ANNUAL REPORT 2018

SUSTAINABLE ARCTIC MARINE AND COASTAL TECHNOLOGY

SAMCoT sfi NTNU

SAMCoT KEY FIGURES	2018	2017	2016	2015*	2014	2013	2012	2011	Accum.Fig
Turnover (in 1000NOK)	27 119	32 086	39 336	75 299	33 666	59 887	45 770	13 859	327 022
PhD Defences	2	5	4	5	3	3	1	0	23
Published Journal Papers	32	10	26	29	16	5	7	7	132
Published Conference Papers	33	38	43	52	40	40	18	15	279
MSc Thesis	5	5	6	11	6	7	8	2	50
Mass Media & Other Popular Media	3	84	36	12	24	11	8	3	181
Industry Partners	8	13	13	13	13	11	11	9	8
Research Partners	10	8	8	8	8	7	7	7	10
Public Partners	2	2	2	2	1	1	1	1	2
PhD Candidates	11 (3)	19 (4)	26 (6)	26 (7)	21 (6)	22 (4)	19 (4)	10 (1)	14
Post Docs	5 (0)	9 (0)	9 (2)	9 (2)	4 (1)	3	1	0	5

SAMCoT PARTNERS

A Centre for Research-based Innovation (CRI - SFI) promotes innovation by supporting long-term research through close cooperation between R&D intensive companies and prominent research institutions. SAMCoT started its activities on April 2011 and will operate until 2019. All SAMCoT partners have in common their international relevance to Arctic Research.

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Print, design and layout - NTNU Graphic Senter att: Maiken Skogstad

2018 SUMMARY OF SAMCOT`S YEAR

SAMCot`s vision from the very beginning in 2011 was to be a leading international centre for the development of robust technology, needed by the industry operating in the Arctic. For this purpose SAMCoT's goal was to perform research that would aid industry in the environmentally-friendly development of the Arctic where unique challenges are presented by ice, frozen soil/permafrost and coastal erosion. In pursuing that goal and in achieving success, SAMCoT is making the host institution NTNU a leading international centre in Arctic Science and Engineering.

There are several ways of transferring knowledge to industry. At SAMCoT we believe that this can be best achieved through strong collaboration between academia and industry; e.g. MScs and PhDs bringing their knowledge directly into the industry by employment or co-work on specific and relevant tasks.

WP1 (Data Collection and Process Modelling) is the most diverse work package in SAMCoT. In 2018 the topics included field-studies of ice conditions and the sea state in the Barents Sea, such as the shape, size, drift and planar rotation of icebergs and melting of sea ice and floes. The package has continuously been providing the other relevant work packages with knowledge of ice mechanics.

WP 2&3 (Material Modelling & Fixed Structures in Ice) has focused on constitutive modelling of ice rubble using both finite element and discrete element approaches. Other work within this package has included a complete thermal-mechanical-hydraulic (TMH) model of frozen soil. With respect to fixed structures, the work has focused on two main areas: ice-induced vibrations and ice ridge actions.

WP4 (Floating Structures in Ice) has in 2018 focused on numerical modelling of what happens to global and local ice loads when a floater interacts with different types of ice (intact level ice, broken ice and icebergs). On the global level, use of fracture mechanics has been developed together with a novel time-stepping scheme for the modelling of discrete ice structure interaction. With respect to local loads SAMCoT has focused on floating-ice impacts in which the structure sustains damage in the shared-energy regime; i.e. both the ice and the structure dissipate energy through inelastic deformations.

WP5 (Ice Management and Design Philosophy). One of the goals of WP5 has been to establish a high-fidelity simulation model of icebreaker actions and action effects that can subsequently be used as a platform for assessing icebreaker efficiency under different ice conditions, and for formulating guidance and control strategies for deployment and operation of an icebreaker fleet. Studies have also been undertaken on the effect of ice management (IM) as part of different types of risk-reducing barriers. IM barriers and functions range from ice detection, ice forecasting, ice alerting and physical ice fighting to disconnection procedures of the protected unit.

WP6 (Coastal Technology). The work in this package aims to develop new knowledge and the analytical and numerical models needed by industry to improve the prediction of 1) Arctic coastal erosion, 2) the behaviour of frozen/thawing soils, and 3) the influence of climate change. This is essential for the design of environmentally friendly and sustainable coastal structures and technologies. This has ranged from CFD modelling of local scour and coastal erosion to modelling of short- and long-term erosion of permafrost coastal bluffs.
I will end this short summary by citing the leader of the SAMCoT Scientific and Advisory Committee, Professor Erland Schulson: "To the building of relationships, to the development of all masters and doctoral students who have either now entered the marketplace or who will shortly, and to all the good work on Arctic Science and Engineering that has been done over the past eight years—a fine legacy indeed--we say: well done SAMCoT".

I take this opportunity to thank all partners, staff, PhD candidates and MSc students, post docs and researchers for their contributions in fulfilling the visions of SAMCoT.

Sveinung Løset
SAMCoT Centre Director

Sveinung Løset, SAMCoT Centre Director

SAMCoT COORDINATOR | ANDREA NILSEN

ANDREA NILSEN

Andrea Nilsen was born in Czechoslovakia in 1968, just a few months after the country`s invasion by the Soviet army. She grew up behind the Iron Curtain in the communist era. As a child she dreamt of traveling and living far away in a land by the sea. Growing up as a single child shaped Andrea`s interest in nature and mountains. She spent her weekends and summer holidays in a family cottage in the wilderness, where she was exploring forests and lakes and learned about nature with her grandfather. She could recognise edible mushrooms at the age of seven and collected them along with forest berries and herbs. Andrea learned to ski at an early age and cross country skiing remains her favorite sport today.

Andrea has turned her interest for travel into a professional career. She studied and graduated from the Travel and Tourism Management college in her home town of Opava. She was very fortunate that shortly after her graduation in 1989, Czechoslovakia was liberated through the Velvet Revolution in which she actively participated. The demonstrations culminated on 17 November 1989 which marked the collapse of communism in Czechoslovakia. Several months later, the Iron Curtain came down. Andrea was free to explore the world and turned her childhood dream into reality. She moved to Toronto in Canada where she got to know the local culture and language while she supported herself working as an au pair. She also pursued her education at the Ryerson University where she studied Business Management. Two years after her arrival in Toronto, Andrea started working as a marketing executive in a software company. Several years later she was headhunted by a Czech firm and decided to return to Prague where she became a Commercial Director for a national travel agency. Her strong desire to showcase the beauty of the historical capital of Prague to the world lead her down the entrepreneurial path. She started her own company, offering conference and meeting services and her company NILSEN DMC is today well established in Norway as well.

Her journey to Norway began at a friend's wedding where she met a "viking" from Norway. A few years later, Andrea got married to her "viking" and moved to Trondheim. Andrea's professional goal is enhancement of international competence and collaboration in public and private sectors and she achieves this by organizing bilateral initiatives. Her expertise in international business management and broad experience and network was invaluable when she worked in the Director's team at BOA Offshore. This experience also serves her well in her current position as administrative leader and coordinator at SFI SAMCoT.

ADMINISTRATIVE REPORTING

SAMCoT stepped into the year 2018 committed to pursue its vision to perform research and to develop key solutions and innovative tools to aid industry in the environmentally-friendly operations conducted in the Arctic. This fragile and unique environment faces challenges presented by ice, frozen soil and coastal erosion.

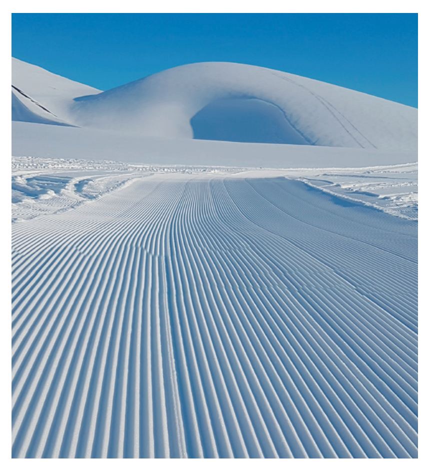
The SAMCoT consortium counted 20 partners in 2018. There were eight industry partners, two public partners and ten research partners including eight international research institutions. NTNU plays an important role as the host institution. In pursuing its goals and in achieving success, SAMCoT has made NTNU – The Norwegian University of Science and Technology –a leading international centre in Arctic Engineering.

In 2018 SAMCoT's governing body the Board, had representatives from Aker BP, DNV GL, Equinor, Kværner, Lundin, NTNU, SINTEF, Total and UNIS (University Centre in Svalbard), with the RCN (Research Council of Norway) as observer.

SAMCoT's board members gathered twice during the year to evaluate the center's activities. The first board meeting in Longyearbyen took place at the end of April. The Board`s agenda featured Activity Updates, Scientific and HSE presentations. Health, Safety and the Environment combined is one of the key priorities for the board members. To gain insight and increase understanding of how HSE is implemented in field trips, the Board participated in a scooter field trip to Barentsburg, organized by UNIS. The Board also discussed in great detail how to facilitate innovation and showcase solutions towards industry partners. Data management and data access has been another priority for SAMCoT and the Board discussed this issue further during its second meeting in October. The centre has created a "Guide to the SAMCoT Data Server" which provides Consortium partners with safe access to data sets categorized by names, descriptions, types of data and accessibility.

The Research Council of Norway watches SAMCoT`s activities closely and monitors progress during an annual site visit. In 2018, the RCN visit took place at the end of August at NTNU, Trondheim. Since SAMCoT is entering its final stage, the RCN representatives were curious about SAMCoT's heritage. The value of SAMCoT is carried into the industry and society as a whole through the PhDs and Post Docs that have been employed by SAMCoT's industry or research partners in Norway and abroad. Several new international projects (AOCEC – Arctic offshore and coastal engineering in changing climate, Nunataryuk – Effect of melting permafrost and DOFI – Dynamics of floating ice, just to name a few) are building on SAMCoT`s research and have received EU funding as well as funding from RCN. The Research Council representatives summarized its site visit with the following words:" SFI SAMCoT delivers high quality research and made an impact in its field. SAMCoT has also positively contributed to research-based education at NTNU and UNIS." The "SAMCoT" brand has positioned itself in the Arctic area and will continue its life in many different ways after the closing of SAMCoT on June 30th, 2019.

SAMCoT's Coordinator Andrea Nilsen has ensured that all administrative and financial reporting has been delivered to the RCN in a timely manner. She has also organised and ensured the smooth running of all the annual events including the Board Meetings, General Assembly, the RCN site visit and the Technical Seminar associated with SAC and EIAC committee meetings as well as communicating the research progress and highlights on SAMCoT`s web pages, in the newsletter, e-room and media.



WP1 LEADER

ALEKSEY MARCHENKO

ALEKSEY MARCHENKO

Aleksey Marchenko was born in 1960 in Moscow in a family of physicists. His father, Prof. Valery M. Marchenko is still active and working at the General Physics Institute of the Russian Academy of Science and is a leading researcher in the field of laser physics. His mother, Elena, an engineer in the field of the physics of crystals retired in the 1990s. Marchenko's son, Sergey, successfully defended his PhD in glaciology at the University of Uppsala in January 2018. He represents the fourth generation of the family working on ice research.

Marchenko has a broad background in mathematics and physics that enabled him to enter the Faculty of Mechanics and Mathematics at Lomonosov Moscow State University (MSU). There Marchenko obtained two PhDs, one in 1986 on the characteristics of surface waves propagating in water layers below the elastic plate imitating ice cover, and a second one in 1996 on mathematical models of drift ice and flexural-gravity waves. It was after talking with Prof. V. Bogorodskii, a cousin of Marchenko's grandfather working in the Arctic and Antarctic Research Institute in St. Petersburg, that he decided to pursue a life-long career in Arctic research. Marchenko focuses on research topics related to the physical and mechanical processes in the ice-water environment and has worked on these topics at several different institutions of the Russian Academy of Sciences between 1985 and 2006, as well as during his research visits to the International Arctic Research Centre IARC at Fairbanks, USA (2001) and Seoul National University (2003). Marchenko has been a professor at the University Centre in Svalbard since 2006, a member of the National Committee on Theoretical and Applied Mechanics (Russia) since 2005, and a member of the Norwegian Scientific Academy for Polar Research since 2010.

DATA COLLECTION AND PROCESS MODELLING

Under Aleksey Marchenko's leadership, 2018 has been a very productive year for WP1. Numerous field activities took place. Starting with field works organized in the Van-Mijen Fjord near Svea, Spitsbergen, on March 5-16, 2018 where a group of researchers in WP1 performed full scale tests on compressive and flexural strength of ice and continuing with field investigations of drift ice performed on Spitsbergen-banken, during the Polarsyssel cruise on April 24 to 30, 2018.

SEA STATE AND ICE CONDITIONS IN THE BARENTS SEA

Sea ice characteristics and SAMCoT GIS

Nataly Marchenko, a dedicated WP1 researcher for SAMCoT Geographic Information System (GIS) continued laser scanning in the Barents Sea during the survey on Polarsyssel. Scanning of investigated ice floes provided 3D point cloud of the floe surface. Combining of surface point cloud with drilling profile information for underwater part gave possibility to build 3D model for the whole floe and calculate volume. Scanning of ice floe composition from the ship deck allowed to characterize the ice field, ice tongue stretching towards the Bear Island.

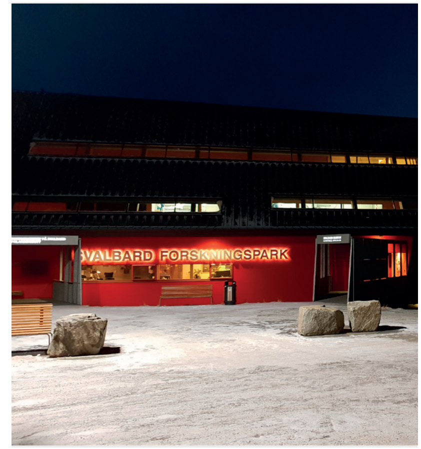
The SAMCoT GIS online, created in 2017, was further developed and tested by SAMCoT partners. The new data, obtained in 2018 were stored. Data collected by WP1 in 2011-2018 were structured and stored on SAMCoT server. In addition to the data presented in SAMCoT GIS online, this data volume contains folders with Sea ice observation, Sea ice drift, Laser scanning, Field investigation at Baydara bay site, Acoustic Doppler Current Profiler (ADCP) measurement at Vestpynten site. The total volume is more than 600 GB.

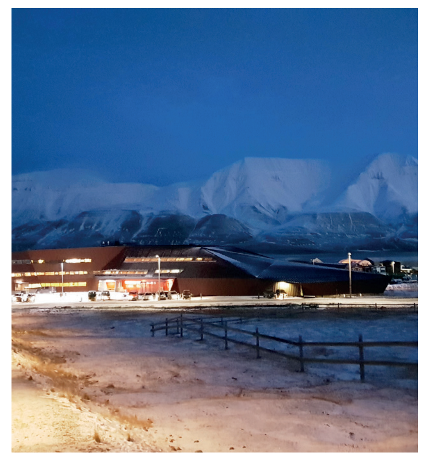
Consolidation of ice ridges

During the Polarsyssel cruise in April, WP1 researchers performed field investigations of drift ice on Spitsbergen-banken. The ship was moored to two drifting floes in two different locations. The first floe was drifting to the South-East from the Hopen Island, and the second floe was drifting to the North of the Hopen Island. The distance from the Hopen Island to the first floe was of about 130 km, the distance between two locations of the field works was of about 80 km, and the distance between the Bear Island and the second floe was of about 75 km. The floes morphology was investigated by laser scanning and drilling, ice cores were taken for the measurements of the ice salinity and temperature, and for the tests of compressive strength. Maximal drafts of the first and the second floes were measured of 2.94 m and 4.56 m.

The ice salinity of the both floes of 4-6 ppt is typical for the salinity of the first-year sea ice. The ice with thickness above two meters can't form under weather conditions in the Barents Sea in 2018 winter. Therefore, we are sure that the floes represent fully consolidated ice ridges. No flat bottoms of the floes similar to smoothed ridge keels confirm the hypothesis. Amount of floes with similar sizes in the region was not large but at the same time the floes chosen for the field works were not exceptional, and it was possible to explore other similar floes. Masses of investigated floes were estimated of about 970 tonn and 770 tonn.

Standard oceanographic measurements performed around the floes included profiling of water salinity and temperature, profiling of water velocities, and high frequency measurements of the fluctuations of the water temperature and salinity in the under-ice boundary layer. Oceanic heat fluxes were calculated during the observation periods by use of the collected data.





The data are used for the simulation of thermodynamic consolidation of drifting ice ridges on Spitsbergen-banken.

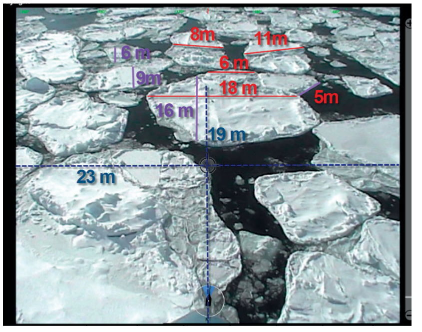
Modeling of iceberg drift

Earlier elaborated model of iceberg drift was used for numerical simulations of drifting tabular iceberg observed in the North-West Barents Sea in 2009. Ice tracker (Oceanic Measurements Ltd) was deployed on the iceberg and transmitted data during 5 days with sampling interval of 20 min. Sea current velocities were measured by onboard Acoustic Doppler Current Profiler (ADCP) mounted in the bottom of Lance. The Lance was moored to a drifting floe on a distance of about 10 km from the drifting iceberg and was drifting with ice during 36 hours. The ADCP records were used for the reconstruction of the drag forces and Froude-Krylov forces on the iceberg keel. The wind drag force on the iceberg sail was calculated using the records of wind velocity by the onboard meteorological station.

Numerical simulations were performed to simulate the iceberg drift during 36 h while water velocities were measured by the ADCP. Simulations were performed with different values of the drag coefficient for model icebergs having shapes of circular and elliptic cylinders. The iceberg sizes were reconstructed by the photographs. The iceberg displaced 36 km in the North-West direction over 36 h of the observations. Simulated trajectory was very similar to the iceberg trajectory with final deviation of 4 km over 36 h. The iceberg rotation was obtained for the model icebergs with the shape of an elliptic cylinder. It was shown that the deviation of simulated trajectories from the observed trajectory is explained by the interaction of the iceberg with drifting floes which is not described by the model. Nevertheless, systematic corrections of observed trajectory with using of the observations may improve the accuracy of the modeling significantly.

MONITORING OF SEA ICE

Two ice trackers were deployed in 2017 and three ice trackers were deployed in 2018 on drifting floes on Spitsbergen-banken. Their purpose was to investigatee the characteristics of drift ice and surface currents, and monitoring of surface wind and waves. All trackers transmitted the coordinates of their geographical positions with sampling interval of 10 min. One tracker was equipped with anemometer and transmitted the data on the wind velocity with same sampling interval. Two trackers transmitted the data on vertical accelerations measured with sampling frequency of 5Hz during 5 min one time per each two hours.



Field works on drifting floe on Spitsbergen-banken, April 28, 2018.

PHYSICAL AND MECHANICAL PROPERTIES OF ICE

Ice strength

The group of researchers in WP1 performed full scale tests on compressive strength and flexural strength of ice during the field works in the Van-Mijen Fjord near Svea, Spitsbergen, on March 5th-16th, 2018. Compressive strength was measured by two methods: uniaxial compression of short cantilever beam (0.8 m length) and side loading of fixed ends beam (4-5 m length). It was confirmed that compressive strength measured in the tests with fixed ends beams is higher than in the tests with short cantilever beams. In-situ analysis of thin sections showed structural changes of ice in compressive zone in the tests with fixed ends beams.

Flexural strength tests were performed with upward and downward loading of free ends of the cantilever beams. From four tests it was discovered that flexural strength obtained in the tests with upward loading is higher than flexural strength obtained in the tests with downward loading of the beam. This unusual behavior of ice is explained by the formation of very brittle layer of granular ice with thickness of 20 cm on the surface of sea ice. The granular layer was formed due to specific weather conditions when warm and rainy weather changed to cold and dry weather over several weeks before the field works.

Full-scale indentation tests were performed on natural sea ice and sea ice subjected to preliminary action of the vibro-plate. The vibro-plate generates vibrations with the frequency of 80 Hz. The weight of the vibro-plate is 400 kg. It was discovered that semi-cylindrical indenter penetrates through the entire ice thickness with higher rates when the ice was subjected to the action of the vibro-plate. The experiments should be further repeated to investigate the influence of ice thinning after the action of the vibro-plate on the indentation strength and rate. The action of the vibro-plate on ice is investigated to understand the changes of ice structure and strength when it is subjected to vibrations.

Preparation of ice by the action of the vibro-plate, March 14, 2018.

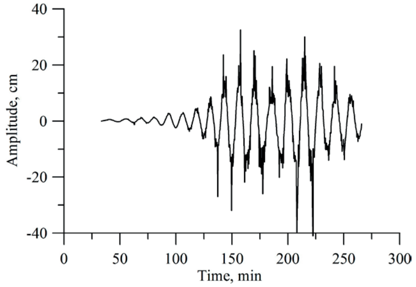
Dynamic effects of ice blocks collisions

In-situ drop block tests were performed to investigate the influence of water on ice-ice collisions. In the tests the truncated ice pyramide was dropped into the hole in the ice where it was sawn from. The pyramide motion can also be conditionally subdivided into three stages including free fall, contact with water, and extrusion of water from the gap between the pyramide walls and the floating ice. It was discovered that the water resistance increases the time of the interaction of the pyramide with floating ice in comparison to the tests with dry collisions of ice blocks. A mathematical model of the wet collisions was elaborated and numerical simulations were carried out.

Illustration of Drop Block tests

SEA ICE AND WATER ACTIONS IN THE COASTAL ZONE

The purpose of this study is to investigate the influence of tidal currents on sea ice in Spitsbergen fjords, which may cause rapid decrease of the ice thickness due to erosion and melting of the ice. The effect was studied in-situ near the narrow channel connecting the Van Mijen Fjord and Lake Vallunden. The strong jet-like tidal currents in the strait driven by semidiurnal tide continue into the lake preventing ice freezing along a narrow strip during high tide and relatively warm weather. Understanding the formation of open water regions or regions with thin ice is important for safe transportation on ice. The researchers estimate conditions and representative time over which strong tidal currents influences ice thickness along a narrow strip in solid ice. Changes of tidal phase and decrease of air temperature influence freezing of the strip in one-two days. While the tidal flow leaves the strait it overflows a shallow bar and generates internal lee waves propagating downslope and mixing the water. Tidal forcing of internal waves was measured using pressure gauges and by scanning of the ice surface during flood and ebb phases. Internal waves were measured using three types of CTD (Current Temperature Depth) instruments and ADCP current meter. The generation of wave packets occurs every tidal cycle when the current flows into the lake, but no generation occurs during the ebb phase of the tide because the currents over the bar slope are low. Parameters of internal waves are estimated. Model simulations confirm generation of internal wave train by the tidal current descending downslope.



Recorded wave train of internal wave with a period of 13.9 min.

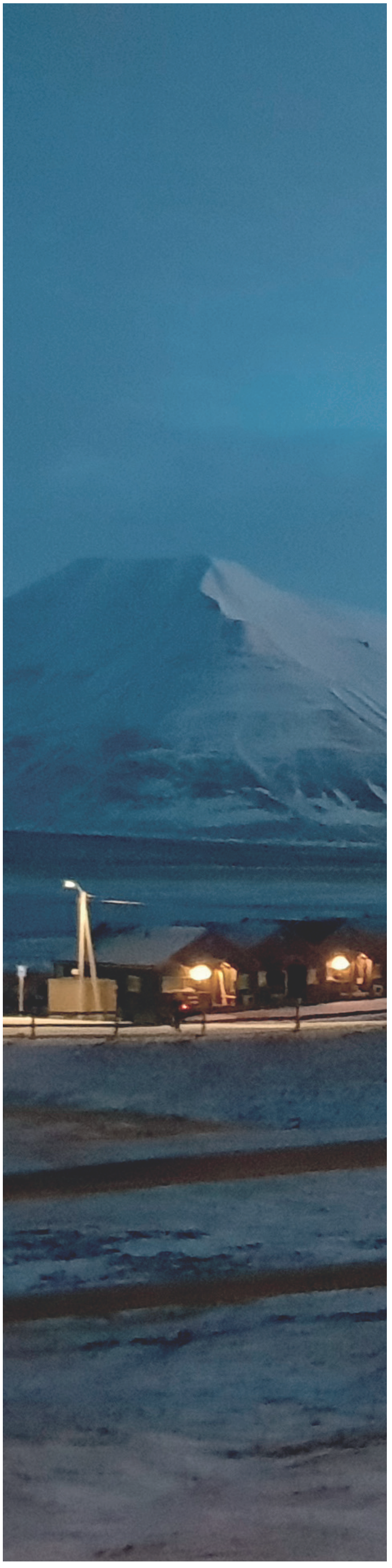
APPLIED OCEANOGRAPHY

Wave damping in the marginal ice zone

The team of researchers processed and analyzed the data collected from two ice trackers (Oceanetic Measurement Ltd) deployed on the drifting floe in April 2017. The ice trackers transmitted the data during 138 h from April 26 to May 02. The data includes measurements of the geographical locations and wind velocity with sampling interval of 10 min, and measurements of vertical accelerations with sampling frequency of 5 Hz performed during 5 min in each two hours. The records of wind velocity correspond well to simulated wind velocities provided by the web (https://earth.nullschool.net). Analysis of the acceleration data showed that their energy increased after 60 h of the data transmission. This influences an increase of the floe movements around its smoothed trajectory. Increasing dispersion of the floe displacement and dispersion of the floe speed demonstrated this effect.

Drift speeds registered by the ice tracker change in the time with semidiurnal period. Their correlation with the recorded wind speed is not evident. Observed variations of the drift speed can be explained by the influence of semidiurnal tidal currents. Maximal drift speed of the ice tracker reached 1.6 m/s on 75th hour of the data transmission.

Peak periods of the vertical floe accelerations recorded by the ice tracker varied between 8 s and 12 s. Oscillations with maximal energy had a period of 8 s. WAVEWATCH III simulations (https://earth.nullschool.net) predicted smaller periods of peak waves over 100 h of the data transmission. The simulated peak wave period of 8 s during the next 20 h corresponds well to the ice tracker data. The simulated wave heights were larger than the wave height calculated from the ice tracker data. It shows that even relatively small ocean areas covered by broken ice have strong influence on the wave spectrum due to the wave damping by ice.



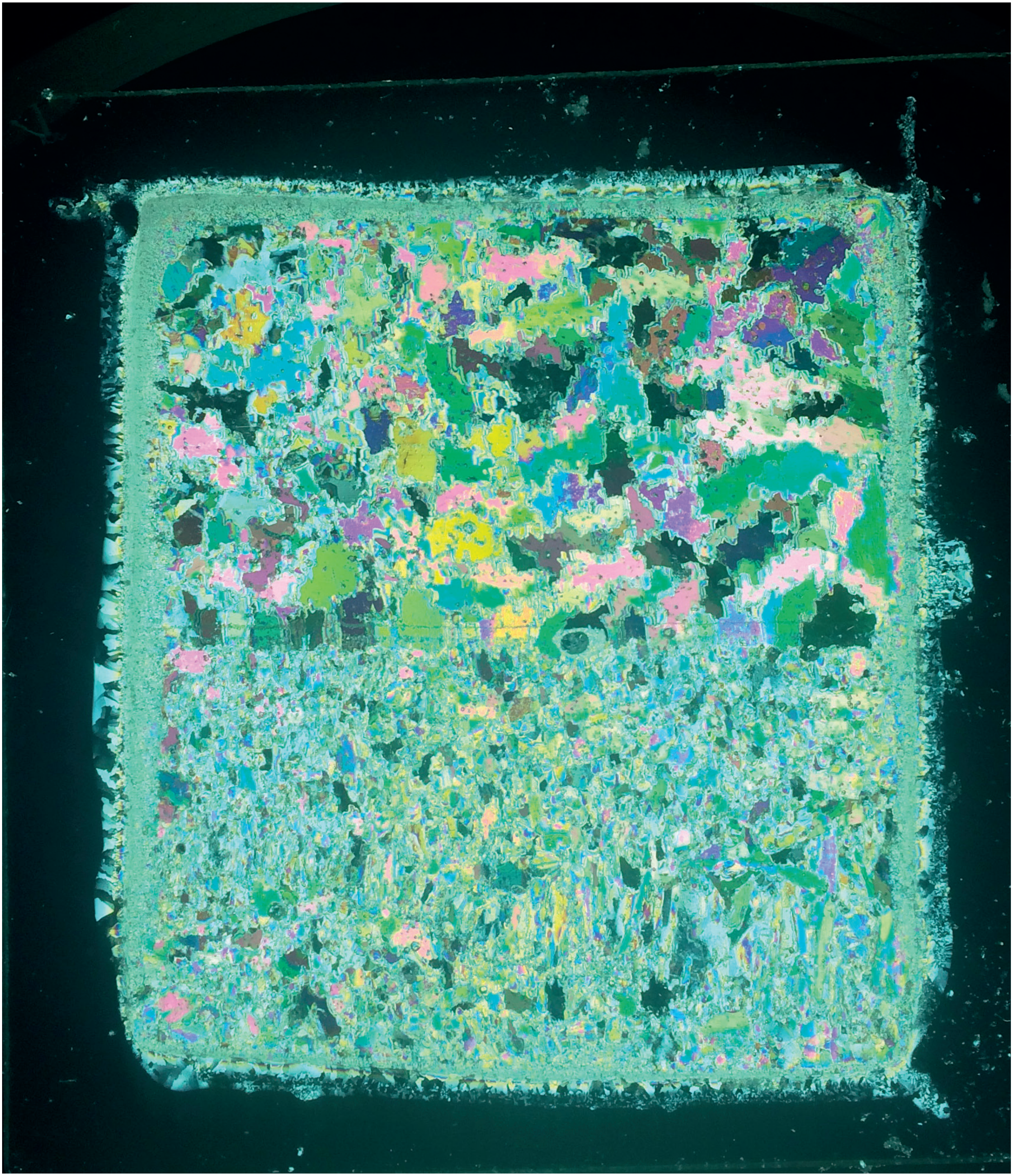
WP3 LEADER KNUT HØYLAND

KNUT HØYLAND

Knut Høyland, the leader of WP2, was born in 1967 and grew up at Blommenholm outside Oslo. He was always interested in mathematics and physics and loved discovering how things like his toys, clock and bike worked. His aunt and uncle were teaching at NTNU and encouraged him from an early age to become an engineer. In 1988 he moved to Trondheim and started studying Marine Technology.

He moved into ice mechanics and Arctic technology with his PhD (1997-2000) and after this spent five years teaching in the department of Arctic Technology at UNIS, Svalbard before returning to a postdoc position, and later a professorship (2009), at NTNU.

He is a member of the International POAC committee and leads the International IAHR Ice committee. He is also a member of the editorial board of the Journal of Cold Regions Science and Technology.



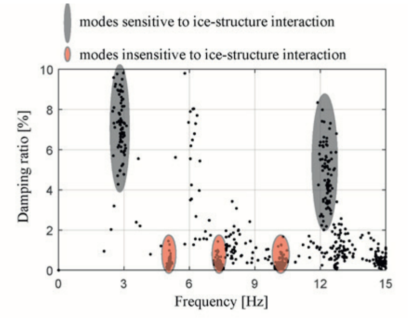
FIXED STRUCTURES IN ICE

Work Package 3 deals with fixed structures in ice and the two focus areas are Ice Induced Vibrations and Ice Ridge Action. Professor Knut V. Høyland leads the work package and Professor Andrei Metrikine (TU-Delft and NTNU) is co-leader with responsibility for ice-induced vibrations.

Ice-induced vibrations

2018 sees the end of the seven-year long collaboration between the two SAMCoT postdocs Torrod Nord (NTNU) and Hayo Hendrikse (TU Delft) on ice-induced vibrations. To highlight this moment, they have written a joint paper summarizing their final results and insights gained during this period, which has been accepted for publication in the Journal of Marine Structures.
A "light" version of the interaction model has been shared in an open-access format to allow its further development and use outside of SAMCoT in the future.
In TU-Delft, Hendrikse and Owen worked on further analysis of the IVOS (Ice-induced vibrations of offshore structures) data. Their work resulted in the paper "Ice-Induced Vibrations of Model Structures with Various Dynamic Properties" which has been presented at the IAHR'18 International Symposium on Ice in Vladivostok and will be presented at POAC'19 (Port and Ocean Engineering Conference under Arctic Conditions) in Delft.

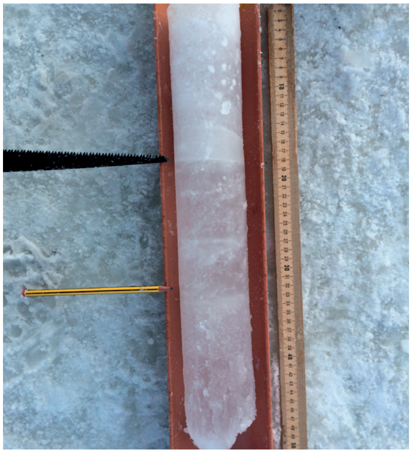
Torodd, Hayo and Øyvind from the NTNU structural dynamics group assessed how the modal parameters of a structure change in different ice-structure interaction scenarios. Simulated and measured data were used in this study, which showed that some structural vibration modes appeared insensitive to the interaction between structure and ice, whereas some vibration modes were highly influenced by the interaction process. The modes which were sensitive to the interaction process displayed great variability in frequency and damping. In addition, the damping of the modes that were sensitive to the interaction process was generally much higher than for the modes that were insensitive to the interaction process. The existence of modes that are insensitive to the interaction process is important for structural health monitoring, as these modes may be used for damage detection. The authors were invited to submit these results to a special issue of the Royal Society of Philosophical Transactions A and a paper has been submitted.



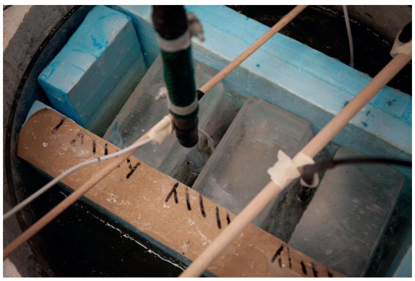
Structural damping identified from ice-structure interaction measurements. Dark grey ellipses indicate modes that are influenced by the interaction process, whereas pink ellipses indicate modes that are marginally influenced by ice-structure interaction. (Figure submitted to the Royal Society of Philosophical Transactions A).

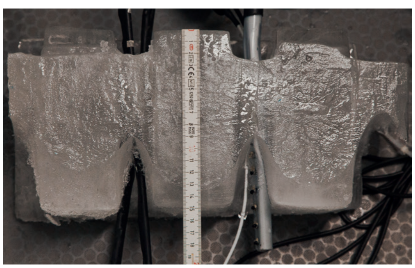
Ice ridge action and ice rubble accumulation

PhD candidate Åse Ervik has rejoined Multiconsult. She spent 2018 finalizing her third journal paper and writing her thesis which will be defended in the spring of 2019. She has addressed three main research topics: a) the development of thermo-mechanical properties in decaying Arctic ice ridges; b) the identification of high global forces and classification of interaction modes in ice ridge interactions with the Norströmsgrund lighthouse and c) numerical modelling of ductile ice interactions with fixed, vertically sided structures. Ervik has written one journal paper and several conference papers on each of these three main topics.



PhD candidate Evgenni Salganik conducts scale-model testing of first-year sea ice ridges. He concentrates on ridge thermodynamics and how the consolidation process systematically changes with changing physical size. In 2018 he presented a paper at the International Ice Symposium (IAHR) in Vladivostok, Russia. He has also carried out a series of small-scale consolidation experiments in NTNU's cold laboratories with fresh-water ice.The figure below shows the experimental set-up.





Experimental setup and b) model ridge after consolidation.

Salganik has also developed a numerical model and with the combined physical and numerical experiments he is able to explain the development of consolidation observed in laboratories and in-situ works. Salganik describes this research work in two journal papers, the first concerns the experiments described above, and the second describes the field work on Svalbard, carried out in 2017.

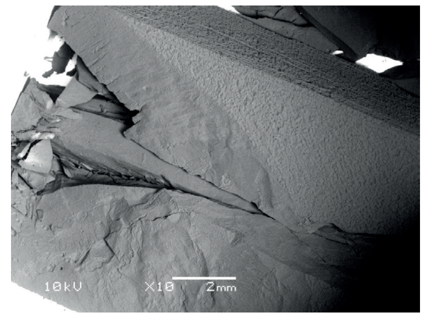
The Aalto ice mechanics group with postdoctoral researcher Janne Ranta addresses statistics of ice rubble pile-up. Determination of ice loads is one of the fundamental problems in ice mechanics. It is also a problem that is central to SAMCoT's WP3 where Ranta was involved as a PhD student. Ice-structure interaction processes are complex, and ice loads related to them depend on several factors. One important aspect of ice-structure interaction problems is ice rubble accumulation and the effect of ice rubble on ice loads. The Aalto ice mechanics group has been using a combined finite-discrete element method (FEM-DEM) to model ice structure interaction processes. This type of modeling accounts for the granular behaviour of the ice rubble.

The discrete element method is a promising tool for investigating complex problems such as ice-structure interaction processes that include an extensive amount of ice rubble. An undisputed benefit of the application related discrete element simulations is their ability to provide data from different scales with complete control and knowledge of all model parameters. During his work, Ranta produced and analyzed a large number of lengthy ice-inclined structure interaction process simulations. The work highlighted many important and complex features of the ice loading process.

As a concrete example, important ice parameter effects appear to be non-linear functions of varied ice parameters; peak ice loads are strongly dependent on the ice thickness, but they show only a weak dependency on the compressive strength of ice. Increase in the ice thickness clearly increases the peak loads within the studied parameter range. The effect of the compressive strength is different, and the data suggests that with high compressive strength values the ice loads become independent of that parameter. The work not only reports load values from simulations but also discusses potential mechanisms behind the load observations. In December 2018, Ranta successfully defended his doctoral thesis at Aalto University and continues working on ice loads as a postdoctoral researcher.

PhD candidate Mark Shortt at University College London (UCL) addresses freeze-bonds in ridges. His research is of an experimental nature, and focuses on the mechanics of freeze-bonds in sea ice. Specifically, Shortt is aiming to establish a relation between the strength of freeze-bonds and contact time. He also plans to investigate the influence of other physical properties on freeze-bond strength, particularly salinity. Over the last year, Shortt has focused on finalising experimental set-ups and conducting preliminary tests.

One of the major aspects of Shortt's research is the microscale deformation of freeze-bonds in-situ under a scanning electron microscope (SEM). In these experiments, millimetre-scale ice samples are deformed using a Deben Microtest deformation stage, which is placed within the chamber of the SEM to enable simultaneous imaging. The stage is cooled via a circulation of super-cooled nitrogen gas. In the past year Shortt has finalised the experimental set-up and has developed a method to record the deformation of the ice samples using SEM imaging. He has also started to conduct tests on fresh level ice and freeze-bonded samples. An SEM image of a level ice sample that failed via axial splitting is shown in the figure below. The methodology and preliminary results will be described in a conference paper to be published at POAC'19.

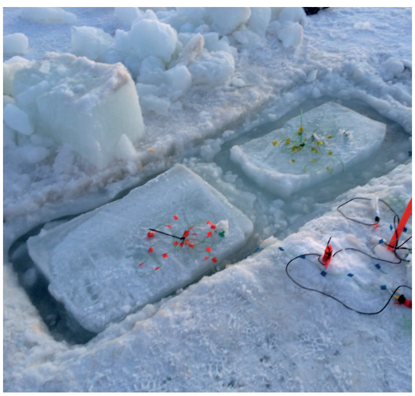


SEM image of a fresh ice sample which failed via axial splitting.

In addition, with the assistance of technicians, Shortt has finished setting up the biaxial cell in the UCL cold rooms. This will be used for future tests on freeze-bonds and ice friction. The set-up involved re-wiring of the temperature controller and calibration of the load cells and displacement transducers at both room temperature and at -15°C. In 2019 Shortt will conduct biaxial slide-hold-slide friction tests, both in air and submerged in saline water. In each test, the hold time and sliding velocity will be varied so that the rate- and state-dependencies can be determined. Additionally, if time permits, the normal load will also be varied to investigate its influence on freeze-bond strength and ice friction.

Shortt has also contributed to two experiments conducted at the HSVA Large Ice Model Basin. In January, he spent two weeks measuring acoustic emissions in a HYDRALAB+ project led by Aleksey Marchenko (UNIS) on the bending rheology of floating saline ice. In November, Shortt measured acoustic emissions in an experiment by TOTAL on brash ice. He also attended and gave presentations at both SAMCoT Ice Rubble Workshops held at NTNU.

In March Shortt spent two weeks in the field in Svea (Svalbard) conducting large scale consolidation experiments. The aim of these experiments was to investigate the effect of gravity drainage on the salinity development of the freeze-bond layer and the overall consolidation time. This was done by cutting four blocks (~1 m2 in area, ~20 cm in thickness) from the level ice, keeping two in the natural orientation and rotating the other two 90°. The blocks were then stacked in an open channel of water such that two set-ups were created, as shown in the figure below. The temperature profiles through the thickness of the ice blocks were monitored using thermistor strings, and the salinity of the freeze-bond layer was deduced via drilling. Due to the low air temperature (approximately -20°C), both experiments had consolidated within a day. After one week, it was found that gravity drainage had increased the salinity of the freeze-bond layer by around 4 ppt.



Field tests on sea ice consolidation conducted in Svea (Svalbard) in March 2018

Shortt attended the 24th IAHR International Symposium on Ice in Vladivostok, Russia, where he gave a presentation and published a conference paper based on his HSVA consolidation experiments conducted in 2017. He also helped to obtain funding for a new Itasca acoustic emissions system, which will be used both in the lab and in the field.

WP4 LEADER | SVEINUNG LØSET

SVEINUNG LØSET

WP4 is led by Professor Sveinung Løset at the Department of Civil and Environmental Engineering, NTNU. His co-lead is Professor Jørgen Amdahl at the Department of Marine Technology, NTNU.

Sveinung Løset was born in 1956 in a small village of 240 inhabitants on the West Coast of Norway. The closest community was Volda where he attended high school. He was the youngest in a family of seven brothers and sisters. They trained him in wildlife and long hikes before he even entered primary school. That led to a passion for the extreme. His father was a schoolteacher and always stressing the importance of learning, knowledge and skills. His closest brother was already a student at the Ship's Department of NTH, so it was easy for Sveinung to select Trondheim as a place to study. Sveinung is Professor of Arctic Marine Technology at The Norwegian University of Science and Technology. He holds a PhD in Marine Technology from NTNU, and a masters degree in physics from the same university. Since 1997 he has held the position of Adjunct Professor at The University Centre in Svalbard. Dr Løset received the Statoil Award 2004, and in 2005 he was awarded a Professorship Honoris Causa at The St Petersburg State Polytechnical University. He is member of the Norwegian Academy of Technological Sciences (NTVA).

FLOATING STRUCTURES IN ICE

The goal of WP4 is to develop new knowledge and new analytical and numerical models of floaters in ice required by industry. This means improving the prediction of loads exerted on floating structures by first-year and multi-year level ice and ridges as well as icebergs. Part of this work is to enable the simulation of time series of the performance of structures in ice. The design of offshore and coastal structures in the Arctic is often governed by the actions of ice in the ocean. This depends broadly on the ice properties, the structure geometry and the interaction speed. In more detail, ice action is a function of the ice feature, the ice properties, the limiting mechanism, the interaction geometry and the ice failure modes.

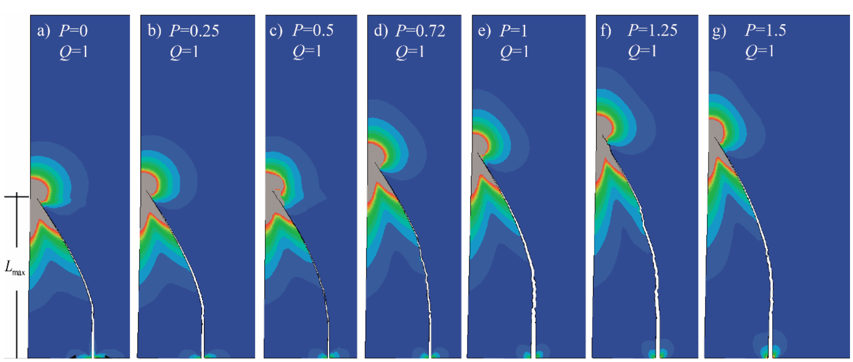
Most of the work in this work package has been performed by the four researchers/postdocs Wenjun Lu, Andre Tsarau, Zaolong Zu, and Ekaterina Kim. In addition, there has been a close collaboration with Dr. Aleksey Shestov in WP1. The three PhD students Marnix v.d. Berg, Chris Keijdener and Runa Skarbø have also contributed strongly to a very productive year in 2018.

Theoretical and numerical studies of sea ice fracture

As part of the basis for including the role of fracture in global ice actions on offshore structures, the third round of the field campaign in the very beginning of 2018 was carried out on sea ice in Svea, Svalbard. The purpose was to examine the fracture properties of sea ice. Several large ice floes were cut and fractured. In this round of the campaign, we varied the orientation of the ice floe to investigate if the c-axis of sea ice has an impact on the global splitting force and the fracture properties of sea ice. THe figure below shows several ice floes, with different orientations, that were tested.

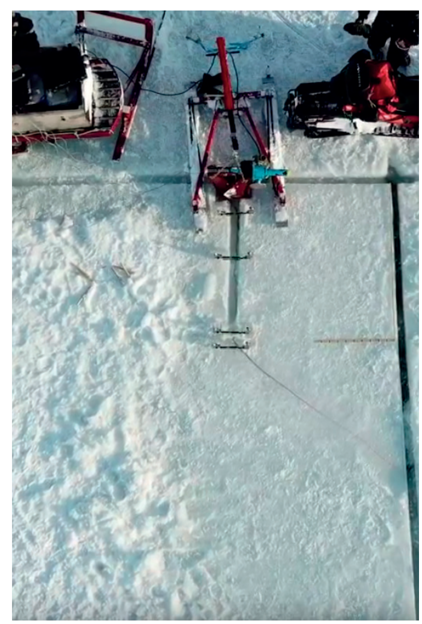
In this test campaign, so-called kink tests (see Figure) were also performed to study the crack path during ice fracturing. This has a direct impact on the application of ice management operations, in which long cracks were kinked inbetween parallel channels. Related numerical simulations with the XFEM code have also been conducted (see Figure). Two journal papers (in Journal of Cold Regions Science and Technology, 2018 Vol. 156) were published in this regard.

Simulations of the crack kinking.

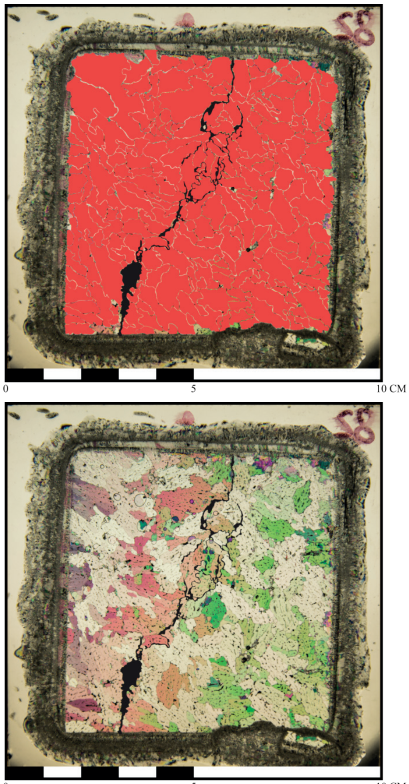


Fracture tests of ice floes with different orientations.

Kink tests (a drone view from above showing the crack path highlighted with red markers).



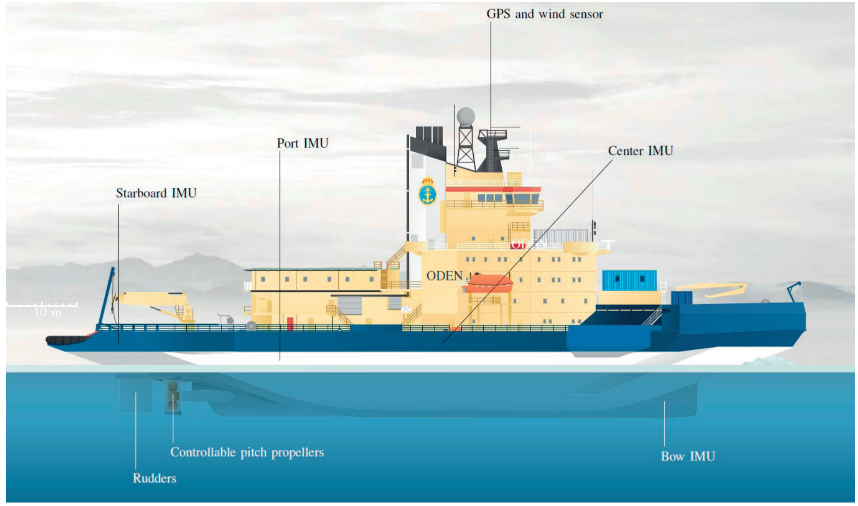
In several of the tests the researchers were able to capture the fracture zone at the crack tip. Some samples were brought back to the cold lab at UNIS where postdoc A. Shestov ran a microstructure analysis of these samples as can be seen in the figure below.



Crack propagation (from bottom to top of the image) near the crack tip zone, shown on the thin section S8 (depth z=-29cm) of ice sample in cross-polarized light (a) and with detected grains (b).

Later in 2018, a journal paper was published by Ø. Kjerstad et al. (2018), describing a method for real-time estimation of full scale global ice load on floating structures. This method allows us to use several (> 4) Inertial Measurements Units (IMUs) together with other ship data (see Figure) to calculate global ice loads in real time on an icebreaking ship.

At the same time, the Simulator for Arctic Marine Structures (SAMS), developed by the NTNU spin-off company ArcISo, was validated in terms of ship transit in the marginal ice zone. The estimation algorithm mentioned



Using measuring devices (IMUs) to estimate global ice loads in real-time.

above is utilised to extract the 'measured ice load history' for comparison with the numerical simulation results. Favourable comparisons were achieved and the validation work was carried out within the scope of WP4 and was published in the Journal of Cold Regions Science and Technology Special Issue, Vol. 156. In total, 9 journal papers, with extensive contribution from WP4, were published in this Special Issue.

HYDRODYNAMICS

On hydrodynamics Tsarau et al. (2018) presented a journal paper of a newly-developed, unique numerical model that enables physically-based, high-fidelity simulations of ice management with the propeller flow of a ship. This model predicts the propeller-flow velocities, calculates the hydrodynamic forces on the ice and integrates the equations of motion of the ice cover, which is represented by an ensemble of rigid bodies that may interact with each other. Data from full-scale tests were used to calibrate the model to simulate the propeller-wash effect on ice floes and ice rubble. Another set of experimental data was utilised to validate the model against the measurements from full-scale trials in which an escort ship equipped with azimuth thrusters was employed to widen an old channel filled with ice rubble. The comparison showed good agreement between the measurements and the numerical results. PhD student Chris Keijdener has finished his doctoral thesis entitled The effect of hydrodynamics on the interaction between floating structures and flexible ice floes - A study based on potential theory. He will defend the thesis in the spring of 2019.

Mr. Keijdener has studied the effect of hydrodynamics on the bending failure of level ice, focusing on the transition from static to dynamic failure, identifying the essential components of this interaction and thereby determining which components can be ignored, and elucidating the relation between the temporal development of the contact force and the velocity-dependence of the ice breaking length.

DISCRETE NUMERICAL MODELLING

ArcISo has given MSc and PhD students at NTNU permission to use SAMS in their studies. Using SAMS, PhD student Marnix van den Berg has studied the effect of floe shape on the load experienced by vertical-sided structures interacting with broken ice. Floe shape is often not taken into account as a parameter in existing calculation methods for the loads of broken ice on structures. Using numerical experiments and model scale test data, van den Berg showed that the floe shape has a large influence on the structure load in interaction scenarios dominated by ice accumulation and clearance. Ice accumulation and clearance are dominant mechanisms in interactions with broken ice with an areal coverage ranging from 30 to 70%.

Floe shape effects are relevant to ice tank tests or numerical simulations that may be performed in the design phase of structures or operations for which the loads from broken ice may be the governing design load. Ice tank tests with broken ice conditions are often performed with square or rectangular floes, as a result of the method that is used to create the broken ice.

The simulation results show that when square floes are used instead of more natural floe shapes, the mean load can be up to 88% higher. A greater length and a higher stability of force chains is the primary mechanism causing the floe shape effect. The floe shape effect is exacerbated in confined conditions, where the force chains may cause bridging between the structure and a rigid boundary.

LOCAL ICE LOADS

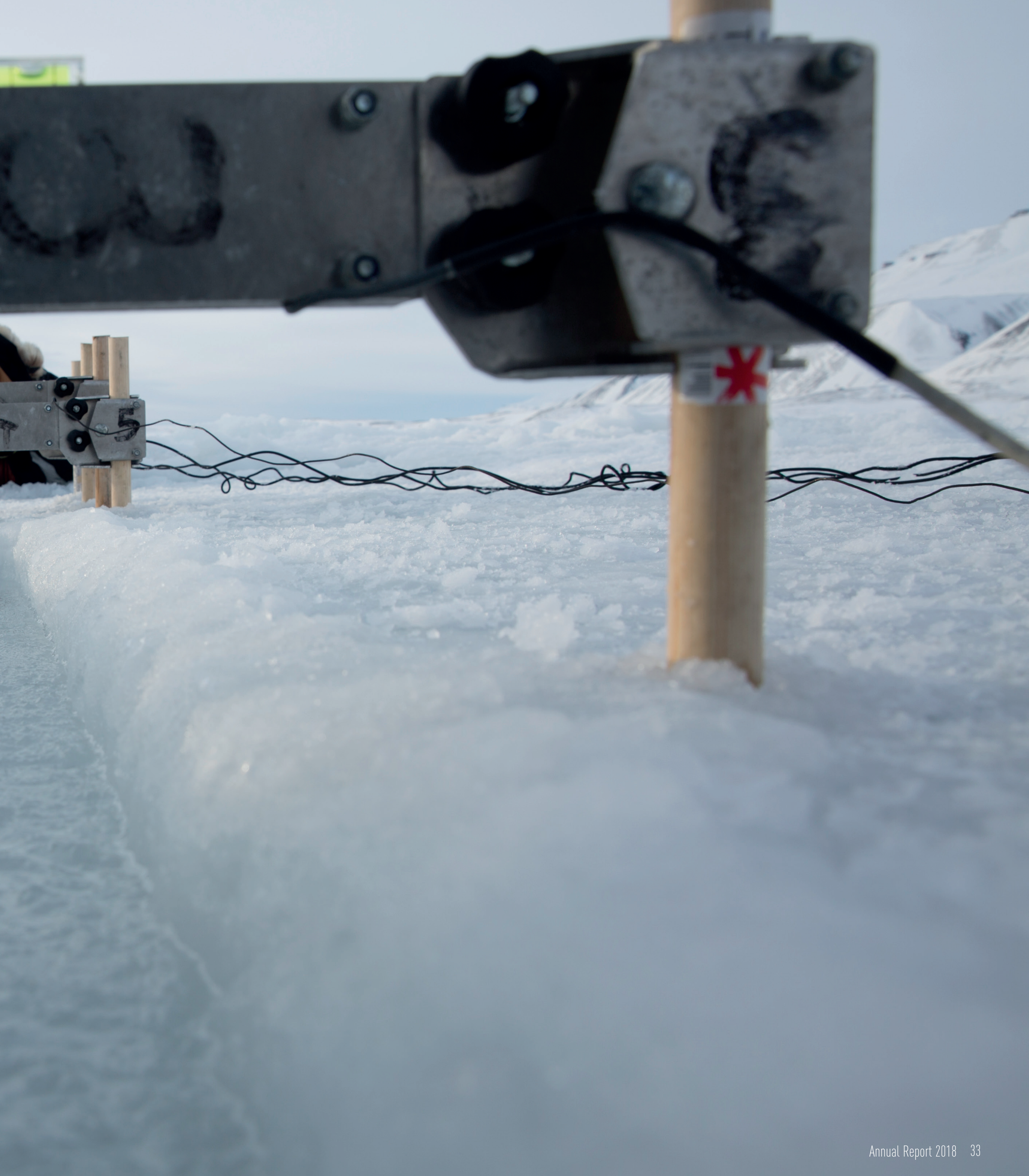
For a structure-ice interaction process, a continuous record of force versus time can be converted to an ice pressure–area curve, or it can be used to find the specific energy of the mechanical destruction of ice (crushing specific energy), that is the energy required to crush a unit volume (or mass) of ice. The highly empirical concept of the ice pressure–area relationship has been incorporated into design codes and practices, but use of the crushing specific energy is limited, although a theoretical and experimental basis exists for this value. In 2018, the researchers focused mainly on the specific energy concept and its application for ice impact problems. They have reviewed the development of the specific energy concept and argue that it is more convenient to use the specific energy for the description of certain ice-structure interaction scenarios, i.e., ice impact crushing with limited energy. Dr. Ekaterina Kim presented the results of this work during a plenary talk at IAHR2018 in Vladivostok.

Results of the three-year work in the Arctic Technology Committee of the International Ship and Offshore Structures Congress (ISSC) have been published in the report where several scientific results from SAMCoT have been highlighted and recommended for further use.

STRUCTURAL INTEGRITY OF SHIPS AND OFFSHORE STRUCTURES IMPACTED BY ICE

Floating glacial ice of various sizes pose great threats to the structural integrity of ships and offshore structures at high northern latitudes. In order to design reliable and cost-effective structures in the polar regions, it is essential to understand clearly the mechanical properties of ice and ice structure interactions. Ice, as a natural material, has very complicated material behaviour under loading, which is often accompanied by complex fracture patterns. From a structural design point of view, Dr Zaolong Yu has focused on developing a 'design ice' model capturing major ice properties and energy absorption capabilities during crushing. He has further studied an existing hydrostatic-pressure dependent plasticity model of ice with associative flow rule. Because associative flow rule for geomaterials like soil often leads to excessive dilatancy, we are exploring the influence of using associative and non-associative flow rule on the final outcome. Instead of calibrating to the ice-pressure area relationship, he calibrated the model to the resistance of ice crushing experiments, which is considered more accurate.

For the ice-structure interactions and structural responses under ice loading, both non-linear finite element methods (NLFEM) and simplified analytical methods are used. The shared energy scheme is used, where force-displacement curves are obtained assuming rigid ice-deformable structure and deformable ice-rigid structure collisions. Under the same force level, both ice and the structure should deform and dissipate energy. A simplified model was proposed for predicting the beam resistance of a single stiffened panel under lateral loading. The model was further extended to account for stiffened panels with several spans. The formulations were verified to be of reasonable accuracy by comparison with NLFEM simulations. The results showed that the boundary axial stiffness were crucial for stiffened panel response and a smaller axial stiffness will lead to a delayed development of axial forces and therefore larger deflections.

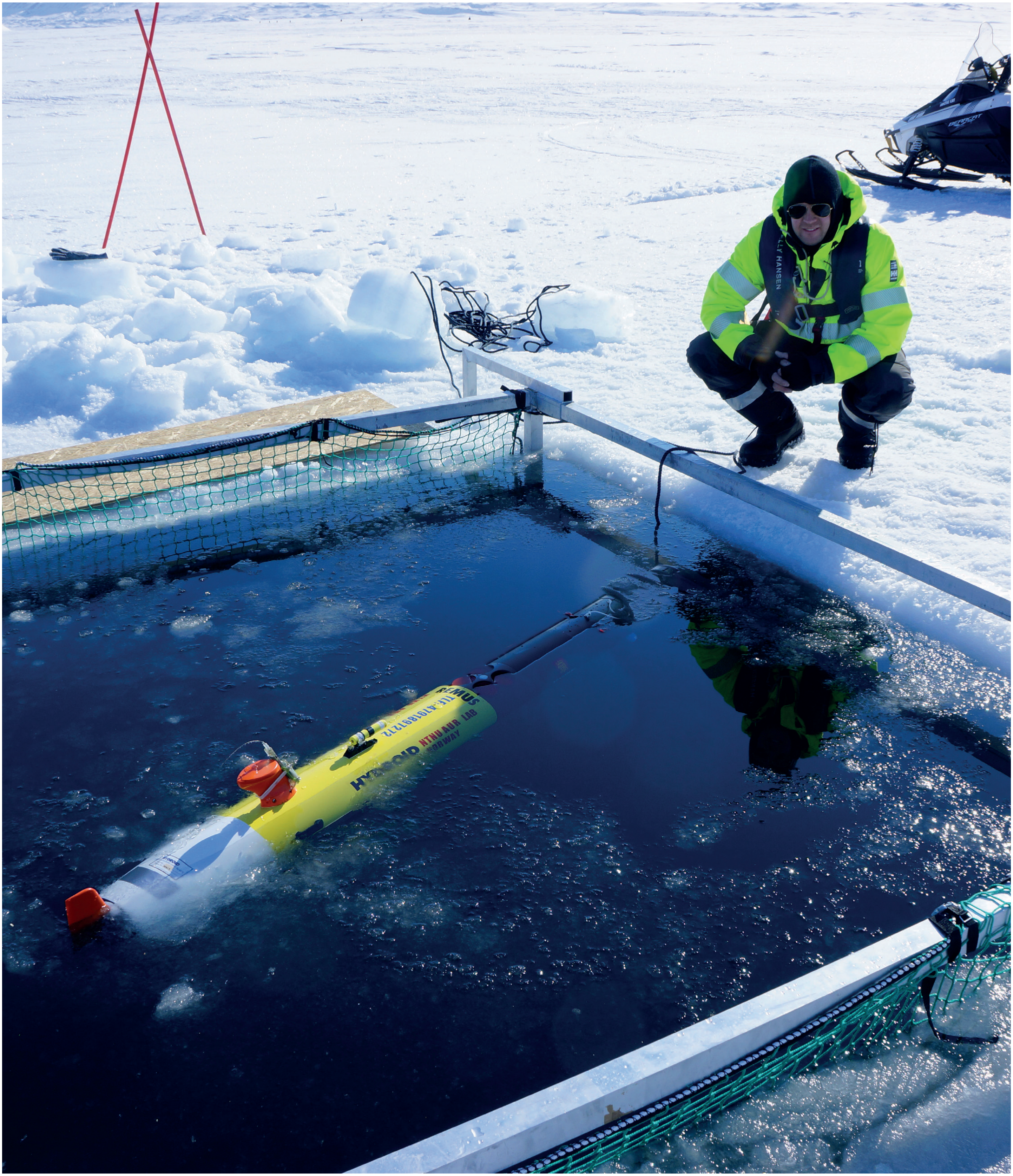


WP 5 LEADER | ROGER SKJETNE

ROGER SKJETNE

Roger Skjetne was born in 1973 on the island of Stord on the West Coast of Norway. The cornerstone business on Stord was Aker Stord, the main construction yard for offshore development projects in Norway. This period was dominated by the large gravity-based structures, big semi-submersibles, and FPSOs (Floating Production Storage and Offloading Vessel), such as Snorre A, Troll A, Nelson, Sleipner, Njord, Norne, Åsgard A. After two years of electrical vocational school, Roger worked as an electrician apprentice, and later as a skilled electrician on these structures. Roger's father also worked offshore for ConocoPhillips on a number of different Ekofisk platforms, for more than 35 years. This gave Roger an interest in the maritime and offshore industries, as well as an interest in electrical and automation systems. It led him to further pursue academic degrees, starting with engineering college in Bergen studying automatic systems, and then to the University of California at Santa Barbara (UCSB) where he was awarded bachelor and master degrees in electrical and control engineering. Eventually, Roger ended up in Trondheim for PhD studies in marine control engineering at NTNU's Department of Engineering Cybernetics. After his PhD defence, for which he was awarded the ExxonMobil prize for best PhD thesis on applied research at NTNU in 2005.

Roger worked for five years for the company Marine Cybernetics AS. He returned to NTNU and the Department of Marine Technology in 2009 for a Kongsberg Maritime Professorship within marine cybernetics. His first assignment at NTNU was to lead a five-year project called Arctic DP, through which he met Sveinung Løset and the Arctic community at NTNU. Roger and his family currently live in Santa Barbara, California, on a research sabbatical at UCSB until summer 2018. Thereafter you can find him living at Ranheim in Trondheim or at his cabin at Nerskogen.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ICE MANAGEMENT AND DESIGN PHILOSOPHY

With the overall aim of improving safety, the objective of WP5 is to better understand the management of sea ice and icebergs that threaten the integrity of floating structures.

To that end, several approaches are in play. These include: the quantification of uncertainty through analysis of sets of "small data"; the detection and monitoring, both remotely and aboard ship, of the concentration, age, shape, size and drift of sea ice and icebergs; the effect of broken ice (as opposed to open water) on the drift of icebergs; the use of motion sensors aboard station-keeping vessels to detect ice drift; the quantification of the risk of allision (i.e., the action of dashing against or striking upon) between ships and other structures and the use of autonomous underwater vehicles to monitor the underside of ice features. One particularly challenging task is to include sea ice thickness to an ice mapping routine.

During the past year the work of WP5 culminated in the publication of Sea Ice Image Processing with MATLAB, by Qin Zhang and Roger Skjetne, C.R.C. Press, February 2018. The book is already being cited.

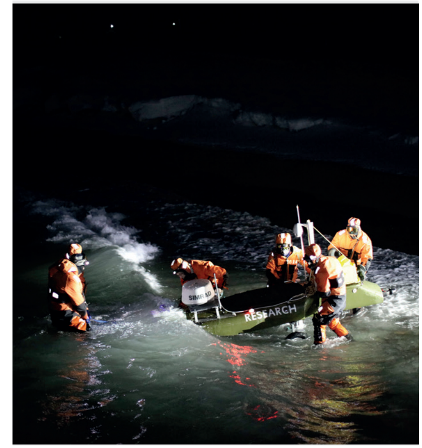
A particular problem in IM-based Arctic offshore operations is the lack of experience and statistical data from which to derive models. Researcher Stian Ruud is considering this problem with a focus on qualitative and quantitative barrier descriptions and the method of safe learning principle. Within the area of ice surveillance, PhD candidate Hans-Martin Heyn is working on statistical modelling and change detection based on on-board measurements of ice-induced accelerations experienced when moving a vessel through different forms of sea ice.

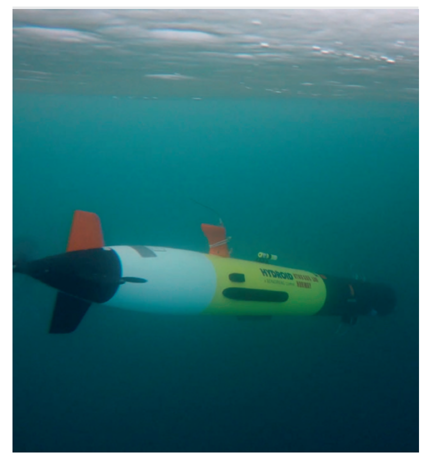
Petter Norgren concluded his research in 2018 and successfully defended his PhD thesis "Autonomous Underwater Vehicles in Arctic Marine Operations: Arctic Marine Research and Ice Monitoring". His thesis considers autonomous underwater vehicles (AUVs) in Arctic marine operations and research. Norgren was motivated by the challenges faced by Arctic AUV operations, such as the presence of drifting sea-ice and navigational issues in the polar regions. His research has involved several cruises and field expeditions to Svalbard, both with SAMCoT and with the NTNU Applied Underwater Robotics Laboratory.

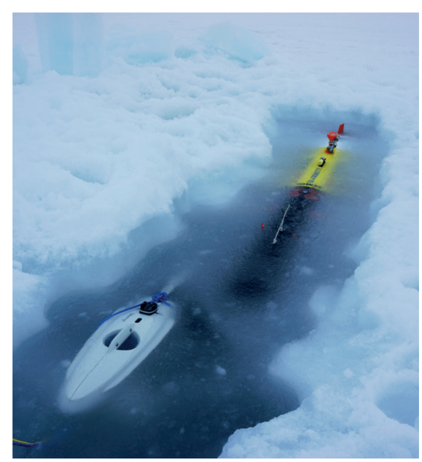
PhD candidate Jon Bjørnø is working on a digital simulation model of the icebreaker Oden, operating in a realistically simulated sea ice environment. The goal is to establish a high-fidelity simulation model of icebreaker actions and action effects which Bjørnø can subsequently use as a platform for assessing icebreaker efficiency under different ice conditions, and for formulating guidance and control strategies for deployment and operation of the icebreaking fleet. These activities define the work package and its ongoing research.

ICE MANAGEMENT OPERATION

Researcher Stian Ruud continued his work on ice management. Operators in Norwegian Arctic waters must comply with regulatory requirements as stated by the Norwegian Petroleum Safety Authority (PSA) regarding risk management and also with requirements stated in ISO 35104 "Arctic operations — Ice management" (published 2018).







PSA requires identification of defined hazards and accident conditions and in the IM context this could be collisions between ice floes and a drilling ship connected to the seabed with a blowout preventer (BOP). PSA requires risk reduction by means of barriers. In the figure below a barrier is indicated as a sequence of barrier element functions that should detect incoming ice and then start disconnection of the Lower Marine Riser Package (LMRP) from the BOP in order to bring the BOP, LMRP, and the drill ship into a safe disconnected state.

Cooperation between academic and industrial partners has enabled a conceptual IM approach based primarily on requirements of the national safety regulations. The method should be practically feasible for industrial applications and also provide the basis for further industrial development and academic research. This work and its results were made possible thanks to contributions from SAMCoT partners: Equinor, DNV GL, Swedish Polar Research Secretariat, Arctic Marine Solutions (AMS) and NTNU. AMS provided the report 'Drilling in ice conditions, A case study for SAMCoT' in 2018.

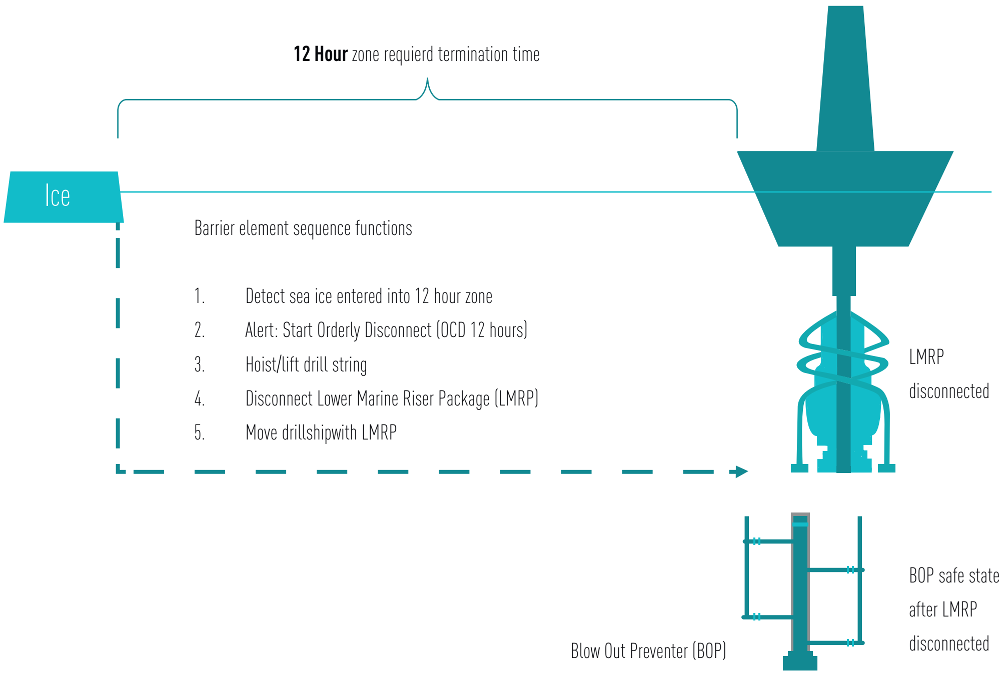
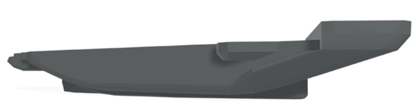


Illustration of one barrier in an event tree showing barrier element sequence functions.

MODELLING OF THE ICEBREAKER ODEN AND FREJ

PhD candidate Jon Bjørnø continued to work on modelling of the hull of icebreakers Oden and Frej. The goal is to improve the hull shape. In 2018, two new vessel models of Oden and Frej were made. A previous model of Oden was replaced by new updated model with more details. The process of making models for both vessels was similar, yet the process of making the Frej model was more challenging due to thelack of digital drawings. This is when SAMCoT`s partner Swedish Polar Research Secretariat played an important role by providing physical copies of the drawings of the icebreaker Frej. Digital copies of the drawings of the icebreaker Oden had been provided on a prior occasion.

To create the hull model Bjørnø used a 3D hull-modeling program to outline the vessels from the drawings and mark important points, frames and waterlines. Then, he exported these models to a 3D creation software for further processing. He divided the models into different objects based on the curvature of the hull, and created models consisting of convex surfaces only. Finally, Bjørnø exported these models into .obj files, enabling import into SAMS for further analysis. The process resulted in high-resolution models for both Oden and Frej. The figures below illustrate the final models.



Model of the icebreaker Oden.

Model of the icebreaker Frej.

ICEBERG MAPPING USING AUVS

PhD candidate Petter Norgren successfully defended his PhD thesis in September 2018. Prior to that Norgren worked on developing a method for the mapping of drifting sea-ice and icebergs using AUVs with an upwards-looking multibeam echosounder. The goal was to estimate the AUV position in an ice-fixed coordinate system using SLAM (Simultaneous Localization and Mapping). SLAM is method used to construct a map of an unknown environment and to simultaneously locate a vehicle on this map.

Norgren tested the method through simulations and with use of the experimental data collected with the HUGIN AUV in the Trondheim fjord. Norgren presented the results of his research in the paper "A multibeam-based SLAM algorithm for iceberg mapping using AUVs" in the Open-Access journal IEEE as well as in his PhD thesis "Autonomous underwater vehicles in Arctic marine operations: Arctic marine research and ice monitoring".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WP6 LEADER

RAED LUBBAD

RAED LUBBAD

Raed Lubbad was born in 1980 in Gaza, Palestine. He grew up by the beach and the Arctic was not on his mind at the time. The sea played a role in his growing curiosity and desire to shape the marine environment. Growing up in a country tormented by political and military conflict was not easy. His father was not able to pursue higher education and worked hard to secure a different future for his children. His parents raised their children to value science and encouraged them to attain the highest academic degrees. Raed was young when his older sisters and later brother traveled abroad to continue their education. He knew then that his turn would come. This happened in 2004 when he was granted a scholarship to pursue a Masters degree in Coastal Engineering at the Norwegian University of Science and Technology in Trondheim.

In Trondheim he met Professor Sveinung Løset who played important role in shaping his future career. Under Sveinung`s guidance, Raed completed his PhD in Arctic Marine Civil Engineering. Since 2011, he holds a position as Associate Professor in the Department for Civil & Environmental Engineering, NTNU. Raed is also involved in technology start-ups; he is one of the co-founders and the managing director of the SAMCoT spin-off company Arctic Integrated Solutions AS (ArcISo).

COASTAL TECHNOLOGY

Coastal zone development in the Arctic is quite demanding. The construction of roads, harbours and other facilities in the Arctic faces several challenges, e.g. exposure to combined actions from waves, currents and ice, high coastal erosion rates, building on permafrost soils, remoteness and lack of local material suitable for construction purposes. Moreover, climate change may result in a warmer Arctic with less sea-ice cover leading to higher wave actions on structures, more unstable permafrost soils and increasing rates of coastal erosion during the service lifetime of our structures.

The goal of WP6 is to develop new knowledge and the analytical and numerical models needed by the industry to improve the prediction of 1) Arctic coastal erosion, 2) the behaviour of frozen/thawing soils, and 3) the influence of climate change. This is essential for the design of environmentally friendly and sustainable coastal structures and technologies.

In order to address these general challenges in line with the industry partners' needs for innovation, several research projects have been carried out:

NUMERICAL MODELLING OF ARCTIC COASTAL HYDRO-DYNAMICS

CFD modelling of local scour and coastal erosion

Nadeem Ahmad successfully defended his PhD thesis "High-Resolution CFD Modelling of Scour in the Marine Environment" at NTNU on 6 December 2018. His research focuses on sediment transport in the marine environment and the vulnerability of coasts to climate change. The research involves numerical modelling with a strong emphasis on developing an understanding of the process of high-resolution sediment transport. Ahmad has examined complex flow and morphological conditions of the marine environment and developed a practical application of an open source computational fluid dynamics (CFD). His research has addressed (i) sediment transport under regular and irregular waves, current, and waves-plus-current flow; (ii) local scour around marine structure including piles, large pile, pipeline, jacket platforms, coastline, and the seawall. He also focuses on optimizing the computational time required for sediment transport modelling.

Ahmad's research work has been published at international conferences and in peer-reviewed journals such as Coastal Engineering, International Journal of Offshore and Polar Engineering, and Ocean Engineering. Recently, he received the Best Paper award at the Fourth International Conference in Ocean Engineering (ICOE2018) organised by the Indian Institute of Technology Madras.

Modelling of ocean waves propagating under sea-ice

PhD candidate Hongtao Li commenced his PhD theses titled 'Measurement and Modelling of Arctic Coastal Environments' in September 2016. In 2018, Li made a summary of findings based on a literature survey on wave-ice interaction mechanisms. He found that a number of physical processes that can explain how waves are damped due to the presence of ice are not well understood. In addition, he found that at present no theoretical model is applicable for describing wave-ice interaction in all different ice types. This work has lead to a contribution to the AIC 2018 conference in Greenland, and a paper written for the IAHR 2018 conference.

In addition to identifying knowledge gaps in wave-ice interaction research, Li explored the data collected during the LS-WICE project (Loads on Structure and Waves in Ice). The aim is to study the ice floe collisions induced by waves. This study resulted in a conference paper published in the proceedings of ISOPE 2018. As a further step, Li utilized the same data set to study the bending of large ice floes responding to different waves. He is writing a conference paper for POAC 2019 to summarize the findings.

Li is also finalizing a journal paper on a new time-derivative estimation method. This work is based on the analysis of the LS-WICE data.

Li will continue the work of quantifying wave energies dissipated by ice floe collisions under wave actions by using LS-WICE data. This work will be finalized around the autumn of 2019.

Measurements and modelling of Arctic coastal environments

Dennis Monteban is a PhD candidate at the Technical University of Denmark (DTU) and NTNU. He started his PhD in November 2016 and the title of his double degree PhD is: 'Measurements and modelling of Arctic coastal environments'. Beside the two partnering universities, the PhD is carried out in close collaboration with Danish Hydraulic Institute (DHI). The two main supervisors of the research project are Jens Olaf Pepke Pedersen from DTU and Raed Lubbad from NTNU.

The focus of Monteban's research in 2018 was partly the Arctic fjord system in Kangerlussuaq, located on the west coast of Greenland. Different numerical models to examine wave and current information were set up using the MIKE software, developed by DHI. This work resulted in a contribution to the AIC 2018 conference, held in Greenland.

In addition to the work on Kangerlussuaq fjord, Monteban investigated a study site in the Barents Sea. New insitu data, which are part of the Barents Sea Metocean and Ice Network (BaSMIN) measurement campaign, became available. This measurement program was performed by Fugro, on behalf of Equinor (former Statoil). Monteban performed a study on the potential of remote sensing observations. The BaSMIN study site was used as an example to demonstrate and validate the data obtained from satellite remote sensing data. This work resulted in a conference paper to be presented at the POAC conference 2019. Monteban also wrote a second paper for this conference, which focused on the change in wave parameters as ocean waves propagate into the sea ice. Again, the in-situ data from the BaSMIN project were used to validate some of the results obtained.

Monteban is currently writing a paper examining wave dispersion in sea ice, this work will be finalized in 2019.

Numerical Modelling of Short- and Long-term Erosion of Permafrost Coastal Bluffs

SAMCoT welcomed PhD candidate Akhsanul Islam in August 2018. The His PhD thesis is titled: 'Numerical Modelling of Short- and Long-term Erosion of Permafrost Coastal Bluffs' and the research project is supervised by Raed Lubbad.

Islam has initially focused on thermoabrasion, one of the major erosional processes of the Arctic coast. The thermoabrasion process is episodic and associated with storm events. During a storm, the non-existent to narrow coast in front of the frozen bluffs in the Arctic faces storm surge flooding; this may lead to the development of a niche (wave cut notch) at the base of the bluffs. When the niche is deep enough, the hanging bluff becomes unstable and a collapse is triggered. Islam has developed a numerical model to predict the risk of shoreline erosion by the collapse of frozen bluffs during an extreme event (e.g. a storm) due to thermoabrasion. An increased number of open sea days is one of the undesired effects of polar icecap retreat. This in turn has a compound negative effect on permafrost-rich coasts. Storms generated in the warm seasons result in a higher storm surge level due to a longer duration of ice-free seas in summer. One of the adverse effects of higher storm surges is the increased rate of niche growth (wave cut notch at the base of the frozen coast) and a greater probability of destabilization of the overhanging cliffs. The overall effect of the polar icecap retreat on the frozen coast is a higher probability of coast retreat among others. The thermoabrasion rate is highly sensitive to sea level rise and the erosion rate may increase significantly during storms in open sea seasons.

The conceptual model developed by Islam identified thermoabrasion erosion as a combination of three separate physical processes: generation of storm surge, wave-cut niche growth at base of bluff and destabilization leading to a collapse. One-dimensional simplified numerical modules were developed for each physical process. The three numerical modules were integrated and calibrated to simulate the thermoabrasion process. The model was applied to field observations atf Baydara Bay, Russia. The results were found to be in good agreement with field measurements.

The risks associated with Arctic coast erosion are very difficult to estimate due to our limited understanding of the physics behind it and the complicated relationship between the physical processes associated with the erosion. The simplified model developed by Islam is valid only for thermoabrasional erosion. This is only part of the bigger picture and therefore needs to be investigated further. The objective of Islam's PhD is to identify the relationship between various physical processes and to link the local variables of the environmental inputs with global climate. A model for short-term Arctic erosion, which works in very high resolution but may be applicable to local cases, is the primary objective. Consequently, one process-based global model for long-term prediction of the fate of the Arctic coast will be developed.

SAMCOT GUIDELINES FOR DATA COLLECTION

Guidelines for development of coastal infrastructure in cold climate

In 2018, several researchers from SINTEF Building and Infrastructure worked on the SAMCoT guidelines for development of coastal infrastructure in cold climate. Work progress on these guidelines was presented at a Technical WP6 meeting, held in Trondheim in June. Twenty representatives from academia, research and industry participated in the workshop. Presentations covered ongoing work on several chapters of the guidelines and discussion and feedback from the participants were taken into account for the continuing work on the guidelines.

Anatoly Sinitsyn worked on synthesis of the previous deliverables on coastal challenges within the SFI SAMCoT. Material from several relevant reports, journal and conference papers, a SAMCoT report, and several PhD and MSc theses were included in the guidelines. In particular, NTNU deliverables on modelling tools applicable for coastal issues were included. Sinitsyn also expanded the chapter on assessment of coastal dynamics on the site.

Ivan Depina also contributed to the guidelines. In particular, he worked on the chapters related to the design of coastal protection structures and pipelines in Arctic environment. These chapters are based on two reports by Depina, which he published earlier in WP6. The chapters have been expanded by including considerations of sustainability, the effects of climate change, and a broader range of coastal hazards.

Yared Bekele contributed the chapters with foundation design in permafrost conditions. The chapters now include design philosophies, typical foundation solutions, an overview of the impact of climate change and the tools for handling these challenges. In this chapter main factors for foundation design and hazards in coastal zone were considered. Yared Bekele prepared a basis for the chapter with general modelling tools in permafrost and improved the chapter on multi-criteria analysis.

Stein Christensen worked on the chapter on solutions and design of typical port infrastructure in Arctic conditions. This chapter includes principal considerations, examples of existing port projects and considerations with regard to climate change. Chapters on site investigations and site monitoring were also finalised.

Deliverables from SAMCoT-inspired projects of SINTEF were included in the guidelines. These are "Monitoring of Arctic Infrastructure" (MonArc, www.sintef.no/prosjekter/monarc/) and "Impact of changing climate on infrastructure in Longyearbyen: Stability of foundations on slope terrain – case study" (FST, www.sintef.no/prosjekter/fst/). Deliverables based on the Permafrost Site of "Norwegian GeoTest Sites" infrastructure project (NGTS, www.sintef.no/prosjekter/norwegian-geotest-sites/) were also linked to the guidelines.

The aim of the SAMCoT guidelines is to be instrumental in the development of infrastructure in coastal areas in cold regions in general, and in the Arctic in particular. The guidelines will provide support to industry and society from initial planning through to design and providing recommendations for monitoring of structures. The guidelines will help provide a holistic view on the development of infrastructure in coastal areas in the Arctic, and to avoid overlooking the most significant issues, which are not fully covered by existing guiding documents.

COLLABORATION WITH MSU

A group of scientists together with students and engineers from the Geological Faculty of Moscow State University (MSU), staff from the scientific research institute of the Russian Academy of Sciences (RAS) and members of high technology company performed fieldwork at Baydara Bay, in September 2018. Due to the danger of polar bear attacks this year, MSU field activity at the coast was limited. The main research activity consisted of measuring the thermal regime and thermal properties of grounds, a wide range of geophysical surveys of the cofferdam construction area and areas with natural conditions, and measuring coastal erosion rate with the DGPS method and LiDAR technology.

MSU researchers visited the Baydara Bay site for the first time in 2012 at the start of SAMCoT WP6. The field data since 2012 and information from early publications with a geocryological description of the site are used as reference data to describe changes over the years. Towards the end of 2018, MSU prepared a data report which presents field data from the 2018 expedition, comparison of the 2018 field data with results obtained in 2013-2017, analyses of geophysical data from the cofferdam area, and data from gas emission experiments. In 2018, in collaboration with N. N. Zubov's State Oceanographic Institute, MSU expanded the coastal research area with the temperature data of additional parametric boreholes.

The presence of sediment with high ice content at the Baydara Bay site promotes active slumping, sloughing, and slippage. Slopes composed by loamy sand and loamy clays soils with less ice content are usually steep. Loamy sand slopes tend to show higher erosion rate than loamy clays slopes. The 2012-2018 survey demonstrates the prevailing influence of storm activity on the coastal retreat rate.

As is known, frost sandy deposits are being eroded more easily than frost clays. However, another factor is significant in the Baydara Bay case – the thickness of coastal deposits. For the high coast area (Site 1) the thickness of sandy sediments reaches 15 meters and for low coast area (Site 2) the thickness of clays and sandy clays with peat layers is close to 10-12 meters. That is why even for sandy easily eroded sediments of high coast area, MSU have found the same retreat rate (4-5 m/year) as for low coast area with clay sediments.

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SPRS - Swedish Polar Research Secretariat Sweden

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TU Delft - Delft University of Technology, The Netherlands

UCL - University College London, UK

UNIS - University Centre in Svalbard, Norway

Soft Engineering, Ukraine

KSRC - Krylov State Research Centre, Russia

Memorial University of Newfoundland, Canada

CRREL - U.S. Army Corps of Engineers, Engineer Research and Development Center, USA

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PHD CANDIDATES

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Ice ridge action, numerical modelling Sep

JON BJØRNØ
Optimal icebreaker deployment and coordination for effective format and ice management tactics.

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Ice drift prediction and mitigation of impact from ice on marine operations

PETTER NORGREN*
Autonomous Underwater Vehicles for operations under ice

MARNIX VAN DEN BERG
Application of AUV for operation under ice, subsurface monitoring of sea ice and icebergs

DENIS MONTEBAN
Measurements and modeling of Arctic Coast Environment

EVGENII SALGANIK
Thermodynamic scaling of first-year ice ridges

MARK SCHOTT
Consolidation of rafted sea ice and the associated risks to offshore structures in the arctic.

MOHAMED AKHSANUL ISLAM
Numericall Modeling of Short and Long term Erosion of Permafrost Coastal Bluffs

HANS-MARTIN HEYN
Arctic TAPM control system with online ice surveillance by onboard sensors

ILIJA SAMARDZIJA
Risk, reliability and ice data in arctic marine environment – how to keep a sufficient safety level with little available data

NADEEM AHMAD*
CFD: Waves + Sediment transport (Ccohesive soil + permafrost)

JULIE MALENFANT-LEPAGE
The critical shear stress of frozen soils

HONGTAO LI
Wave energy dissipation due to ice floes collisions

*PhDs promoted in 2018

POSTDOCTORAL RESEARCHERS

TORODD NORD
Ice-induced vibrations – analysis of measurements

ERSEGUN DENIZ GEDIKL
Ice-induced vibrations of offshore structures

ANDREI TSARAU
Floater-intact level ice interaction (processes in the waterline)

SEYED A. G. AMIRI
THM Engineering model (Elastic-Plastic-Creep)

ZHAOLONG YU
Local ice loads and structural damage assessment

MSC STUDENTS

MAREN SALTE KALLELID
A Study of the Strength and the Physical Properties of Glacier-ice Runways

PREBEN JENSEN HOEL
Digital Twin of Vessels in Arctic Environments

ANDRE NILSSON ROLANDSEN
Digital Twin of Vessels in Arctic Environments

FAN ZHANG
Rubble Macro-porosity of Level Ice Accumulation on Wide Sloping Offshore Structures

MOHAMED AKHSANUL ISLAM
Numericall Modeling of Short and Long term Erosion of Permafrost Coastal Bluffs

DAVID MASSEY
Numerical Simulation of Ice-Rubble Mound Breakwater Interactions

MARIA PONTIKI
Bayesian Damage Prediction on Berm Breakwaters in the Arctic

DISSEMINATION

SAMCoT`s Scientific Advisory Committee expressed their satisfaction with the dissemination work of the centre in their report for 2018: ´It is clear, particularly from the relatively large number of journal papers, that the leaders of the work packages are taking seriously the importance of disseminating in the archival literature the knowledge and understanding that has come and continues to come from the work. The SAC expects that in due course SAMCoT papers will be well cited by the arctic research community. Of equal importance to published work is SAMCoT's development of young people`.

Nadeem Ahmad

Nadeem Ahmad successfully defended his PhD thesis "High-Resolution CFD Modelling of Scour in the Marine Environment" at NTNU on December 6, 2018. His research focuses on sediment transport in the marine environment and the vulnerability of coasts to climate change. The research involves numerical modelling with a strong emphasis on high-resolution sediment transport process understanding.

Ahmad's research work has been recognised on international conferences and in the standard peer-reviewed journals such as Coastal Engineering, International Journal of Offshore and Polar Engineering, and Ocean Engineering. Recently, he has received the Best paper award at the Fourth International Conference in Ocean Engineering (ICOE2018) organised by the Indian Institute of Technology Madras.

Petter Norgren

Petter Norgren finished writing his doctoral thesis "Autonomous Underwater Vehicles in Arctic Marine Operations: Arctic marine research and ice monitoring" in 2018. The highlight for him was the successful public defence at NTNU on September 3, 2018. His thesis considers autonomous underwater vehicles (AUVs) in Arctic marine operations and research.

Norgren was motivated by challenges that Arctic AUV operations face, such as the presence of drifting sea-ice and navigational issues in the polar regions. His research has involved several cruises and field expeditions to Svalbard, both with SAMCoT and with NTNU Applied Underwater Robotics laboratory. Through these campaigns, Norgren gained valuable experience in real Arctic AUV operations, both under-ice and in open water.

PhD Theses (2)

Norgren, P. - Autonomous underwater vehicles in Arctic marine operations. Arctic marine research and ice monitoring. NTNU Doctoral theses 2018:255

Ahmad, N. - High-Resolution CFD Modelling of Scour in the Marine Environment. NTNU Doctoral theses 2018:371

Published International Refereed Journal Papers (32)

Shestov, A., Høyland, K.V. and Ervik, Å. - Decay phase thermodynamics of ice ridges in the Arctic Ocean. Journal of Cold Regions Science and Technology.

Ahmad, N., Bihs, H., Arntsen, Ø., Myrhaug, D. and Kamat, A. - Three-dimensional numerical modelling of wave-induced scour around piles in a side-by-side arrangement. The Journal of Coastal Engineering

Ahmad, N., Bihs, H. and Arntsen, Ø. - CFD Modelling of Arctic Coastal Erosion due to Breaking Waves. International Journal of Offshore and Polar Engineering

Berg, vd M., Lubbad, R. and Løset, S. - An implicit time-stepping scheme and an improved contact model for ice-structure interaction simulations. Journal of Cold Regions Science and Technology

Ervik, Å., Høyland, K.V., Shestov, A. and Nord, T. - On the decay of first-year ice ridges: Measurements and evolution of rubble macro-porosity, ridge drilling resistance and consolidated layer strength. Journal of Cold Regions Science and Technology

Ervik, Å., Nord, T., Høyland, K.V., Samardzija, I. and Li, H. - Ice-ridge interactions with the Norströmsgrund lighthouse: Global forces and interaction modes. Journal of Cold Regions Science and Technology

Fenz, D., Younan, A., Piercey, G., Barrett, Freeman R. and Jordaan, I. - Field measurement of the reduction in local pressure from ice management. Journal of Cold Regions Science and Technology

Gedikli E. D., Chelidze, D. and Dahl, M.J. - Observed mode shape effects on the vortex-induced vibration of bending dominated flexible cylinders simply supported at both ends. Journal of Fluids and Structures

Hendrikse.,H., Ziemer, G. and Owen, C.C. - Experimental validation of a model for prediction of dynamic ice-structure interaction. Journal of Cold Regions Science and Technology

Heyn, H. M. and Skjetne, R. - Time-frequency analysis of acceleration data from ship-ice interaction events. Journal of Cold Regions Science and Technology

Heyn, H. M. and Skjetne, R. - Time-frequency analysis of acceleration data from ship-ice interaction events. Journal of Cold Regions Science and Technology

Holub, C., Matskevitch, D. Kokkinis, T. and Shafrova S. - Near-field ice management tactics–Simulation and field testing. Journal of Cold Regions Science and Technology

Keijdener, C., Hendrikse, H. and Metrikine, A. - The effect of hydrodynamics on the bending failure of level ice. Journal of Cold Regions Science and Technology

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Kjerstad, Ø., Løset, S.., Skjetne, R. and Skarbø, R. - An Ice-Drift Estimation Algorithm Using Radar and Ship Motion Measurements. Journal of IEEE Transactions on Geoscience and Remote Sensing

Le, T.M.H., Depina, I., Guegan, E. and Sinitsyn A. - Thermal regime of permafrost at Varandey Settlement along the Barents Sea Coast, North West Arctic Russia. Journal of Engineering Geology

Lu, W., Lubbad, R. Shestov, A. and Løset, S. - Parallel Channels' Fracturing Mechanism during Ice Management Operations. Part I: Theory. Journal of Cold Regions Science and Technology

Lu, W., Lubbad, R., and Løset, S. - Parallel Channels' Fracturing Mechanism during Ice Management Operations. Part II Experiment. Journal of Cold Regions Science and Technology

Lubbad, R., Løset, S., Lu, W., Tsarau, A. and vd Berg, M. - An overview of the Oden Arctic Technology Research Cruise 2015 (OATRC2015) and numerical simulations performed with SAMS driven by data collected during the cruise 2015 (OATRC). Journal of Cold Regions Science and Technology

Marchenko, A. - Thermo-mechanical loads of confined sea ice on structures. The Journal of Philosophical Transactions A of the Royal Society

Marchenko, A., Dianskii, N. A., Panasenkova, I. I. and Fomin, V. V. - Modeling Iceberg Drift in the Barents Sea from Field Data. Journal of Russian Meteorology and Hydrology

Mitchell, D.A. and Shafrova, S. - Application of a free drift tactical ice forecast model in pack ice conditions. Journal of Cold Regions Science and Technology

Nord, T., Samardzija, I., Hendrikse, H., Bjerkås, M. and Høyland, K.V. - Ice-induced vibrations of the Norströmsgrund lighthouse. Journal of Cold Regions Science and Technology

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Ranta, J., Polojärvi, A. and Tuhkuri, J. - Scatter and error estimates in ice loads – Results from virtual experiments. Journal of Cold Regions Science and Technology

Ranta, J., Polojärvi, A. and Tuhkuri, J. - Limit mechanisms for ice loads on inclined structures: Buckling. Journal of Cold Regions Science and Technology

Renshaw, C. E., Marchenko, A., Schulson, E. M. and Karulin E. - Effect of compressive loading on first-year sea-ice permeability. Journal of Glaciology

Rostami, H., Amiri, A.G. and Grimstad, G. - Back analysis of Caen's test by the recently developed frozen/unfrozen soil model. Plaxis Bulletin

Seidel, M. and Hendrikse, H. - Analytical Assessment of sea ice-induced frequency lock-in for offshore wind turbine monopiles. Journal of Marine Structures. Journal of Cold Regions Science and Technology

Shestov, A., Høyland, K.V. and Ervik, Å. - Decay phase thermodynamics of ice ridges in the Arctic Ocean. Journal of Cold Regions Science and Technology

Tsarau, A., Lubbad, R. and Løset, S. - A numerical model for simulating the effect of propeller flow in ice management. Journal of Cold Regions Science and Technology

Published International Conference Papers (33)

Ahmad, N., Bihs, H., and Arntsen, Ø. - Numerical Modelling of Scour around an Offshore Jacket Structure using REEF3D. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Chen, X., Ji,S. and Høyland, K.V. - An Experimental Study of Saline Ice Growth. International Association for Hydro-Environment Engineering and Research (IAHR)

Gedikli, E.D., Chelidze, D. and Dahl, J.M. - Active control of exible cylinders undergoing vortex-induced vibrations using piezo stripe actuators. IMAC, Conference and Exposition on Structural Dynamics

Gedikli, E.D. and Nord, T. - Discovering Pressure Modes in Ice-induced Vibrations Using Proper- Orthogonal Decomposition. INT-NAM, International Symposium on Naval Architecture and Maritime

Gedikli, E.D., Chelidze, D. and Dahl, J.M. - A Novel Method for Manipulating Flexible Cylinder Vortex-Induced Vibrations. NT-NAM, International Symposium on Naval Architecture and Maritime

Gedikli, E.D., Chelidze, D. and Dahl, J.M. - Bending Dominated Flexible Cylinder Experiments Reveal Insights into Modal Interactions for Flexible Body Vortex-Induced Vibrations. International Society of Offshore and Polar Engineers (ISOPE)

Heijkoop, A.N., Nord, T. and Høyland, K.V. - Strain-controlled cyclic compression of sea ice. International Association for Hydro-Environment Engineering and Research (IAHR)

Heyn, H-M., Skjetne, R. and Scibilia, F. - Distributed sensing of ice loads acting against the hull of a stationkeeping vessel in ice. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Isaev, V., Koshurnikov, A., Komarov, O. and Sergeev D. - Engineer-geocryological scientific-educational field work of Moscow university Master of Science students at polar regions of European Russian Arctic. European Conference on Permafrost (EUCOP4)

Isaev, V., Koshurnikov, A.V., Buldovich S.N. and Alexutina, D. - Integrated long-term research on Baydara Bay coastal line dynamic retreat (Kara sea). European Conference on Permafrost (EUCOP4)

Li, H., Lubbad, R. and Monteban, D. - Review of wave-ice interaction studies. International Association for Hydro-Environment Engineering and Research (IAHR)

Li, H. and Lubbad, R. - Laboratory Study of Ice Floes Collisions under Wave Action. International Society of Offshore and Polar Engineers (ISOPE)

Lubbad, R., Løset, S., Lu, W., Tsarau, A. and v.d. Berg, M. - Simulator for Arctic Marine Structures (SAMS). International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Katharina, A., Saud Afzal, M. and Depina, I. - Numerical Modelling of Arctic Coastal Erosion due to Thermodenudation.

Malefant-Lepage. J., Doré, G. and Lubbad, R. - Critical shear stress of frozen and thawing soils. C - European Conference on Permafrost (EUCOP4)

Marchenko, A. - Wave Attenuation in Marginal Ice Zone of Arctic Pack Ice to the North of Spitsbergen. International Society of Offshore and Polar Engineers (ISOPE)

Marchenko, A., Karulin, E., Karulina, M., Sakharov, A., Chistyakov, P., Sodhi, D. and Sliusarenko, A. - Scale effects in compressive strength of sea ice. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Influence of the Water Temperature on Thermodynamic Consolidation of Ice Rubble. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, N. - Sea ice observation and comparison with ice maps during a cruise in the Western Barents Sea in April 2017. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, N. - The Northernmost Airport Runway. How and why should we perform laser scanning? International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, N. - Reconstruction of ice drifting lines in the Barents Sea, Using IFREMER Sea Ice Products. International Society of Offshore and Polar Engineers (ISOPE)

Monteban, D., Pedersen, J.O.P., Nielsen, M. H. and Ingeman-Nielsen, T. - Modelling of hydrodynamic and wave conditions for a new harbor in Søndre Strømfjord.

Owen, C.C. and Hendrikse, H. - Ice-Induced Vibrations of Model Structures with Various Dynamic Properties. International Association for Hydro-Environment Engineering and Research (IAHR)

Ranta, J., Polojärvi, A. and Tuhkuri, J. - Peak ice loads and buckling in ice-inclined structure interaction. International Association for Hydro-Environment Engineering and Research (IAHR)

Ruud, S. and Skjetne, R. - Ice management and design philosophy. International Marine Design Conference (IMDC)

Salganik, E. and Høyland, K.V. - Thermodynamics and Consolidation of Fresh Ice Ridges for Different Scale and Configuration. International Association for Hydro-Environment Engineering and Research (IAHR)

Samardzija, I. - Two applications of a cross-correlation based ice drift tracking algorithm; ship-based marine radar images and camera images from a Ffxed structure. International Association for Hydro-Environment Engineering and Research (IAHR)

Samardzija, I., Høyland, K.V. Næss, A. and Leira, B. - Probabilistic assessment of ice environment and ridge loads for the Norströmsgrund Lighthouse. International Association for Hydro-Environment Engineering and Research (IAHR)

Saud Afzal, M., Schneider, A.K. and Lubbad, R. - Development of Predictive Tool for Coastal Erosion in Arctic; A Review

Shestov, A. - Birefringence in Ice Crystals. Principles and Application in Sea Ice Microstructure Studies. International Association for Hydro-Environment Engineering and Research (IAHR)

Shortt, M., Sammonds, P. and Bailey E. - The Physical Characteristics of Consolidated Saline Ice: Results from Ice Tank Experiments. International Association for Hydro-Environment Engineering and Research (IAHR)

Teigen, S.H., Lindvall, J.K, Samardzija, I and Hansen, R. I. - Station-keeping trials in ice: Ice and metocean conditions. Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Tsarau, A. v.d. Berg, M., Lu, W., Lubbad, R. and Løset, S. - Modelling results with a new simulator for Arctic Marine Structures – SAMS. Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Books, Articles to Books (4)

Karulina, M., Marchenko, A., Sakharov, A., Karulin, A. and Chistyakov, P. - Experimental Studies of Sea and Model. Article in book

Marchenko, A. - Analytical Solutions Describing Zonal. Article in book

Velarde, M.G., Tarakanov, R.Y. and Marchenko A. - Ocean in Motion. Book.

Zhang, Q. - Sea Ice Image Processing with Matlab. Book preview

MSc Theses (5)

Kallelid,, M.S. A Study of the Strength and the Physical Properties of Glacier-ice Runways. MSc Theses, NTNU

Zhang, F. Rubble Macro-porosity of Level Ice Accumulation on Wide Sloping Offshore Structures. MSc Theses, NTNU

Hoel, P.B. & Rolandsen, A.N. Digital Twin of Vessels in Arctic Environments - Extending a Simulation Environment to allow for External Control. MSc Theses, NTNU

Islam, A. M. Erosion in the Arctic: A Thermoabrasion Model to Predict Shoreline Change After an Extreme Event. MSc Theses, NTNU

Massey, D. Numerical Simulation of Ice-Rubble Mound Breakwater Interactions. MSc Theses, NTNU

Key Notes and Oral Presentations (59)

Ahmad, N., Bihs, H. and Arntsen, Ø. - High-Resolution CFD Modelling of Scour in the Marine. Presentation of the doctoral thesis

Ahmad, N., Bihs, H. and Arntsen, Ø. - Wave-induced liquefaction of seabeds and its effects on marine structures – Theory, Experimental and Numerical approaches. Trial lecture for the degree of Philosophia Doctor

Bekele, Y. and Sinitsyn, A. - Engineering Considerations for Foundation Design in Permafrost Areas. SAMCoT WP6 Meeting

Bekele, Y. Multi-Criteria Decision-Making (MCDM) - Approaches for Locating Coastal Structures. Application Example to Pipeline Landfall Selection. SAMCoT WP6 Meeting

Bekele, Y. Multi-Criteria Decision-Making (MCDM) - Approaches for Locating Coastal Structures. Application Example to Pipeline Landfall Selection. Workshops Other

Chernyak, J. - Current change sea level in the Russian Arctic. Workshops Other

Chernyak, J. - The software complex Permafrost 3D. Workshops Other Chernyak, J. - Distribution pattern of frozen saline deposits of the Arctic Coast. Workshops Other

Christensen S.O. - Soil investigations, field and laboratory tests. SAMCoT Meeting

Depina, I. - Solutions and design for coastal protection: Report and input in Technical Note. SAMCoT WP6 Meeting

Depina, I. - Solutions and considerations for pipeline design: Report and input in Technical Note. SAMCoT WP6 Meeting

Eik, K. J. - ISO 34104 Petroleum and natural gas industries, Arctic operations, Ice management: Status September 2018. Workshops Other

Eik, K. J. - Ice incursion incident – SeaRose FPSO 2017. Workshops Other

Gong, H. - DEM Modelling on Ship-Ridge Keel Interaction. Workshops Other

Heyn, H-M. - Distributed sensing of ice loads acting against the hull of a station-keeping vessel in ice. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Islam, A. M. - Erosion in the Arctic: Thermoabrasion Model to Predict Shoreline Change after an Extreme Event. Workshops Other

Li, H. - Modelling the propagation of waves in the presence of sea ice. Workshops Other

Løset, S. - Nordområdene. Invited lecture at Ptil

Løset, S. - Simulator for Arctic Marine Structures (SAMS). The First Polar Equipment Technology Innovation Forum, China

Løset, S. - Arctic Engineering at NTNU - Norway, SAMCoT, ArcISo. Workshops Other

Løset, S. - SAMCoT Overall Status. RCN Site Visit

Løset, S. - SAMCoT WP4 Status. RCN Site Visit

Løset, S. - SAMCoT Overview. General Assembly

Løset, S. - SAMCoT WP4 Status. SAC MeetingLøset, S. SAMCoT ASM2 Side Event: Arctic Science Cooperation with Norway, Berlin, 24.10.2018

Løset, S. - SAMCoT Status. Meeting NTNU Rectorate 02.11.2018

Lubbad, R., Løset, S., Lu, W., Tsarau, A., v.d. Berg. Simulator for Arctic Marine Structures (SAMS). International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Lubbad, R. Coastal Technology. SAMCoT Technical Workshop

Marchenko, A., Karulin, E., Karulina, M., Sakharov, A., Chistyakov, P., Sodhi, D. and Sliusarenko, A. Scale effects in compressive strength of sea ice. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. Influence of the Water Temperature on Thermodynamic Consolidation of Ice Rubble. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. Wave attenuation in marginal ice zone of Arctic pack ice to the North of Spitsbergen. International Society of Offshore and Polar Engineers (ISOPE)

Marchenko, A. - Influence of the water temperature on thermodynamic consolidation of ice rubble. Workshops Other

Marchenko, N. - Sea ice observation and comparison with ice maps during a cruise in the Western Barents Sea in April 2017. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, N. - The Northernmost Airport Runway. How And Why Should We Perform Laser Scanning? International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, N. - Reconstruction of Ice Drifting Lines in the Barents Sea, Using IFREMER Sea Ice Products. International Society of Offshore and Polar Engineers (ISOPE)

Marchenko, N. - Benefits of Spatial Collaboration in Arctic Research Project Using ArcGIS Online. (ESRI)

Malefant-Lepage. J. - Erodability characteristics of frozen/thawing soils. Workshops Other

Monteban, D. - Wave-ice interactions studied with SAR. Workshops Other

Nilsen. A. - SAMCoT WP Adm Activities/Update2018. SAMCoT Board Meetings

Nilsen. A. - SAMCoT WP Annual Report 2018. SAMCoT Board Meetings

Samardzija, I. - Towards understanding the correlation between level ice thickness and ridge keel depth statistics. Workshops Other

Sinsabvarotom, Ch. - Probabilistic Analysis of Ice and Sloping Structure Interaction Based on ISO Standard by using Monte Carlo Simulation. Workshops Other

Rohlén, Å. - Case study on Drilling in ice conditions: Follow-up regarding study for SAMCoT Workshops Other

Ruud, S. - IM & Design Philosophy - Status and actions. Workshops Other

Ruud, S. - Ice management and design philosophy. International Marine Design Conference (IMDC)

Ruud, S. - Modelling Ice Management Performance. Workshops Other

Ruud, S. - Ice Management and Design Philosophy. Workshops Other

Ruud, S. - Comment to Standard Norge related to voting on ISO/FDIS 35104 from SAMCoT WP5.2

Salganik, E. - Consolidation experiments in fresh ice ridges. Workshops Other

Samardzija, I. - Two applications of a cross-correlation based ice drift tracking algorithm; Ship-based marine radar images and camera images from a fixed structure. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Shestov, A. - Birefringence in Ice Crystals. Principles and Application in Sea Ice Microstructure Studies. International Association for Hydro-Environment Engineering and Research (IAHR)

Shortt, M. - A Field Study Investigating the Effect of Brine Drainage on the Consolidation of Sea Ice. Workshops Other

Sinitsyn, A. - Guidelines and Technical Note for development of coastal infrastructure in cold climate – Update. Workshops WP6

Sinitsyn, A. - Guidelines and Technical Note for development of coastal infrastructure in cold climate – Update. Presentation at SAMCoT Board Meetings.

Sinitsyn, A. - Guidelines and Technical Note for development of coastal infrastructure in cold climate – Update. Workshops Other

Sinitsyn, A. - Guidelines and Technical Note for development of coastal infrastructure in cold climate – Update. Workshops Other

Skjetne, R. - SAMCoT WP5 Status. RCN Site Visit

Skjetne, R. - SAMCoT WP5 Status 2018. SAMCoT Technical Workshop

Skjetne, R. - SAMCoT WP5 Status. SAC Meeting

Teigen, S.H., Lindvall, J.K. and Hansen, R. I. - Station-keeping trials in ice: Ice and metocean conditions. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Mass Media & Other Popular Media (3)

Bazilchuk, N.R. - When a hole in the ice is a big problem (Video). GEMINI

Nilsen, A. - SAMCoT Annual Report 2018. NTNU Graphic Center

Nilsen, A. - SAMCoT Newsletters 2018 (1). NTNU Graphic Center

FIGURES 2018

In October 2018, SAMCoT's Centre Management Group (CMG) presented the Cost, Time and Resources (CTR) plans for 2019. SAMCoT's Board approved them. In December, the Research Council of Norway (RCN) approved SAMCoT's CTRs for 2018 and 2019. The tables below show, following the European Free Trade Association (EFTA) Surveillance Authority (ESA) reporting format, the funding and incurred costs for 2018 as reported by the Centre on January 20 2019 to the RCN.

SFI Annual accounting report 2018 - Project Characteristics and Costs (All figures in 1000 NOK)

Item	Host NTNU	Stiftelsen SINTEF	UNIS	Equinor	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	AkerBP	Lundin	Kværner	Norwegian Coastal Adm.	Swedish Polar Research Secretariat	DTU	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	Total cost
WP1			3 500								33									17	3 551
WP3 & IVOS	3 950			12		66	1 176				33				306	731	890	323		17	7 504
WP4	3 247			12		66		47			33									17	3 423
WP5	1 955			43		66	21	47			33									17	2 182
WP6	1 922	3 590		12		66					33								176	17	5 816
EIAC				103	39	66	72	19		33	33										364
SAC	152																				152
SFI Equipment	53		198																		251
SFI Administration	3 175	102	501	23	63		13														3 876
Total budget	14 454	3 692	4 199	206	102	328	1 282	112		33	199				306	731	890	323	176	87	27 119

SFI Annual Work Plan 2018 - Funding (All figures in 1000 NOK)

ITEM	Host NTNU	Stiftelsen SINTEF	UNIS	Equinor	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	AkerBP	Lundin	Kværner	Norwegian Coastal Admin	Swedish Polar Research Secretariat	DTU	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	Other private funding	RCN Grant	Other Public funding	Total state aid	Total cost
WP1			1 138	245	241	362	160	60		250	133									17		1 600		2 738	6 944
WP3 & IVOS	2 519			257	241	362	1 336	60	200	250	133				-21	64	265	123		17		1 600		4 119	11 526
WP4	801			257	241	362	160	107	200	250	133									17		1600		2 401	6 529
WP5	340			288	241	362	181	107	200	250	133									17		1 600		1 940	5 660
WP6	201	566		257	241	362	160	60	200	250	133	330							49	17		1600		2 131	6 558
EIAC				103	80	39	71	19	200	33	33														578
SAC																									0
SFI Equipment																			107						107
SFI Administration	1 488	566	501	23	63		13																	1 989	4 642
Total budget	5 350	1 132	1 639	1 431	1 348	1 848	2 081	412	1000	1 283	699	330			-21	64	265	123	49	87		8 000		15 319	27 119