2017
Annual Report

CIRFA – Centre for Integrated
Remote Sensing and Forecasting
for Arctic Operations

2017 IN REVIEW

Last year was an active year in the SFI CIRFA – Centre for Integrated Remote Sensing and Forecasting for Arctic Operations. It is time to take a step back and summarize some highlights of 2017.

Administration: In 2017, the administrative staff in CIRFA consisted of the Centre leader, the administrative coordinator, and the IT engineer. The Centre administration was central in planning and organizing of the Centre's activities, such as the Centre-Management meetings, scientific seminars, and workshops. We had two board-meetings, and several joint meetings with industry. The IT engineer, who started in January, had special focus on supporting the service demonstrations, which are planned to be developed in work package WP7.

Hiring: CIRFA has no now 11 PhD students and 3 postdocs in work, fully financed by the Centre. The PhD projects cover the whole research program; remote sensing of ocean, sea ice, oil spill, iceberg detection, numerical modelling, and arctic drone technology. The PhDs come from Norway (7), Germany (1), Ireland (1), Hungary (1), and USA (1), 5 are females and 6 are males. Two of the postdocs come from Norway (females) and one comes from France (male). CIRFA has also employed a full-time administrative coordinator and an IT engineer, and is currently in the process of contracting an associate professor in a tenure track position affiliated to the Department of Physics and technology at UiT the Arctic University of Norway.

Research: The research in CIRFA aims are to improve surveillance capabilities in Arctic operations, improve understanding of important geophysical processes, and improve assimilation methods and forecasting services. In general, the work consists of theoretical studies, algorithm developments, data collection and data processing. Also, in 2017, a large focus was on algorithm development related to the three applications areas: met-ocean remote sensing, sea ice remote sensing, and oil-spill remote sensing. Progress was made in all these areas, and more focus is now being put towards testing new algorithms in large scale processing tasks to evaluate operational potentials. As these activities get more mature, there will be even more interaction with user partners and stakeholders to get feedback on the proposed developments. With an operational testbed available, we are in the position to assimilate new satellite products into numerical models and evaluate the benefits of integrated products. Integration and cross-WP interaction are key activities. In WP5, the impact on model predictions of the assimilation of radial sea surface velocities from coastal HF-radars are currently being studied. This study will soon also include satellite derived sea surface velocities provided from the Sentinel 1 Doppler product.

Field campaigns, with combined in-situ and remote sensing data collections, are still important for the CIRFA research. In 2017, CIRFA was involved in field campaigns in Ny-Ålesund (sea ice), the Fram Strait (sea ice). We also conducted a large-scale laboratory remote sensing experiment in the Hamburgische Schiffbau-Versuchsanstalt (HSVA) tank to study oil-in-ice. This was organized together with the PETROMAKS-2 project, MOSIDEO. The experiment was a success and will found basis for future research. For more details on CIRFA's research activities, see work package summaries in this report, and our web site https://cirfa.uit.no.

Publications: The publication rate of CIRFA is steadily increasing, as PhD students and postdocs start to achieve publishable research results. In 2017, CIRFA researchers contributed to 17 journal papers in well-acknowledged journals. CIRFA has also actively contributed at many international scientific conferences in scientific committees, with oral presentations and posters (e.g. POLinSAR 2016, IGARSS 2016, POAC-2016). For details, sea publications on our web site https://cirfa.uit.no.

Outreach: CIRFA organizes monthly scientific seminars, with internal and external presenters. In 2017, we started to stream the presentations to reach an audience outside Tromsø. This has been a success and will be continued. CIRFA was presented at relevant political/industrial meeting places like Arctic Frontiers (Tromsø), the European Academies' Science Advisory Council (Tromsø), Beredskapsforum, Oslo, OTC 2017 (Houston), and Arctic Partnership Week (Busan, Korea).

CIRFA arrangements: CIRFA was the host of the first INTPART-funded Arctic Field Summer Schools in May of 2017. This is a series of three summer schools, where graduate students from Norway, USA and Canada are engaged in exploring science questions related to Arctic challenges. In 2017, this included a one-week field cruise on board R/V Lance to the ice edge north-west of Svalbard, plus a one-week workshop in Tromsø. We organized a Young Scientist Forum (YSF) for PhDs and postdocs, with focus on skills in "application writing". In 2017, the YSF included a one-day scientific workshop at Malangen Brygge, with high-ranked, international participants present. CIRFA again organized its annual conference at Sommarøy Arctic Hotel in October 2017, with more than 60 participants. More or less all partners were present, in addition representatives from collaborating institutions and companies. The Scientific Advisory Board (SAB) of CIRFA was present at the conference, and provided, after the conference, their comments and recommendations based on their update on on-going research and activities. In the end of April 2017, CIRFA organized a joint WP3/WP5 workshop at Jet Propulsion Laboratory (JPL), Pasadena, together with its collaborators at JPL on the topic of oil spill remote sensing and modelling.

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Contact information

CIRFA is hosted by the Department of Physics and Technology and the Faculty of Science and Technology at UiT - the Arctic University of Norway.

Visiting address: CIRFA, Siva Innovasjonssenter Tromsø, Sykehusvegen 21, 9019 Tromsø, Norway

Centre Leader: Prof. Torbjørn Eltoft, tel: (+47) 776 45184, e-mail: torbjorn.eltoft@uit.no

Administrative Coordinator: Lise Nordgård, tel: (+47) 776 23291, e-mail: lise.nordgard@uit.no

https://cirfa.uit.no

CIRFA – INDUSTRY PARTNER

Edmond Hansen
Multiconsult

Multiconsult is one of the leading firms of consulting engineers and designers in Norway. With roots going back to 1908, the company has played an important role in Norway's development and economic growth. Thanks to its 2,100 highly skilled members of staff, the company is able to provide a range of services including multidisciplinary consulting and design, project engineering and management, verification, inspection, supervision and architecture – both in Norway and overseas.

Every project that involves design and planning of large structures requires a metocean design basis, i.e., a report describing the physical environment at the site of construction. Normally, it contains one part providing the design levels of the relevant physical parameters at the site, and one part describing the operational values. The parameters in question are typically wind, waves, current, temperature, ice thickness, ice concentration, and so forth.

The design levels are values of the relevant parameters with selected return periods, i.e., a statistical measure of how often extreme values of a parameter occur. Any structure is designed against a set of design values. The operational part describes and quantifies how often given levels of the parameters are exceeded, and the duration of events of exceedance. This overview is used for planning of the construction phase, operations at the site, and maintenance during the life cycle. The data sources for a metocean design basis are direct measurements supplemented by historical observations, and data from numerical models simulating past conditions (hindcast data).

However, data availability is often poor. Time series are normally short, and are typically point observations. This is particularly true in the Arctic. With the advent of high-resolution data from various sensors carried by satellites, this situation is gradually improving. Remote sensing products are already widely used for design purposes of offshore structures. In the Arctic, such products are either used directly (e.g., ice concentration, ice extent), or indirectly through incorporation into modeled hindcast data.

CIRFA aims at providing new results and knowledge that will be used to obtain much needed environmental data from the Norwegian Arctic. Data are obtained from regions where little measured data exists, or with improved resolution and coverage. Moreover, CIRFA aims at providing data for operational use, i.e., not only for design and planning. The operational setup will result in databases which, over time, will be important sources of environmental data for engineers.

CIRFA is also providing knowledge about remote sensing technology to industrial players in the Norwegian Arctic. It brings scientists and engineers together, and provides a network for remote sensing product development and, ultimately, application of such products.

With its participation in CIRFA, it is the aim of Multiconsult to stay in the forefront within Arctic engineering. Its metocean engineers should incorporate the latest remote sensing technology into their analyses of Arctic environmental data.

Ultimately, improved knowledge about the environment should lead to improved safety at lower costs. CIRFA should be a major driver in this process.

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 Norg

Aker BP

OMV Norge

Total E&P Norge

Aker Solutions

Multiconsult

Globesar

Aranica

Maritime Robotics

FOREWORD

Professor Torbjørn Eltoft
Centre Leader, CIRFA

CIRFA's goal is to develop improved remote sensing and forecasting technology for safer industrial operations in the North. This includes integrated remote sensing products, with as detailed information as possible over the area of interest. Regional overviews are also of interest. This information should be available at the site in near real time, independent of weather and light conditions. Key services would be forecasting of weather, sea ice and ice bergs dynamics, and ocean state.

At the outset, CIRFA's stakeholders were thought to be oil companies. Oil companies conducting exploration and/or production in Arctic areas would definitely benefit from advanced remote sensing surveillance capabilities. Better monitoring is expected to support safer operations. However, petroleum operations are not the only operations in need for improved monitoring technologies. Due to the climate change, the sea ice conditions in the Arctic have changed towards thinner, predominantly, first year ice. This has opened for more ship traffic, and many tourist ships are often sailing in ice-infested waters, both in the Arctic and Antarctica. In March this year, we could read in newspapers that the Canadian/Chinese gas tanker "Eduard Toll" had sailed through the Northern Sea Route (NRS) midwinter, without assistance from an ice breaker. This is a clear manifestation of the fact that the present ice conditions encourage shipping companies to save time and money by crossing the Northern Sea Route (NRS), even in winter conditions. Also ship traffic would benefit from advanced remote sensing surveillance products and services. It is not difficult to envision that the more detailed the ice maps are, and the more precise the forecast is, the less hazardous would these transits become.

CIRFA has 5 oil companies as user partners. These partners provide the necessary feedback to CIRFA researchers when it comes to observation and service needs of the petroleum industry in Arctic operations. CIRFA does not have user partners from the shipping sector. This is in many respects unfavorable, and efforts will be made to try to extend the partner list into this sector. On the other hand, we note that CIRFA has research partners and collaborators with large experience from maneuvering ships in sea ice. CIRFA has benefited from collaborations with other projects with frequent ship cruises into the ice. We will continue with this also in the future. The Nansen Legacy and the MOSAIC are two up-coming projects, where CIRFA will be involved, and where we will use the opportunity to test out algorithms, sensors, and models, and get access to in-situ measurements. The research topics of these projects also have strong connections to some of CIRFA's focus areas, which will add additional benefit.

The key message is that CIRFA's research on the development on integrated remote sensing, high-resolution sea-ice mapping, modelling and forecasting have relevance in several industrial sectors. This is a big incitement for further work. This annual report gives a glimpse of the broad spectrum of the activities CIRFA was engaged in last year. I would like to acknowledge the CIRFA staff for their contributions to our achievements in 2017.

Professor Torbjørn Eltoft,

Centre Leader, CIRFA

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

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
- Improve monitoring capabilities
- Improved assimilation methods and forecasting services

The research tasks areorganized in seven work packages centered around three application areas:
- Ocean
- Sea ice and icebergs
- Oil spill remote sensing

The work should generate new, innovative algorithms and processing schemes, which foster new services and products. The processing schemes are implemented and demonstrated in WP7. Integration and cross WP activities are key activities, as illustrated in the figure below.
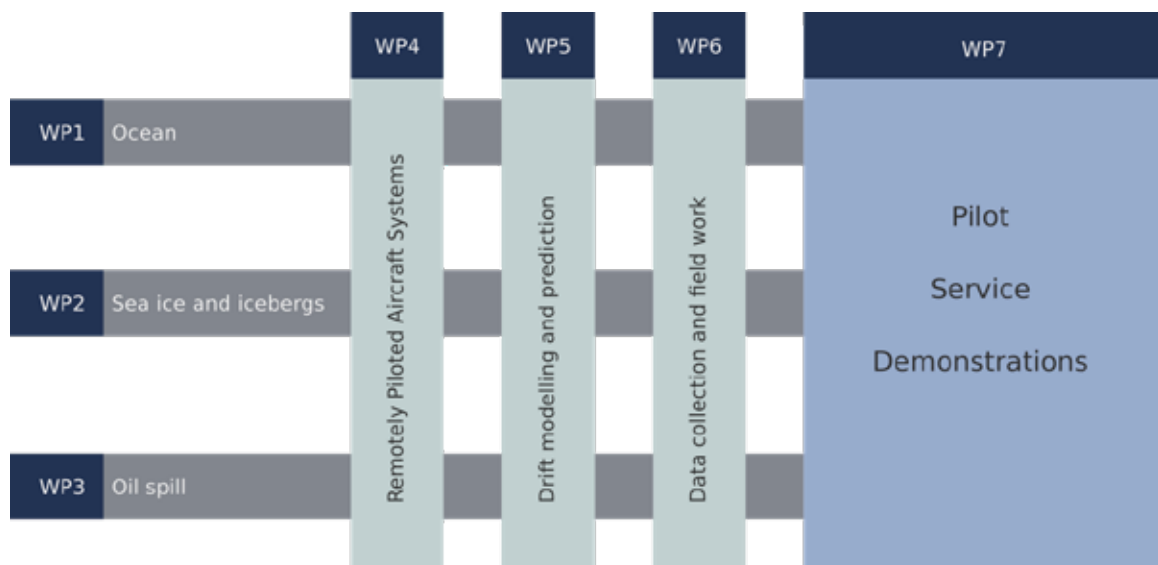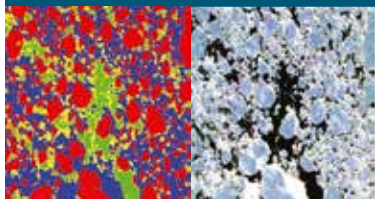
The different WP and their key activties are listed below:

WP1
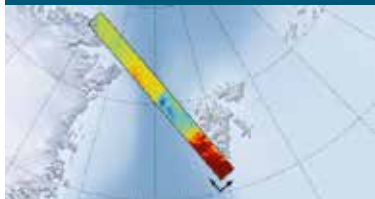
Ocean Remote Sensing

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.
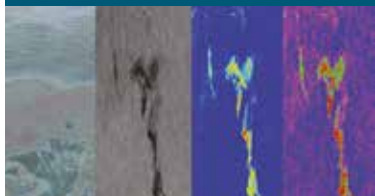
WP2

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..
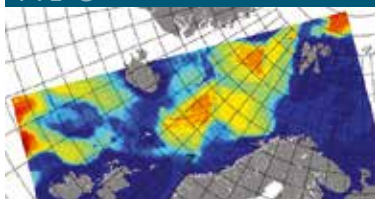
WP4

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

CIRFA does research on algorithms and methods to reliably detect, monitor, integrate and interpret multi-sensor data describing the physical environment of the Arctic. The focus is on analysis and interpretation of Synthetic Aperture Radar data. The research also addresses methods for assimilating satellite-based information into models to perform predictions of sea ice state, meteorological and oceanographic conditions on both short and long timescales. Below, a few scientific high-lights from 2017 are included.

Comparing SAR-Based Short Time-Lag Cross Correlation and Doppler-Derived Sea Ice Drift Velocities

In a recently accepted paper, Thomas Kræmer et al. (2018) show some initial results on estimating the Doppler radial surface velocities over Arctic sea ice using the Sentinel-1A (S1A) satellite. The study presents a quantitative comparison between ice drift derived from the Doppler shifts and drift derived using the traditional cross correlation between a pair of S1A and Radarsat-2 images with a time lag of only 25 min. The experiment demonstrates that the Doppler technique is capable of measuring a velocity signal from the ice, if the ice is fast moving. But, for typical sea ice speeds, the uncertainties may grow beyond the actual speed of the ice motion. The paper is published in IEEE Transactions on Geoscience and Remote Sensing. Read more in Kræmer et al. (2018).

Validation of Sea Ice Topographic Heights Derived from TanDEM-X Interferometric SAR Data

This work investigates the potential of measuring local sea ice surface topography over a fast-ice area in the Fram Strait using an interferometric SAR dataset acquired by TanDEM-X. The area of interest consists of multi-year ice, with ridges as high as 2 to 3 meters. Spatially overlapping helicopter surveys, with a time lag of about 8 hours to the InSAR acquisitions, were conducted to collect additional information about sea ice conditions in the area. Also, at the same time stereo camera images were acquired from the helicopter and processed using photogrammetric techniques to derive sea ice surface heights over a 2D grid. It is found that 80 % of the ridges with height values greater than 0.5 m can be estimated with an RMSE value of 0.3 m or less compared to the stereo camera data. The relative error is decreasing significantly at larger surface heights. The paper will be published in IEEE Transactions on Geoscience and Remote Sensing z Read more in Yitayew et al. (2018).

Iceberg Detection in Open and Ice-Infested Waters Using C-Band Polarimetric Synthetic Aperture Radar

A recently published paper performs investigations of ice object detection and characterization using full-polarimetric SAR data. Icebergs represent a significant threat to shipping, offshore oil and gas installations, and subsea pipelines in some Arctic areas. In this regard, satellite-borne synthetic aperture radar (SAR) has become a well-established tool for detecting ice-objects in the often dark and cloud-covered polar regions. The detection of small icebergs floating in non-homogeneous sea clutter environments is, however, still a challenging task. The paper proposes a new, segmentation-based methodology for automatic detection and characterization of ice objects in high-resolution polarimetric SAR images. Initial results using a time series of RADARSAT-2 images, containing numerous of icebergs broken off from glaciers in Kongsfjorden on Svalbard, demonstrate that the proposed approach is viable. The paper was published in the September issue of IEEE Transactions on Geoscience and Remote Sensing in 2017 by V. Akbari and C. Brekke.

Successful Oil-in Ice Experiment in the Hamburg tank

In March April 2017 WP3 of CIRFA, together with the PETROMAKS 2 research project MOSIDEO (http://mosideo.no), conducted a successful large-scale on oil-in-ice experiment at the Hamburgische Schiffbau-Versuchsanstalt (HSVA) tank. The objective was twofold. Firstly, the oil-spill detection capabilities of oil in sea ice were investigated with remote sensing sensors, including a tomographic ground-based radar system, a wideband radar, a hyperspectral camera, and a hyperspectral laser induced fluorescence imaging sensor. A particular focus of the remote sensing measurements was to quantify the detectability of oil as it approaches the ice surface during warming. Secondly, using a destructive sampling approach, the micro-scale interaction of oil with sea ice was investigated following an under-ice oil spill during freezing and a subsequent warming event. The data collected during the three-week experiment will found basis for detailed research by CIRFA's WP3 team in coming months. PhD candidates will use the data in for their thesis work.
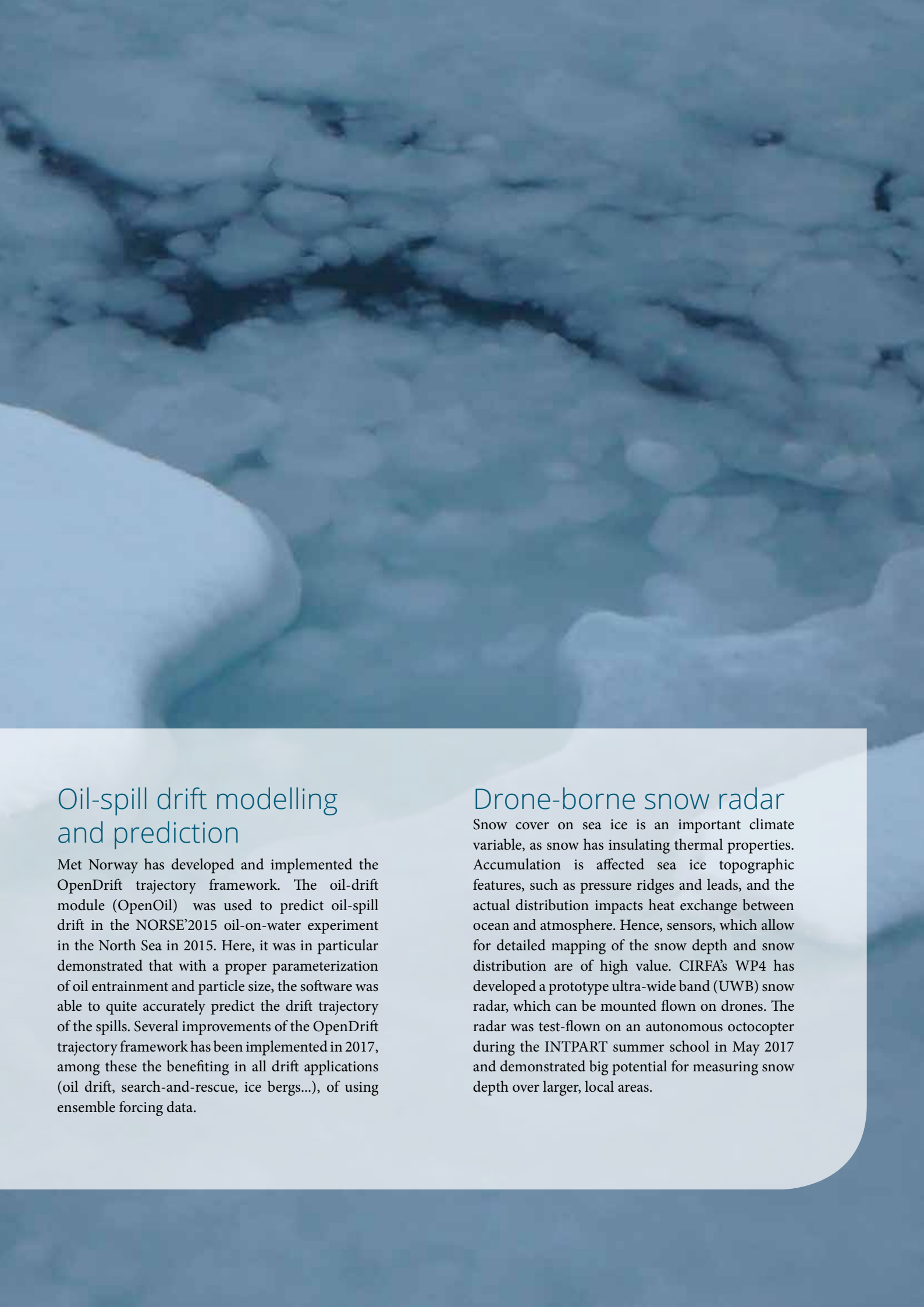
INNOVATION HIGHLIGHTS

CIRFA's innovations activities are oriented towards development of integrated remote sensing products and services, with the objective to improve monitoring and forecasting capabilities in the Arctic of benefit to industrial operators, science, and society in general. Below, we highlight some of CIRFA's most mature Innovation Activities.

Wind from SAR

CIRFA has facilitated the set-up of an operational processing-line at KSAT for generating oceanic wind-maps from synthetic aperture radar data. The product is based on algorithms developed at NORUT, and installed at KSAT, as part of the work in WP 1 of CIRFA. The system can process ocean wind field from various satellite missions, modes of operation and polarizations, and uses model input for calibration. The system has been running in an operational environment for a couple of months, and results in terms of geophysical quality, throughput and stability are very good.

Sea ice segmentation

WP2 of CIRFA has further refined the advanced and automatic UiT-algorithms for analyzing narrow-swath quad-polarization SAR images over sea ice. The algorithms have now been modified to also accommodate wide-swath, dual-polarization SAR data from Sentinel 1 and Radarsat 2, which will allow them to be implemented and tested in operational large-scale processing. Even if the transition to wide-swath data has revealed some new challenges related to the signal's incidence dependence angle and system noise, initial tests show great operational potential, and in Q2 2018 a semi-operational *ice-water mask* will be available. The ice-water mask will subsequently be integrated as an additional layer into IA 1 product, and significantly improve the wind estimation maps in ice-infested waters.

Oil-spill drift modelling and prediction

Met Norway has developed and implemented the OpenDrift trajectory framework. The oil-drift module (OpenOil) was used to predict oil-spill drift in the NORSE'2015 oil-on-water experiment in the North Sea in 2015. Here, it was in particular demonstrated that with a proper parameterization of oil entrainment and particle size, the software was able to quite accurately predict the drift trajectory of the spills. Several improvements of the OpenDrift trajectory framework has been implemented in 2017, among these the benefiting in all drift applications (oil drift, search-and-rescue, ice bergs...), of using ensemble forcing data.

Drone-borne snow radar

Snow cover on sea ice is an important climate variable, as snow has insulating thermal properties. Accumulation is affected sea ice topographic features, such as pressure ridges and leads, and the actual distribution impacts heat exchange between ocean and atmosphere. Hence, sensors, which allow for detailed mapping of the snow depth and snow distribution are of high value. CIRFA's WP4 has developed a prototype ultra-wide band (UWB) snow radar, which can be mounted flown on drones. The radar was test-flown on an autonomous octocopter during the INTPART summer school in May 2017 and demonstrated big potential for measuring snow depth over larger, local areas.

Leader of the management team; Prof. Torbjørn Eltoft

Team:

Ellen Ingeborg Hætta
Administrative coordinator

Thomas Kræmer
IT Engineer

Marit Helgesen
Advisor, UiT

Work package 0
CENTRE MANAGEMENT

The Centre management team of CIRFA, consisting of the Centre leader, the Administrative coordinator, one IT Engineer and one Advisor, connects the Centre's business for all actors involved through different organized meetings and activities. Administrative meetings are held every week to make sure that the Centre completes priority tasks. In addition leadership meetings, where all the WP`s leaders and the Centre management team are present, are held every three weeks. The project has an active website http://cirfa.uit.no, where news and information about activities in the Centre are posted. Ellen Ingeborg Hætta has worked as the Administrative coordinator at CIRFA in a 50% position for 2 ½ years. From 2018, CIRFA has employed a new full-time administrative coordinator, Lise Nordgård.

The management team is responsible for the daily running of the Centre, and shall ensure that the Centre:

1. Coordinates legal contractual, research and technology development, patent applications, ethical, financial and administrative work.
2. Organizes and completes tasks within deadlines, resources and quality levels.
3. Optimizes future innovation and value creation for the user partners, other segments of the Norwegian business sector and society; and.
4. Delivers reports within expected quality standards.

**Work Package Leader;
Prof. Harald Johnsen,
Norut/UiT**

Team:

Geir Engen
Senior Researcher, Norut

Tom Grydeland
Senior Researcher, Norut

Vegard Nilsen
PhD Fellow, Norut

Katalin Blix
Associate PhD Fellow, UiT

Work package 1
OCEAN REMOTE SENSING

Objectives and motivation:

Ocean surface is the complex boundary between two very dynamic and stochastic media, the ocean and the atmosphere. High-resolution sea state information derived from remote sensing data can improve modelling and forcasting.

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.

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.
- Perform extensive product calibration and validation analysis.
- Support short range forecasting of ocean state through coupling with high-resolution numerical models in collaboration with work package 5

Achievements 2017

The research efforts have been concentrated on the following activities:

- Implementation and testing of processing system in an operational environment.
- Developing innovative algorithm for ocean wind vector retrieval (PhD activity).
- Satellite and in-situ data collection and processing as part of the Finnmark drifter experiment.

A first version of an operational ocean processing system has been installed and tested in the operational environment at Kongsberg Satellite Services. The system can process ocean wind field from various satellite missions, modes of operation and polarization. The results achieved in terms of geophysical quality, throughput and stability are very good. Example products from Radarsat-2 and Sentinel-1A missions are shown in figure below.

The PhD activity has been developing estimators and geophysical model function to support a stand-alone SAR ocean wind/wave/current retrieval algorithm. The research goal is to derive a consistent retrieval of ocean parameters without using any external data such as numerical models. A paper on wind vector retrieval is submitted to SeaSAR 2018 conference (ESRIN, 7-10 May).

The Finnmark drifter experiment has in this phase dealt with collecting Sentinel-1 IW data, HF-radar (located at Fruholmen Lighthouse) data, and surface drifter data. In addition Arome model data is collocated with Sentinel-1 IW data, for retrieval of surface current. A comparison of surface current from the different instrument measurements is scheduled for 2018.

Outreach:
Outside CIRFA, the team has close cooperation with European Space Centre (both ESRIN and ESTEC), as well as with research institutes in Europe such as Ifremer (France), OceanDataLab (France), TU Delft (The Netherlands). The research activity has been presented at various international workshops/conferences such as the Copernicus S-1 Quality Working Group Meeting, 10 – 11 May at ESRIN (Italy), the GlobCurrent Workshop, 21-23 March 2017 ESRIN (Italy), and SPIE Remote Sensing 2017, 11-14 September, Warsaw (Poland).
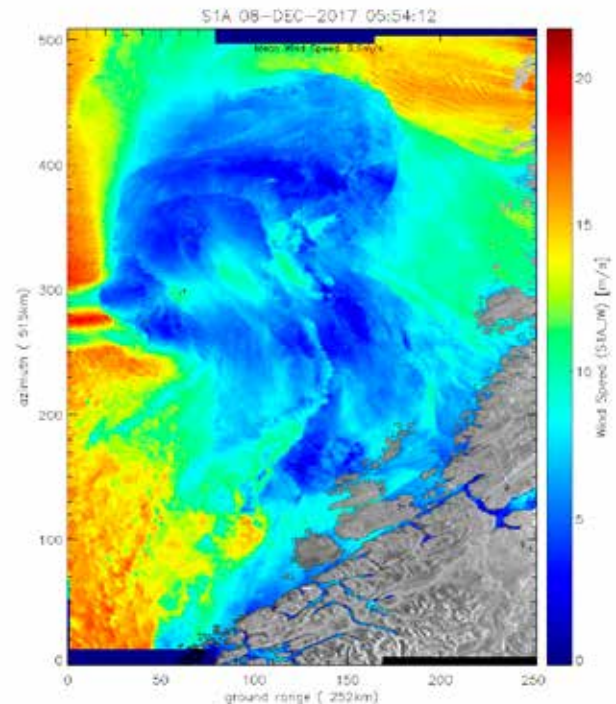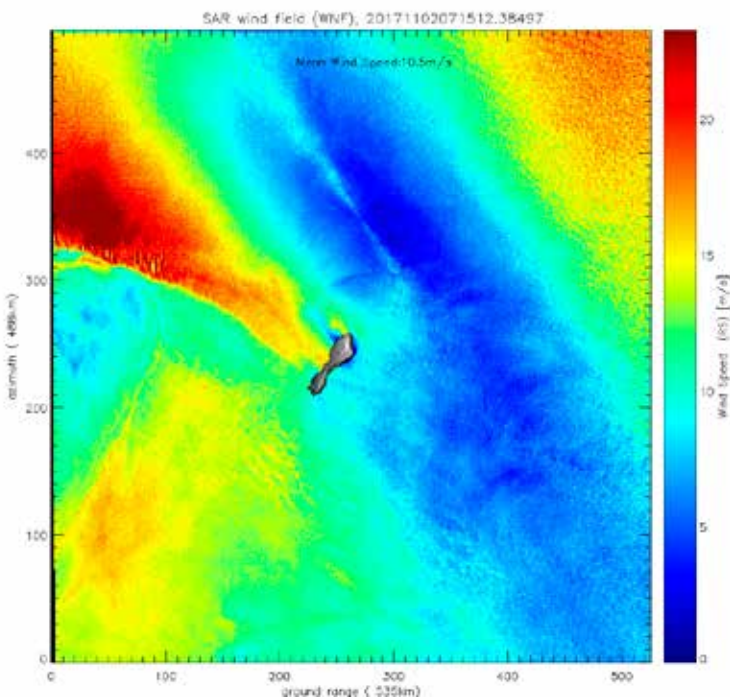
Left: Ocean wind speed derived from Radarsat-2 ScanSAR mode around Jan Mayen. Right: Ocean wind field derived from Sentinel-1a IW mode outside coast of Mid-Norway.

Work Package Leader;
Prof. Wolfgang Dierking,
AWI/UiT

Work Package Co-Leader;
Assoc. Prof. Anthony Doulgeris,
UiT

Team:

Sebastian Gerland
Senior Researcher, NPI

Wenhui Lang
Visiting Researcher,
Hefei Univ. of Tech., China

Jean Negrel
Postdoctoral Researcher, NPI

Vahid Akbari
Associate Postdoctoral Researcher,
UiT

Anca Cristea
Associate Postdoctoral Researcher,
UiT

Johannes Lohse
PhD Fellow, UiT

Ingri Halland Soldal
PhD Fellow, NERSC

Xu Xu
Associate PhD Fellow, UiT

Temesgen Gebrie Yitayew
Associate PhD Fellow, UiT

Jakob Grahn
Associate PhD Fellow, UiT

Thomas Kræmer
Associate PhD Fellow, UiT

Work package 2

MONITORING SEA ICE AND ICEBERGS

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. Remote sensing is a key technology for characterizing the ice surface and detecting ice objects to prevent hazards in Arctic operations.

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 2017

This year's focus has been on sea ice classification and iceberg detection, with both tasks beginning to draft journal papers. Both tasks rely heavily on ground-truth data to understand remote sensing characteristics and for training machine-learning algorithms. Ground truth measurements are sparse in the Arctic, with usually only a few campaigns each year, and we coordinate as best that we can with field planning, i.e. through WP6 and other international partners. Nevertheless, there is often not a high success rate with matching helicopter flights and ground measurements and co-locating satellite scenes, partly due to weather and operating logistics and complicated by the minimum 3-day ordering cycle for some satellite systems. To try to alleviate this restriction, we aim to extend our training opportunities by manually labelling ice types in many SAR scenes, and using the expertise of ice analysts from the Norwegian Ice Service in Tromsø. However, for this to work well, we need to be confident that the pseudo-ground-truth class labels are correct.

We note that the segmentation algorithm has proven useful for identifying statistically distinct regions in the SAR images and generally agrees with other algorithms as demonstrated in collaboration with Suman Singha from DLR. Segments in SAR images have been subsequently labelled by an ice expert, from a purely remote sensing point of view. We now need to evaluate this remote sensing identification to actual ground-truth data, where it exists, such that we can identify where the labelling is good or poor. This comparison with actual ground-truth data will both give us confidence where it already works well, give us directions to where efforts may improve the labelling, or indicate SAR remote sensing limitations.

Any classes that we are confident with will then expand our potential training data to all scenes labelled by the expert and open up for studying the SAR features and characteristics, and possibly give insights into how to automate this, currently, manual identification. This strategy is depicted in the following figure, and the red boxed comparison is being prepared for a journal paper led by Jean Negrel.
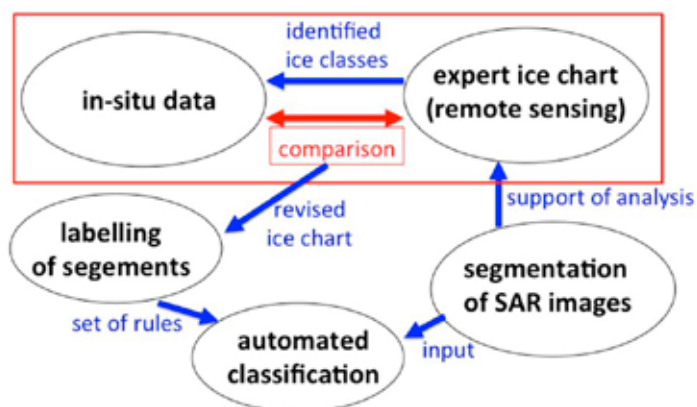
Learning strategy for sea ice classification improvements

Other research progress in WP 2

- PhD student Johannes Lohse developed a decision-tree algorithm for sea ice classification that performs similarly to the all-at-once classification method (only 2% improvement), but also gains further insights into feature interpretation for different tasks. A journal paper is in preparation. Results are illustrated in figure on next page.

- The performance of the decision-tree approach and of different polarimetric features for iceberg detection were investigated (V. Akbari, J. Lohse).

- Our operationally targeted wide-swath image segmentation algorithm, incorporating the incidence angle variation into the statistical modelling, has progressed with the first coded implementation now producing results, but also raising some further questions. The first paper is now being drafted by Anthony Doulgeris and Anca Cristea.

- Postdoc Jean Negrel explored optimizing the segmentation algorithm to identify the thin ice edge obtained from field measurements in Kongsfjorden. A journal paper is in press.

- A study on using multi-frequency SAR for sea ice classification and its validation was finished and the report delivered to ESA (W. Dierking in a team from Chalmers University of Technology, Sweden).

- W. Dierking contributed to devising an approach for lead detection (with colleagues from University of Bremen, Germany), and to the implementation of a new method for retracking of altimeter signals received from sea ice (with colleagues from China and Finland).

- PhD student J. Grahn and members of the CIRFA team implemented and analyzed different theoretical models describing the interaction of radar waves with the sea ice surface and volume to support further improvements of ice parameter retrievals.

- I. Halland Soldal implemented and tested algorithms for iceberg detection. She was awarded a two-month internship at the Open University, Faculty of Science, Technology, Engineering, and Mathematics in the framework of the "Space Placements in Industry Scheme" to work with Dr. Marino on a detector that combines the Sentinel-1 HH-and HV-polarized channels.

- Studies on methods for improving the detection of sea ice deformation and quantification of deformation parameters were continued (W. Dierking with colleagues at AWI).

Relation to users, stakeholders and research communities (e.g. workshops, conferences, field work)

▫ In October, a meeting took place between Dean Flett from the Canadian Ice Service, Nick Hughes and Frode Dinessen from the Norwegian Ice Service, and members of the CIRFA team to discuss needs and expectations of the mapping agencies, closer interactions with CIRFA, and the potential of recent and future satellite technologies for sea ice classification and iceberg detection and tracking.

▫ In December, members of WP2 and WP5 met to exchange information about work progress and to develop a strategy for exchange of data and results.

▫ Anthony Doulgeris visited the NSIDC in Boulder, Colorado, USA for six months to collaborate with Ted Scambos on Landsat archived data in the Canadian Archipelago to analyse structural or textural changes in the sea ice over the last four decades.

▫ Wolfgang Dierking participated in the meeting of the International Ice Charting Working Group in which he is co-chair of the Applied Science and Research Standing Committee. The meeting was held in Hobart/Australia at the end of September.

Paper highlight:

1. Suman Singh from DLR visited CIRFA for one month to worked closely with Malin Johansson on linking in-situ and airborne data with satellite imagery collected during N-ICE with the objective to improve and validate ice type classification. To be published in IEEE Transactions on Geoscience and Remote Sensing in 2018.

2. The use of interferometric SAR for the retrieval of sea ice parameters has recently gained increased interest. W. Dierking and colleagues from Airbus and DLR published a feasibility study on the retrieval of sea ice surface topography in "The Cryosphere", in which they provided the theoretical background and investigated the potential of different mission scenarios. Results of retrievals were shown from TanDEM-X data acquired close to the coast of Alaska, and the influence of ice conditions and satellite orbit constellations was discussed. This work was extended in a study presented by T. Yitajew, W. Dierking, and colleagues from CIRFA and NPI, who compared ice surface topography retrieved from Tandem-X images obtained over fast ice in Fram Strait with coincidently acquired data from stereo-photography and a laser profiler. The elevation derived from Tandem-X imagery compared well with the measurements of the other sensors for surface heights larger than 0.5 m. This work will be published in 2018 in the IEEE Transactions on Geoscience and Remote Sensing
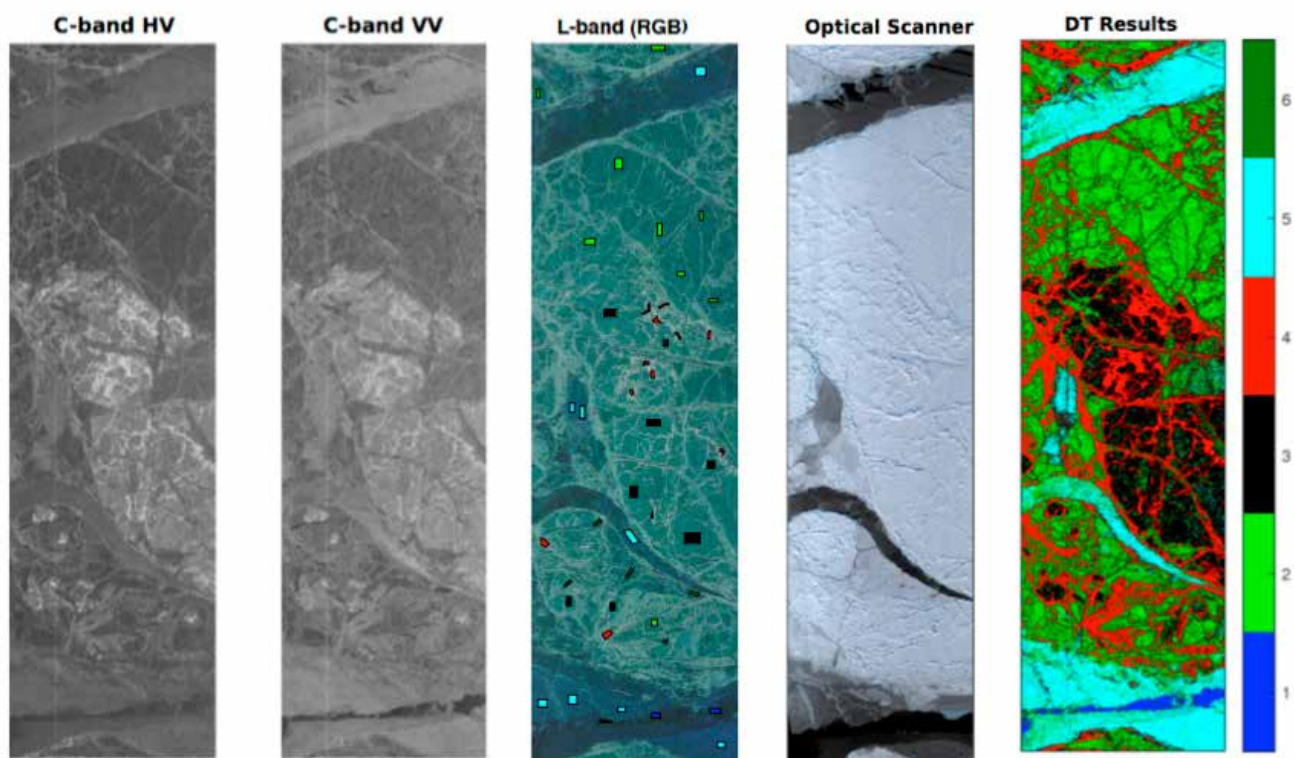
Example of trained Decision-Tree classier (right-most) with C-band input images (left two), overlaid training boxes on L-band image (middle, R=HV, G=HH, B=VV) and photograph used for visual confirmation of classes (second from right).
The coloured classes are: 1) open water; 2) grey-white ice; 3) level ice; 4) deformed ice; 5) nilas; and 6) grey ice.

Work Package Leader;
Prof. Camilla Brekke, UiT

Work Package Co-Leader;
Dr. Christian Petrich,
Norut Narvik

Team:

Cathleen Jones
Adj. Prof., Jet Propulsion Lab,
California Inst. of Tech./UiT

Laurent Ferro-Famil
Adj. Prof., Univ. Rennes 1/UiT

Martin Gade
Visiting Researcher,
University of Hamburg, Germany

Fabrizio Argenti
Visiting Researcher, Univ. Firenze

Stine Skrunes
Postdoctoral Researcher, UiT

Malin Johansson
Associate Postdoctoral Researcher,
UiT

Megan O'Sadnick
Researcher, Norut Narvik

Martine Mostervik Espeseth
PhD Fellow, UiT

Cornelius Quigley
PhD Fellow, UiT

Marianne Myrnes
PhD Fellow, UiT

Work package 3
OIL SPILL REMOTE SENSING

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 spill`s 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. 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 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 behavior, 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 2017:

Several international research articles were published in 2017 by researchers within WP3 either as the lead author or as a co-author. We are for instance still disseminating results from the NORSE 2015 campaign. In particular, a couple of publications in high impact journals should be mentioned; PhD student Martine Espeseth was the lead author on an article in IEEE Transactions on Geoscience and Remote Sensing in July 2017 and Post. Doc. Stine Skrunes and coauthors submitted one manuscript to Remote Sensing of Environment that is currently in it final stage of revision. These publications addresses key research foci within task 3.1, such as emerging radar technology, including full polarimetric and hybrid-polarity SAR, and effects of the wind direction and incidence angle on SAR measurements of slicked and unslicked sea surfaces. Cornelius Quigley joined task 3.1 as a Ph.D. student in the fall of 2017. His current research focus is on retrieval of dielectric properties of slicks from full polarimetric SAR measurements.

In 2017, two new Ph.D. students were hired and started up their projects within task 3.2; Marianne Myrnes and Megan O'Sadnick. A three week laboratory experiment was conducted in Hamburg in the spring, involving researchers both from CIRFA and MOSIDEO, a collaborating project funded by the Research Council of Norway through the PETROMAKS2 program. A massive amount of data was collected from oil-in-ice experiments in an indoor tank. The work also involved a number of remote sensing systems being tested out, such as a wide band radar and a tomographic SAR system. The first

conference proceeding paper from the tomographic radar system measurements of oily sea ice is expected to be published in the summer of 2018. Field work in Beisfjorden has also been conducted within task 3.2, and more fjords in Nordland and Troms shall be visited. The goal with these campaigns is to study ice to examine the impact of ice in fjord environments on the fate and effect of oil and pollutants and related response activities.

A workshop with participants from WP3, WP5, and colleagues from Jet Propulsion Laboratory took place at Caltech in April 2017. The focus of the meeting was on analysis of SAR measurements of oil slicked sea surfaces, integration of remote sensing data with oil drift models, and future opportunities for joint oil-on-water experiments.

Progress in the planning of upcoming oil-on-water campaigns in 2018 and 2019 were made in 2017. With respect to these future experiments, a goal within CIRFA is to better synchronize in-situ data collection of the surface slicks and remote sensing measurements from various platforms. A collaboration between KSAT, NOFO and CIRFA on remote sensing of produced water at the Brage oil production field was also initiated last year.

The work package team members contributed to a number of both national and international conferences in 2017.

Four Ph.D. students are now working on projects within WP3, two in each subtask.
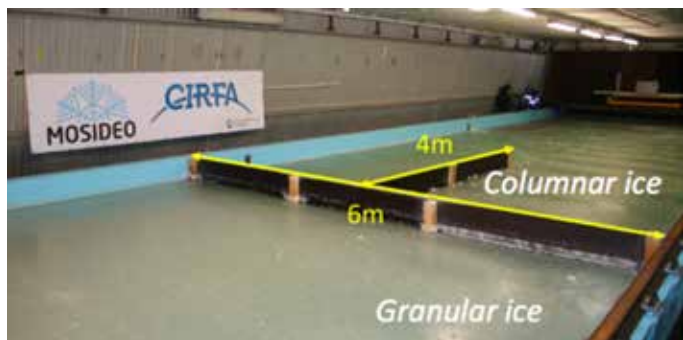
Artificially grown sea ice at the HSVA facilities in Hamburg. Photo: Marianne Myrnes.

Participants at the WP3/WP5/JPL workshop in California, USA.

Martine in Texas under a conference in Fort Worth, Texas, USA 23.-28. July 2017

Work Package Leader;
Assoc. Prof. Rune Storvold,
Norut/NTNU

Work Package Co-Leader;
Prof. Tor Arne Johansen,
NTNU

Team:

Svein Jacobsen
Professor, UiT/Norut

Stian Andre Solbø
Senior Researcher, Norut

Agnar Sivertsen
Senior Researcher, Norut

Richard Hann
PhD Fellow, NTNU

Rolf-Ole Jenssen
PhD Fellow, UiT

Work package 4
RPAS TECHNOLOGY

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.
- Develop onboard data processing and improve 'concepts of operation' allowing for integration in non-segregated airspace

Achievements in 2017

In 2017, a prototype ultra wide band (UWB) radar was completed (Prof Svein Jakobsen and Rolf-Ole Jenssen). It was made ready for mounting on the Norut "Kraken" multirotor drone. The radar was used in the HSVA experiment organized by WP3. Though the radar signal is strongly absorbed by sea-ice and penetration is poor the hope was to see improved penetration in presence of oil. The radar was flown on the Kraken as part of the INTPART summer school and was used to successfully measure snow depth on sea-ice. Plans for upgrade of the radar to increase range, to increase feasebility for fixed wing, and beyond line of sight operations have been made and will be implemented in 2018.

At the HSVA experiment, WP4 also provided an autonomous instrument package consisting of a remote sensing reflectance spectrometer, RGB camera and TIR camera that was mounted on the moving boom collecting data at fixed intervals (Rolf-Ole Jenssen, Stian Solbø, Tom Grydeland and Andreas Tøllefsen).

A field experiment was conducted on Svalbard April 25th –May 8th on real time detection and tracking of ice-floes and icebergs and deicing on small UAS. This work was in collaboration with the ARCEx and AMOS projects. Near real time data analysis and data transfer was coupled with navigation to optimize tracking. In addition data was collected to work on revisiting and recognition of ice-floes with purpose of addressing drift velocities.

Within research addressing atmospheric icing, CFD flow model simulation system was set up to study effect of ice aggregation on wing performance. Ice structures has been 3D printed and will be used to test simulations in wind tunnel experiments. Participation is planned with a US experiment in May 2018 where measurements of mixed phase cloud particles properties will be conducted on UAS flight in Ny-Ålesund.

Real time monitoring, navigation, analysis and stitching of image data while detecting icebergs and mapping ice edge on test flights in Kongsfjorden, Svalbard. The left panel show the new NLIVE real time analysis and visualization tool. The database also allow for annotation and sharing in real time over the internet as well as synchronized distributed viewing and analysis data back in time.

**Work Package Leader;
Dr. Kai H. Christensen,
Met Norway**

**Work Package Co-Leader;
Prof. Rune Graversen, UiT**

Team:

Keguang Wang
Researcher, Met Norway

Knut-Frode Dagestad
Researcher, Met Norway

Ann Kristin Sperrevik
Researcher, Met Norway

Sindre Fritzner
PhD Fellow, UiT

Runa Skarbø
PhD Fellow, UiT

Patrick Stoll
Associate PhD Fellow, UiT

Work package 5

DRIFT MODELING AND PREDICTION

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).
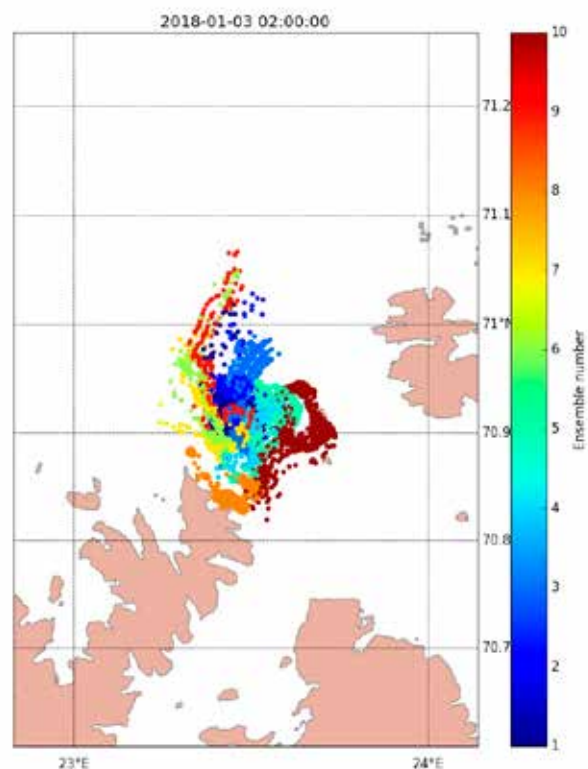
Achievements in 2017

A coupled ocean-sea ice modeling system with a 2.5 km horizontal resolution was configured and tested (see Fig. 1). This modeling system shares the same domain as MET Norway's Arctic weather prediction model AROME-Arctic. Further tests and configuration of the EPS are part of the activities in 2018. Sea ice data assimilation methods based on ensembles were tested in 2017, and PhD candidate Sindre Fritzner obtained promising results using so-called multivariate techniques. Such techniques utilize dependencies between different model variables so that observations of one parameter (e.g. ice thickness) can be used to adjust another parameter (e.g. ice concentration).

Several improvements of the OpenDrift trajectory framework has been implemented in 2017, in particular related to parameterisation of oil entrainment and drift in the oil drift module (OpenOil). Among the generic improvements, benefiting all drift applications (oil drift, search-and-rescue, ice bergs...), is the use of ensemble forcing data. This is expected to be especially valuable for the upcoming ensemble ocean-sea ice modeling system, by providing a quantification of the uncertainties in the predicted trajectories.

We also participated in field campaigns last year. PhD candidate Runa Skarbø took part in Statoil's sea keeping trials in the Baltic Sea in March, collecting marine radar data for input to her method for tactical ice drift predictions. Ground truth observations in the form of drift beacons were also collected, and analysis of the field data continues in 2018. In collaboration with WP1, we also performed a field experiment investigating the currents entering the Barents Sea. The main purpose of this activity is to investigate the potential in using satellite SAR observations (WP1) as a source of surface currents for data assimilation (WP5). The Institute of Marine Research (IMR) assisted us with insitu deployments, and 21 surface drifters were released on Oct. 16-17. This area is monitored by the Fruholmen HF radar, and the IMR also deployed current profilers (ADCPs) in the area. A detailed comparison of the currents observed by the different instruments will be made in 2018. Our aim is to assess the quality and error statistics of SAR derived currents so that these can be used in the ocean data assimilation.

OpenDrift simulation using ensemble input. The case is a simplistic oil spill drift experiment with a release just north of Sørøya, with surface particles being passively advected by the ocean model surface currents and with 2% wind drift added. For this test we used the atmospheric ensemble "MEPS" to provide 10 different wind forcings, and the colors show the drift induced by each ensemble member.

Drifter trajectories obtained during the first part of the Finnmark experiment in October 2017. The IMR assisted with drifter deployments, which were made northwest of Sørøya from R/V Johan Hjort.
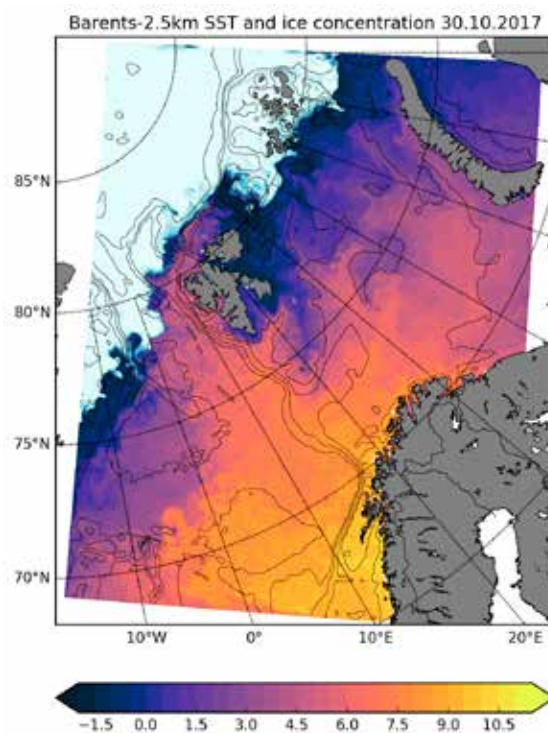
The coupled ocean-sea ice modeling system. The figure shows sea surface temperature (SST) and sea ice concentration produced during a test run. The model domain is the same as the operational Arctic weather prediction model AROME-Arctic to facilitate direct coupling to the atmospheric model.

Work Package Leader;
Dr. Sebastian Gerland, NPI

Work Package Co-Leader;
Assoc. Prof. Rune Storvold,
Norut/NTNU

Work Package Co-Leader;
Prof. Camilla Brekke, UiT

Team:

Penelope Wagner
Researcher, Met Norway

Jean Negrel
Postdoctoral Researcher, NPI

Work package 6
DATA COLLECTION AND FIELDWORK

Objectives and motivation:

The objective of this CIRFA work package is to organize dedicated field campaigns on and over Arctic sea ice and ocean to combine accurate in-situ, Remotely Piloted Air Systems (RPAS), aircraft and helicopter observations, and satellite data, and improve validation shortcomings by seeking new and refined methods.

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 sta-tions 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 Insti-tute was frozen into drifting ice in the Arc-tic Ocean north of Svalbard), annual cam-paigns 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.mosaicob-servatory.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 need-ed 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 2017

Work in WP6 in 2017 included both planning and conducting Arctic and laboratory fieldwork, as well as duties that need to be done after the respective campaigns; including sample and data processing, and further on work with the data all the way to presentations and peer-review publications in scientific journals. The activity was closely coordinated with other work packages in CIRFA (WP2, 3 and 4). Postdoctoral researcher Jean Negrel, who has 50% of his position in WP6, contributed to the work centrally through participation in two fieldwork campaigns and with data processing and publishing of results.

Relation to users, stakeholders and research communities
Through fieldwork, CIRFA work was discussed and communicated with other scienists and non-scientists, through meetings before, alongside, and after the actual fieldwork, in Tromsø, Longyearbyen, on RV Lance and in Ny-Ålesund. Around the INTPART cruise, lectures were given about fieldwork practices and the science background, and cruise participants could visit the freezer laboratory facilities at the Fram Centre in Tromsø. Results from the project work in WP6 and collaborating WPs were disseminated in different ways: Presentations of results were given at important international conferences, thus reaching the scientific communities in different disciplines; Arctic Frontiers, Tromsø, Norway (January 2017), Arctic Science Summit Week Prague, Czech Republic (April 2017), AMAP Arctic Climate Conference Reston, VA, USA (April 2017), and the IGS Symposium in Boulder, CO, USA (August 2017). In addition, updates were also posted on social media on CIRFA`s website and @oceanseaicenpi (Instagram, Twitter, Facebook).

Fieldwork
Two main sea-ice based fieldwork campaigns were arranged in 2017: A campaign in Kongsfjorden, working on landfast sea ice in the inner fjord, and an expedition with RV Lance to the marginal ice zone northwest of Svalbard (northern Fram Strait), a main component of the closely related RCN INTPART project, both in May 2017. The Kongsfjorden work was closely coordinated with WP2 of CIRFA and with the UAV survey done by the Norut team (collaboration with WP4). UAV flights were planned and conducted using input from field observations, and flight tracks were interactively adjusted depending on the shape and position of the fast ice edge in the fjord. Sea ice samples were taken, ice and snow thickness measured, and the exact shape of the ice edge mapped with GPS from a boat.

Beyond new fieldwork, 2017 studies in WP6 included also data and sample processing from 2016 samples and new 2017 sea ice samples, originating from Kongsfjorden fast ice (2016 and 2017 samples and data) and from drifting sea ice in the marginal ice zone northwest of Svalbard (2017 samples and data) and from Fram Strait (2016 samples and data). In the freezer lab, the preparation of thick and thin sections of selected ice samples helps to say more on which ice types can be found in the regions sampling took place.

Another important activity in 2017 was the ice tank experiment at the HSVA in Hamburg, Germany, in March. CIRFA (WP3 and 6) could add a component to an already planned experiment, where ice was generated in the large ice tank at HSVA, and behavior and detectability of oil in ice could be studied.

Peer-review scientific publications 2017
Parts of the work in WP6 ended up in scientific peer-reviewed publications which came out in 2017. The new results deal with use of satellite SAR to aid a better understanding of the Arctic sea ice system (Rösel et al. 2017), with focus on methods, improving image analysis, combination of satellite observations with airborne and ground measurements (Johansson et al. 2017, Negrel et al. 2017), and applications for other disciplines (Assmy et al. 2017). This work was performed in close collaborations with other work packages of CIRFA, and partly also with other research projects.

Work Package Leader;
Torunn Tøllefsen, KSAT

Work Package Co-Leader;
Dr. Nick Hughes, Met Norway

Work Package Co-Leader;
Dr. Jan Petter Pedersen, KSAT

Team:

Gudmundur Jøkulsson
Director Systems Development,
KSAT

Thomas Kræmer
IT Engineer, UiT

Work package 7
PILOT SERVICE DEMONSTRATION

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.
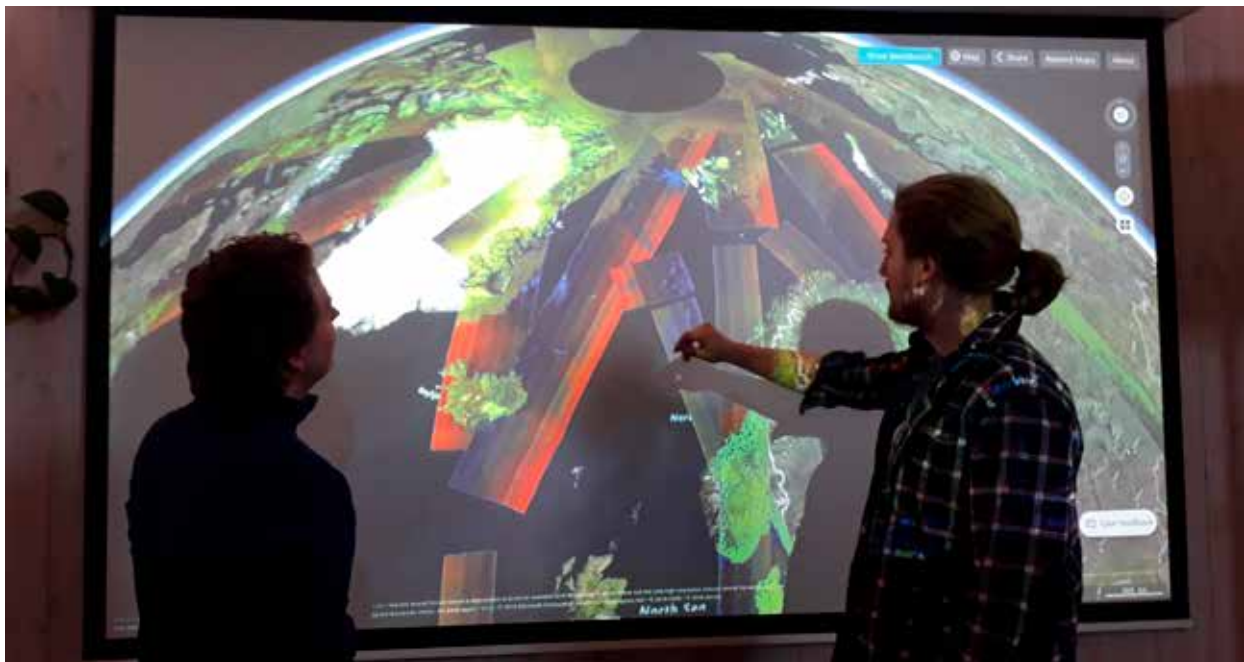
Johannes Lohse (WP2) and Thomas Kræmer (WP7) discussing remaining challenges for automated sea ice analysis.

Achievements in 2017

CIRFA services rely on linking remote sensing and in-situ measurements to forecast models. The focus of WP7 the past year has been on supporting cross work package collaboration, identifying the needs of modelers and setting up plans to provide the needed input. Through these discussions the maturity of the available analyses have been mapped, resulting in a demonstration plan which will guide the development for the remainder of the project. At the same time, systems are being set up which can support simple ingestion of remote sensing analyses into models and at the same time allow visualization and sharing of results using standard interfaces.

Through an internal project, KSAT has improved their infrastructure and CIRFA now has access to dedicated computing resources in the KSAT private cloud for running demonstrations and testing algorithms. Another important contribution from KSAT is a better interface for searching in KSAT catalogues which makes it simpler to run demonstrations requiring data that is not publicly available. Available infrastructure is not limited to KSAT, however. In the coming years it will be just as important to be able to make use of cloud platforms such as the Copernicus Data and Information Access Services (DIAS) and the European Space Agency's (ESA) Thematic Exploitation Platforms (TEP). WP7 is adapting existing algorithms to allow them to run on such systems, providing more flexibility in how and where we run our analyses.

A fully automated SAR wind product is up and running and being tested by KSAT. At the same time an updated sea ice segmentation algorithm is being tested at MET. The MET office has given useful feedback indicating that masking out water before segmentation improves the algorithms ability to distinguish between different ice types. The next phase is therefore to extend or combine the segmentation with an automated ice/water classification. The ice/water mask will directly benefit several work packages (WP1, WP2, WP5, WP6). This includes for example improved ocean wind in Arctic regions, sea ice area concentration for model assimilation and high resolution ice charts.

At this stage feedback from CIRFA partners has been limited to KSAT and MET, being the two main service providers. Several products are expected to stabilize in 2018 and it will be more natural to involve also industry partners in a feedback loop at that time. To prepare for this, we are taking care to make results available using standard formats for geographical information systems (GIS) which should allow industry partners to explore CIRFA results using their own tools and portals.

Feedback from industry users was obtained for example through a collaboration on produced water involving NOFO, KSAT and CIRFA as well as CIRFA's participation in a BaSEC/NOFO exercise. CIRFA also participated in a H2020 Innovation Training Network proposal, lead by Prof. Manolis Koubarakis, National and Kapodistrian University of Athens. The ITN application included several CIRFA industry partners and also included Serco who is involved in the development of the DIAS platform for ESA.

CIRFA has also involved partners in supervision of master students. Nick Hughes at the Norwegian Ice Service (WP7 / Met) co-supervising a student on further development of sea-ice edge detection from SAR algorithm. Nick presented at Arctic Shipping Summit in December in London.

ARCTIC FIELD SUMMER SCHOOLS

Norway–Canada–USA Collaboration

CIRFA 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 INTPART project supports research and education collaboration among UiT-the Arctic University of Norway, University of Alaska Fairbanks (UAF), USA and University of Calgary (UC), Canada. Through a series of summer schools, we want to engage graduate students from Norway, USA and Canada in exploring science questions related to Arctic challenges. The students will get field experience from the physical Arctic environment, hands on knowledge on how measurements are performed to support scientific questions, and learn how environmental changes can be studied and monitored through the use of advanced remote sensing technologies. The education partners will gain field experience, observational data, and material that can be used in their university teaching courses, as well as real research data publishable in scientific journals.

The first field school in the Spring of 2017 included a one-week field cruise on board R/V Lance to the ice edge north-west of Svalbard, plus a one-week workshop in Tromsø. The cruise introduced the 15 students to techniques for sea water sampling, snow and ice thickness monitoring, snow pit and ice coring measurements, UAV/drone observations, and satellite image acquisition, as well as general awareness, navigation and safety in the Arctic. The subsequent workshop included lectures about current topics, techniques and challenges in the Arctic, as well as beginning to explore the in situ data and satellite images obtained during the field cruise.

The students were very active participants throughout the cruise and workshop and submitted reports in the months following. The reports demonstrated that the students have learned the connections between field measurements and remote sensing imagery, and the 'big picture' perspective relating to Arctic monitoring and the climate. A few reports are actually the beginnings of scientific journal papers with international scientific collaboration. By all reports from participants and partners, this year's field school appears to have been a great success.

The second field school is well into the serious planning for a field school in Alaska from May 29 to June 9, 2018. The overall theme of the school is the study of processes of the Arctic coastal environment at the intersection between the marine, terrestrial, atmospheric and cryospheric environments using ground-based

and remote sensing observations. The course will be primarily based in and near the Barrow Environmental Observatory (BEO) and will be conducted in close collaboration with UIC Science (Ukpeaġvik Iñupiat Corporation), where the participating students will receive introductory lectures and collect in-situ and remote sensing data to be analyzed in collaboration with their instructors.

We recently presented a poster at the Arctic Frontiers 2018 conference in Tromsø in January. The final field school will be a Capstone Synthesis Workshop in Calgary in 2019.

IGARSS

At the 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS2017) in Fort Worth Texas there were several presentations given by scientists from or associated to CIRFA. A number of the presentations related to WP2 and addressed topics such as sea ice classification work lead by Temesgen Yitayew presented by Camilla Brekke and work on ice berg detection lead by Vahid Akbari presented by Malin Johansson. Sea ice classification work done as a part of the scientific exchange between DLR and CIRFA was presented by Suman Singha (DLR) where Nick Hughes and Malin Johansson were among the co-authors. In addition, Anthony Doulgeris presented two works conducted together with previous guest researchers: the first with Prof. Lang, among others, from Hefei University of Technology, China, on an improved sea ice incidence angle correction method; and the second with Dr. Hu from the Chinese Academy of Science, presenting a numerical speed-up approach for a statistical modelling method with a broad range of applications.

WP3 also received attention with one presentations by Camilla Brekke about oil spill dispersion and Martine Espeseth presented work lead by Stine Skrunes about oil spill detection and characterization and Malin Johansson presented a poster about how to separate oil spills from newly formed sea ice. For further information about the titles of the talks please see the "Publication" section in this report.

Martine Espeseth (Foto. Malin Johansson)

Arctic frontiers Emerging Leaders

The Arctic Frontiers Emerging Leaders (AFEL) program selects 30 young professionals from different countries to discuss opportunities and challenges in the Arctic. The candidates participate in a series of technical, social and cultural events accompanied by mentors from academia, politics and business. The program starts in Bodø, and continues on the Norwegian Coastal Steamer, Hurtigruten, with the final destination in Tromsø. The final part of the AFEL program is the participation in the annual conference in Tromsø, the Arctic Frontiers. During the program the participants are challenged to engage in presentations and discussion.

In 2017 CIRFA associated Katalin Blix was one of the selected participants in the AFEL program. Her participation resulted an ongoing successful collaboration with the Hungarian Embassy in Norway to strengthen bilateral relationships within research between Hungary and Norway. Katalin`s AFEL poster was awarded the most outstanding poster at the science section of Arctic Frontiers.

Informal tech talks

CIRFA WP7 does not yet have any PhD positions although two positions are being announced in 2018, expected to start June 2018. WP7 is currently supporting CIRFA demonstrations by helping other work packages to define their service demonstrations and transitioning the research from using commercial development environments with expensive licenses to open source alternatives which can be more easily used in production. At UIT, the CIRFA group have bi-weekly discussions on technical topics aiming to make students more proficient in working efficiently with satellite data and handling larger datasets. We have also had informal technical presentations and discussions including several members of the remote sensing community including UiT, Norut, Met, NPI and NERSC. These meetings are a nice forum for discussions between research partners facing similar challenges.

Young scientist forum (YSF)

The CIRFA Young Scientist Forum (YSF) is a chance for PhDs and PostDocs within CIRFA or associated with CIRFA to get together and learn complementary skills. The CIRFA YSF 2017 took place 5-7 September and was co-organized with the UiT Earth Observation (EO) group seminar, resulting in a three-day workshop. The first day was mainly aimed at the young scientists and the main topic for the YSF was research proposal writing. Presentations on the topic were given by representatives from the Department of Research and Development at UiT and from Nofima. The day ended with a "research speed dating" session to make the scientists more familiar with each other's projects and to establish connections between them. The next two days were spent in Malangen, with in total 23 participants from the CIRFA YSF and the EO group, including external professor IIs and specially invited speaker Martin Gade from the University of Hamburg. Martin Gade was chosen as his research includes links to several of the WP's within CIRFA and he was by the students seen as an inspirational scientist. The program was a mix of scientific presentations, a programming course and a panel discussion on life as a scientist.

This years YSF takes place in the Vilmarksentret, Kvaløya just outside Tromsø on 16 March 2018 and features a presentation from Martin Skedsmo from Norinova on the topic of Innovation.

Photo: R. Shadbakhsh.

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Student exchange

Martine M. Espeseth is a PhD student at UiT. She is a member of work package 3; Oil Spill Remote Sensing. In this text she tells us about her international exchange experience to California, USA in 2016, and her expectations for the upcoming exchange later this year.

"During the spring of 2016 I went on an exchange to Jet Propulsion Laboratory (JPL) for 3 months. In this period, I worked closely with my co-supervisor Cathleen E. Jones, and Benjamin Holt. Being part of the earth observation group at JPL provided me with new impulses and understanding in the topic of remote sensing. Experiencing this new vibrant environment provided me with an excellent opportunity for growth, both personally and as a scientist. This stay facilitated ample opportunity for sharing of knowledge within CIRFA.

My next stay at JPL will further solidify the close collaboration between UiT and JPL within CIRFA. Major focus areas during the stay will be to plan the oil-on-water exercise in 2019, acquiring new skills and impulses, and continuing/finalizing on-going research efforts."

Master Degrees during 2017

During 2017 three MSc students submitted their master thesis. In addition 6 new MSc students started with their master programme at CIRFA in 2017 and will all graduate in 2018.

Name	Gender	Topic
Arja Beate Kvamme	F	A classification Strategy for Multi-Sensor Remote Sensing Data – An analysis and implementation of Meta-Gussian classification schemes
Jonas Toennis	M	Spectral measurement improvement through optical tree delineation
Kai Magne Kaspersen	M	Marine and Satellite Radar Reviews

RESEARCH FACILITIES

Oil-in-ice tank studies at HSVA

If an aerial survey does not find oil in an ice-covered region is this because there is no oil or is this because it cannot be detected?

The behavior oil in sea ice-covered waters can be quite dynamic. Oil that had frozen into the ice in winter will re-emerge in spring. Oil that was beneath the ice originally will move upward through widening brine channels as the ice warms, eventually reaching the surface. Detecting oil that is at or near the surface is substantially easier than detecting oil beneath or inside sea ice, expanding the range of suitable remote sensing techniques.

In order to gain ground-truth data during various stages of oil surfacing, CIRFA measured the response of a range of remote sensing techniques in the Hamburg Ship Model Basin (HSVA) Arctic Environmental Test Basin (AETB). Remote sensing measurements were accompanied by detailed studies of the ice microstructure and distribution of oil performed under collaborating PETROMAKS2 research project MOSIDEO.

Experiments took place during three weeks from 15 March to 4 April 2017, involving 14 researchers that performed the equivalent of one man-year of laboratory work and had no accidents to report. Participating institutes were UiT, Northern Research Institute Narvik and Tromsø, Université de Rennes 1, NTNU, and University of Alaska Fairbanks. Six of the participants were Ph.D. students or became Ph.D. students shortly after the experiments.

The ice tank was 6 m x 30 m wide, which made it possible to separate the tank to grow ice under two different growth conditions simultaneously: calm conditions, and wind. In order to generate a realistic granular ice layer, the water surface had been agitated by a row of fans. This was the first time wind-driven agitation had been used for granular ice generation at HSVA, and project participants were very pleased with the results. The different ice conditions led to distinctly different behavior of oil in ice which had not been documented this clearly before.

The first two weeks were used to form the ice cover, perform 54 controlled oil spills beneath the ice, and let the ice overgrow the oil lenses. CIRFA partner Statoil provided 300 liters of Troll B crude oil for the experiments. The ambient temperature had been gradually raised during the last week of the experiment, resulting in oil surfacing. A regimented measurement schedule could be followed in the AETB throughout the entire experiment because participants coordinated time and space very closely. Oil analyses were performed simultaneously in a separate cold laboratory and a chemical laboratory.

Much of the data analysis lies now in the hands of the hardworking Ph.D. students.

Tomographic SAR measurements of a partially oil-covered ice (credit: © Giuliani von Giese)

Sampling of ice with oil (credit: © Giuliani von Giese)

Ny-Ålesund

In 2015 Norut established an RPAS operation facility at Ny-Ålesund that is customized for RPAS operations. The facility consists of an operations room (20 sqm) and an hangar/workshop (50 sqm). The facility is located in the first floor of the airport tower in Ny-Ålesund.

Computing infrastructure

Demonstrations in CIRFA will take different forms. To support analyses that are relevant for demonstrating in an operational setting dedicated infrastructure for storage and computing is now in place at KSAT which allows testing out algorithms as close as possible to the satellite data stream. On the other hand, analysis of archive data to support calibration and validation will benefit from using high performance computing (HPC) resources at UIT. The university is the host of the new supercomputer Fram as well as the new National e-Infrastructure for Research Data (NIRD). This means that UIT is currently operating two large computing clusters, Fram and its predecessor Stallo.

Drones

Norut has a large number of drones with MTOW between 0.7 kg and 135 kg, both multirotor and fixed wing. Altogether about 30 aircraft that is registered with the CAA and insured.

The Norut RPAS platforms most relevant for CIRFA and currently used in the project are shown in the table below.

Cryowing **Explorer Aircraft (Cryowing Roamer)**		A long endurance equipped with satelitte communication and long range broadband radios. (reserve aircraft specification) 110 cc (62 cc) gas powered engine. Precision dual frequency GPS with RTK Wing span 5.2 m (3.8 m) MTOW: 60 kg (35 kg) Payload max 15 kg (10 kg) Cruise speed 30 m/s (30 m/s) Range 1200 km (400 km) Endurance 12 hrs (4 hrs)
Cryowing **Scout**		A small twin engine electric fixed wing with thermal and visual cameras. Wing span 2.5 m MTOW: 9 kg Payload max 3 kg Cruise speed 18 m/s Range 150 km Adapted to arctic conditions and equipped with onboard processing capacity and broadband link allowing up to 70 km HD video links.
Cryocopter		An electric octocopter with thermal, visual and hyperspectral sensors. Adapted to arctic conditions and equipped with onboard processing capacity and broadband link up to 50 km

FIELDWORK

Ultra Wideband Snow Sounder (UWiBaSS)

The ultra wide band snow sounder (UWiBaSS) is a ground penetrating radar developed for drone mounted operations. UWiBaSS will enable autonomous, drone based measurements of snow-cover over large, and hard-to-reach regions.

The task of extracting snow state parameters from sea ice sheets by manually digging snow pits, is a time consuming – potentially high risk- task, and yields low area coverage. A practical solution to this problem can be found by mounting an Ultra Wide Band (UWB) radar system onto a unmanned aerial vehicle (UAV) to obtain information about depth, density and stratigraphy of the snowpack. Hence, increasing personnel safety and extending coverage area.

Preliminary results show that the radar system is capable of obtaining snow depth information, and works well while mounted on a UAV platform with little additional noise from vibrational movement.

Development includes antenna design, radar software development, post processing algorithms for the retrieved data and radar system design. The main design parameters for the radar system is unambiguous range, range resolution, penetration depth and weight. Here, each parameter has seen several improvements for each design iteration over the last year.

The field work is performed in cooperation with Norut (Northern Research Institute) where a specially build octocopter drone was built for the purpose of carrying the UWiBaSS as payload.

Data collection with the radar system were conducted on several different areas and snow conditions including Arctic sea ice, north of Svalbard in May 2017.

All figures taken from paper in progress: "Drone Mounted UWB Radar for Airborne Measurements of Snow Packs."

Illustration of UWiBaSS snow measurement on sea ice. Actual airborne radar measurement is superimposed on image, showing air-snow interface at top and snow-ice interface at bottom. Photo: Rolf-Ole Rydeng Jenssen

20 m transect on Arctic sea ice, where in situ snow depth was measured with 1 m spacing. Photo: Rolf-Ole Rydeng Jenssen
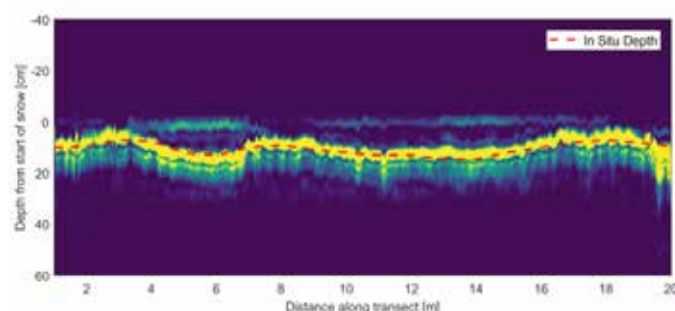
Correlation between in situ snow depth and radar image for a 20 m transect taken on Arctic sea ice.

Behind the scenes

When planning satellite image acquisitions during a fieldwork campaign many different aspects needs to be considered even before the satellite image data ordering starts. What are the scientific goals of the fieldwork campaign? How many and what types of scenes are available for the campaign? What are the most important aspects, e.g.;

- overlap in time and space between the satellite images and in-situ data?
- a time series of satellite images over the same area?
- overlap between multiple types of satellite images?
- satellite data with a specific incidence angle range?

Once this is established the cruise plan and other scientific interests are jointly considered. Larger campaigns often have multiple goals and concern multiple research groups. There may be specifically designated time slots that one has to adhere to or other groups may also have an interest in satellite data and teamwork and coordination is needed so that orders don't cancel each other out.

Recent satellite scenes are used to investigate the current environmental conditions. Time series, weather forecasts, drift buoy patterns as well as knowledge gained from old campaigns within the area are used to assess what can be expected to happen during the time period of the field work campaign.

Thereafter it is time to order the satellite scenes. Satellite scenes are either acquired according to predefined schedules or they have to be ordered to be acquired. If the predefined scenes provide the basis for the science their schedules dictate the fieldwork data collection and the additional satellite data that is ordered. For the scenes where the user defines their preferences, the type of data, time of the day that is most suitable and incidence angle needs to be considered. If there are more scenes available that meet the above criteria's than there is quota for, considerations regarding the best available scenes has to be made.

Finally, once the fieldwork campaign is up and running monitoring of updates along route is needed as changes often happen, e.g. slower/faster than expected progress through sea ice, bad weather and satellite data cancellations. Adjustment to these changes are necessary, including changes of present orders or potential new orders. This requires close communication between the field and the satellite data ordering persons. Finally, hardly anything goes to plan, but we do our best and with good team work it is worth it.

(Foto: credit Laura deSteur)

Framstredet

After encouraging results from the campaign in 2016 in Kogsfjorden, CIRFA members joined the annual sea ice monitoring campaign in Kongsfjorden realised by the Norwegian Polar Institute (NPI) again in 2017. The proof-of-concept experiment to map the fast ice edge and icebergs in the fjord using a hand-held GPS having given satisfactory results, we were eager to achieve a broader mapping of the ice in the fjord.

During the two campaigns, ice samples were collected to analyse the physical and chemical property of the ice. Thickness drilling were realised along transects on various locations to assess the global ice situation in the fjord. Snow thickness measurement were also realised where this was possible.

The ice conditions in the fjord were significantly different in 2017 compared to 2016. The ice extent was reduced but the ice was overall much thicker (from 2 to 18 centimetres in 2016 to 10 to 30 centimetres in 2017). During both campaign we were able to collect ice samples over 9 different ice stations. Unfortunately, the difference in the ice extent did not allow us to repeat the sampling at the same locations between the two years (with the exception of one ice station). However, this year we were able to map all the ice edge accessible to the boat, along with 11 icebergs (Fig. 1). In addition to the GPS mapping of the ice, a timelapse camera (Fig. 2) was installed to take pictures of the fjord ice every 4 hours to monitor the changes in the ice conditions during the melting season (Fig. 3).

During the time of the campaigns, several Radarsat-2 (quad-polarimetry synthetic aperture radar satellite) scenes were acquired. The information collected on the ice will allow us to better study the radar wave interaction with the thin ice. The laboratory work to realise the thick and thin sections has already been achieved for most of the ice cores and the processing of the Radarsat-2 scenes is on-going.

Autonomous timelapse camera set up. The camera was firmly attached to the rock to prevent it from moving, facing the inner fjord to capture the evolution of the sea ice cover.
Photo: Jean Negrel
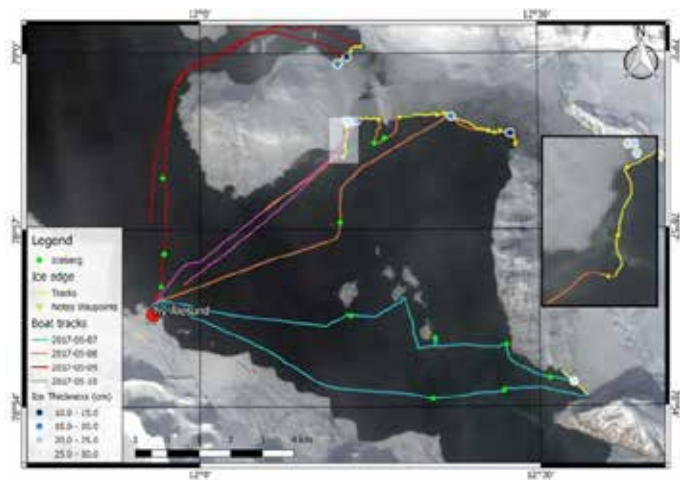
Satellite map of Kongsfjorden with the boat tracks and the ice stations. The dots representing the different ice stations are coloured according to the ice thickness measured (from dark blue for the thinnest to white for the thickest). The figure also presents the eleven icebergs located using the GPS tracks (green diamonds) and the ice edges (yellow lines). The zoom box presents a detail of the ice edge where the field report mentioned rotten/drifting ice, we can see this ice disappearing for the Landsat scene.
Background: USGS/NASA Landsat 8 7th of May 2017

Example of one picture taken by the timelapse camera (11th of May 2017). We can see the sea ice cracking near the shore due to tidal motions stressing the ice floe. Without this connection to the land, the ice will then drift away easily and disappear. Photo: Jean Negrel

CIRFA COLLABORATION WITH INDUSTRY

As a Centre for Research-based Innovation, CIRFA is depending on good communication and interaction with its industry partners and stakeholders. This is essential in order to ensure relevance of the research projects, including the initiated plans for our PhD candidates and postdocs, and to keep our stakeholders informed about research directions and results. CIRFA puts high priority in this information exchange and has in the last year had several joint events with our user partners. Some examples of joint meetings are mentioned.

We had a joint meeting with The Norwegian Coastal Administration (Kystverket) to inform them about our research related to oil spill remote sensing and to discuss future collaborations. We had a workshop with NOFO - The Norwegian Clean Seas Association for Operating Companies, together with some of CIRFA's oil company partners, where we presented results from the NORSE'2015 experiment in the North Sea, and discussed possible future collaboration related to NOFO's up-coming oil-on-water experiments. We had a joint meeting with NOFO and Kongsberg Satellite Services (KSAT), discussing KSAT's oil-spill detection services. In relation to CIRFA's research on sea ice remote sensing, we had a joint workshop with the Norwegian and Canadian Ice Services, where we was informed about their working procedures, and we discussed how the CIRFA research might contribute with innovations potentially useful in their operational services. Other collaborative interactions are high-lighted below.

Joint exercise by the Norwegian Clean Seas Association for Operating Companies (NOFO) and the Barents Sea Exploration Collaboration (BaSEC)

A joint exercise by the Norwegian Clean Seas Association for Operating Companies (NOFO) and the Barents Sea Exploration Collaboration (BaSEC) was conducted in March 2017 where CIRFA was given the opportunity to send an observer. The exercise aimed to test the weatherization of cleanup tools such as booms and skimmers as well as practicing maneuvering with sea ice in the booms. For CIRFA it was useful to get an impression of some of the challenges faced when running a cleanup campaign in sea ice. It was also very useful to hear and see how the industry operates and get feedback on their experiences with using meteorological and remote sensing tools, including expectations with respect to future products.

Innovation project prototype in spring 2018

As it is already implied by the title SFI (senter for forskningsdrevet innovasjon), innovation is one of the major goals within CIRFA. However, the traditional main objective of the university is rather research than innovation and most of the PhD projects are therefore laid out to focus on research. Consequently, it has so far been difficult for many PhD students within CIRFA to include innovation in our daily work.

With the beginning of the spring semester 2018 we have therefore started a new approach: PhD students with a four-year contract are supposed to spend 25% of their work time on institute duties, which usually means working as teaching assistant in various courses. Instead of teaching, isf I; PhD. Johannes Lohse, will during this semester spend the allocated time working on innovation.

The first challenge at hand was to find an innovative project short enough to be completed in a limited amount of time, but large enough to demonstrate that we can in fact contribute to innovation. After some discussion we decided to implement a processing chain which automatically downloads SAR images (Sentinel-1 to begin with), calibrates and geo-locates the images, performs a simple ice-vs-water classification and uploads a resulting geotiff file for potential users. The word "simple" may be a little fast and loose when it comes to the automatic separation of ice and water in a wide-swath SAR image, but I use it to stress that the classifier itself should not be the focus of attention at an early stage. We agreed that the first goal should be to establish the full processing chain with a classifier that produces an acceptable result. The algorithm itself can then be changed or improved at a later stage. At this point, the basic research from the actual PhD projects of Johannes will feed back into the innovation part of CIRFA, as it was initially intended to do.

Statoil's Sea-Keeping Trials in Ice

PhD candidate Runa Skarbø was involved in Statoil's Sea-Keeping Trials in Ice in March 2017 (SKT2017). The two-week SKT trials were conducted as full-scale sea keeping trials in ice in the Gulf of Bothnia, with two ice-classed offshore vessels. Vessel Magne Viking was moored in ice, while vessel Tor Viking was performing ice management.

During SKT2017, Skarbø collected data from the marine radar for ice drift estimation in the form of radar images from both vessels. Preliminary analyses of the ice drift estimation, as shown in Figure 7, show satisfying correlation between ice drift measured with physical drift beacons on the ice and drift estimation using the marine radar.

Skarbø's PhD topic is tactical ice drift prediction for ice management, and mitigation of impact from sea ice on marine operations. She is currently working on a simulation model which predicts the ice drift on a tactical level (6 hours up to 3 days ahead), and which assimilates real-time state estimations of relevant parameters for improved forecasts. For real-time ice drift estimation, she is using algorithm for ice drift estimation using the marine radar (see Kjerstad et al. (in press))[1]. She is also looking at assimilating data from SAR remote sensing for ice characteristics such as sea ice type, concentration, thickness and drift on a regional scale. The model will provide valuable input to ice management, and may also be used to estimate and predict forces on the hull, valuable for i.e. DP applications such as thrust allocation. Several journal papers will be written on her model and the SKT2017 data in 2018.

Mooring hook-up in ice during SKT2017.

Skarbø installing the hardware for capturing radar images on Tor Viking bridge during SKT2017
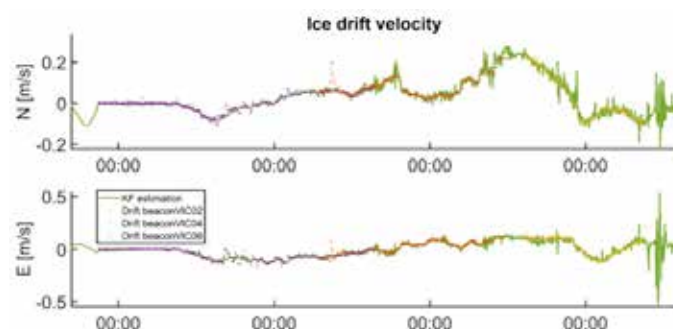
Ice drift velocity from 06 to 10 March, northwards drift (top) and eastwards drift (bottom). Drift velocity measured by drift beacons (dots), and preliminary estimates by the Kjerstad algorithm (green line) shows satisfying correlation.

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1   Kjerstad, Øivind K., Sveinung Løset, Roger Skjetne, and Runa A. Skarbø. in press. 'An Ice-Drift Estimation Algorithm Using Radar and Ship Motion Measurements', IEEE Transactions on Geoscience and Remote Sensing (TGRS).

INTERNATIONAL COLLABORATION

CIRFAs international network is largely based on the network the partners themselves have established. Some international partners are listed below:

University of Alaska, Fairbanks	USA
University of Calgary	Canada
University of Rennes 2	France
CLS	France
IFREMER	France
ONERA	France
Alfred Wegener Institute	Germany
DLR	Germany
University of Hamburg	Germany
JAXA	Japan
Jet Propulsion Laboratory	USA

Open University

In July and August 2017, our PhD student Ingri H. Soldal attended an internship at the Open University in Milton Keynes, UK. The internship was funded by the Space Placements in INdustry (SPIN) program which is managed by the UK Space Agency and Satellite Applications Catapult.

During the internship Ingri got to work on automatic iceberg detection together with Dr Armando Marino, whom is a collaborator of Dr Wolfgang Dierking. The research included a further development of Dr Marino's previous work on iceberg detection.

In addition to the scientific work Ingri got to visit the Harwell Science and Innovation Campus; attend the RSPSoc2017 conference in London; contribute to a poster session at the Open University; and visit the Mars Science Lab at Imperial College London.

Ingri and Dr Marino have continued their collaboration after the internship and are planning to publish a paper together during 2018.

Visiting Researchers

Throughout the year, CIRFA has had the pleasure of hosting several guest researchers:

Name	Affiliation	Gender	Duration	Topic
Cathleen E. Jones	Jet Propulsion Laboratory, California Institute of Technology, USA	F	4 weeks	WP3 Oil Spill Remote Sensing
Laurence Ferro-Famil	University of Rennes 1, France	M	4 weeks	WP3 Oil Spill Remote Sensing
Martin Gade	Univeristy of Hamburd, Germany	M	4 days	WP3 Sea Ice Remote Sensing
Dean Flett	Canadian Ice Service, Canada	M	1 week	WP2 Sea Ice Remote Sensing
Andreas Reigber	DLR	M	1 week	
Szymon Klepacz	Poland	M	2 months	WP2 intern
John Yackel	University of Calgary, Canada	M	2 weeks	INTPART
Vladimir Alexandrovich Alexeev	Univeristy of Alaska, Fairbanks	M	2 weeks	INTPART
Hajo Eicken	University of Alaska, Fairbanks	M	2 weeks	INTPART
Brent Gordon Thomas Else		M	2 weeks	INTPART
Brian Moorman	University of Calgary, Canada	M	1 week	INTPART

SCIENTIFIC OUTREACH

An important goal for CIRFA is to communicate research-activities and findings from the different scientific projects. Some examples of the outreach activities in 2017 summarized below.

CIRFA conference 2017

CIRFA arranged its second annual conference at Sommarøy Arctic Hotel in October 2017. More than 60 participants attended the conference with representatives also from the partners, collaborating institutions and companies. All four members of the CIRFA Scientific Advisory Board (SAB) participated. The conference lasted for two days and featured lectures from invited key-note speakers, the center's PhD students and postdoctoral students. The conference also had time for discussions about the Center's research and innovation activities.

CIRFA seminars

CIRFA organize monthly scientific seminars with internal and invited external presenters. The seminars are streamed for the interested parties outside of Tromsø. For more information, visit our website http://cirfa.uit.no

The topics addressed during the seminars in 2017 were:
- Regional ocean circulation modeling; Kai Christensen, Met.no
- Arctic Sea Ice Characterization Using Fully Polarimetric Air-Borne and Space-Borne Synthetic Aperture Radar; Suman Singha, Remote Sensing Technology Institute (IMF), German Aerospace Center (DLR)
- Sea surface currents retrival using along-track interferometric Synthetic Aperture Radar; Anis Elyouncha, PhD Student, Earth and Space Sciences, Chalmers University of Technology, Sweden.
- A comparison between optical and SAR classification results for thin sea ice in Storfjorden; Cornelius Quigley, PhD fellow, CIRFA/UiT – the Arctic University of Norway.
- Iceberg Detection in Open Water and Sea Ice using C-Band Radar Polarimetry; Vahid Akbari, Postdoctoral researcher, UiT – the Arctic University of Norway.
- Observation of the Taylor Energy Oil Slick in the Gulf of Mexico using NASA's UAVSAR L-band Airborne SAR Instrument; Cathleen E. Jones, NASA Jet Propulsion Laboratory, California Institute of Technology & UiT – the Arctic University of Norway.
- Analysis of Scattering from Sea Ice based on the Finite Element Method; Xu Xu, PhD student, UiT – the Arctic University of Norway.
- Arctic Ocean bottom pressure from GRACE: Lessons about ocean circulation and the flow variability through Bering Strait; Johannes Lohse, PhD student, UiT – the Arctic University of Norway.
- Sea Ice Classification: What Can We Learn From Airborne Data?; Adjunct Professor Wolfgang Dierking, UiT/Alfred Wegener Institute

The Nansen Legacy

The Nansen Legacy is a Norwegian multidisciplinary initiative (2018–2023) to understand and predict the natural and human influences on the hitherto ice-covered Barents Sea ecosystem beyond the present ice edge. It has 10 Norwegian partner organizations. The Legacy's vision is to establish a novel and holistic Arctic research platform and provide the integrated scientific knowledge base required for the sustainable management of the environment and marine resources of the Barent Sea and adjacent Arctic Basin through the 21st century.

The project will pursue its vision by addressing the following overarching objectives:

1. Improve the scientific basis for sustainable management of natural resources beyond the present ice edge

2. Characterize the main human and natural influences on the changing Barents Sea ecosystems and their response – past, present, and future

3. Resolve the mechanisms governing the Barents Sea ice cover and climatic state, including predictive capability

4. Optimize the use of emerging technologies, logistic capabilities, research recruitment and stakeholder interaction to explore and manage the emerging Arctic Ocean.

Several CIRFA work packages and researchers will be connected to The Nansen Legacy research, and CIRFA will collaborate with the project in many areas of mutual interest.

Arctic Ocean Technology and Law of the Sea research (ATLAR)

The ATLAR projects integrates four disciplines, remote sensing, Arctic oceanography, marine biology and the Law of the Sea to understand the ongoing changes in the Arctic marine environment. This unique team includes four technologies from four centers, Center for Integrated Remote sensing and Forecasting for Arctic operations (CIRFA), Center for Arctic Gas Hydrate, Environment and Climate (CAGE), Department for Arctic Marine Biology (AMB) and K. G. Jebsen Centre for the Law of the Sea (JCLOS), at three faculties at UiT the Arctic University of Norway to gather expertise to develop innovative technologies to minimize the anthropogenic impact on the Arctic Oceans.

The project has started up in the autumn of 2016, and since then the partners have produced numerous results individually by participating in national and international conferences

with contribution, and publishing peer-reviewed articles. The ATLAR team also shows strong collaboration by organizing regular meetings and events. The outcome of these gatherings is an article, which is under preparation by the four partners.

Collaboration with PETROMAKS 2 project MOSIDEO

The ice tank experiments at the Hamburg Ship Model Basin (HSVA) were jointly conducted by WP3, WP6 and Research Council of Norway PETROMAKS2 research project MOSIDEO. The development of the sea ice pore structure and distribution of oil in the ice was characterized under MOSIDEO, providing reference data to evaluate CIRFA remote sensing data against. MOSIDEO stands for Microscale interaction of oil with sea ice for detection and environmental risk management in sustainable operations, is led by Norut Narvik, involves two Ph.D. students, and runs from 2015 through 2019. Project partners are Norut Tromsø, NTNU, and the University of Alaska Fairbanks.

MOSIDEO Ph.D. student Marc Oggier inspecting the distribution of oil in ice at the HSVA ice tank. Photo: Chris Petrich.

SFI SIRIUS

In September 2017 the two SFIs CIRFA and SIRIUS had a workshop in Tromsø to explore how the two centers could collaborate for mutual benefit. The initiative came from Statoil who is an industry partner in both SFIs. SIRIUS does research on scalable computing, linked data and semantic technologies, while CIRFA has interesting applications and large volumes of data which are useful for testing methods developed in SIRIUS. The outcome of the workshop was the definition of two PhD positions, one financed by CIRFA which will focus on scalable data access and one financed by SIRIUS which will focus on semantic modelling of Earth observation (EO) data. SIRIUS also

invited Prof. Manolis Koubarakis, National and Kapodistrian University of Athens, to the workshop to give a presentation on his work on linked EO data. Through further discussions with Prof. Koubarakis and SIRIUS we submitted a proposal for an H2020 innovative training network (ITN). In a world overflowing with data, it is increasingly important to have a high degree of computer literacy in addition to domain knowledge. Hence, the stated goal of the ITN is to train the next generation scientists with skills in both EO and computer science to allow rigorous analysis involving large quantities of EO data. The project involves CIRFA partners Kongsberg Spacetec and Met and has a strong focus on industry involvement through secondments both with industry partners and other research institutions.

PETROMAKS 2

PETROMAKS 2 is a joint effort between UiT The Arctic University of Norway and P. P. Shirshov Institute of Oceanology Russian Academy of Science, and their respective partners. It addresses the urgent need of environmental monitoring of the Barents Sea, with a particular focus on marine pollution from the petroleum industry & shipping and its lookalikes.

The aim of this project is to contribute to improvement of the environmental monitoring capability by satellite of marine pollution. The project pursues this goal by investigating the added value of multipolarization synthetic aperture radar in observing produced water from oilrigs, by looking at the information loss in detection of newly frozen sea ice while going from high resolution multipolarization radar data to data with medium resolution and reduced polarization dimensionality, and finally by development of a detection algorithm for mapping dark surface slicks in the Barents Sea in medium resolution Sentinel-1A and -1B acquisitions.

The outcome of this project has a clear relevance to satellite service providers and oil spill preparedness and clean-up organizations.

AMOS

Several Ph.D students and a Post.Docs have participated in CIRFA field activities as well as used remote sensing and UAS data from CIRFA in research on atmospheric icing and de-icing systems as well as development for autonomous tracking on icebergs and growlers. One student from AMOS has had short research stays at Norut and CIRFA in Tromsø. This work has resulted in two conference papers published in 2017. Rune Storvold, WP leader in WP 4 has an adjunct position at AMOS, and Co-WP lead in WP4 Tor-Arne Johansen is a co-PI in AMOS. Collaboration between AMOS and CIRFA is also taking shape on micro satellites.

2018 AND BEYOND, OUTLOOK

Oil on water campaigns in 2018 and forward

Since 2011, UiT The Arctic University of Norway has been involved in Norwegian Clean Seas Association for Operating Companies' (NOFO's) oil on water exercises ("Olje på vann øvelser (OPV)" in Norwegian). The exercise usually takes place at the Frigg field in the North Sea in June each year. These exercises have involved releases of real oil into the water, clean-up procedures and experiments with new equipment in addition to ship based, aerial, and satellite based surveillance and data collection.

In synthetic aperture radar remote sensing of oil spills on the sea surface, there is a clear need for verifications of the characteristics of the slicks based on in situ data and auxiliary (optical) remote sensing measurements. NOFO's exercises at the Frigg field is a unique and well suited arena to accomplishing this. CIRFA's aim is to develop better models to predict the transport of the oil and to better understand the interaction between the signal and the slick covered sea surface; ultimately leading to better algorithms for oil spill detection and characterization applicable to satellite service provides and costal monitoring agencies.

During the annual exercise in 2015, UiT together with MET Norway and the Jet Propulsion Laboratory (JPL)/National Aeronautics and Space Administration (NASA) carefully planned and conducted a separate science experiment focusing on remote sensing of freely drifting and evolving oil spills. The experiment turned out to be a great success, and several scientific international journal papers are now either submitted or published as an outcome.

The surface signature of an oil spill crucially depends on the vertical distribution of the oil. This distribution in turn depends on the physiochemical properties of the oil and the turbulent mixing by wind and waves. We wish to repeat the experiment collecting more in situ parameters that are relevant for both verification of remote sensing data and for validation of the oil spill drift model. For 2018, CIRFA (WP3 and WP5) is written into NOFO's oil release application to the Norwegian Environment Agency as a participant on the remote sensing and metocean parameter collection side of the exercise. This activity should be seen as a warm-up to next year's exercise (OPV2019), where CIRFA hope to have the German Aerospace Center (DLR) engaged with their F-SAR, which is a multipolarization and multifrequency SAR system, in addition to having an increased focus on upper ocean turbulent mixing and in situ oil slick parameter collection.

If NOFO decides to go ahead with an oil spill clean-up and preparedness exercise in icy conditions in 2020, which has been indicated, CIRFA certainly aim to get involved aiming at demonstrating scientific and innovative developments within WP3 and WP5 in particular.

Assimilation of high-resolution SAR images

As part of our goal to combine our work within CIRFA we are planning to start assimilating SAR observations of sea-ice concentration. So far we have seen that assimilation of passive microwave observations have a huge impact on our 20km resolution model, while for our new high resolution model it is important to have high resolution observations from SAR. Our hope is that the combination of SAR observations and our new high-resolution model will not only give more accurate forecasts, but also give valuable information back to the remote sensers in WP2. The need for model feedback can be seen in the SAR image by large amount of noise and variations. In addition we believe that not only concentration, but also both thickness and drift from the model forecast can be used by WP2. This will lead to increased observation and model accuracy, and safe planning of Arctic operations. In the three figures ice concentration from the same area is plotted for SAR images from Radarsat-2, the EUMETSAT OSISAF product based on passive microwave and our 20 km resolution model. The SAR images has much higher resolution than the passive microwave observations, and will decrease the observation uncertainty significantly. RADARSAT is an official mark of the Canadian Space Agency.
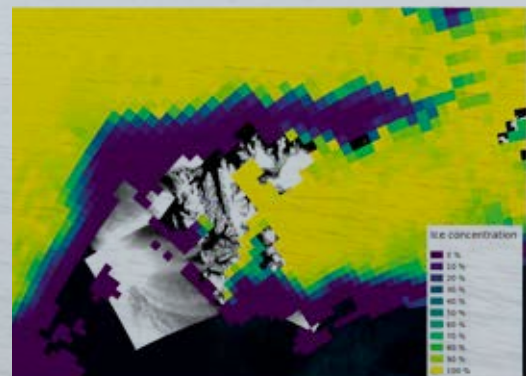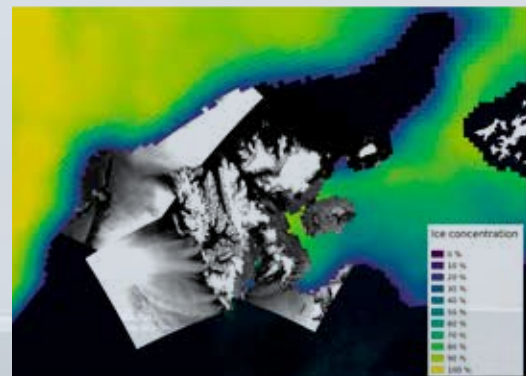
SAR image RADARSAT-2
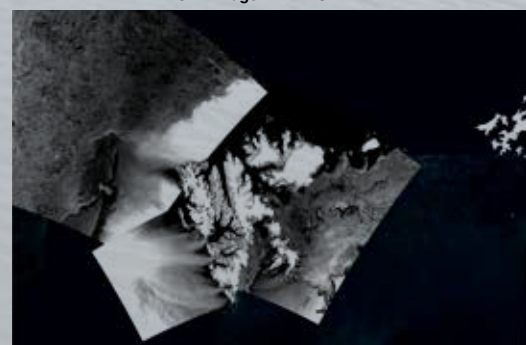
ORGANISATION

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
Norut

Edmond Hansen
Multiconsult

Richard Hall
Statoil
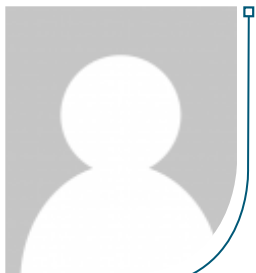
Oddvar Ims
Eni Norge

Jan Petter Pedersen
KSAT

During the CIRFA Assembly meeting, October 2017 it was decided that four of the seven Board members (Morten Hald, Faculty of Science and technology, UiT; Nalan Koc , Norwegian Polar Institute; Oddvar Ims, Eni Norge; and Edmund Hansen, Multiconsult will be replaced in 2018. The following new members were elected for a period of two years, from 1.1.2018:

Arne O. Smalås
Dean, Faculty of Science and Technology, UiT (Chair)

Lars Anders Breivik
MET.no

Svein Olav Drangeid
OMV

Jeremy Cutler
TOTAL

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. Irena Hajnsek
Swiss Federal Institute of Technology (ETH) Zürich, Switzerland
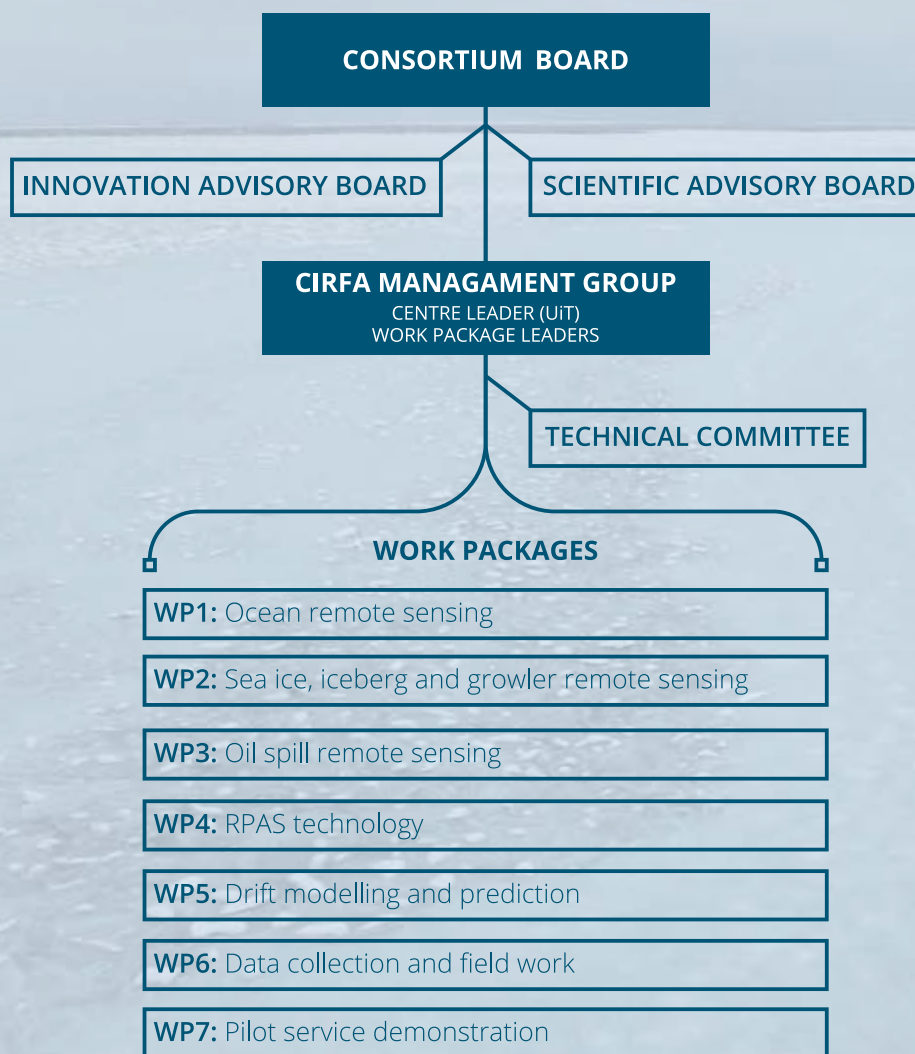
Innovation Advisory Board (IAB)

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.

Richard Hall, Statoil
Caroline Dezecot, Statoil
Ove Stapnes, Eni Norge
Basile Bonnemaire, Multiconsult
Martin Skedsmo, Norinnova
Torbjørn Eltoft, Centre leader, UiT
Jan Petter Pedersen, KSAT

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,
- Oil Spill Remote Sensing

CONSORTIUM BOARD

INNOVATION ADVISORY BOARD

SCIENTIFIC ADVISORY BOARD

CIRFA MANAGAMENT GROUP
CENTRE LEADER (UiT)
WORK PACKAGE LEADERS

TECHNICAL COMMITTEE

WORK PACKAGES

WP1: Ocean remote sensing

WP2: Sea ice, iceberg and growler remote sensing

WP3: Oil spill remote sensing

WP4: RPAS technology

WP5: Drift modelling and prediction

WP6: Data collection and field work

WP7: Pilot service demonstration

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

Cornelius Quigley
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

FINANCES

Funding sources

The Research Council	8 919
Industry partners	8 436
The Host Institution (UiT)	6 957
Research partners	3 368
Total	27 679

Costs per activity

Management	4 514
WP1 Ocean RS	2 699
WP2 Sea Ice RS	3 478
WP3 Oil Spill RS	6 066
WP4 RPAS Technology	4 491
WP5 Modeling and prediction	3 803
WP6 Field work and data collection	1 904
WP7 Pilot Service Demonstration	724
Total	**27 679**

Costs per partner

Research partners:	
UiT/NT	11 876
Norut	4 907
Norut Narvik	1 972
NTNU	2 388
Norwegian Polar Institute	1 827
Met.no	1 958
NERSC	962
Industry partners:	
Statoil	363
Eni Norge	102
Total E&P Norge	147
OMV Norge	169
Aker BP	
Aker Solutions	120
Multiconsult	155
KSAT	240
Spacetec	
Maritime Robotics	370
Aranica	123
Globesar	
Total	**27 679**

PUBLICATIONS

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Negrel, J., Gerland, S., Doulgeris, A.P., Lauknes, T.R., Rouyet, L. (2017): *On the potential of GPS tracking of fjord ice features for remote sensing validation.* Poster presentation at Polar Ice, Polar Climate, Polar Change, Remote sensing and modeling advances in understanding the cryosphere. Boulder, Colorado, USA, 14–19 August 2017 (https://www.igsoc.org/symposia/2017/boulder/proceedings/).

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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.