



2019

Annual Report

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



THE YEAR 2019 IN REVIEW

CIRFA continued its research activities in 2019 to develop improved understanding, new advanced analysis methods, and better interpretation capabilities concerning SAR imaging related to the Centre's three main application areas; ocean, sea ice, and oil spills remote sensing. As in previous years, the research includes development of new algorithms, validated through large-scale field campaigns employing drones, models and ground-based measurements. On the algorithmic side, the research has been extended to also emphasize multi-sensor data fusion and machine learning/deep learning technologies.

In addition to these efforts, CIRFA has had a stronger focus on showing CIRFA's innovation potential by implementing and testing out new algorithms and signal processing procedures in operational testbeds at our user partners, MET Norway and KSAT. Towards this end, the goal has been to demonstrate that the algorithms, either alone or in combination with models, will generate improved services in terms of better sea ice monitoring capabilities, better met-ocean information (wind, waves, currents), and better oil spill detection and characterization.

In June 2019, CIRFA WPs 3, 4, 5 and 7 organized a major field experiment in connection to NOFO's (Norsk Oljevernforening For Operatørselskap) annual Oil-on-Water exercise, in which SAR observations were made with the German F-SAR airplane and in-situ measurements were conducted from UiT's research vessel R/V *Helmer Hanssen*. The campaign was a follow up of the successful 2015 experiment with NASA's UAVSAR, with the objective to improve drift modeling and remote sensing characterization of freely drifting oil slicks. On board R/V *Helmer Hansen* was a diverse team of international researchers consisting of participants from Norway, Canada, USA, and Australia. In spite of quite rough weather conditions, the experiment was successful. More or less all planned measurements were conducted.

August 14th to September 19th, CIRFA joined the CAATEX (Coordinated Arctic Acoustic Thermometry Experiment) field cruise. The cruise, conducted with the Coast Guard vessel KV *Svalbard* in the Arctic Ocean, was the first time a Norwegian ship reached the North Pole. CIRFA researchers conducted sea ice observations with a drone-mounted wide-band snow radar and optical sensors, and measurements with a coherent radar system carried out from the ship. In support of the cruise, CIRFA organized co-located polarimetric SAR acquisitions from Radarsat 2. In addition, Sentinel-1 SAR data, which is continuously collected by ESA, is available from some sites.

CIRFA continues to strengthen its interaction with the Centre's user partners, aiming to clarify their needs and expectations related to remote sensing-based information services and products. In this regard, we have had dialog meetings with user partners, and in September, WP5 and WP2 organized a workshop at Oslo Science Park on research in CIRFA on sea ice and ocean modeling, including data assimilation. The workshop had participants from the Centre's research and user partners, University of Oslo, the Institute of Marine Research, in addition to one invited international expert from Canada.

Also in 2019, CIRFA researchers made many strong contributions in a broad spectrum of fields. Our team published 16 journal papers, and had 47 international conference contributions, some of which were invited contributions.

Educating young scientists, with specialized competence in the field of integrated remote sensing, is a main responsibility of CIRFA. On the 5th of December 2019, Martine Espeseth defended her PhD thesis "*Analysis of Oil Spill and Sea Ice Measurements Using Full-Polarimetric and Hybrid-Polarity Synthetic Aperture Radar data*" as the first PhD candidate from CIRFA. Additionally, on September 13, Katalin Blix, which has been associated to the Centre, defended her PhD thesis "*Machine Learning Water Quality Monitoring*". Both are now hired in postdoc positions in CIRFA. Currently, CIRFA has hired 15 PhD students, and at least 3 more PhDs and 2 more Postdocs will be employed in 2020.

The Centre maintains international collaborations by inviting international capacities to our meetings, hosting visiting researchers and students, and participating in relevant workshops and meetings abroad.

CIRFA held its 2019 annual conference at Sommarøy Arctic Hotel, with around 60 participants from partners, and collaborating institutions and companies. This took place in October.

CIRFA continues to organize monthly scientific seminars with internal and invited external presenters, and these are streamed for the interested parties outside of Tromsø.

In September, the MOSAiC expedition departed from Tromsø. CIRFA researchers Polona Itkin (UiT) and Dmitry Divine (NPI) joined leg 2 of the expedition. Their mission was to collect satellite remote sensing data and in-situ data from the vessel during parts of the Polar Night.

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CIRFA – A PARTNER’S PERSPECTIVE



Richard Hall, Equinor
Chair of the Board CIRFA

As always, we start with safety. “Wash your hands” has become the safety phrase, and today it is repeated constantly as we go about our daily lives.

When I was asked as the new CIRFA Chair of the Board to write this foreword for the CIRFA annual report, the term COVID-19 was being used by only a handful of medical experts around the world. Now, everyone knows what COVID-19, or to give its common name, Coronavirus, is, and are adjusting to the profound effect it is having on our lives.

CIRFA, like everything else, will learn to adapt both in the short-term and the long-term to the changes brought about by COVID-19. How exactly we will change is not yet clear, but it is likely our lives will be even more digital than ever before.

Looking back first, in 2019 CIRFA reached the half-way point, passing the midway evaluation with confidence, while at the same time receiving constructive criticism to guide CIRFA towards a long-term, sustainable future.

The annual review captures the feedback received. The CIRFA team is a successful, productive team and this is reflected in the photographs of both CIRFA members and their many different users engaged in the discussions. This engagement has been an important step in developing trust in the new information products being developed and produced.

The CIRFA team has put down good foundations in understanding and preparing satellite Data, and this will allow them to produce new and better Information that is relevant for their users.

Information, and to with what level of confidence we can trust the information, is a key ingredient to any decision-making process, not least to make good, safe decisions. Our weather services are a good example of this as they inform the user of the level of

confidence in a weather forecast with a traffic-light signal. If, for example the forecast is a grey but dry cloud with low confidence we have the information that we should maybe prepare for rain and take a rain jacket. While the same forecast but with a high confidence might lead to a decision of leaving the rain jacket at home.

Understanding how Users will use the information extracted from satellite data to make decisions is key to CIRFA both developing new and innovative solutions and communicating these results to the users.

As CIRFA is a Centre for Research-based Innovation, innovation is at the heart of the research. But measuring innovation is not an easy task.

However, in these times of change, I am reminded of an old English proverb that states “necessity is the mother of invention”. Which, according to the Oxford Dictionary is “when the need for something becomes imperative, you are forced to find ways of getting or achieving it”.

Finding innovative solutions as to how CIRFA can continue and thrive certainly fits into this definition.

As we develop and deliver the CIRFA results together, we will find new ways of working together. Technically, cloud solutions will have even greater focus, both for processing the ever-expanding amount of data, but also to collaborate with colleagues spread across the world. We will have to be courageous and not only learn how to openly collaborate via video-link, but also how to care for each other even if we are sitting in different parts of the world.

The next year is going to be interesting, hopefully for all the right reasons.

Stay safe.

FOREWORD



Professor Torbjørn Eltoft
Centre Leader, CIRFA

The argument for establishing CIRFA was the need for research on integrated remote sensing and forecast modelling in support of Arctic operations. CIRFA is now engaged in a broad portfolio of research activities, and has had many nice achievements during its years of existence. Here, attention will be paid to sea ice remote sensing, which has been and still is an important topic in CIRFA.

Sea ice is considered to be a big threat to many operators in the High North. As sea ice melts and gets thinner due to climate change, it opens new areas to ship traffic and other human activities, and its characteristics change in a way that makes it even more difficult to monitor and predict. Hence, from a monitoring perspective, it has become even more important to develop new, high-resolution reliable monitoring and prediction capabilities for sea ice.

Daily ice charts for the Arctic are currently produced by the Norwegian Ice Service (NIS) as part of their operational responsibility for European waters. These ice charts are of relatively low resolution, and analyzed and drawn manually by a sea ice analyst based on available satellite data. New updated ice charts are available on weekdays (Monday-Friday), but not during weekends. The national ice centers of other Arctic countries like Canada, Russia, and USA, are also using interactive interpretation of satellite imagery as their main technique for creating sea ice maps. These are produced according to international and national standards defined by the World Meteorological Organization (WMO).

The most common data for generating sea ice maps is synthetic aperture radar (SAR) images, in which spatial characteristics are determined by the sea ice backscatter. The ambitious goal of CIRFA is to develop methodologies to automatically generate reliable, high-resolution ice maps from SAR data, and when possible, supported by auxiliary data. This is an ambitious goal in light of the fact that such efforts have been going on for more than 40 years, since the launch of SEASAT in 1978, but still there are no reliable automatic sea ice classifiers available. The reason is that SAR signatures of sea ice is ambiguous, depending on imaging geometry, season and weather conditions at acquisition, frequency and incidence angle of the radar signals, in addition to ice type. This makes the interpretation of SAR images very challenging. Even binary classification between ice and open water is difficult, due to ambiguities resulting from varying wind speeds over the ocean.

CIRFA is addressing sea ice classification from several angles. The most mature algorithms are based on a Bayesian approach,

and can be used to produce both unlabeled (unsupervised) as well labeled (with ice type) image segments (supervised). The methods are employing a simple mixture of Gaussian models to represent spatial variations in the signal features. The models incorporate *ice type*-dependent incidence-angle dependencies and additive noise directly into the statistical model, which is thought to increase performance and robustness. The preliminary results are encouraging, and the algorithms are now being tested out in an operational setting.

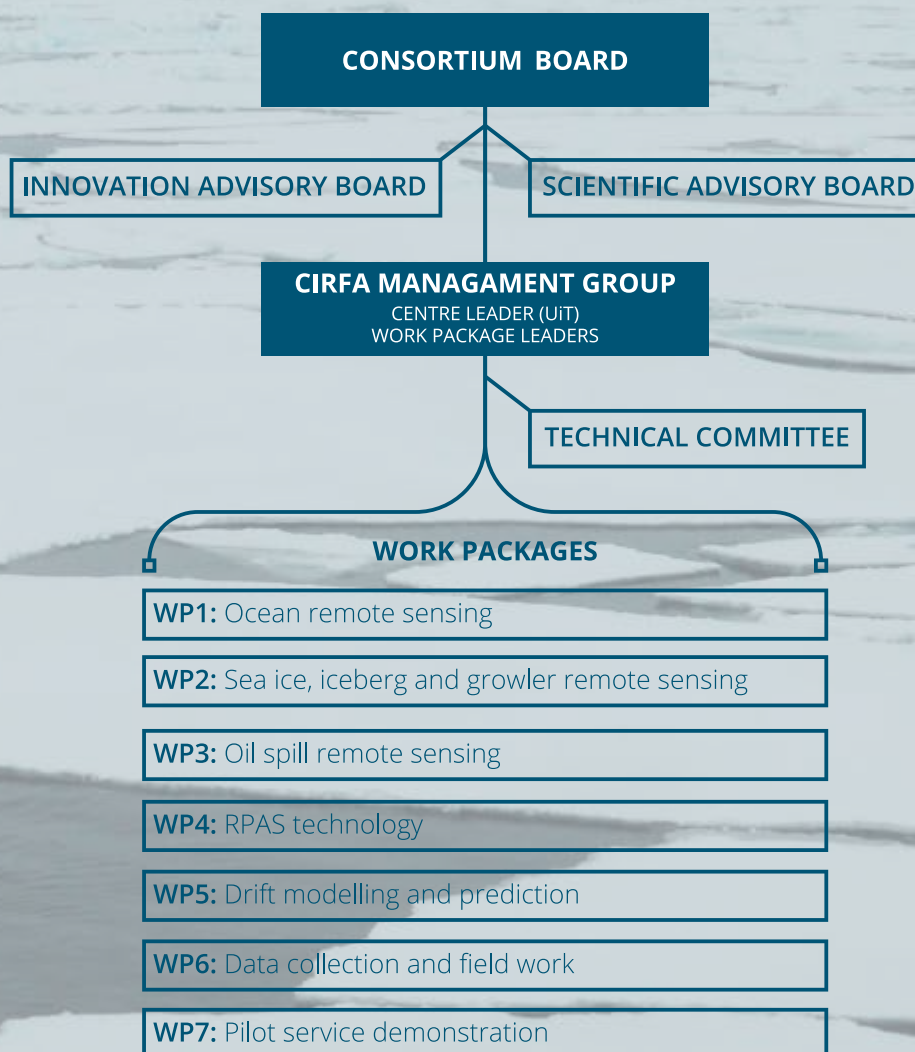
CIRFA is also exploring sea ice classification based on deep learning network architectures. Deep neural networks are flexible, powerful and highly scalable machine learning algorithms, which have proved themselves to be useful in several remote sensing applications. Even though there are many challenges related to the use of these methods for sea ice classification, e.g. scarce and poor training data, our preliminary results are encouraging. This avenue of research is being further investigated both in CIRFA and ExtremeEarth, and an associated H2020 project (see own information box).

To resolve the ambiguity issues associated to SAR imaging of sea ice, CIRFA is also investigating multi-modal data analysis techniques for sea ice classification, in which SAR data from Sentinel-1 is combined with optical data from Sentinel-2 and -3. In the near future, also microwave radiometer and altimeter data will part of the multi-modal approach.

All application areas have their own specific challenges. Sea ice remote sensing has been selected here to illustrate the fact that information extraction from remote sensing data is not always a straight forward task, and that there are many research issues that need to be thoroughly addressed. Today, the world is overloaded with remote sensing data from a multitude of satellites. The two ESA SAR satellites Sentinel-1 A and B provide more than 6 terabytes of data every day. But, data is not enough. As the available amount of data is increasing, the need for better and more *automated* data analysis methods is getting more and more imperative. This is of course not only an issue related to sea ice remote sensing, but equally relevant for other application areas, like oil spill and met-ocean remote sensing.

Satellite-based monitoring of the Arctic is important and will be even more critical in the future. The Arctic is an important area to Norway, and it receives political attention for several reasons, among these an expected abundance of natural resources. In a white paper from the Norwegian Government, it is stated that the High North is considered to be Norway's most important strategic area of responsibility. Thus, it is in Norway's national interest to be able to continuously monitor the area with respect to its *environmental conditions, ship traffic, fisheries and exploitation of natural resources, and for national security reasons*. In this context, the research being done in CIRFA is both timely and important.

ORGANIZATION



Consortium Board

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.



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



Kjell Arild Høgda
NORCE



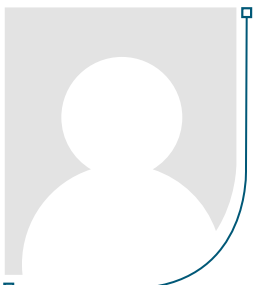
Lars Anders Breivik
MET Norway



Svein Olav Drangeid
OMV



Richard Hall
Equinor



Robert Bridges
Total



Jan Petter Pedersen
KSAT

During the CIRFA General Assembly Meeting in October 2019 it was decided that four of seven board members (Robert Bridges (Total), Svein Olav Drangeid (OMV), Lars Anders Breivik (MET Norway) will be replaced in 2020. Also the chair of the Board, Arne O. Smålås, will be replaced in 2020.

The following new members were elected for a period of two years from 1. November 2019 – 1. November 2021:



Richard Hall (Chair)
Equinor



Edmond Hansen
Multiconsult



Terje Solheim
AkerBP



Harald Steen
Norwegian Polar Institute

Scientific Advisory Board

The Scientific Advisory Board (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.



Henning Skriver
Technical University of Denmark (DTU)



James Maslanik
University of Colorado in Boulder, Colorado, USA



Charlotte Hasager
Technical University of Denmark (DTU)



Irena Hajnsek
Swiss Federal Institute of Technology (ETH) Zürich, Switzerland

CIRFA Management Group

Torbjørn Eltoft, Centre Leader, UiT
Harald Johnsen, WP 1 Leader, NORCE
Wolfgang Dierking, WP 2 leader, AWI/UiT
Anthony Doulgeris, WP 2 Co-Leader, UiT
Camilla Brekke, WP 3 Leader, Co-leader CIRFA, UiT
Christian Petrich, WP 3 Co-Leader, SINTEF Narvik
Rune Storvold, WP 4 Leader, NORCE
Tor Arne Johansen, WP 4 Co-Leader, NTNU
Kai H. Christensen/Johannes Röhrs WP 5 Leader, MET Norway
Rune Graversen, WP 5 Co-Leader, UiT
Sebastian Gerland, WP 6 Leader, NPI
Hugo Isaksen, WP 7 Leader, KSAT
Nick Hughes, WP 7 Co-leader, Norwegian Sea Ice Service, MET Norway

Innovation Advisory Board

Richard Hall (Chair), Equinor
Ove Stapenes, ENI
Martin Skedsmo, Norinova
Julien Moisan, Innovation Norway
Jan Petter Pedersen, KSAT
Torbjørn Eltoft, CIRFA

CIRFA Reference Group

Geir Løland, PTIL
Tor Husjord, Maritimt Forum
Bent Ove Jamtli, Hovedredningssentralen
Øyvind Rinaldo, Kystverket



Image: WPL in a CMG meeting (Photo: Lise Nordgård)

PARTNERS



Research partners:

NORCE
 MET Norway
 Nansen Environmental and Remote Sensing Centre (NERSC)
 Norwegian Polar Institute
 Norwegian University of Science and Technology (NTNU)
 SINTEF
 UiT The Arctic University of Norway (UiT)

User partners:

Aker BP
 Equinor
 Kongsberg Satellite Services (KSAT)
 Maritime Robotics
 Multiconsult
 OMV Norge
 Total E&P Norge
 Vår Energi

* Aranica, GlobeSAR and Spacetek left the project from 1. April 2020.

** NORUT Tromsø has become NORCE, and NORUT Narvik has become SINTEF from 1. April 2020.

OBJECTIVES

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

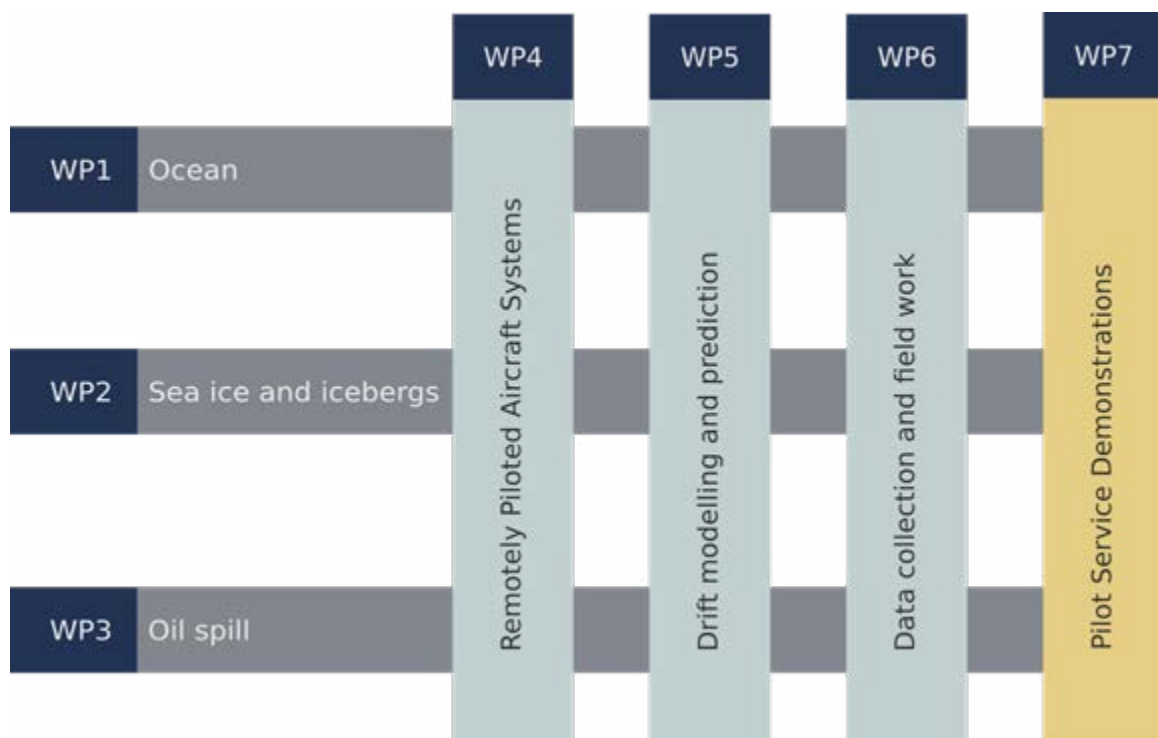
CIRFA will contribute to:

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

The research tasks are organized in seven work packages centered around three application areas:

- ▣ Ocean
- ▣ Sea Ice and Icebergs
- ▣ Oil Spill and 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 below.





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

RESEARCH HIGHLIGHTS

Impact of noise in polarimetric analysis of oil slick scenes

A recently published paper by Espeseth et al. (2020) examines the effects of both additive and multiplicative system noise on X-, C-, and L-band synthetic aperture radar (SAR) data covering oil slicks. The objective is to understand the sensitivity of a set of commonly used polarimetric features to both additive and multiplicative noise when observing marine oil slicks. The analysis covers: 1) studies on how the feature values behave as a function of both the simulated noise and true noise (additive and multiplicative) within the radar measurements; 2) identifying the minimum SNR for which the data are too contaminated by the noise to provide reliable information concerning the oil slick properties; and 3) exploring the feature behavior when the additive noise power is subtracted from the second-order sample covariance and coherency matrix. The analysis is based on quad-polarimetric data from the L-band sensor Uninhabited Aerial Vehicle Synthetic Aperture Radar, the C-band sensor Radarsat-2, and dual-polarimetric (two co-polarization channels) data from the X-band sensor TerraSAR-X (obtained offshore Norway during a series of oil-on-water field campaigns).

Read more in: Espeseth et al.: “*The Impact of System Noise in Polarimetric SAR Imagery on Oil Spill Observations*” IEEE Transactions on Geoscience and Remote Sensing, 2020.

Using CIRFA algorithms to determine changes in the sea ice season in Svalbard fjords based on time series of SAR images from multiple satellites

In this paper, Synthetic Aperture Radar (SAR) satellite images are used to monitor Arctic sea ice in two fjords on Svalbard based on systematic data records dating back to 1991. A semi-supervised classification method is used to separate open water and sea ice, utilizing ERS-1/2, Envisat ASAR, RADARSAT-2 and Sentinel-1 SAR images. The classification method combines automatic segmentation with a manual segment selection stage. Since the algorithm requires only the backscatter intensities and incidence angle values as input, it is transferable between SAR sensors, and suitable to develop consistent long-term records, that can therefore be used in climatological studies. Sea ice classification methods that are transferable between SAR sensors are essential to develop consistent long-term records, that can later be used in climatological studies. In this study, we investigate the sea ice conditions in two Svalbard fjords, Kongsfjorden and Rijpfjorden. Both fjords are known to have a seasonal ice cover. The satellite image dataset consists of weekly to daily records from 2002 until now, but with less frequent records between 1991 and 2002. Time overlaps between different sensors are investigated to ensure consistency in the reported sea ice cover. The classification results have been validated against high-resolution SAR data as well as in-situ measurements and sea ice maps from Ny-Ålesund. For both fjords it is found that the length of the sea ice season has shortened since 2002, and for Kongsfjorden the maximum sea ice coverage has become significantly lower after 2006.

Read more in: Johansson et al.: “*Consistent ice and open water classification combining historical synthetic aperture radar satellite images from ERS-1/2, Envisat ASAR, RADARSAT-2 and Sentinel-1A/B*”, Annals of Glaciology, 2019.

Retrieval of dielectric constant in marine oil slicks from polarimetric SAR data

The paper presents a method to retrieve the dielectric properties of oil slicks from polarimetric synthetic aperture radar data. The method is based on the polarimetric two-scale model, in which the ocean surface is modeled as an ensemble of randomly orientated, slightly roughened, tilted facets, where the scattering from each facet is modeled by the small perturbation model. Two parameters need to be estimated from the data; the large-scale roughness variance and the dielectric constant of the scattering medium. The original model utilizes both the co-polarization and cross-polarization channels to determine these parameters simultaneously from a series of look-up tables. Since the signal-to-noise level of oil slicks often are very low, especially for the cross-pol channels, the model is here adapted to estimate the roughness characteristics of the scattering surface first, before the dielectric properties are inferred, using only co-pol channels. The performance of the altered scattering model is then evaluated by applying it to multiple sets of quad-polarimetric data containing verified oil slicks, acquired from oil-on-water clean-up exercises in the North Sea. The retrieved estimates for the modulus of the dielectric constant indicate that the model is able to invert for values similar to the actual value of 2.3, which is the dielectric constant of pure crude oil at the lower limit, with successively higher values being found up at the edges of the slicks. The potential of this method to identify the thicker parts of an oil slick will be further investigated.

Read more: Quigley et al.: “Retrieval of Marine Surface Slick Dielectric Properties from Radarsat-2 Data via a Polarimetric Two-Scale Model”, IEEE Transactions on Geoscience and Remote Sensing, 2020.

Higher order statistics to solve ambiguities in model-based polarimetric decomposition

Model-based decomposition is a common method to disentangle polarimetric SAR images into contributions from various scattering mechanisms. This paper presents a new general framework for solving polarimetric decompositions of extended scattering surfaces by utilizing more statistical information of the radar signal and include radar texture models. Polarimetric target decomposition methods generally suffer from the deficiency that they try to find more physical parameters than there are equations and are, thus, underdetermined with no unique solution. The common approach is to make certain assumptions, thus fixing some parameters, allowing the other parameters to be solved freely. The latter explains how to obtain additional equations from higher-order moments to find unique solutions, and, in addition, to address the issue of textured product models in the case of non-Gaussian statistics. Preliminary results are demonstrated for a well-known real polarimetric synthetic aperture radar scene for the three-component Freeman–Durden decomposition.

Read more in: Eltoft and Doulgeris: “Model-based polarimetric decomposition with higher order statistics”, IEEE Geoscience and Remote Sensing Letters, 2019.

INNOVATION HIGHLIGHTS

Ice-type dependent incidence angle variation in sea ice classification

Researchers in Work Package 2 of CIRFA have developed a completely new approach for doing sea ice classification from SAR images. SAR imagery of sea ice is generally characterized by a continuous decrease of backscattered intensity with incidence angle. In the log-domain, this decrease is approximately linear over the typical range of space-borne SAR instruments. The challenge is that the rate of decrease is dependent on surface type, and hence, if not corrected for, it hampers classification. This is especially notable in wide-swath scenes, where the incidence angle may significantly change from near to far range. A global correction does not mitigate the deteriorating effect it has on classification. The new approach is to incorporate the type-dependent incidence angle variation directly into the classification algorithm. A constant mean vector of a Gaussian PDF in a Bayesian

classifier is replaced with a linearly variable mean, which varies with class. During training, the classifier first retrieves the slope and intercept of the linear function describing the mean value, and then calculates the covariance matrix as the mean squared deviation relative to this function. The algorithm has been tested on a large collection of manually validated SAR scenes of sea ice, and the results show that the method significantly improves classification.

A poster describing the method won the 1st price at the *International Glaciological Society - 2019 Sea Ice Symposium* in Winnipeg, Canada, August 2019 (authored by J. Lohse, A. Doulgeris, and W. Dierking), and the method is currently undergoing more extensive testing and validation.



CIRFA - Industry collaboration on oil spill characterization

This innovation project between KSAT and CIRFA is entering into its second year, where testing and verification is on the agenda. The project attempts to calculate the relative thickness of an oil slick from an SAR image using only one polarization. It is hence not restricted to a specific sensor. Oil spill preparedness planning requires fast and relevant information about a potential oil slick, and after the oil slick is detected, information about type, thickness, and drift direction is essential. Therefore, this innovation project has focused on developing an algorithm that automatically estimates the damping ratio from SAR data, assuming that the damping ratio represents a proxy to relative oil thickness, and is most likely the best option to extract relative oil thickness from SAR data. This project

demonstrates a fruitful collaboration between KSAT (Hugo Isaksen), CIRFA (Martine Espeseth and Thomas Kræmer), and NOFO as the possible end-user. Below is an example of the output of this algorithm. The left image is a Sentinel-1 intensity image and the right image is the damping ratio, where the darkest regions represent areas with high damping, indicating a relatively thick oil layer.

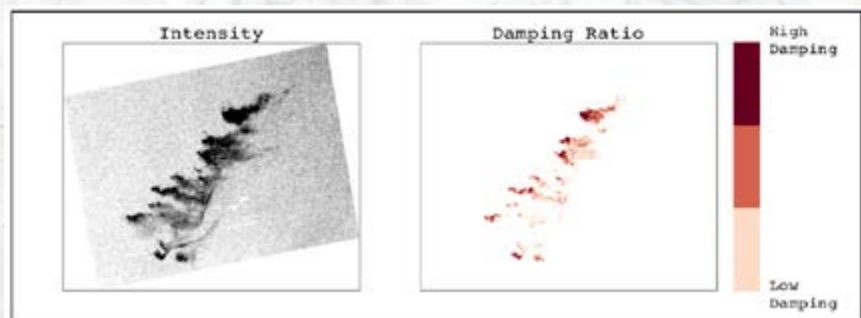


Image compiled by Martine Espeseth



Work Package Leader
Harald Johnsen
NORCE, UiT

Team: members



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Researcher, NORCE

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Heidi Hindberg
Researcher NORCE

Artem Moiseev
PhD Fellow, NERSC, NORCE

Dennis Monteban
PhD Fellow

Work package 1

OCEAN REMOTE SENSING

Objectives and motivation:

The ocean surface is the complex boundary between two very dynamic and stochastic media, the ocean and the atmosphere. Better forecasting of the ocean state and understanding of the physical processes going on at the ocean/atmosphere interface require combined capacity in remote sensing, numerical modelling, and in-situ observations.

Synoptic maps made from space of ocean surface winds, waves and currents are core inputs to better characterization and parameterizations of oceanic mesoscale and sub-mesoscale dynamics, as well as important contributions to the understanding of ocean-atmosphere interaction and research on numerical modeling. The newly launched Sentinel satellites will greatly improve the capabilities of providing such high-

resolution information from space due to the enhanced time and space coverage offered. This work package will develop the use of satellite technology to advance the understanding of the Arctic Ocean processes and dynamics, and contribute to better prediction of polar lows, now-casting, and short range forecasting of ocean states through coupling with high-resolution numerical models.

Key research tasks:

- ▣ Develop physical and statistical methodologies to improve the reliability of satellite-derived met-ocean parameters.
- ▣ Develop algorithms, products and a processing system for providing ocean state parameters from satellite observations beyond what is achievable today.
- ▣ Perform extensive satellite product calibration and validation analysis using independent measurements.
- ▣ Study the dynamics of polar lows by combining remote sensing and numerical modeling.
- ▣ Support short range forecasting of ocean states through coupling with high-resolution numerical models in collaboration with work package 5.

Achievements 2019

The R&D has been concentrated on the assessment of Sentinel-1 ocean coastal and global current measurements, the evaluation of Sentinel-1 data for wave characterisation in the marginal ice zone (MIZ), and the operationalization of met-ocean processing system at Kongsberg Satellite Services (KSAT) based on achievements from CIRFA R&D.

- ▣ The R&D on the retrieval and geophysical validation of coastal current retrieved from Sentinel-1 data has resulted in a peer review paper recently accepted for publication in JGR Ocean.
- ▣ The R&D on the wave propagation in the MIZ derived from Sentinel-1 data has led to a peer review paper published in JGR Ocean in 2019 (DOI: 10.1029/2019JC015311).
- ▣ The R&D on ocean wind vector retrieval from Sentinel-1 data has led to a peer review paper published in IEEE TGRSS in 2019 (DOI: 10.1109/TGRS.2019.2909838)
- ▣ A PhD study on polar lows has started, and several interesting cases are identified for detailed analysis (see figure below).
- ▣ The operational met-ocean processing system established at KSAT has been upgraded and extended to better support user and R&D needs such as the processing of wind speed from both co- and cross-pol data. The system performs processing of met-ocean parameters in near real-time for input to external user services provided by KSAT.

Outreach:

The team has close cooperation with European Space Centre (both ESRIN (Italy) and ESTEC (The Netherlands)), as well as with research institutes in Europe such as Ifremer (France), OceanDataLab (France), TU Delft (The Netherlands), DLR (Germany), DTU (Denmark) and Chalmers (Sweden). The research activity has been presented at various international workshops/conferences. The polar low activity has also achieved external funding (ESA) to develop machine learning techniques for polar low detection and tracking from SAR data.

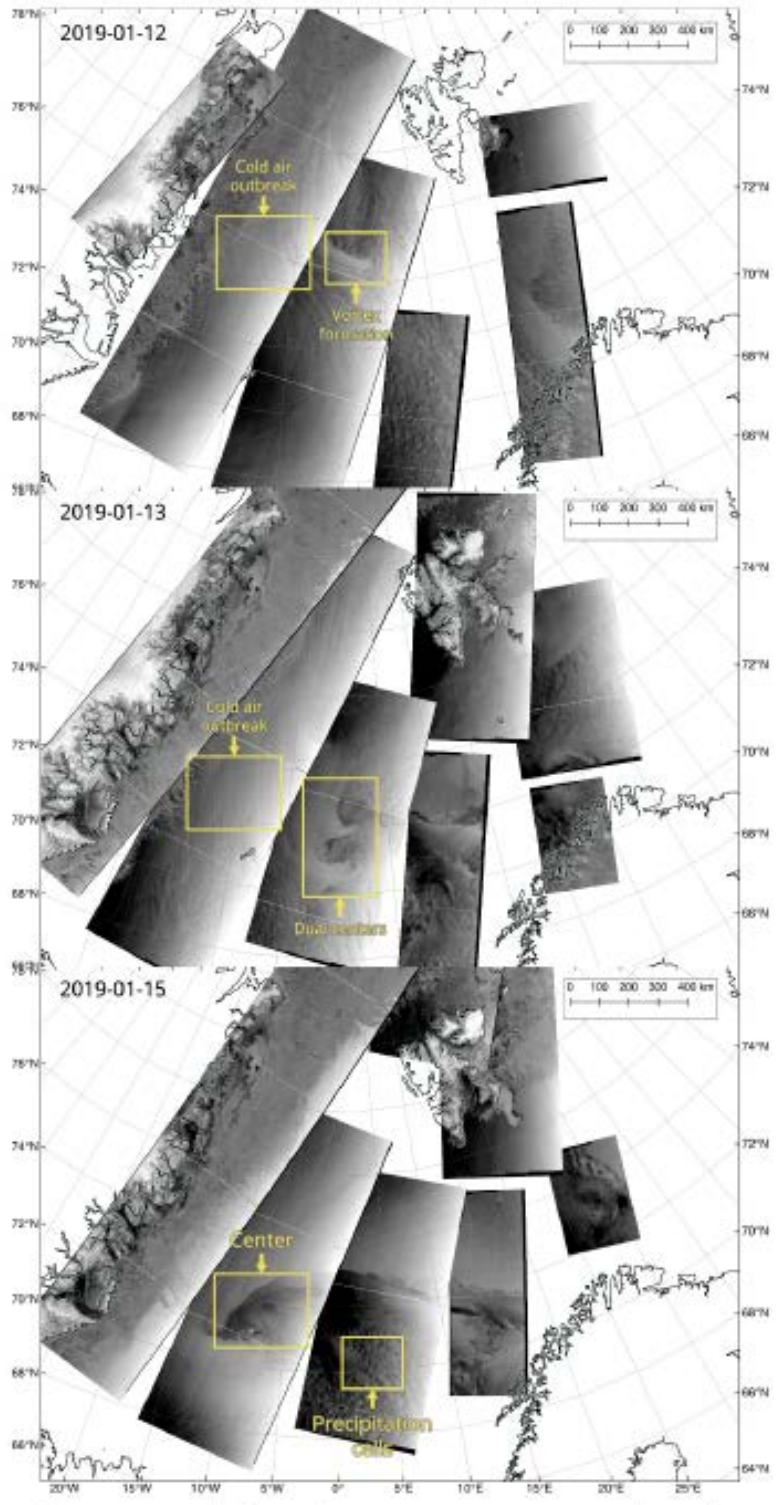


Figure: Development of a polar low in the Norwegian sea over a period of 4 days as imaged by Sentinel-1. The polar low is characterised by a cold air outbreak, vortices and precipitation cells (courtesy of Jakob Grah, NORCE).



Work Package Leader
Wolfgang Dierking,
AWI/UiT



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

Team members:

Sebastian Gerland
Senior Researcher, NPI

Anca Cristea
Researcher, UiT

Johannes Lohse
PhD Fellow, UiT

Ingri Halland Soldal
PhD Fellow, NERSC

Thomas Kræmer
Head Engineer, UiT

Sophie Kühnlenz
PhD Fellow, UiT

Eduard Khachatryan
PhD Fellow, UiT

Saloua Chlaily
Associate Postdoc (WP2 and WP3)

Salman Khaleghian
Associate PhD (WP2 and WP7)

Andrea Marinoni
Assoc. Prof. (WP2 and WP3)

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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 skin-like new ice to cover several meters for multi-year ice. Remote sensing is a key technology for characterizing the ice conditions and detecting icebergs 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 methods based on statistics, machine and deep learning, and image processing techniques to develop robust and reliable procedures for monitoring status and changes of the sea ice cover.
- Improve methods for the retrieval of sea ice drift and deformation.
- Investigate new, robust methods for iceberg detection and characterization, including drift trajectory predictions.
- Optimize the development procedures such that the new algorithms can be integrated into the workflow of the operational ice centres.

Achievements 2019

Further progress was made regarding the incidence angle dependence of the radar intensity and the variable noise floor in Sentinel-1 Wide-Swath SAR imagery. In the approach developed by Anthony Doulgeris, the incidence angle sensitivity is not treated as an image property but as an ice class property. Johannes Lohse incorporated this concept into a supervised Bayesian classification algorithm. For training and validation, he used a large data set of overlapping SAR and optical images acquired over the entire Arctic. He showed that the classification accuracy resulting from the new concept is higher compared to an incidence angle correction applied globally to the image. Johannes Lohse, Anthony Doulgeris, and Wolfgang Dierking submitted an article describing the method to *Annals of Glaciology*, which will be published in 2020. Feedbacks of end users on this method were very positive. Anthony Doulgeris and Anca Cristea have been dealing with incorporating the variable noise-floor patterns encountered in Sentinel-1 Extra Wide-Swath scenes in a generic segmentation algorithm. First results look promising but more work is required. Another approach was chosen by Saloua Chlaily who used a wavelet approach to remove the noise from Sentinel-1 images acquired at HV polarization.

Another recent focus of the group is the combination of different data sources for sea ice classification. The aim is to develop methods for the retrieval of information about ice cover properties using multi-resolution, multi-sensor, and/or multi-temporal satellite images. A recent PhD project is embedded in this context. It is carried out by Eduard Khachatryan with support of Andrea Marinoni and Saloua Chlaily. They developed a data fusion framework based on graph theory considering mutual information. The idea of the method is to perform attribute selection by means of information theory-based metrics across datasets acquired by multiple remote sensors, so to retrieve the relevant attributes (and discard the redundant or unreliable ones) for accurate remote sensing data analysis, while guaranteeing the physical interpretability of the outcomes. In tests on dual-polarization Radarsat-2 with optical Landsat-8 images, and on Sentinel-1 and Sentinel-2 imagery, the new method outperformed other approaches for finding the relevant attributes.

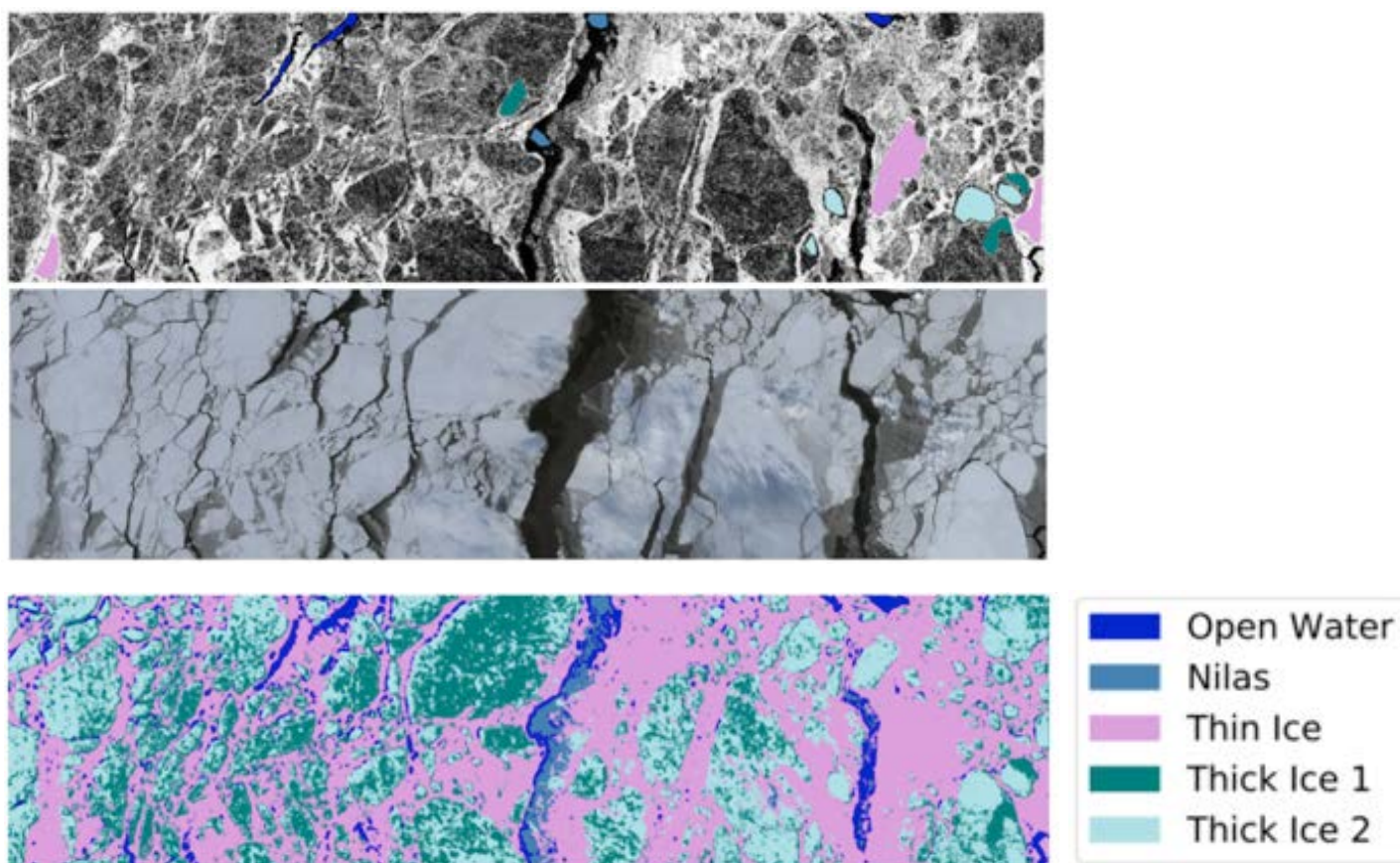


Figure. Top: Radarsat-2 HH-polarization, middle: Landsat-8, bottom: result of classification. 91 attributes were available, the maximum classification accuracy was achieved with less than half of them. Image compiled by Eduard Khachatryan and Saloua Chlaily.

Other research progress

Ingri Halland Soldal, Wolfgang Dierking, Anton Korosov, and Armando Marino published a paper in *Remote Sensing* on the detection of small icebergs captured in fast ice, using extra-wide-swath Sentinel images.

Vebjørn Karisari (WP7) and Johannes Lohse collected and archived a series of Sentinel-1 SAR and complementary Sentinel-2 optical images for retrieving training and validation data to be used for developing and testing segmentation and classification algorithms.

Together with Anthony Doulgeris and Nick Hughes from the Norwegian Ice Service, Johannes Lohse and Thomas Krämer have developed a processing chain for automated operational sea ice classification.

Malin Johansson (WP3), Anthony Doulgeris, and Suman Singha (DLR) studied sea ice type separation using L-band SAR imagery. They submitted a description and the results of this study to *Transactions on Geoscience and Remote Sensing*.

Sophie Kühnlenz started a PhD project at CIRFA which has the final goal to predict near-future changes in sea ice charts from forecasts of sea ice drift. Together with Wolfgang Dierking she developed a plan for the necessary steps towards this goal.

Wolfgang Dierking, together with Harry Stern and Jennifer Hutchings from the US finished their study of error propagation in retrievals of sea ice drift and deformation and submitted a paper to *The Cryosphere*.

Salman Khaleghian and Andrea Marinoni have been working on the development of deep learning architectures for iceberg detection and advanced machine learning techniques for sea ice

mapping, with the objectives to provide accurate characterization of the sea-ice edge and precise discrimination between ships and icebergs.

Andrea Marinoni and Saloua Chlaily developed a new scheme for automatic selection at data, feature, and decision level of multimodal remote sensing records for enhanced sea ice classification. This approach will be used to enhance the design of architectures of ensemble learning and deep learning for multimodal remote sensing data analysis, so that the integration of algorithms of multimodal data fusion in scalable and efficient data processing frameworks will be possible.

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

Johannes Lohse was the winner of the best poster award in the category “Technical Science” at the IGS Sea Ice Symposium. He collaborated with Kystverket on local sea ice mapping, and together with Anthony Doulgeris and colleagues from the Norwegian Ice Service he was involved in a project that deals with the use of ICEWATCH data for validation of ice type classification algorithms.

Anthony Doulgeris was a co-organizer of the third INTPART Arctic Field school in Canada in May. From July to December he was on sabbatical in Hobart, Australia, where he collaborated with three institutions - CSIRO, UTAS and AAD (Commonwealth Scientific and Industrial Research Organization, University of Tasmania, Australian Antarctic Division). The collaboration sees the CIRFA methods being tested on the Antarctic sea ice and also for ship and oil spill detection.

Wolfgang Dierking served as guest editor for a special issue of the journal *Remote Sensing* on combining SAR and complementary data for retrieval of sea ice parameters.

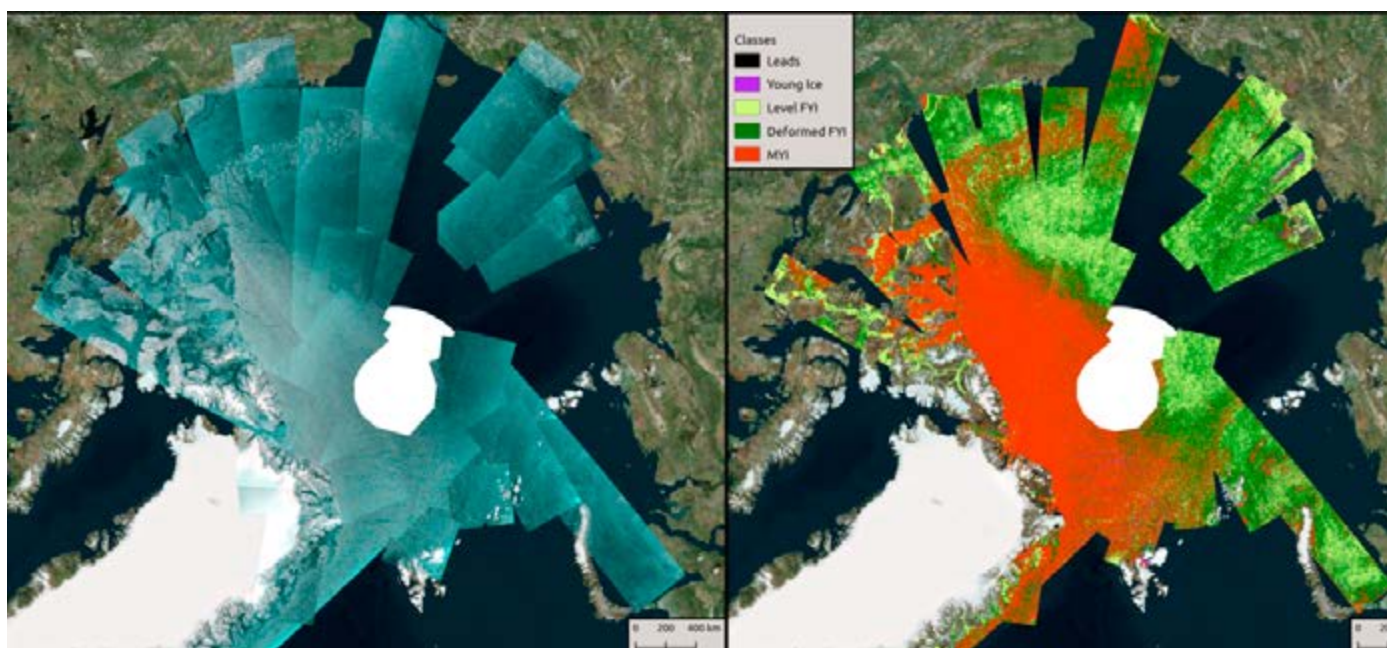


Image: Lohse et al. 2020, *Annals of Glaciology*



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*Postdoctoral fellow from
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Cornelius Quigley
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Marianne Myrnes
PhD Fellow, UiT

Anca Cristea
Researcher, UiT

Andrea Marinoni,
Assoc. Prof., 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 spills transport is also important in a combat situation. Integration of remote sensing measurements and modelling efforts is essential in validating and improving drift models for oil spills. Remote sensing imagery from satellites is applied in operational oil spill screening operations, where false alarms are a major issue. There is also a need to establish proven methods for oil spill detection in ice-infested waters as oil & gas exploration, shipping, and tourism

are expanding their activities into Arctic regions. To develop remote sensing techniques for sea ice conditions requires at first instance an understanding of the oil's fate and behavior within sea ice, and secondly knowledge about the interaction between the remote sensing signal and the oil-ice layers. This work package aims to develop new techniques for solving the look-alikes ambiguity related to detection of oil on water, and to study methods for detecting and monitoring of oil in ice.

Key research tasks:

- Develop accurate remote sensing information retrieval techniques for reliable oil slick detection and characterization on open water.
- Improve the modelling of oil 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 2019

- Dashika Manral from India did her Master's project at CIRFA as an ERASMUS+ exchange student. The title of her thesis was: "Assessing sensitivity of oil spill drift modeling".
- Stine Skrunes and co-authors had a first paper on remote sensing of produced water published in Remote Sensing.
- Martine Espeseth and co-authors had a paper on system noise in SAR data and its impact on oil spill observations accepted for publication in IEEE TGRS.
- Benjamin Holt and Brent Minchew affiliated with JPL and MIT, respectively, visited CIRFA.
- Dmitry Ivonin affiliated with IO RAS visited CIRFA.
- NORSE2019 was successfully conducted in the North Sea in June 2019. We had participants from Canada, Australia, USA, Germany and Norway. UiT's R/V *Helmer Hansen* took part at sea, while DLR's F-SAR was in the air.
- As part of NORSE2019, a first pilot on a relative thickness parameter derived from SAR imagery was conducted in collaboration with NOFO, KSAT and NORCE. The parameter was included in KSAT's oil spill report and fed directly into NORCE's NLive system for visualization on board R/V *Helmer Hansen* and at NOFO's headquarters.
- Andrea Marinoni, Martine Espeseth and Malin Johansson each gave a presentation at IEEE IGARSS 2019 in Japan disseminating WP3 research results.
- Megan O'Sadnick and Christian Petrich presented WP3 results at three international conferences: EGU General Assembly, POAC, and the IGS Sea Ice Symposium.
- Marc Oggier published the first journal paper on oil behavior during the HSVA oil-in-ice experiments.
- Hugo Isaksen (KSAT/WP7) and Camilla Brekke contributed with popular science talks at the event "Tekna X: Satellitt- og romteknologi – og dens betydning for Nord-Norge" at Prelaten, Tromsø.
- Camilla Brekke gave three invited talks in the spring term at IO RAS in Moscow, at University of Zurich and at Royal Society of Edinburgh, respectively. Cathleen Jones was a co-author on two of the talks.
- Torbjørn Eltoft and Camilla Brekke participated with talks at the SATA winter school in Longyearbyen, Svalbard.
- Cornelius Quigley submitted his first journal article to IEEE TGRS on the retrieval of oil slicks dielectric properties from radar. The article is now accepted and is expected to be on print in 2020.
- Martine Espeseth successfully defended her PhD thesis 5 December 2019. The title of the thesis was: "Analysis of Oil Spill and Sea Ice Measurements Using Full-Polarimetric and Hybrid-Polarity Synthetic Aperture Radar data".



Image: Martine Espeseth collecting data through the real-time NLive System developed by NORCE (Photo: Stine Skrunes).



Image: Andrei Ivanov, Malin Johansson, Camilla Brekke and Dmitry Ivonin Outside IO RAS in Moscow (Photo: Mikhail Krinitskiy)



Image: Megan O'Sadnick and Øystein Kleven performing a survey of fjord ice conditions in the winter of 2018/19 (Øystein Kleven, SINTEF Narvik)



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Rolf-Ole Jenssen
PhD Fellow, UiT

Research partners:
NORCE, NTNU, 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 operations 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 and tracking
- Develop onboard data processing and improve 'concepts of operation' allowing for real-time operational support and ultimately integration into non-segregated airspace.

Achievements 2019

Modelling and simulation of ice aggregation

WP 4 published papers on aircraft icing and aerodynamic effects, optimization of de-icing systems. Hann investigated coupling of cloud particle composition with aircraft icing by comparing modeled aggregation with data gathered in the VTT icing wind tunnel experiment in spring. This work was done in collaboration with the NTNU spin-off company UBIQ Aerospace.

Ship-based drone data collection and real-time distribution in connection with oil spills

In connection with OPV 19 we demonstrated real time data capture and distribution by ship based drone system equipped with a custom hyperspectral/IR/RGB sensor package fusing drone data and external (AIS/met/satellite) data in a map based system developed by NORCE (NLive) transferred in near real time by satellite communication. This service is available to stakeholders by a web-based interface allowing for real time feedback.

Sea-ice properties mapping in support of ice navigation

The WP demonstrated combining ship based radars and drones for improved path planning for navigating ships in ice-covered

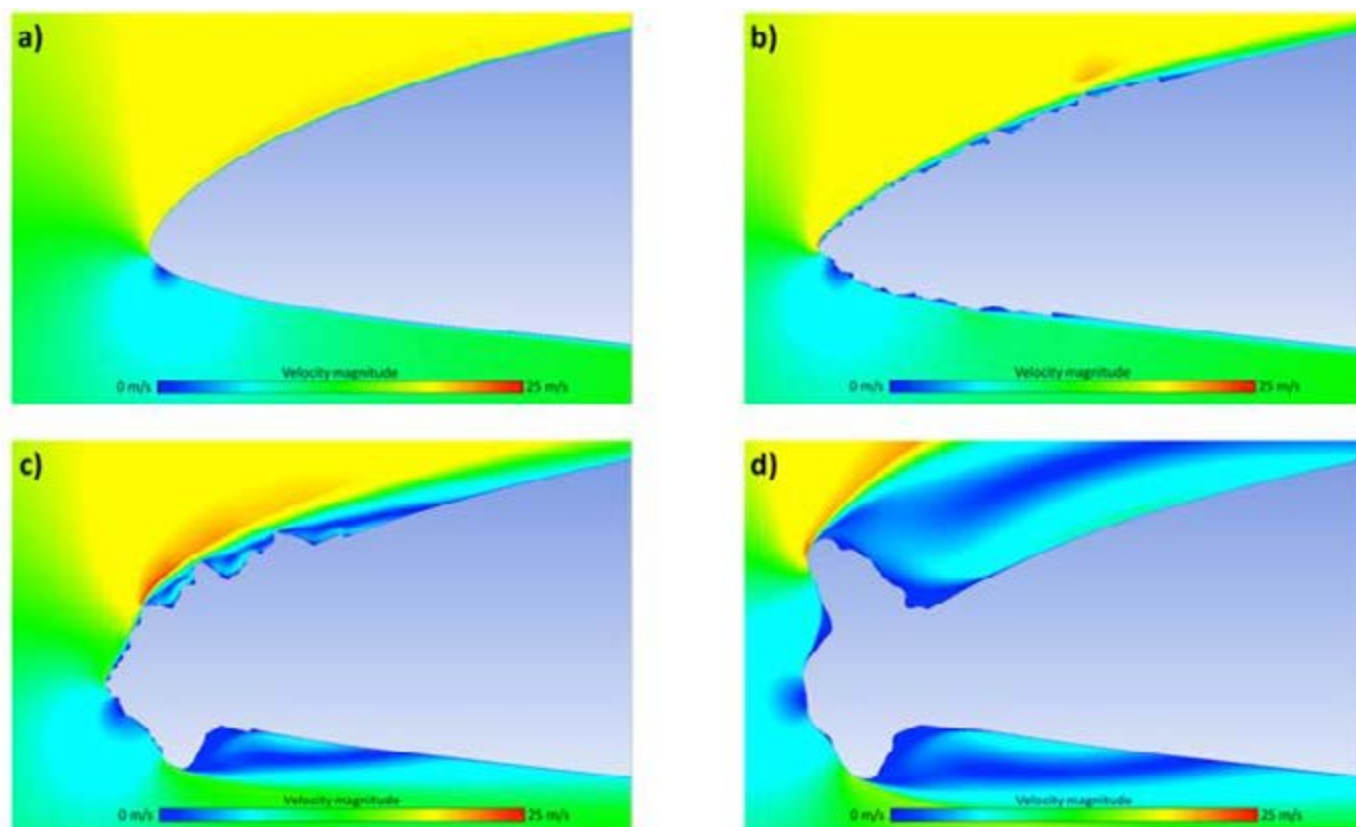
waters. We tested the use of different types of drones and sensors for mapping leads, ridges and ice types on the KV *Svalbard* cruise to the North Pole. In addition, we demonstrated the ability to discriminate between first year ice, second year ice and multi year ice using UWB radar. See more details about the CAATEX experiment later in the report.

NLive real-time visualization and data distribution system

The NLive real-time visualization and data distribution system where CIRFA has contributed to the development to support the drone operation and data fusion, was adopted by Nordic Unmanned AS for use in their 4 year contract with the European Maritime Safety Agency. The system will support the use of drones from Coast Guard vessels in the EU for emergency response and environmental emission enforcement.

Outreach

Keynote lecture on use of drones in support of sea-ice navigation at the IDEA19 workshop in Helsinki Nov 8th.



FENSAP results for the velocity field of the clean (a), rime (b), glaze (c), and horn* (d) cases.

Images: Richard Hann.



Image: Rime ice shape from experimental testing in the icing wind tunnel at VTT in Finland.



Image: Operation of de-icing system in the icing wind tunnel.



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Work package 5

DRIFT MODELING AND PREDICTION

Objectives and motivation:

The objectives of this work package are to assimilate observations collected within CIRFA into forecast models for the ocean circulation and the sea ice, and to produce probabilistic ocean, sea ice and drift forecasts.

Ocean and ice forecasting at high latitudes, including the forecasting of drift of icebergs, oil-spills and other pollutants, is challenging due to the lack of observations. Improved operational forecast systems require increased amounts of high-resolution information and efficient algorithms for ingesting the observations into the ocean and ice models. Also, because of the observational uncertainties and the

chaotic nature of the flow, the forecasts have to be probabilistic. Data assimilation and ensemble forecasting using coupled ocean-sea ice models is therefore central to the work in WP5. Other important contributions include collecting insitu data for validation of the models for oceanic transport, such as oil spills, and several field experiments with drifters have been executed.

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 2019

Data assimilation of sea ice observations in high resolution ocean model

Ensemble Kalman filter data assimilation techniques have been tested and successfully applied to a high resolution, couple ocean-sea ice model for the Barents Sea. As part of Sindre Fritzner's PhD project, the study has shown that assimilation of ice charts has a larger impact on the assimilation system compared to assimilating passive microwave assimilations.

Assimilation of sea level anomaly in a coastal ocean forecast model

Variational data assimilation in a high-resolution coastal model has been extended to include ocean current observations from HF radar stations and sea level anomaly derived from satellites. While the HF radar observations provide information on small scale and high-frequency, current features such as ocean eddies and tides, and the sea level anomaly observations provide details of geostrophic large-scale currents, such as the North Atlantic Current.

Oil-on-water experiment

Extensive field work has been carried out in conjunction with the NOFO oil-on-water exercise. CIRFA WP5 has deployed surface drifters, a subsurface current meter and a sailbuoy to accurately sample drift currents, waves and wind that control the fate of an oil spill.



Image: Fieldwork during OPV campaign 2019 (Photo: Johannes Röhrs)



Image: SVP deployment (Photo: Johannes Röhrs)



Work Package Leader
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Work Package Co-Leader
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Work Package Co-Leader
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Postdoc CIRFA, Researcher ALSIM

Dmitry Divine
Researcher, NPI

Work package 6

DATA COLLECTION AND FIELDWORK

Objectives and motivation:

Partners centrally involved in this work package are the Norwegian Polar Institute, NORCE, and UiT The Arctic University of Norway. WP 6 functions as a validation and calibration platform for remote sensing data, as well as organizing the collection of ground truth data for assessing the work conducted in other work packages.

Aside new expeditions organized by CIRFA, also long-term monitoring data from land stations are used for calibration and validation purposes to support the remote sensing research. Examples of such auxiliary data sets obtained together with collaborating institutions are archived data collected during previously conducted national and international campaigns; like N-ICE2015 (a halfyear experiment where R/V *Lance* of the Norwegian Polar Institute was frozen into drifting ice in the Arctic Ocean north of Svalbard), annual campaigns of the Norwegian Polar Institute, NOFO's annual oil-on-water exercises, future data takes from the MOSAiC expedition,

which was started in September 2019, lasting a full year with a drift of R/V *Polarstern* with the transpolar drift (www.mosaicobservatory.org), and the cruises within the Norwegian Nansen Legacy project (www.nansenlegacy.org). Some cruises are completed already. Hence, the objective of WP 6 is to design field campaigns in connection with satellite and RPAS measurements, and to carefully plan and conduct the measurements needed for calibration and validation of remote sensing products, with close coordination and collaboration with other CIRFA work packages.

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 2019

- ▣ Coordinating fieldwork observations and remote sensing (together with other work packages), for CAATEX cruise with KV *Svalbard*, three Nansen Legacy cruises with R/V *Kronprins Haakon* and the MOSAiC Expedition in the transpolar drift with R/V *Polarstern* (ongoing), with observations, data and sample collections.
- ▣ Contributions to publication about changes of Kongsfjorden sea ice (Pavlova et al. 2019) in *Advances in Polar Ecology*.
- ▣ Presentations at conferences (for example at Arctic Frontiers, Tromsø, Norway; IGS Sea Ice Symposium Winnipeg, Canada; Svalbard Science Conference, Oslo, Norway).

Outreach 2019

- ▣ Popular-scientific article in the Fram Centre magazine (Fram forum; <https://framsenteret.no/forum/2019/kongsfjorden-sea-ice-development-observed-from-ground-air-and-space/>) about fieldwork and satellite remote sensing in Kongsfjorden, Svalbard.



Image: Dmitry Divine taking sea ice samples on fjord ice in Kongsfjorden, Svalbard, in spring 2019. Results about Kongsfjorden sea ice changes were published in 2019 by Pavlova et al. (Photo: Sebastian Gerland, NPI)



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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 pilot services showing the provision of integrated environmental information to end-users involved in Arctic operations.

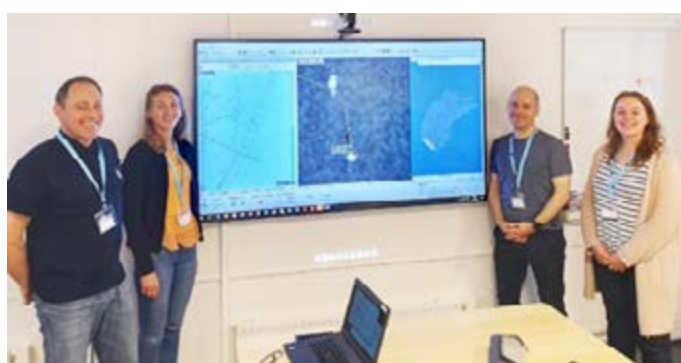
The objective of this work package is to demonstrate the implementation of R&D results into pilot services to be delivered to end-users with operational needs. The services will be based on multi-sensor data acquired from various sensors and platforms, accessed via improved communication infrastructure and brought into analysis and decision through 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 Norway to show the provision of integrated environmental information to end-users involved in Arctic operations.
- Develop a visualization solution associated with the integrated pilot services demonstrations.

Achievements 2019

WP7 supported WP3 in developing a near real-time damping ratio map in support of the oil-on-water field campaign (OPV2019). Detections by KSAT operators were automatically run through the damping ratio analysis, producing a detection report and a web map layer. The detection report accompanied KSAT's oil spill detection report and the web map layer allowed NOFO to see the relative thickness map in their common operating picture (COP) tool. In addition, the NORCE drone pilots received the same map layer in their planning tool Nlive. The demonstration successfully showed a working system for processing and delivering satellite-derived information in near real-time in a form directly usable by CIRFA partners, running on top of the processing infrastructure that KSAT has developed and made available to CIRFA.

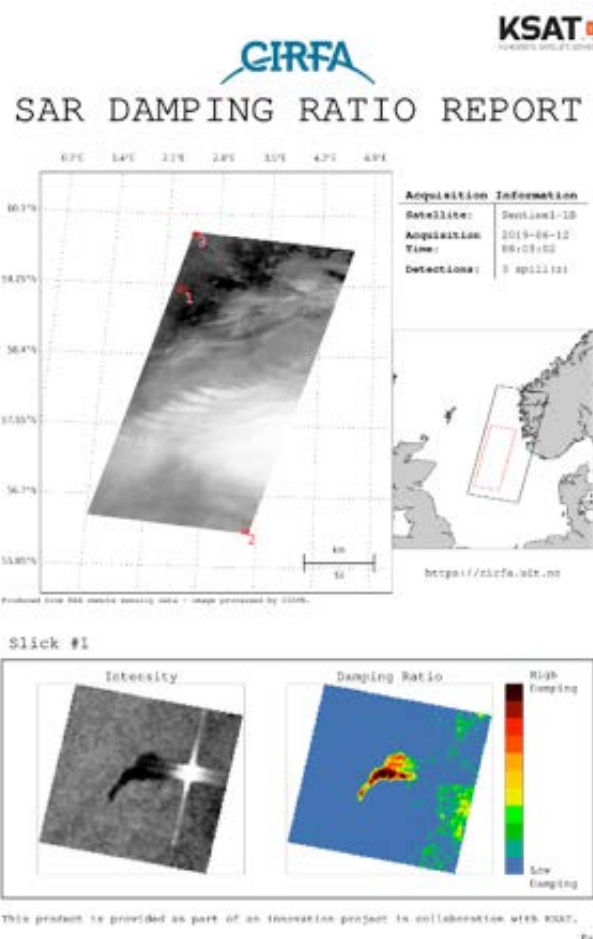


From UiT, Martine Espeseth and Stine Skrunes, and from KSAT, Hugo Isaksen and Jon Christian Richards monitoring the OPV2019 exercise from NOFO headquarter (Picture: KSAT)



Martine Espeseth and Stine Skrunes at NOFO headquarters during the OPV2019 campaign. (Picture: KSAT)

UiT and MET continue to work on assembling high quality training and validation datasets. The set of overlapping Sentinel-1 and -2 images assembled over the past couple of years keeps being extended for sea ice type classification, but we are also now including iceberg observations into the dataset. This work supports the development of classification and drift forecast algorithms in WP2, but also nicely complements work in the H2020 ExtremeEarth project that started up in January 2019.



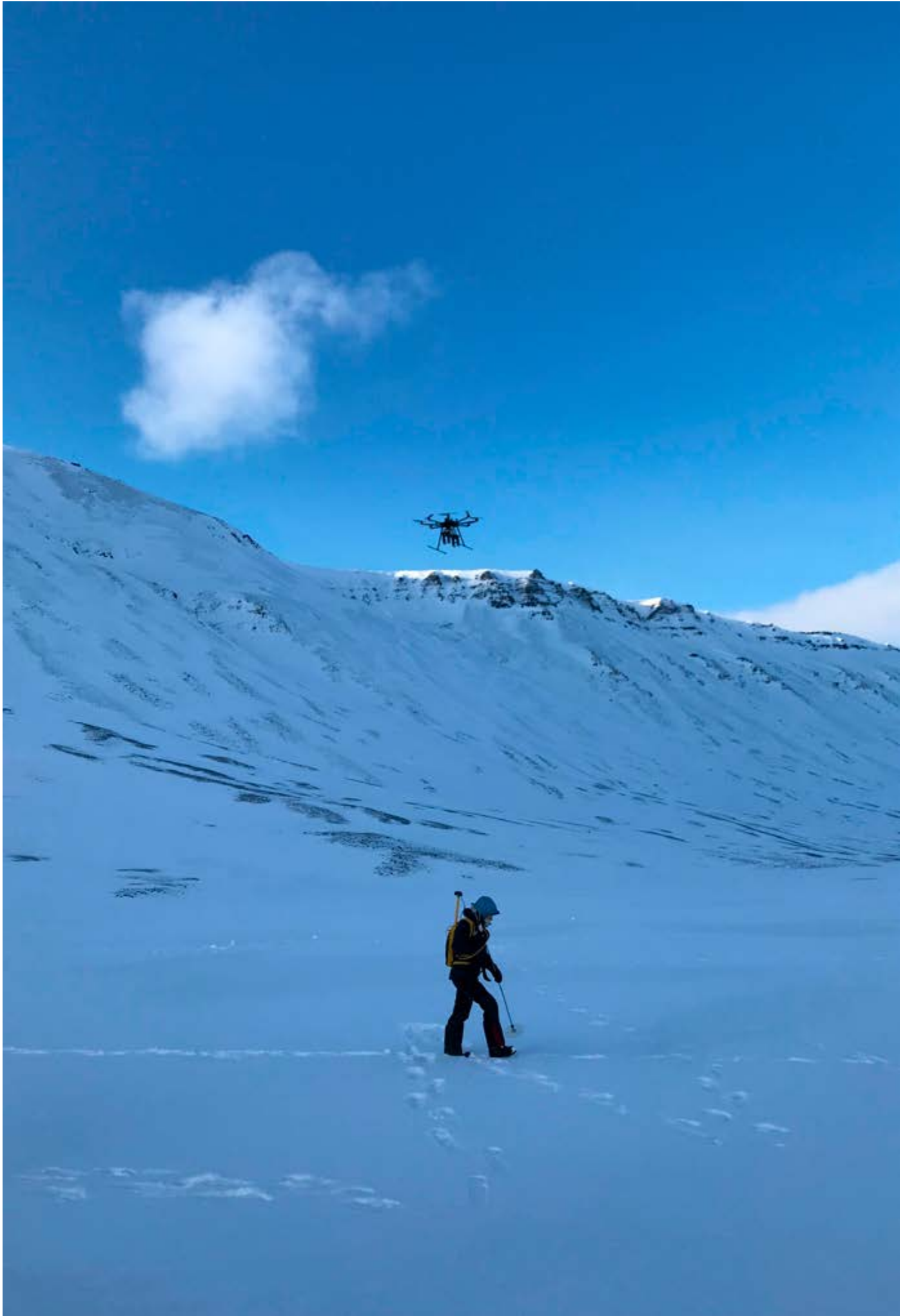
Damping ratio report delivered during OPV2019. (Figure: CIRFA / KSAT)

MET took over the responsibility for maintaining and promoting the ice observation platform IceWatch which is now hosted at <http://icewatch.met.no/>. As part of development activities and to increase the number of observations coincident with satellite images that can then be used to validate CIRFA products, a mobile phone app is being developed through the ESA Citizen Science Earth Observation Lab (CSEOL).

UiT has started discussions aiming to obtain more routine observations from R/V *Kronprins Haakon*, mainly ship radar images and camera images. Regular and semi-automated data collection from cruises into the ice fits nicely with CIRFA's need for validation data and the data could be made available in IceWatch.

Together with WP2 we are now starting to run Johannes Lohse's ice type classification algorithm on a daily basis. This is primarily to test the system and workflow, while Johannes keeps working on improving the classification accuracy. The output is an ice type map, an ice/water mask, and an ice concentration map.

NORCE has implemented a processing chain for retrieving wind, wave and RVL (radial velocity, part of ocean current) from many different missions in combination with WP1. Work is underway to try to combine the measured RVL with an object detection method to try to separate icebergs from ships in detection results. As the ice/water mask from WP2 is made available, this will be used as input to the processing chains for wind, wave and RVL.



FIELDWORK AND DATA COLLECTION

During 2019, a wide array of fieldwork activities was conducted in CIRFA and associated with CIRFA. Here, we report about selected fieldwork activities: NORSE2019, CAATEX2019, and UWIBASS operations.

NORSE 2019

CIRFA conducted its first research cruise on remote sensing and modelling of oil pollution in the marine environment in June 2019

The Norwegian Radar oil Spill Experiment (NORSE2019) was performed by CIRFA and research partners in the North Sea in June 2019. The experiment was conducted as part of NOFO's annual oil-on-water exercise. By integrating NORSE2019 in NOFO's annual exercise, CIRFA could perform scientific experiments and at the same time take advantage of NOFO's infrastructure, expertise and well established framework for environmentally precautions operations. UiT The Arctic University of Norway's R/V *Helmer Hanssen* took part in the experiment, leaving for the study site 11 June and returning back to Stavanger on 14 June 2019, respectively.

This experiment involved measurements of oil slicks and ocean by sensors from high up in space to down at the sea floor; satellites, aircraft, drones, met-ocean buoys, CTD (conductivity, temperature and density), in-situ sampling of oil types and a moored ADCP (acoustic doppler current profiler). In-situ measurements, aerostat measurements, drone flights and two oil emulsion releases were conducted from R/V *Helmer Hanssen*.

The composition and release of the oils on the sea surface were done by NOFO personnel. In the air, we had one aircraft from DLR dedicated to the NORSE2019 experiment, carrying the F-SAR instrument as payload. The planning of these flights was done as a collaborative effort between DLR, UiT and NOFO. In addition, the LN-KYV aircraft from the from the Norwegian Coastal Administration was involved with NOFO in the oil-on-water exercise, and interleaved with the DLR aircraft over the site and NORSE2019 activities. From space, we had satellite acquisitions from Sentinel-1B, TanDEM-X and COSMO-SkyMed of the free-floating oil slicks at sea.

The campaign was planned, organized and conducted as a joint WP3, WP4, WP5 and WP7 effort. CIRFA thanks all participants involved in the campaign. A special thank you to NOFO for all the support and help on the logistics and to the awesome crew on R/V *Helmer Hanssen*!



Image: Participants on R/V *Helmer Hanssen* during the NORSE2019 campaign. The cruise leader was Thomas Kræmer with Camilla Brekke and Knut-Frode Dagestad as project leader and co-project leader, respectively. (Photo: staff from R/V *Helmer Hanssen*)



Image: Stine Skrunes and Martine Espeseth with representatives from DLR in front of the F-SAR aircraft at Sola during NORSE2019.

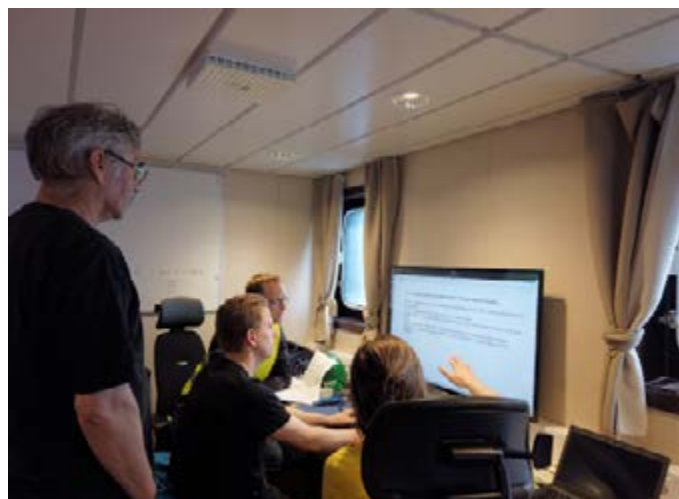


Image: Cruise planning on board R/V *Helmer Hansen* (Photo: Malin Johansson)

CIRFA contribution to CAATEX2019:

During the CAATEX cruise, ice monitoring using a Ku-band interferometric imaging radar, ultra-wideband ground penetrating radar, ultra-wideband snow sounder (UWiBaSS), satellite SAR for navigation, and ice mapping using UAV were performed by CIRFA researchers.

Tom Rune Lauknes, NORCE (CIRFA), Rolf-Ole Rydeng Jenssen, UiT (CIRFA), André Kjellstrup, NORCE (CIRFA)

Summary

CIRFA participated in the Coordinated Arctic Acoustic Thermometry Experiment (CAATEX) cruise with the Norwegian coast guard vessel KV *Svalbard*, to the north pole in the period August 14 to September 9, 2019, coordinated by the Nansen Environmental and Remote Sensing Center. During the CAATEX cruise, NORCE operated an imaging radar system and several different UAV platforms. The radar was mainly operated during the periods where the vessel was stationary in the ice, providing valuable information about ice drift and ice conditions. The main objective of CIRFA's part of the experiment was to collect observations of sea ice drift and ice coverage and type, at different positions along the route up to 90°N. In addition to the science data collection, the potential of using a high-resolution imaging radar for navigation in ice-infested waters was also demonstrated. NORCE operated a fixed-wing unmanned aircraft system (UAS), which was used to collect high-precision optical imagery, which is very valuable for validation purposes by providing information about ice morphology. UiT and NORCE operated an ultra-wideband radar system on a multirotor UAS platform. The radar, which is able to detect layers in the snow and ice, was operated along selected profiles where also snow and ice samples were collected by the Norwegian Polar Institute. During the cruise, CIRFA tasked high-resolution Radarsat-2 satellite SAR scenes which were used during the cruise for navigation. Processing and interpretation of the collected data from the radar and the UAS is ongoing. NORCE also participated in daily processing and interpretation of satellite SAR imagery from Sentinel-1, which was instrumental in the navigational decision-making process.

The experiment has demonstrated a novel use of an imaging radar system. Comparison between a traditional marine radar and the interferometric imaging radar demonstrates clear potential for improved characterization of ice conditions. The UWiBaSS radar could be used to provide sea ice condition data products, or as an "in situ" tool to supplement SAR imagery. The large spatial coverage compared to manual measurements could give a better understanding of snow backscatter effects in SAR images. The collected scientific dataset has a great value for validation of satellite-based ice classification algorithms, as well as providing novel information about sea ice dynamics at high temporal and spatial scales. The datasets have a great potential for student projects, both at PhD and master level.



Figure 1: Left: The GPRI radar system consists of three rotating antennas, mounted inside a protective radome. The spatial baseline between the antennas provide sensitivity to topography. Right: The radome was mounted on the bridge roof on the forward port side. The shaded field shows the approximate field of view of the radar. Note that the radar operated up to a distance of ca. 4 km. Image: Gamma Remote Sensing AG and NORCE



Figure 4: The figure shows the sailing route of KV *Svalbard* (green), locations of ice stations with UAS operations (white squares) and areas with GPRI radar operations (red). Image: NORCE



Figure 5: Left: View from the bridge of the vessel showing the radar image from the GPRI Ku-band radar (left monitor) and the traditional ship radar (right monitor). Right: a closeup of the GPRI radar visualization. Ridges are highly visible. Image: NORCE

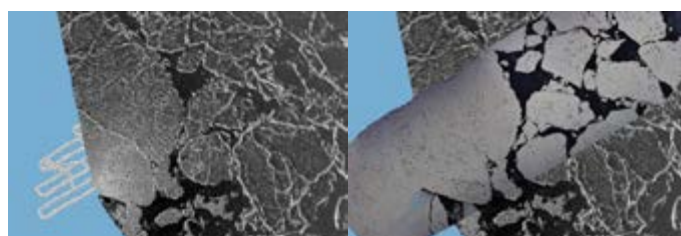


Figure 6: Left: A GPRI Ku-band radar image from 31.08.2019. Right: On top of the radar image is shown an orthomosaic produced by the fixed-wing UAS platform. Image: NORCE

The Ultra Wide Band Snow Sounder (UWiBaSS) is a UWB radar system specifically designed for drone-borne snow and ice measurements. The UWiBaSS was operated at each ice station except two, where the weather did not permit drone operations. At the remaining ice stations, the UWiBaSS was flown in 100–300 m transects where in situ freeboard, snow and ice thickness was collected in 20 m intervals.

Preliminary results from the UWiBaSS measurements show the detection of the increase in salinity which might be used to identify sea ice types

The salinity profile in Figure 7 shows that the ice starts to become saline at approximately 30 cm. The detected interface in the radar image (Figure 8) is varying between 10 and 40 cm. Based on the assessment from the ice experts working on the ice, this ice type was classified as second year ice. This leads us to believe that the radar is measuring the thickness of second year ice, but not the thickness of first year ice, and therefore, not the total ice thickness. On second year ice we can expect to have a layer of ice with little to no salinity at the top and a sharp increase in salinity further down the ice. The thickness of the low salinity ice is expected to vary as seen in the radar image.

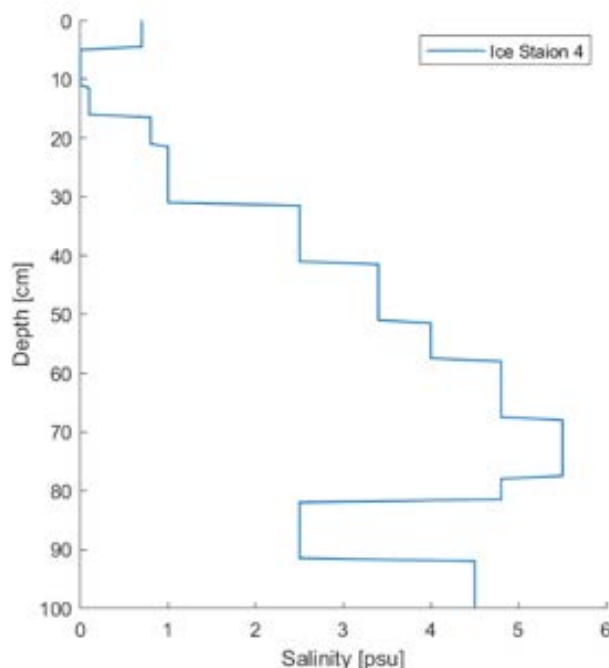


Figure 7: Ice Station 4. In situ salinity profile taken at approximately the center of the transect. Image: Rolf Ole Jenssen, NORCE

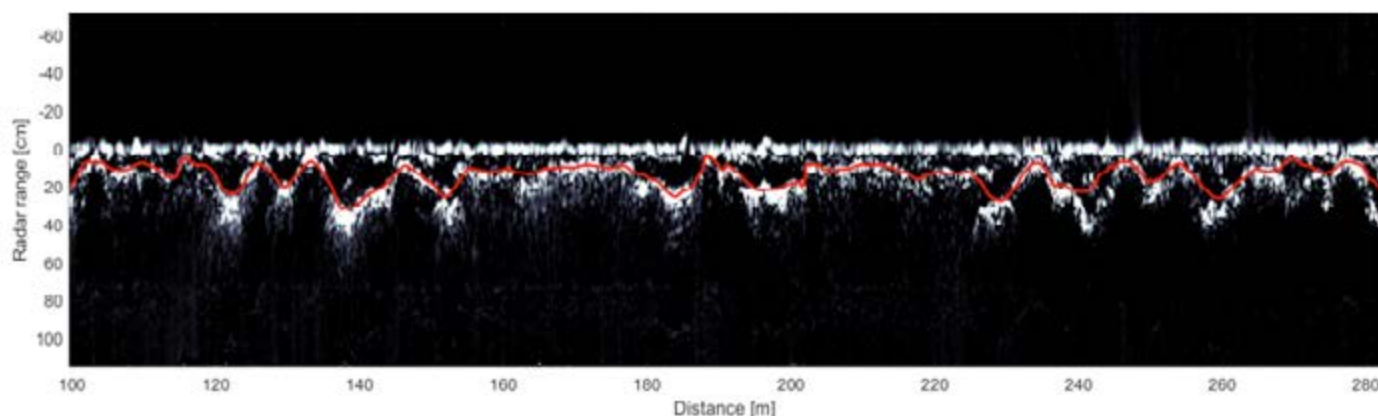


Figure 8: Ice station 4. Radar image showing the Air-Snow interface at 0 cm and a distinct interface at varying depth between 10 and 40 cm, marked with red line using a detection algorithm. Image: Rolf Ole Jenssen, NORCE

There was no significant snow cover to measure during the campaign. However, the UWiBaSS have previously been verified as a snow measurement sensor in (Jenssen et. al, 2019). The ability to measure snow cover as well as the thickness of second (and most probably multiyear) ice could be used to identify different ice types and map composite ice sheets.

Acknowledgment

Funding for the NORCE activities during the CAATEX cruise has been provided by the RESICE project funded by the Norwegian Ministry for Climate and Environment via their Arctic 2030 program, and by CIRFA.

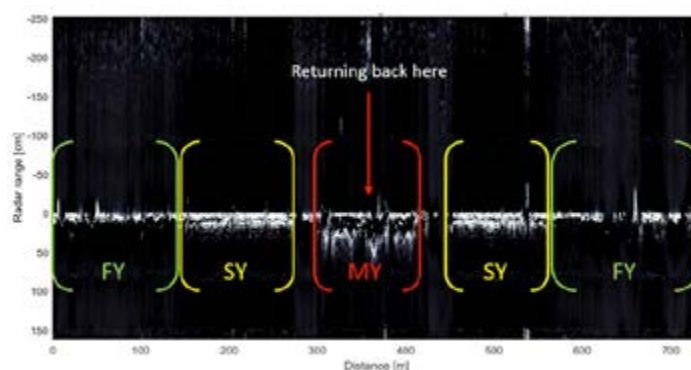


Figure 9: Ice station 7. Example of ice identification, with drone flying in transect back and forth. This interpretation needs more verification from sea ice experts, but three different regions is found. Image: Rolf Ole Jenssen, NORCE

OTHER PROJECTS

Extreme Earth



EXTREME EARTH

Two of CIRFA's research partners, UiT and MET Norway, are partners in the H2020 project ExtremeEarth, which was granted funding by the EU Commission in August 2018. The project aims at developing “*Extreme Earth*” *Analytics techniques and technologies* that scale to the petabytes of big Copernicus data, and applying these technologies in a Food Security Use Case and a Polar Use Case using the affiliated ESA Thematic Exploitation Platforms (TEPs). Keywords defining the project are: *Deep Learning Algorithms, Big Data, and Cloud Computing*. The project shall advance the state-of-the-art in the area of multimodal remote sensing by developing distributed, scale-out deep learning techniques for the classification of remote sensing data based on architectures that can effectively exploit the spatial, spectral, and temporal properties of Sentinel data.



UiT and MET Norway are involved in the “Polar Use Case” of the project, where the goals are to establish a large training data base and to construct and implement machine learning and/or deep learning architectures for sea ice type classification based on Copernicus data. Sentinel-1 SAR data is the primary data source. These tasks are associated with major challenges due to the ambiguities related to SAR imaging of sea ice (see Foreword). It is also well known that deep learning architectures, which often have many parameters to be adjusted, require a lot of training data to be properly trained. In the Polar Use Case, the amount of training data is scarce, and the certainty of the class labels of pixels and/or patches are often uncertain. ExtremeEarth has here been able to benefit greatly from the work being done in CIRFA on establishing good training and validation data.

The work addresses scalable deep learning architectures focused on the specific challenges associated to remote sensing applications. So far, the investigations have focused on *water* versus *sea ice* discrimination. Two different convolutional neural network (CNNs) architectures, an *ad hoc* CNN network and a VGG16 architecture, have been tested. The preliminary results are promising. In the future, novel architectures based on semi-supervised learning approaches are going to be explored to further improve efficiency and scalability.

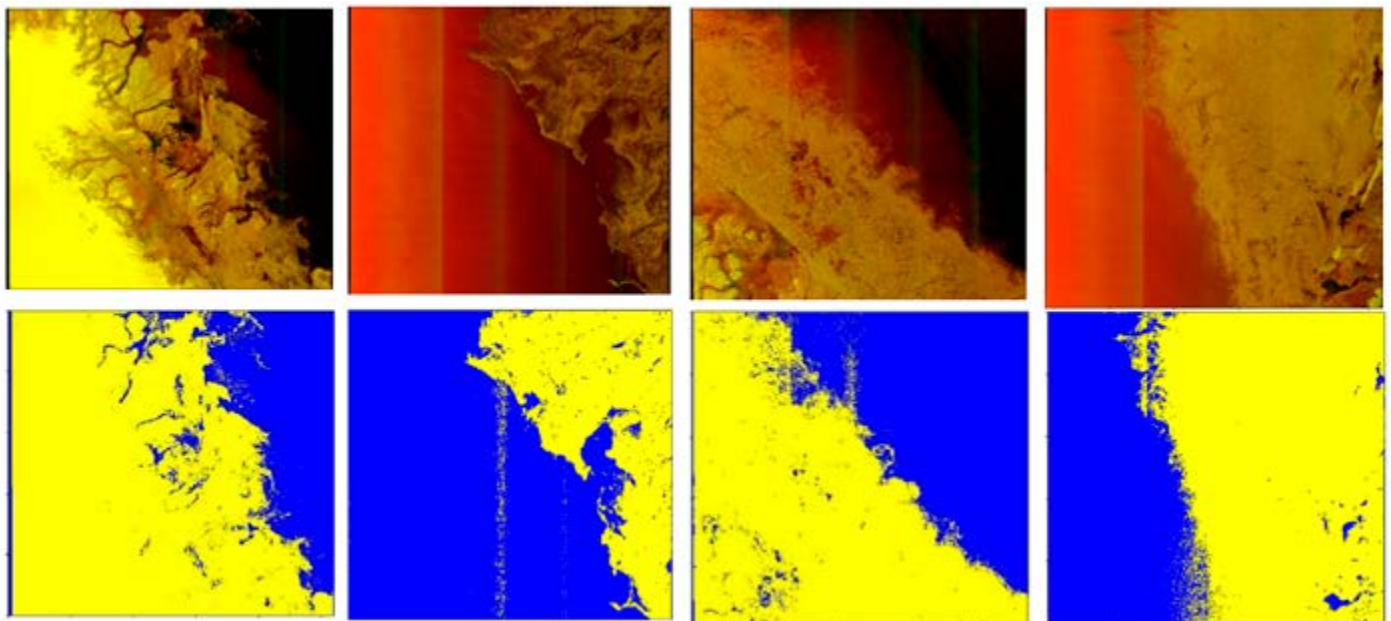


Image: Results from open water versus sea ice classification using VGG-16 architectures.

CIRFA activities in The Nansen Legacy project

The Nansen Legacy is the Norwegian Arctic research community's joint effort to establish a holistic understanding of a changing marine Arctic climate and ecosystem. The project will provide a scientific knowledge base needed for future sustainable resource management in the transitional Barents Sea and the adjacent Arctic Basin. It is a collaborative project between ten Norwegian research institutions, and will run from 2018-2023. Activities in the project will include international cooperation, and several cruises with the new, ice-going R/V *Kronprins Haakon*.

Muhammad Asim is a PhD student in the Nansen Legacy project and associated with CIRFA and WP3. CIRFA is also about to hire a new PostDoc in the Nansen Legacy project.

The research activity within the Nansen Legacy project at CIRFA is currently focused on ocean colour remote sensing. The aim of the project is to develop Machine Learning (ML) based remote sensing algorithms to estimate water quality parameters such as Chlorophyll-a (chl-a), Colored Dissolved Organic Matter (CDOM), and Total Suspended Matter (TSM) to examine the biochemical and physical changes occurring in the northern Barents Sea. The work is being conducted in close collaboration with marine biologists at the Faculty of Biosciences and Fisheries at UiT and partner institutes in the Nansen Legacy project.

The in-situ measurements and its corresponding satellite data are matched in time and space and given as an input to the ML models. The ML models including deep neural networks are trained and validated to learn the mapping of water-leaving remote sensing reflectance (R_{rs}) to the field-measured concentration of water constituents. Finally, the model's output is validated on satellite images for mapping the spatial concentration of predicted water quality variables to represent the biophysical signatures of the Barents Sea.

In the next phase of the project, we intend to collect in-situ data from the northern Barents Sea and in the marginal ice zone by using vessels, Autonomous Underwater Vehicles (AUVs), gliders and R/V *Kronprins Haakon*.

BRAGE

The collaboration between Wintershall, KSAT and UiT continued also in 2019 with further satellite and in-situ data collection over the operational oil platform Brage. The platform legally releases produced water; a mixture of low concentration oil and water, and these releases can often be observed in satellite images. Wintershall measured the concentration and volume of produced water being released at pre-determined intervals before the satellite image acquisitions. The satellite data configuration was kept constant for the different acquisitions, and we could therefore eliminate one variable from the analysis. Thereby reducing the main variables to met-ocean parameters such as wind and currents, and the produced water volumes and

concentrations. Two years of overlapping satellite and in-situ data were used in a publication (Skrunes et. al., 2019) at the end of 2019, and a conference presentation and further data collection for 2020 is already in the pipeline. During 2020, analyses of the data will continue and will be expanded to also include produced water platforms, these ones operated by Equinor.

SIDRIFT

Sea Ice Deformation and Snow for an Arctic in Transition (SIDRIFT) is a project funded by the RCN. The project started in May 2019 by launching a pre-study of sea ice drift and deformation using Sentinel-1 satellite images and in situ data from N-ICE2015. Researcher Polona Itkin (PI for SIDRIFT) was visiting the Colorado State University (project participants Glen Liston) from July to September 2019. Her research stay was funded by UiT, and facilitated further development of the numerical model (SnowModel). The first results from this stay are included in a manuscript submitted to JGR-Oceans. Wenkai Guo was hired as a post-doc researcher in November 2019. Guo's main objective for the project is classification of medium-resolution radar images collected by Radarsat-2 (from 2010 and onwards) and Sentinel-1 (2014 and onwards). The two regions of interest for the project are the Fram Strait and the MOSAiC expedition region. Polona Itkin is participating in the second leg of the MOSAiC expedition from December 2019 to March 2020.



Image: In-situ data collection next to R/V Polarstern at approximately 86° N
(Photo: Gunnar Spreen, University of Bremen)

MOSAIC

MOSAIC is an international research expedition that started at the end of September 2019 and will last until October 2020. The main objective of the expedition is to collect data on ice, ocean, atmosphere, bio-geo-chemical cycles and ecosystem across a full seasonal cycle of the Arctic Ocean. These data will facilitate process studies of the Arctic climate system that is currently undergoing a major climate change. The same data will also support validation and development of new satellite remote sensing sensors, techniques as well as numerical models. The research is concentrated around the German research icebreaker R/V *Polarstern* that was frozen into the Arctic pack ice in October 2019 in the Northern Laptev Sea, and that is currently moving toward the Fram Strait in the Transpolar Drift. To make this ambitious international expedition possible, the 12-month duration was divided into 6 legs, each lasting approximately 2 months. On leg 2, lasting from 15 December 2019 to 3 March 2020, CIRFA researchers Polona Itkin (UiT) and Dmitry Divine (NPI) joined the expedition. Large numbers of radar remote sensing images were acquired to overlap with the in-situ data collection onboard the research vessel. Information about the MOSAiC expedition can be found at <https://mosaic-expedition.org>.



Image: The Russian icebreaker *Akademik Fedorov* and R/V *Polarstern* at the initial phase of Leg 1. (Photo: Gunnar Spreen, University of Bremen)

OIBSAR

In 2019, there has been two meetings in the RCN PETROMAKS-2 project OIBSAR. The first one saw Camilla Brekke and Malin Johansson visiting our Russian partners from P. P. Shirshov Institute of Oceanology Russian Academy of Science in Moscow in April 2019. During this visit did Prof. Camilla Brekke give a very well attended talk where among other things she presented work done in collaboration with Prof. Cathleen Jones (JPL). Researcher Dmitry Ivonin came to visit Tromsø for one week in autumn, and during this visit a joint submission to the EUSAR conference in 2020 was finalised. Detection and characterization of oil slicks and newly formed sea ice results were presented during, e.g. IGARSS, ESA Living Planet 2020, IGS – Sea Ice at the Interface and Arctic Frontiers. Three papers in collaboration with WP2 (Johansson et. al., 2019, Graham et. al., 2019 and Olsen et. al., 2019) and one in collaboration with WP3 (Skrunes et. al., 2019) were finalised and published. An additional paper (Ivonin et. al. 2020) was submitted and is undergoing review.



Image: Visit to P. P. Shirshov Institute of Oceanology Russian Academy of Science in Moscow (Photo: Malin Johansson)



Image: The project meeting dinner was hosted by our Russian collaborators at IO RAS. Representatives from Scanex, IO RAS and UiT are present in the photo.

EDUCATION AND TRAINING

ARCTIC FIELD SUMMER SCHOOLS: Norway–Canada–USA Collaboration

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

This **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. Three summer schools have engaged 48 graduate students in exploring science questions related to Arctic challenges, and given the education partners material to be used in their university teaching courses and publications.

The **final field school** was a Capstone Synthesis Workshop at Kluane Lake Research Station, Yukon, Canada, in May/June 2019. The school added Glaciers to our Arctic topics, re-visited the sea ice and snow topics already covered in the first two field schools, and placed a significant focus on human activities in the Arctic environment, stakeholder needs, and First Nation peoples.

The project includes an **exchange program** that can fund student or staff exchange between the partners. For example, CIRFA PhD student Johannes Lohse made use of the fund to collaborate with Andy Mahoney from UAF and they did further fieldwork in Alaska that sprang from work started during the 2018 field school. The exchange program continues throughout 2020.

The INTPART project was presented with a poster (right) at the 2020 Arctic Frontiers conference, Tromsø, in January.

Arctic Field Summer Schools:
training and awareness in the Arctic

Anthony P. Doulgeris, Vladimir A. Alexeev & Maribeth Murray
UiT - The Arctic University of Norway, Tromsø
University of Alaska Fairbanks (UAF), USA
University of Calgary (UC), Canada
anthony.p.doulgeris@uit.no

The INTPART Field School Project
The Arctic Field Summer Schools project is funded by the Research Council of Norway (RCN) and the Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education (Duka), under the grant agreement number 2671702/05.

A series of three summer schools
engaged nearly 150 graduate students in exploring science questions related to current Arctic challenges, and brought together leading Arctic researchers from the partner institutions. Each partner organized a Field School and each had their own unique styles and emphases.

2017 Norwegian Field School
1 week field cruise to the marginal ice zone, NW Svalbard, on board R/V Lance
• May 2017, 15 Students and 12 Arctic researchers
• Ocean, snow and ice measurement field training
• UAV/drone optical and radar imagery and processing
• Satellite (PALSAR) imagery acquired (co-located with field data)
1 week remote sensing workshop at CIRFA/UiT - The Arctic University of Norway, in Tromsø
• Lectures on Arctic science and remote sensing topics
• Analysis of collected data and satellite images
• Plan and present student projects

2018 Alaskan Field School
10 day Field School at Utqiagvik (Barrow), Alaska
Arctic Coastal Environments in Rapid Transition
• May/June 2018, 16 Students and 11 Arctic researchers
• Permafrost, Land fast sea ice, Lagoon ice, Tundra
• Coastal erosion, Sediment transfer, Hydrology, and weather events
• Remote sensing, GIS/GIS analysis, and time series analysis
• Arctic people - living in and utilizing sea ice
1 day student workshop at IARC/UAF, Fairbanks, Alaska
• Open presentations of student projects

2019 Canadian Workshop
15 day Capstone Synthesis Workshop, at the Kluane Lake Research Station, Yukon, Canada
• May/June 2019, 19 Students and 8 Arctic researchers
• Added Glaciers to the cryosphere reports
• Summarize the state of the art in remote sensing of ice and polar ocean conditions, re-visited previous schools work
• Remote sensing time series to observe changing conditions
• The impacts of climate change on the Arctic environment, ecosystems and people
• Focus on human activities in the Arctic environment, stakeholder needs, and First Nation peoples

Educational Benefits
• Obtain reusable material for future teaching resources
• Learn different ways to run summer schools
• Publish Field School results in scientific journals

Acknowledgements
Photography: Johannes Lohse / Norwegian Polar Institute, Ron Hogg / NERC, Anthony P. Doulgeris, Vladimir Alexeev, Tanya Gribben / UiT - The Arctic University of Norway, Steve McManus / University of Calgary

SATA

CIRFA people, Torbjørn Eltoft, Camilla Brekke and Hugo Isaksen (KSAT), contributed to the PhD course SVF-8086 “Society and advanced Technology in the Arctic” (SATA) with three talks given at Longyearbyen, Svalbard, 17th and 18th October. The course is funded through the SIU project “Society and Advanced Technology in the Arctic: Norwegian-Russian Triple Helix PhD Course” lead and coordinated by Rasmus Bertelsen (HVL/UiT).



Image: Students and lecturers inside one of the antennas at SVALSAT. Bottom: Maja-Stina Ekstedt, station manager SVALSAT. (Photo: Hugo Isaksen).

Learn how to write opinion editorials

In 2019 CIRFA's Young Scientists and Researchers attended a course by forskning.no on “Learn to write opinion editorials – How to get people to read what you write”.



Image: CIRFA staff participating in a course by forskning.no (Photo: Malin Johansson)

MIDWAY EVALUATION

In September, CIRFA got the feedback from the RCN regarding the midway evaluation. The conclusion was that CIRFA will receive contract and funding for the final three-year period without any further changes in the project. Congratulations to CIRFA's researchers, students and partners!



Image: CIRFA staff celebrating the results from the RCN regarding the midway evaluation (Photo: Lise Nordgård)

PhD thesis completed on projects in the centre in 2019

Name	Title of thesis
Katalin Blix	Machine Learning Water Quality Monitoring
Martine Espeseth	Analysis of Oil Spill and Sea Ice Measurements Using Full-Polarimetric and Hybrid-Polarity Synthetic Aperture Radar data



Image: PhD defense of Martine Espeseth. (Photo: Lise Nordgård)



Image: Candidate and committee at Katalin Blix' s defense (Photo: Lise Nordgård)

MSc thesis completed in the centre in 2019

Name	Title of thesis
Joakim Lillehaug Pedersen	Comparison of the Ice Watch Database and Sea Ice Classification from Sentinel-1 Imagery
Øystein Fredriksen Skogvold	Arctic Thin Sea Ice Thickness Regression Models for Sentinel-2
Sandra Susann Solheim Nesse	Remote Sensing of Coastal Waters
August Krokan	Ice-water Classification in the Barents Sea from Sentinel-1 EW SLC Images
Daniel Norum Danielsen	Target Decomposition of Quad-Polarimetric SAR Images as an Unmixing Problem
Åshild Kiærbech	An investigation of the robustness of distance measure-based supervised labelling of segmented remote sensing images
Darshika Manral (ERASMUS student)	Assessing sensitivity of oil spill drift modelling

OUTREACH

CIRFA seminars

Name	Institution	Title of presentation
Trevor Bell	SmartIce/memorial University of Newfoundland	SmartIce
Cornelius Quigley	UiT/CIRFA	Retrieval of the dielectric properties of oil slick using SAR via a polarimetric two-scale model
Anca Cristea	UiT/CIRFA	Incidence angle dependencies in polarimetric SAR images
Nima Pahlevan	NASA Goddard Flight Center	Freshwater Remote Sensing: Living in the moment yet keeping an eye on the future
Andrea Marinoni	UiT/CIRFA	Assessment of Polarimetric variability by distance geometry for enhanced classification of oil slicks using SAR
Darshika Manral	ERASMUS student	Assessing sensitivity of oil spill drift modelling
Pål Gunnar Ellingsen	IVT/UiT	Presentation of his research
Rolf Ole Rydeng Jensen and Tom Rune Lauknes	Norce	NORCE and UiT operating drone and radars during the CAATEX cruise to the North Pole
Alister Everett	MET Norway	The Ice Watch Observing Network and Activities at MET Norway
Benjamin Holt Campaign	JPL	Overview of the 2015 Sea State and Boundary Layer Physics
Brent Minchew	MIT	in the Emerging Arctic and Thoughts on Going Forward New Insights into the Mechanics of Glacier Beds from Time-Dependent Surface Velocity Field

Conferences/Workshops

Conference / Workshops attended

- ▣ Arctic Frontiers 2019
- ▣ Baltic Sea Science Conference
- ▣ CIRFA Annual Conference 2019
- ▣ EarthVision 2019
- ▣ EGU General Assembly 2019
- ▣ IGARSS2019
- ▣ IGS Sea Ice Symposium 2019
- ▣ International Conference on Port and Ocean Engineering under Arctic Conditions (POAC) 2019
- ▣ International ice charting working group (IICWG)
- ▣ International Ocean Colour Science (IOCS) Meeting 2019
- ▣ Jenter og Teknologi 2019, UiT
- ▣ Living Planet 2019
- ▣ Polinsar 2019
- ▣ Svalbard Science Conference 2019
- ▣ Thematic workshop with focus on modeling – CIRFA, 2019
- ▣ 5th Sentinel-3 Validation Team meeting, ESA-ESRIN 2019
- ▣ 6th Scotland Norway Waves and Marine Hydrodynamics Symposium 2019



Image: PhD students Katalin Blix and Martine Espeseth and researcher Malin Johannsson represented at IGARSS 2019 (Photo: Malin Johannsson)

PhD Student Richard Hann won an Oral Presentation Award

PhD Student Richard Hann received an outstanding oral presentation award from the SAE at their International Icing conference 2019.

He gave two talks:

- 1) «Experimental Investigations of an Icing Protection System for UAVs» and 2) «UAV Icing: Ice Accretion Experiments and Validation»



Image: PhD Student Richard Hann with his award (Photo: Richard Hann)

PhD student Johannes Lohse won the best poster award at the IGS conference 2019

At the Sea Ice Symposium of the International Glaciological Society, PhD student Johannes Lohse won the best poster award.



Image: Johannes Lohse receiving the best poster award from the Science Steering Committee during the memorable banquet at the IGS Sea Ice Symposium. (Photo: Malin Johansson)

CIRFA on winning team in Norwegian Space Center hackathon

In September, Thomas from WP7 attended as a solo participant in a hackathon organized by Startuplab, the Norwegian Space Center and CIRFA partner Equinor. Together with a team of three other solo participants, they won one of the five prizes in the hackathon.

Find out more on <https://satellitehackaton.no/>.



Image: Thomas Kræmer on the winning team in Norwegian Space Center hackathon (Photo by StartupLab)

Researcher Grand Prix

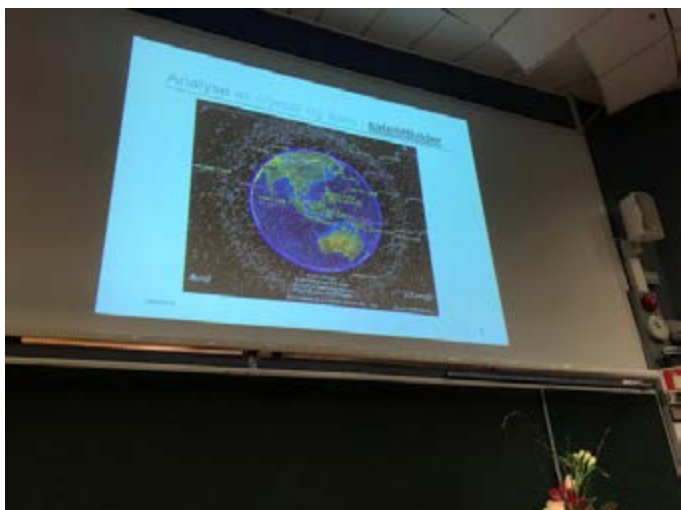
PhD candidate Katalin Blix was one of ten selected participants of the Norwegian regional Research Grand Prix (NGP) in 2019. The event aims to convey science in an entertaining way. The PhD candidates explain their research in four minutes to a larger audience, which is also streamed in the Norwegian national TV. Katalin enjoyed every moment of the project and she learned how to make her work easily understandable. The time and energy that went into the project made it a fantastic experience that Katalin is proud of. She highly recommends to other PhD candidates to apply for being part of such an opportunity.



Image: PhD student Katalin Blix with her topic for Researcher Grand Prix (Photo: Katalin Blix)

“Jenter og teknologi”

“Jenter og Teknologi” is a national project coordinated by Næringslivets Hovedorganisasjon (NHO). It is a workshop held all over Norway that aims to inspire and inform high-school girls about science and technology as a career option. Martine Espeseth gave a presentation about earth observation where she highlighted interesting research topics and opportunities within this field. The overall goal was to motivate the students to choose an academic career, preferably within earth observation.



CIRFA Annual Conference 2019

This year's annual conference took place at Sommarøy Arctic Hotel in October. We had two interesting days with presentations from invited speakers, internal speakers, a poster session and also an interactive session. PhD candidate Lanqing Huang from the Earth Observation and Remote Sensing group at ETH Zurich won the poster award of the conference.



Image: Sommarøy (Photo: Lise Nordgård)



Image: PhD Student Martine Espeseth presenting at the “Jenter og Teknologi” conference (Photo: Camilla Brekke)



Image: Winners of the best poster together with Harald (NORCE) and Sebastian (NPI) who evaluated the posters (Photo: Lise Nordgård)

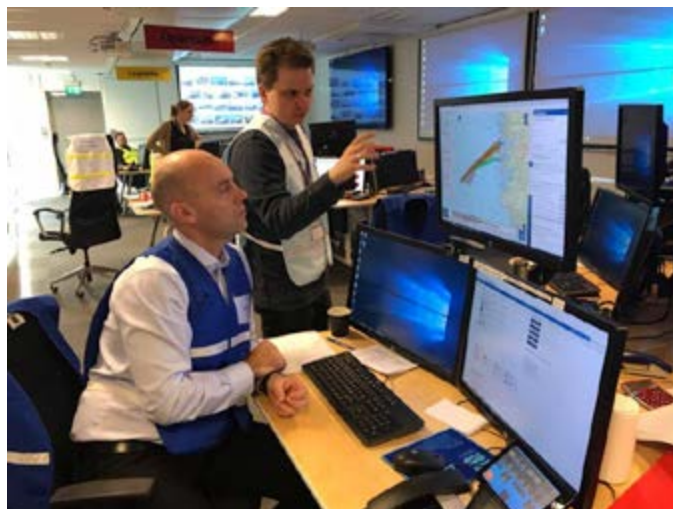
KNOWLEDGE TRANSFER AND COLLABORATION WITH CIRFA PARTNERS

Martine Espeseth (UiT) has spent one day a week at KSAT, making use of their extensive archive of satellite imagery and oil spill detections to improve the oil spill characterization developed in WP3. One such parameter, the damping ratio, was demonstrated pre-operationally during the annual oil-on-water exercise by NOFO. The demonstration took detections produced by KSAT, ran it through the damping ratio analysis and results were delivered in near real-time to the NOFO operation center as well as to drone operators and researchers on board the vessel R/V *Helmer Hanssen* on site.

Though they are not a formal partner in CIRFA, NOFO is still a significant and relevant contributor to CIRFA's development, as they represent the first response in the event of an accidental discharge of oil. Malin Johansson, Cornelius Quigley and Thomas Kræmer from UiT and Megan O'Sadnick, Irina Sæther, Nga Dang, and Christian Petrich from SINTEF Narvik, visited NOFO in January, where they observed NOFO's weekly tabletop exercise for oil spill response. During the oil-on-water exercise, Martine Espeseth and Stine Skrunes from UiT participated in the exercise from NOFO headquarters and helped to coordinate observations.

MET and UiT are collaborating in several projects with overlapping interests, mainly CIRFA and ExtremeEarth. People from both partners are working towards generating good training and validation datasets, which is a time consuming, but crucial part of algorithm development. MET has recently hired several CIRFA master students into positions which will continue to be involved with CIRFA and ExtremeEarth.

Equinor wants CIRFA to monitor the Barents Sea for point targets such as icebergs or ships using free and open data from the Copernicus satellites. Multiconsult also has an interest in long time series of iceberg detections. Although a processing chain is set up which can do object detection in near real-time and save results to a database, a few challenges remain, such as reducing false alarms and correctly labelling objects (sea ice, iceberg, ship). Thomas Kræmer visited Multiconsult and gave a presentation on the challenges with confidently detecting icebergs from low-resolution satellite images.



Images: CIRFA visiting NOFO (Photo: Malin Johansson)



Images: CIRFA visiting KSAT (Photo: Malin Johansson)



Collaboration with KSAT: Algal product development

The collaboration between KSAT and Katalin Blix at CIRFA aims to calibrate and develop algal products for both Norwegian and global waters. Optical sensors onboard the Sentinel satellites of the Copernicus mission are utilized to retrieve various water quality products. This information is then used to characterize algae types and their distributions in the oceans. The aim is to be able to detect the occurrence of Harmful Algae Blooms (HABs) by using data acquired by the optical sensors on the Sentinel satellites. The final HABs products will be produced by KSAT's processing chain.

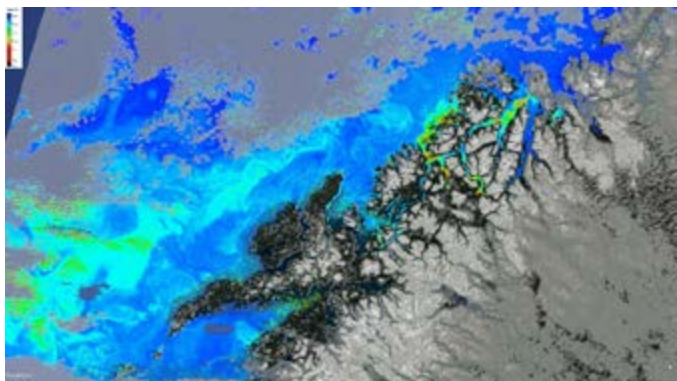


Image: The image shows Chlorophyll-a (Chl-a) concentration in mg m^{-3} by the coast of Northern Norway. Chl-a content is a water quality parameter frequently used for describing algae abundance. Green-red color indicates high Chl-a, while blue is low Chl-a concentration. The data used for producing the image was acquired by the Ocean and Land Color Instrument (OLCI) onboard the Sentinel-3 satellite at the 3rd of June 2019. Chlorophyll-a data were processed by Katalin Blix.

Workshop with focus on modeling



Dialog meeting with TOTAL

Tobjørn Eltoft, Lise Nordgård and PhD candidate Cornelius Quigley visited TOTAL. The companies offices are located in the skyscrapers in La Défense, Paris, France.



Image: CIRFA visiting TOTAL in Paris (Photo: Lise Nordgård)



Images: Kai H. Christensen from MET Norway welcoming participants to the Sea Ice Workshop in Oslo Science Park (Photo: Lise Nordgård).

International Collaboration

- ❑ CSIRO (Australia)
- ❑ University of Tasmania (Australia)
- ❑ Aerospace Information research Institute and Institute for Digital Earth, Chinese Academy of Science (China)
- ❑ University of Calgary (Canada)
- ❑ University of Alaska (Fairbanks)
- ❑ JAXA (Japan)
- ❑ University of Rennes (France)
- ❑ CLS (France)
- ❑ Grenoble INP (France)
- ❑ ONERA (France)
- ❑ IFREMER (France)
- ❑ Alfred Wegner Institute (Germany)
- ❑ DLR (Germany)
- ❑ University of Bremen (Germany)
- ❑ University of Pavia (Italy)
- ❑ University of Trento (Italy)
- ❑ Jet Propulsion Laboratory (USA)
- ❑ University of Extremadura (Spain)
- ❑ Chalmers University (Sweden)
- ❑ SMHI (Sweden)
- ❑ KTH Stockholm (Sweden)

Visiting senior researchers from other countries in 2019

Name and position	Organization	Nationality
Wolfgang Dierking, Prof.	Alfred Wegner Institute	GE
Cathleen E. Jones, Adj. Prof.	Jet Propulsion Laboratory	USA
Dimitry Ivonin	Shirshov Institute of Oceanology RAS	RU
Benjamin Holt	JPL	USA
Brent Minchew	MIT	USA
Nima Pahlevan	NASA	USA

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



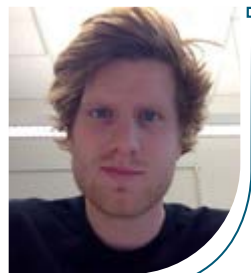
Marianne Myrnes
PhD Fellow, UiT



Richard Hann
PhD Fellow, NTNU



Rolf-Ole Jenssen
PhD Fellow, UiT



Sindre Fritzner
PhD Fellow, UiT



Runa Skarbø
PhD Fellow, NTNU



Muhammad Asim
PhD Fellow



Salman
Associate PhD Fellow, UiT



Katalin Blix
Associate PhD Fellow, UiT



Eduard
Associate PhD Fellow, UiT



Sophie
PhD Fellow, UiT



Megan O'Sadnick
PhD Fellow, Norut Narvik



Stine Skrunes
Postdoc, UiT



Polona Itkin
Researcher, SIDRiT



Wenkai Guo
Associate Postdoc, UiT



Ann Kristin Sperrevik
Associate Postdoc, MET Norway



Malin Johansson
Researcher, UiT



Anca Cristea
Researcher, UiT



Saloua Chlaily
Researcher, UiT

FINANCES

Funding sources

The Research Council of Norway	10 627
Industry partners	6 071
The host institution (UiT)	7 177
Research partners	3 221
Total	27 096

Costs per activity

Management	3 851
WP1 Ocean RS	2 328
WP2 Sea Ice RS	3 940
WP3 Oil Spill RS	4 097
WP4 RPAS Technology	5 964
WP5 Modeling and Prediction	3 758
WP6 Field work and Data Collection	353
WP7 Pilot Service Demonstration	2 804
Total	27 096

Costs per partner

Research partners:

UiT/NT	12 894
NORCE	6 456
Sintef Narvik	1 838
NTNU	966
Norwegian Polar Institute	375
MET Norway	2 894
NERSC	438

Industry partners:

Equinor	446
Vår Energi	104
Total E&P Norge	157
OMV Norge	148
Aker BP	
Aker Solutions	
Multiconsult	251
KSAT	244
Maritime Robotics	
Total	27 096

PUBLICATIONS 2019

Journal Papers

Dagestad, K.-F. and Röhrs, J. (2019) *Prediction of ocean Surface trajectories using satellite derived vs. modeled ocean currents*. Remote Sensing of Environment, 223, 130-142. <https://doi.org/10.1016/j.rse.2019.01.001>

Eltoft, T. and Doulgeris, A.P. (2019) *Model-based polarimetric decomposition with higher order statistics*. IEEE Geoscience and Remote Sensing Letters, 16, 992-996. DOI: [10.1109/LGRS.2018.2889682](https://doi.org/10.1109/LGRS.2018.2889682)

Fritzner, S., Graversen, R., Christensen, K.H., Rostosky, P., and Wang, K. (2019) *Impact of assimilation sea ice concentrations, sea ice thickness and snow depth in a coupled ocean-sea ice modelling system*. The Cryosphere 13, 491-509. <https://doi.org/10.5194/tc-13-491-2019>

Graham, R.M., Itkin, P., Meyer, A., Sundfjord, A., Spreen, G., Smedsrud, L.H., Liston, G., Cheng, B., Cohen, L., Divine, D., Fer, I., Fransson, A., Gerland, S., Haapala, J., Hudson, S.R., Johansson, A.M., King, J., Merkouriadi, I., Peterson, A.K., Provost, C., Randelhoff, A., Rinke, A., Rösel, A., Sennéchaël, N., Walden, Von P., Duarte, P., Assmy, P., Steen, H., and Granskog, M.A. (2019) *Winter storms accelerate the demise of sea ice in the Atlantic Sector of the Arctic Ocean*. Scientific Reports, 9(9222), DOI:[10.1038/s41598-019-45574-5](https://doi.org/10.1038/s41598-019-45574-5)

Halland-Soldal, I., Dierking, W., Korosov, A., Marino, A. (2019) *Automatic detection of small icebergs in fast ice using satellite wide-swath SAR images*, Remote Sensing 11, 806, [doi:10.3390/rs11070806](https://doi.org/10.3390/rs11070806)

Hann, R., Borup, K.T.; Zolich, A.P., Sørensen, K.L., Vestad, H. N., Steinert, M., Johansen, T.A. (2019). *Experimental Investigations of an Icing Protection System for UAVs*. SAE technical paper series 2019; Volume 2019-June. <https://doi.org/10.4271/2019-01-2038>

Jenssen, R.O.J., Jacobsen, S.K., Eckerstorfer, M. (2019). *Drone-Mounted Ultrawideband Radar for Retrieval of Snowpack Properties*. IEEE Transactions on Instrumentation and Measurement 2019; 69(1), 221-23: <https://doi.org/10.1109/TIM.2019.2893043>

Johansson, M., Malnes, E., Gerland, S., Cristea, A., Doulgeris, A.P., Divine, D.V., Pavlova, O. and Lauknes, T.R. (2019) *Consistent ice and open water classification combining historical synthetic aperture radar satellite images from ERS-1/2, Envisat ASAR, RADARSAT-2, and Sentinel-1A/B*. Annals of Glaciology, <https://doi.org/10.1017/aog.2019.52>

Lohse, J., Doulgeris, A.P., and Dierking W. (2019) *An Optimal Decision-Tree Design Strategy and Its Application to Sea Ice Classification from SAR Imagery*, Remote Sensing 11, 1574, <https://doi.org/10.3390/rs11131574>

Nielsen, V., Engen, V., and Johnsen, H. (2019) *A Novel Approach to SAR Ocean Wind Retrieval*. IEEE Transactions on Geoscience and Remote Sensing 57(9), 6986-6995, DOI:[10.1109/TGRS.2019.2909838](https://doi.org/10.1109/TGRS.2019.2909838)

Monteban D., Johnsen H., Lubbad R. (2019) *Spatiotemporal observations of wave dispersion within sea ice using Sentinel-1 SAR TOPS mode*, Journal of Geophysical Research (JGR) – Ocean, 124(12), 8522-8537, <https://doi.org/10.1029/2019JC015311>

Oggier, M., Eicken, H., Wilkinson, J., Petrich, C., O'Sadnick, M. (2019) *Crude oil migration in sea-ice: Laboratory studies of constraints on oil mobilization and seasonal evolution*. Cold Regions Science and Technology, 174, 102924. <https://doi.org/10.1016/j.coldregions.2019.102924>

Olsen, L.M., Duarte, P. Peralta Ferriz, C., Kauko, H.M., Johansson, A.M., Peeken, I., Ròzanska-pluta, M., Taterk, A., Wiktor, J., Fernández-Méndez, M., Wagner, P.M., Pavlov, A.K., Hop, H., Assmy, P. (2019) *A red tide in the pack ice of the Arctic Ocean*, Scientific Reports 9(9536), DOI:[10.1038/s41598-019-45935-0](https://doi.org/10.1038/s41598-019-45935-0)

Pavlova, O., Gerland, S. and H. Hop (2019): *Changes in sea-ice extent and thickness in Kongsfjorden, Svalbard (2003-2016)*. In Hop, H., Wiencke, C. (eds.): The ecosystem of Kongsfjorden, Svalbard. Advances in Polar Ecology, 2, 105-136, Springer Nature Switzerland AG. DOI: [10.1007/978-3-319-46425-1_4](https://doi.org/10.1007/978-3-319-46425-1_4).

Skrunes, S., Johansson, M.A and Brekke, C. (2019) *Synthetic Aperture Radar Remote Sensing of Operational Platform Produced Water Releases*. Remote Sensing, 11 (23). [doi:10.3390/rs11232882](https://doi.org/10.3390/rs11232882)

Verfuss, U.K., Aniceti, A.S., Harris, D.V., Gillespie, D., Fielding, S., Jimènes, G., Johnston, P., Sinclair, R.R., Sivertsen, A., Solbø, S.A., Storvold, R., Biuw, M. and Watt, R. (2019) *A review of unmanned vehicles for the detection and monitoring of marine fauna*; Marine Pollution Bulletin, 140, 17-29. doi.org/10.1016/j.marpolbul.2019.01.009

Other Disseminations

Blix, K. (2019) *Machine Learning for Monitoring Arctic Waters by using Sentinel 3 OLCI*. Oral presentation at the 5th Sentinel 3 Validation Team meeting, Frascati, ESA-ESRIN.

Blix, K. (2019) Fjernmåling. Forsker Grand Prix 2019.

Blix, K. (2019) *Machine Learning for Remote Sensing Complex Waters*. Poster presentation at the International Ocean Colour Science (IOCS) Meeting 2019, Busan, South Korea, 2019-04-09-2019-04-12.

Blix, K. (2019) *Machine Learning for Remote Sensing of Arctic Waters*. Oral presentation at du Québec à Rimouski (UQAR).

Blix, K. (2019) *Machine Learning for Remote Sensing Applications*. Oral presentation at the University Laval, Quebec, Canada.

Blix, K. and Eltoft, T. (2019) A generalized Chlorophyll-A estimation model for complexity-diverse Arctic waters. [IGARSS 2019](#).

Blix, K. and Eltoft, T. (2019) *Machine Learning Remote Sensing for Ecosystem Monitoring in the Arctic*. Oral presentation at [ArcticFrontiers2019](#)

Brekke, C. (2019) *Overvåking og varsling for Arktiske operasjoner. Tekna X: Satellitt- og romteknologi – og dens betydning for Nord-Norge*.

Brekke, C. and Jones, C.E. (2019) *SAR Imaging of Oil Spills in Open Water – Interpretation and Information Retrieval Techniques*. Oral presentation at the 6th Scotland Norway Waves and Marine Hydrodynamics Symposium; 2019-05-08 – 2019-05-10

Brekke, C. (2019). *Remote Sensing of Marine Pollution by Synthetic Aperture Radar*. Remote Sensing Colloquium; 2019-05-28

Brekke, C., Jones, C.E. (2019) *SAR Oil Spill Imaging, Interpretation and Information Retrieval Techniques*; 2019-04-10

Christensen, K.H., Kristensen, N.M., Brændshøj, J., Batrak, Y., Samuelsen, E.M., Kristiansen, J., Breivik, L.A. (2019) *Weather and ocean forecasting for increased preparedness in the Arctic*. Oral presentation [ArcticFrontiers2019](#)

Cristea, A., Doulgeris, A.P. (2019) *Incidence angle in narrow-swath Quad-polarimetric SAR images*. Oral presentation at [Polinsar2019](#)

Doulgeris, A.P., Alexeev, V., Moorman, B. (2019) Arctic Field Summer School: open house and student presentations. INTPART Arctic Field School 2019.

Eltoft, T. (2019) *Microwave Remote Sensing of Sea Ice at UiT/ CIRFA*. Oral presentation at the University of Laval, Takuvik.

Espeseth, M., Skrunes, S., Brekke, C. and Johansson, A.M. (2019) *The Impact of Additive Noise on Polarimetric Radarsat-2 Data Covering Oil Slicks*. IGARSS 2019

Fajt, N., Hann, R. (2019). *The Influence of Meteorological Conditions on the Icing Performance Penalties on a UAV Airfoil*. European Conference for Aeronautics and Space Sciences 2019.

Fritzner, S., Graversen, R., Christensen, K. and Wang, K. (2019) *Assimilation of high-resolution ice charts in a coupled ocean-sea-ice model*. [IGARSS 2019](#).

Gerland, S., Divine, D., Negrel, J., Pavlova, O., Eltoft, T., Hughes, N., Storvold, R., and Søreide, J. (2019): *Kongsfjorden sea ice development observed from ground, air and space*. Fram Forum 2019

Granskog, M., Itkin, P., Graham, R., Meyer, A. Sundfjord, A., Spreen, G., Smedsrud, L.H., Liston, G., Cheng, B., Cohen, L., Divine, D.V., Fer, I., Fransson, A., Gerland, S., Haapala, J., Hudson, S., Johansson, M., King, J.A., Merkouriadi, I., Peterson, A.K., Provost, C., Randelhoff, A. Rinke, A., Rösel, A., Sennechael, N., Walden, Von P., Duarte, P., Assmy, P., Steen, H. (2019) *Role of winter storms on the evolution of sea ice in the Atlantic sector of the Arctic*. Oral presentation at IGS – Sea Ice Symposium 2019.

Hann, R. (2019). *UAV Icing: Comparison of LEWICE and FENSAP-ICE for Anti-Icing Loads*. I: AIAA Scitech 2019 Forum. American Institute of Aeronautics and Astronautics (AIAA) 2019 ISBN 978-1-62410-578-4

Hann, R. (2019). *Unmanned aerial vehicles (UAVs) in cold climate and wind energy applications*. Winterwind Conference 2019

Hann, R., Hallén, J. (2019) *Drönare lär av vindkraften*. Svensk vindkraft [Fagblad] 2019-01-1

Hann, R. (2019) *UAV Icing: Comparison of LEWICE and FENSAP-ICE for Anti-Icing Loads*, AIAA Scitech 2019 Forum, AIAA SciTech Forum, (AIAA 2019-1286), <https://doi.org/10.2514/6.2019-1286>

Hann, R., Hodson, A., Jonassen, M.O. (2019) *Glacier Mapping and Wind Estimation with UAVs on Svalbard*. Svalbard Science Conference; 2019.

Itkin, P., Oikkonen, A., Spreen, G., Korosov, A. (2019) *Bridging temporal and spatial scales of sea ice deformation*. Oral presentation at [IGS 2019](#).

- Itkin, P., Rampal, P., Ølason, E. and Williams, T. (2019) [Is it really getting younger? Sea ice type and age in a model simulation and satellite remote sensing Products](#). Oral Presentation at [IGS 2019](#).
- Johansson, M., Doulgeris, A.P. and Brekke, C. (2019) *Investigating the occurrence of newly formed sea ice in the Barents Sea using archived Sentinel-1 SAR data*. Poster presentation at [IGS 2019](#).
- Johansson, M., Espeseth, M., Brekke, C. and Skrunes, S. (2019) *Separation and characterisation of mineral oil slicks and newly formed sea ice in L-band synthetic aperture radar*. IEEE International Geoscience and Remote Sensing Symposium proceedings 2019.
- Johansson, M., Gerland, S., Cristea, A., Malnes, E., Doulgeris, A.P., Divine, D., Pavlova, O. and Lauknes, T.R. (2019) *Sea ice and open water classification using historical multi-sensor synthetic aperture radar satellite datasets, applied to two Svalbard fjords*. Oral presentation at IGS - Sea Ice Symposium 2019.
- Johansson, M., Malnes, E., Gerland, S., Vickers, H., Lauknes, T.R., Doulgeris, A., Cristea, A., Divine, D. (2019) *28 years of fjord ice coverage in Kongsfjorden, Svalbard, observed by satellite radar*. Oral presentation at [ArcticFrontiers2019](#)
- Lohse, J., Doulgeris, A.P., and Dierking, W. (2019) *Ice Type Mapping from Sentinel-1 Considering Surface-Type Dependent Effect of Incidence Angle*. Poster presentation at IGS - Sea Ice Symposium 2019.
- Lohse, J., Doulgeris, A.P., Dierking, W. (2019) *New Strategies for Automated Sea Ice Classification at CIRFA*. International Ice Charting Working Group Meeting; 2019
- Lohse, J., Doulgeris, A.P., Dierking, W. (2019) *Strategies for Automated Sea Ice Classification at CIRFA - Algorithm Development and Application Examples*. CIRFA Annual Conference 2019
- Karlson, B., Artigas, F., Johansson, J., Johansson, M., Lehtinen, S., Lizon, F., Louchart, A., Seppälä, J., Stemman, L. (2019) *Distribution and size structure of cyanobacteria and other plankton in the Baltic Sea and the Kattegat-Skagerrak investigated using a multi-method approach*. Oral presentation at Baltic Sea Science Conference 2019
- Marci, D., Marinoni, A., and Gamba, P. (2019) *Mapping mineral abundances on the moon Surface using CHANGË-1 IIM data*. [IGARSS 2019](#)
- Marinoni, A., Espeseth, M., Gamba, P., Brekke, C. and Eltoft, T. (2019) *Assessment of Polarimetric variability by Distance Geometry for Enhanced Classification of Oil Slicks Using SAR*. IEEE International Geoscience and Remote Sensing Symposium proceedings 2019
- Marinoni, A., Johansson, M., Espeseth, M., Brekke, C. (2019) *Multidimensional distance geometry analysis for classification of PolSAR images in Arctic scenarios*. Oral presentation at [Polinsar 2019](#)
- Oikkonen, A., Haapala, J., and Itkin, P. (2019) *The impact of waves on sea-ice deformation*. Poster presentation at [IGS – Sea Ice Symposium 2019](#).
- O'Sadnick, M., Petrich, C., Brekke, C., and Skarðhamar, J. (2019) *Changes in sea-ice coverage in Norwegian fjords since 2002 and relationship to climatic, oceanographic and topographic variables*. Poster presentation at IGS - Sea Ice Symposium 2019.
- O'Sadnick, M., Petrich, C., Kleven, Ø., Brekke, C. Skardhamar, J. (2019). *Cold and dry vs warm and wet: how two winters of differing weather impacted sea-ice conditions and properties in seven northern Norwegian fjords*. IGS - Sea Ice Symposium 2019.
- O'Sadnick, M., Petrich, C., Brekke, C., Skardhamar, J. (2019) *Ice Extent in Norwegian Fjords from 2000 to 2019*. CIRFA Annual Conference 2019.
- O'Sadnick, M., Petrich, C., Kleven, Ø., Brekke, C., Skardhamar, J. (2019). *Ice Formation in Norwegian Fjords- Findings from two years of field research*. CIRFA Annual Conference 2019.
- O'Sadnick, M., Petrich, C., Dang, N., Kleven, Ø., Brekke, C. and Skardhamar, J. (2019) *The importance of sea ice properties in assessing the risks present in coastal regions of the Arctic*. [EGU General Assembly, Vienna, Austria, 7-12 April, 2019](#).
- O'Sadnick (2019) *How studies of Norwegian fjord ice can help create a safer future for the Arctic*, ScienceNordic 2019.
- Petrich, C., O'Sadnick, M., Brekke, C., Myrnes, M., Maus, S., Salomon, M.L., Woelk, S., Grydeland, T., Jenssen, R.O.R., Eicken, H., Oggier, M., Ferro-Famil, L., Harkati, L., Rebane, O., Reimer, N. (2019) *Mosideo/cirfa tank experiments on behavior and detection of oil in ice*. Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions 2019 ; Volum 2019-June. s.1-11
- Petrich, C. (2019) [The color of ice](#). Poster presentation at IGS - Sea Ice Symposium 2019.
- Petrich, C. (2019). *Oil-In-Ice Work at SINTEF Narvik*. NOFO Monday Spill Response Exercise 2019.
- Petrich, C. (2019) *Sea Ice*. LTU G0008B Snow and Ice 2019.
- Petrich, C., O'Sadnick, M., Brekke, C., Myrnes, M., Maus, S., Salomon, M., Woelk, S., Grydeland, T. and Jenssen, R.O. (2019) *Joint MOSIDEO/CIRFA tank experiments on behavior and detection of oil in ice*. Poster presentation at [IGARSS 2019](#).

- Petrich, C., O'Sadnick, M.E., Brekke, C., Myrnes, M., Maus, S., Salomon, M.L., Woelk, S., Grydeland, T., Jenssen, R.R., Eicken, H., Oggier, M., Ferro-Famil, L., Harkati, L., Rebane, O., Reimer, N. (2019). Joint MOSIDEO/CIRFA tank experiments on behavior and detection of oil in ice. IGS - Sea Ice Symposium 2019.
- Petrich, C., Langhorne, P., and Eicken, H. (2019) [Desalination of sea ice in a fluid dynamics model](#). Poster presentation at IGS - Sea Ice Symposium 2019.
- Petrich, C., O'Sadnick, M., Kleven, Ø. and Sæther, I. (2019) *Acquiring sea ice data under high probability of loss of equipment*. Oral presentation at IGS- Sea ice symposium 2019
- Petrich, C., O'Sadnick, M., Kleven, Ø. (2019). *Acquiring data under high probability of loss of equipment*. EGU General Assembly 2019.
- Petrich, C., O'Sadnick, M., Kleven, Ø., Sæther, I. (2019) *A low-cost coastal buoy for ice and metocean measurements*. International Conference on Port and Ocean Engineering under Arctic Conditions 2019. Poster presentation at [IGARSS 2019](#).
- Petrich, C., O'Sadnick, M.E., Kleven, Ø., Sæther, I. (2019). *A low-cost coastal buoy for ice and metocean measurements*. In proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions 2019
- Quigley, C.P., Eltoft, T. (2019) *Retrieval of the dielectric properties of oil slick using SAR via a Polarimetric Two-Scale Model*. Oral presentation at [Polinsar2019](#)
- Röhrs, J., Dagestad, K.F., Asbjørnsen, H., Nordam, T., Skancke, J., Jones, C.E. and Brekke, C. (2019) *Vertical mixing and horizontal drift of oil spills: simulations with the open source oil spill model OpenOil*. [EGU General Assembly, Vienna, Austria, 7-12 April](#).
- Semmling, M., Divine, D., Gerland, S., Wickert, J., and Schuh, H. (2019) [Estimation of sea-ice concentration using signals of a global navigation satellite system](#). Poster presentation IGS - Sea Ice Symposium 2019.
- Singha, S., Johansson, M. and Doulgeris A.P. (2019) *Towards operational sea ice type retrieval using L-band synthetic aperture radar*. IGARSS 2019.
- Singha, S., Johansson, M., Doulgeris, A.P. (2019) *Arctic Sea Ice Classification Using ALOS-2 Palsar-2 L-Band SAR Images*. Oral presentation at ESA Living Planet Symposium 2019
- Skrunes, S. (2019) Slik kan vi bruke satellitter for å finne oljesøl i Arktis. Teknisk Ukeblad.
- Winter, A., Hann, R., Wenz, A., Wolfgang, A., Gryte, K., Johansen, T.A. (2019). *Stability of a Flying Wing UAV in Icing Conditions*. European Conference for Aeronautics and Space Sciences 2019.
- Yitayew, T.G., Dierking, W., Divine, D., Eltoft, T. and Negrel, J. (2019) *Sea ice topographic height retrieval from Tandem-X interferometric SAR data*. Oral presentation [IGARSS 2019](#).



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.

