997-1001. DOI: 10.1109/LGRS.2016.2558543.

Espeseth, M.M., Brekke, C., Anfinsen, S.N. (2016): *Hybrid-Polarity and Reconstruction Methods for Sea Ice with L- and C-band SAR.* IEEE Geoscience and Remote Sensing Letters, 13 (3), 467-471. DOI: 10.1109/LGRS.2016.2519824.

Fors, A.S., Brekke, C., Doulgeris, A.P., Eltoft, T., Renner, A., Gerland, S. (2016): *Late-summer sea ice segmentation with multi-polarisation SAR features in C and X band.* The Cryosphere, 10 (1), 401-415. DOI: 10.5194/tc-10-401-2016.

Fors, A.S., Brekke, C., Gerland, S., Doulgeris, A.P., Beckers, J.F. (2016): *Late Summer Arctic Sea Ice Surface Roughness Signatures in C-band SAR Data.* IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 9 (3), 1199-1215. DOI: 10.1109/JSTARS.2015.2504384.

Hollands, T., Dierking, W. (2016): *Dynamics of the Terra Nova Bay Polynya: The potential of multi-sensor satellite observations.* Remote Sensing of Environment, 187 (2016), 30–48. DOI: 10.1016/j.rse.2016.10.003.

Jones, C., Dagestad, K.-F., Breivik, Ø., Holt, B., Röhrs, J., Christensen, K., Espeseth, M., Brekke, C., Skrunes, S. (2016): *Measurement and Modeling of Oil Slick Transport.* Journal of Geophysical Research – Oceans. 121 (10), 7759-7775. DOI: 10.1002/2016JC012113.

Marino, A., Dierking, W., Wesche, C. (2016): *A Depolarization Ratio Anomaly Detector to Identify Icebergs in Sea Ice Using Dual-Polarization SAR Images,* IEEE Transactions on Geoscience and Remote Sensing, 54 (9), 5602-5615 . DOI: 10.1109/TGRS.2016.2569450.

Skrunes, S., Brekke, C., Jones, C., Holt, B. (2016): *A Multisensor Comparison of Experimental Oil Spills in Polarimetric SAR for High Wind Conditions,* Journal of Selected Topics in Applied Earth Observation and Remote Sensing, 9 (11), 4948-4961. DOI: 10.1109/JSTARS.2016.2565063.

Other publications 2016

Akbari, V., Brekke, C., Doulgeris, A.P., Storvold, R., Sivertsen, A. (2016): *Quad-Polarimetric SAR for Detection and Characterization of Icebergs.* Paper and talk (# 731). Living Planet Symposium, Prague, Czech Republic, May 2016.

Arienzo, A. (2016): *Scattering characteristics of oil slicks and look-alikes inferred from PolSAR data.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Arienzo, A., Eltoft, T., Brekke, C., Johnsen, H., Doulgeris, A.P., Miegebielle, V. (2016): *Analysis of roughness and dielectric properties of ocean and oil slick using the Extended Bragg model in Polarimetric SAR images.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Blix, K., Eltoft, T. (2016): *Ocean Color Remote Sensing of the Marginal Ice Zone in the Arctic.* Poster presentations at The Colour and Light in the Ocean from Earth Observation (CLEO) conference, Frascati, Italy, 6- 8 September 2016.

Brekke, C., Jones, C.E., Breivik, Ø., Skrunes, S., Holt, B., Christensen, K. (2016): *NORSE2015 – Characterizing Experimental Oil Spills by Multi-polarization Synthetic Aperture Radar.* Poster (#1400). Living Planet Symposium, Prague, Czech Republic, May 2016.

Dierking, W. and 22 coauthors (2016): *Selected European Studies On Sea Ice Classification And Drift Retrieval As Basis For Collaborative Projects During Dragon 4, Dragon 3 Final Results & Dragon 4 Kick-Off Symposium, Wuhan,* China, 4 July 2016 – 8 July 2016.

Eltoft, T. (2016): *Integrated Remote Sensing in Arctic operational services.* Break out session: Maritime Arctic Services, Arctic Circle Assembly, Reykjavik.

Eltoft, T. (2016): *Integrated remote sensing: A key technology in Arctic industrial operations.* Oral presentation in ONS 2016, Technical Session 7. Stavanger, 28 Aug.-1 Sept, 2016.

Eltoft, T., C. Brekke, H. Johnsen, R. Storvold, S. Gerland, W. Dierking, J. P. Pedersen (2016): *CIRFA – Centre for Integrated Remote Sensing and Forecasting for Arctic Operations, a new Centre for Research-based innovation hosted by UiT-the Arctic University of Norway.* White paper. Arctic Observing Summit 2016, Fairbanks, AK, USA, March 2016. 7 pages.

Espeseth, M.M. (2016): *The Hybrid-Polarity SAR mode.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Espeseth, M.M., Skrunes, S., Brekke, C., Salberg, A.-B., Jones, C.E. (2016): *Oil spill characterization in the hybrid-polarity SAR domain using log-cumulants.* Presentation 10004-42 at SPIE Remote Sensing, 26-28 September, Edinburgh, U.K.

Espeseth, M.M., Skrunes, S., Jones, C.E., Brekke, C., Holte, B., Doulgeris, A.P. (2016): *Time Series Analysis of Oil Spill Observation in the Hybrid-Polarity SAR Domain.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Fritzner, S. (2016): *Comparison of EnKF and optimal interpolation on Arctic sea ice.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Fritzner, S. (2016): *Data assimilation of Arctic sea ice using EnKF.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Hansen, E., Borge, J., Høyland, K.V. (2016): *Effects of the observational footprint on the ice thickness distribution.* 23rd IAHR International Symposium on Ice Ann Arbor, Michigan USA, May 31 to June 3, 2016.

Hann, R. (2016): *Icing and anti-icing on UAVs for cold climate applications.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Johansson, M., Brekke, C., Spreen, G., King, J.A., Gerland, S. (2016): *Newly Formed Sea Ice in Arctic Leads Monitored by C- and L-Band SAR.* Paper and talk (#1932). Living Planet Symposium, Prague, Czech Republic, May 2016.

Johansson, A.M., Singha, S., King, J., Doulgeris, A.P., Gerland, S., Spreen, G., Ressel, R., Busche, T. (2016): *Investigating Monostatic TS-X DRA acquisitions and Near-coincident C and L – band Fully Polarimetric SAR for Arctic Sea Ice Characterization.* TSM/TDM science team meeting 2016.

Johnsen, H., Nilsen, V., Engen, G., Mouche, A., Collard, F. (2016): *Ocean Doppler Anomaly and Ocean Surface Current from Sentinel 1 Tops Mode.* Paper and talk (#2972). IGARSS Beijing, China, 10-15 July 2016.

Jones, C.E., Dagestad, K.F., Breivik, Ø., Holt, B., Röhrs, J., Christensen, K.H., Espeseth, M.M., Brekke, C., Skrunes, S. (2016): *NORSE – results from the NOFO 2015 Oil-on-Water exercise.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Jones, C.E., Espeseth, M.M., Holt, B.M., Brekke, C. Skrunes, S. (2016). *Characterization and discrimination of evolving mineral and plant oil slicks based on L-band synthetic aperture radar (SAR).* SPIE Remote Sensing, 26-28 September, Edinburgh, U.K.

Lauknes et al. (2016): *High-Resolution Mapping of Sea Ice, Icebergs and Growlers in Kongsfjorden, Svalbard, using Ground Based Radar, Satellite, and UAV.* Poster presentation at AGU Fall Meeting 2016, San Francisco, USA, December 2016.

Lavergne, T. (2016): *Ocean Surface Currents : From satellite images to improved forecasts.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Lohse, J. (2016): *Sea Ice classification strategies from fully polarimetric SAR data.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Meyer et al. (2016): *@OceanSeaIceNPI: Positive Practice of Science Outreach via Social Media.* Oral presentation at AGU Fall Meeting 2016, San Francisco, USA, December 2016

Negrel, J. et al. (2016): *Observing Arctic fjord ice from in situ to satellite. Examples of the Kongsfjorden 2016 spring campaign.* Poster presentation at the Nordic Branch Meeting of the International Glaciological Society. Tromsø, Norway.

Negrel, J., et al. (2016): *In situ validation of segmented SAR satellite scenes of young Arctic thin landfast sea ice.* Poster presentation at AGU Fall Meeting 2016, San Francisco, USA, December 2016.

Negrel, J., Gerland, S., Doulgeris, A.P. (2016): *Observing Arctic fjord ice from in situ to satellite – Examples of the Kongsfjorden 2016 spring campaign.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Nilsen, V. (2016): *Ocean doppler estimation using SAR doppler with CDOP(arome) correction verified with buoys.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Nilsen, V. (2016): *Ocean state from SAR as input to ocean state modelling.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Rösel, A., King, J. Gerland, S., Wagner, P.M., and Doulgeris, A.P. (2016): *Sea ice and snow in the Arctic Ocean north of Svalbard during N-ICE2015.* Poster (#1850). Living Planet Symposium, Prague, Czech Republic, May 2016.

Skarbø, R. (2016): *Near field ice drift prediction for marine operations in the Arctic.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Skrunes, S. (2016): *Oil spill observation using synthetic aperture radar.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Skrunes, S., Espeseth, M.M., Brekke, C., Jones, C.E., Holt, B. (2016): *The effect of imaging geometry on oil spill detection using multipolarization SAR.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Skrunes, S., Jones, C.E., Brekke, C., Holt, B., Espeseth, M.M. (2016): *On the Effect of Imaging Geometry on Multipolarization SAR Features for Oil Spill Observation.* Paper and talk (# 1439). Living Planet Symposium, Prague, Czech Republic, May 2016.

Soldal, I.H. (2016): *Automatic detection of icebergs using high-resolution SAR and optical image.* Poster presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Soldal, I.H., Eltoft, T.E., Dierking, W., Sandven, S. (2016): *Detection and quantification of icebergs using Synthetic Aperture Radar and optical images.* Oral presentation at the CIRFA Conference 2016, Sommarøy, Tromsø, 13-14 September 2016.

Soldal, I.H., Eltoft, T.E., Sandven, S., Dierking, W. (2016): *Detection and quantification of icebergs using SAR and optical images.* Presentation at SONARC meeting, autumn 2016.

Sperrevik, A.K. (2016): *HF radar data assimilation and improvement of ocean models.* Presentation at South Africa-Norway Science Week 2016, Cape Town, 2 Nov. 2016

Other publications 2015

Akbari, V., Anfinsen, S.N., Doulgeris, A.P., Eltoft, T. (2015): *A Change Detector for Polarimetric SAR Data Based on the Relaxed Wishart Distribution.* IGARSS Milan, Italy, 26-31 July 2015.

Brekke, C. (2015): *Joint UiT/JPL/NASA oil spill campaign: first impressions.* SOLab workshop, St. Petersburg, Russia, 22-24 June 2015.

Brekke, C., Pedersen, S.W. (2015): *Innslag på TV2 Nyhetskanalen.* TV2 Nyhetskanalen, 2015-06-19.

Brekke,C., Pedersen, C. (2015): Samarbeider med NASA. iTromsø, 2015-06-04.

Brekke, C., Resvoll, J. (2015): *Spesialfly fra NASA forsker på oljesøl.* NRK Troms, 2015-06-02.

Doulgeris, A.P., Eltoft, T. (2015): *Aspects of model-based decompositions in radar polarimetry.* IGARSS Milan, Italy, 26-31 July 2015.

Eltoft, T. (2015): *Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA).* Oljeindustriens Miljø & Teknologikonferanse, 2015.

Eltoft, T. (2015): *Monitoring Sea Ice with Space-borne Synthetic Aperture Radar.* ALOS-2 Symposium, Akihabara, Tokyo, Japan, 17 Nov, 2015.

Eltoft, T. (2015): *Remote Sensing - hvordan kan fjernanalyse bidra til å løse utfordringer i nordområdene.* Arctic Safety Summit 2015.

Eltoft, T. (2015): *CIRFA: Radar remote sensing of Arctic sea ice.* SOLab workshop, St. Petersburg, Russia, 22-24 June 2015.

Eltoft, T., Brekke, C., Skrunes, S. (2015): *Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA): Oil Spill Detection and Characterization.* Interspill 2015, Amsterdam, Netherlands, 2015.

Eltoft, T., Doulgeris, A.P., Brekke, C., et al. (2015): *Imaging sea ice structure by remote sensing sensors.* POAC Trondheim, Norway, 14-18 June 2015.

Eltoft, T., Grahn, J., Doulgeris, A.P., et al. (2015): *A first analysis of polarimetric Arctic sea ice scenes from PALSAR-2.* ALOS-2 2nd PI Workshop, 2015.

Fors, A.S., Doulgeris, A.P., Renner, A.H.H., et al. (2015): *On the relation between polarimetric synthetic aperture radar (SAR) features and sea ice melt pond fraction.* IGARSS Milan, Italy, 26-31 July 2015.

Gerland, S., Spreen, G., Granskog, M., et al. (2015): *Seasonal Changes of Arctic Sea Ice Physical Properties Observed During N-ICE2015: An Overview.* Fall Meeting of the American Geophysical Union, San Francisco, USA, December 2015.

Hu, D., Doulgeris, A.P., Qiu, X. (2015): *An unsupervised method for equivalent number of looks estimation in complex SAR scenes.* IGARSS Milan, Italy, 26-31 July 2015.

Johansson, M, Brekke, C., Spreen, G., King, J. (2015): *Newly formed sea ice in Fram Strait leads monitored by X-, C- and L-band SAR.* ALOS-2 Symposium, Akihabara, Tokyo, Japan, 17 Nov 2015.

Johnsen, H. (2015): *Sentinel-1A Ocean Data - experiences, challenges, opportunities.* SOLab workshop, St. Petersburg, Russia, 22-24 June 2015.

Johnsen, H. (2015): *Ocean Currents and Sentinel 1.* Ocean Current Workshop. IFREMER, Brest, Germany, 2-3 Nov 2015.

Petrich, C. (2015): *ColdTech and oil in ice in Narvik.* Nordområdekonferansen 2015, Narvik, 17 Nov 2015.

Skrunes, S., Jones, C.E., Holt, B., Brekke, C. (2015): *Norwegian Oil-on-Water Exercise Campaign for Development of a Multi-Frequency SAR Slick Characterization Capability.* IGARSS Milan, Italy, 26-31 July 2015.

Storvold, R., Sweatte, C., Ruel, P., Wuennenberg, M., Tarr, K., Raustein, M., Hillesøy, T., Lundberg, T., Sumich, M., Johansen, K.-S. (2015): *Arctic Science Remotely Piloted Aircraft Systems (RPAS) Operator's Handbook.* Oslo: AMAP 2015 (ISBN 978-82-7971-090-5) 25 s.

About the SFI scheme

The main objective for the Centres for Research-based Innovation (SFI) is to enhance the innovation in the industry sector through long-term research based on close collaboration between industry and academic partners.

The SFI scheme will:

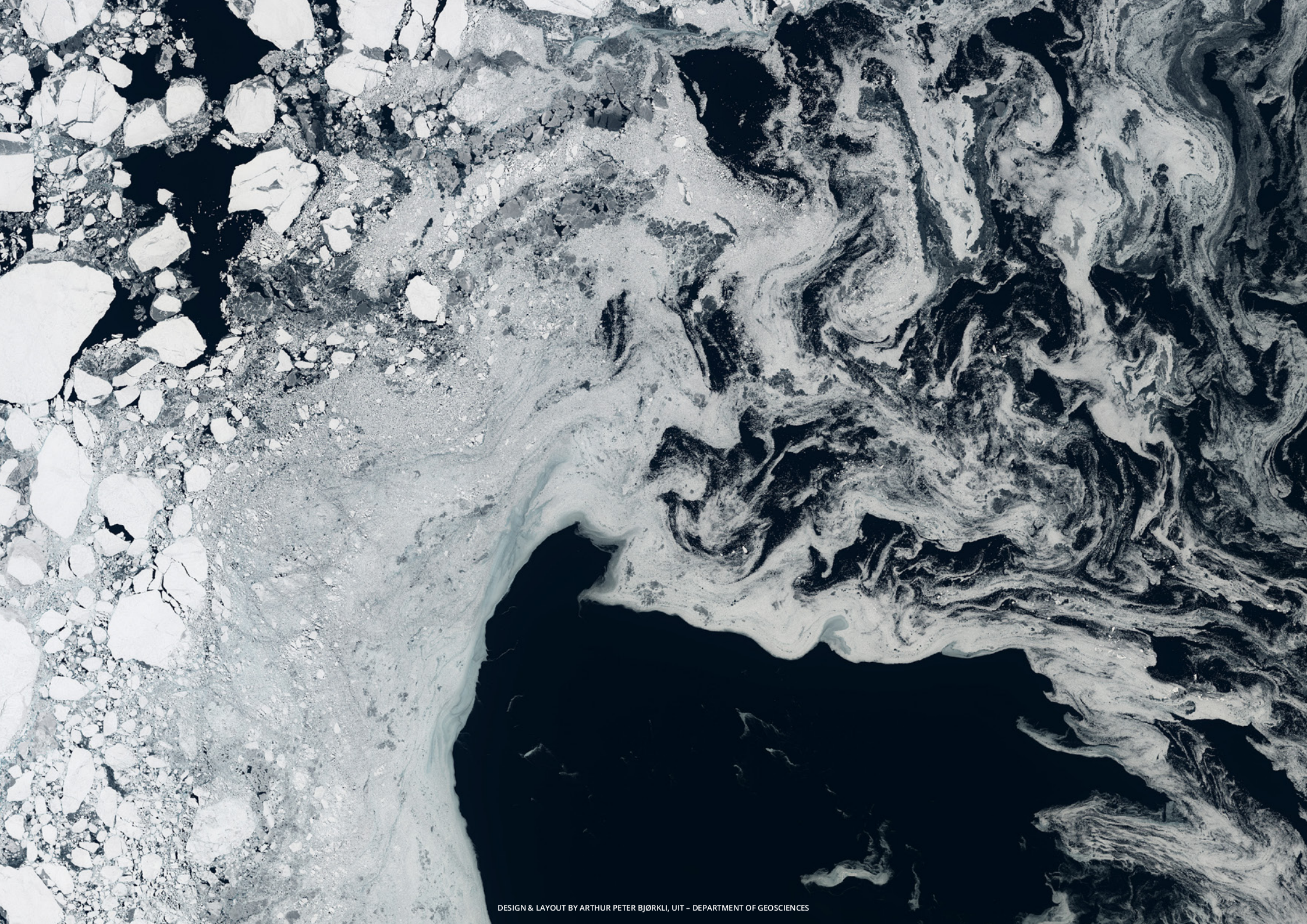
- Encourage enterprises to innovate by placing stronger emphasis on long-term research and by making it attractive to establish R&D activities in Norway.

- Facilitate active alliances between innovative enterprises and prominent research groups.

- Promote industrially oriented research on the cutting edge of international research.

- Stimulate researcher training in fields relevant to the industry, and encourage the transfer of research-based knowledge and technology.

The SFI centres are managed by the Research Council of Norway (RCN), and are co-financed by the host institution, partners and the RCN. The centres are established for a period of maximum eight years.



DESIGN & LAYOUT BY ARTHUR PETER BJØRKLI, UIT – DEPARTMENT OF GEOSCIENCES