Sustainable Arctic Marine and Coastal Technology

SAMCoT

Annual Report 2014

sfi Centre for Research-based Innovation

NTNU – Trondheim
Norwegian University of Science and Technology

SAMCoT KEY FIGURES	2014	2013	2012	2011	Accum. Fig.
Turnover (in 1000NOK)	33 666	59 887	45 770	13 859	**153 182**
Industry Partners	13	11	11	9	
Research Partners	8	7	7	7	
Public Partners	1	1	1	1	
PhD Candidates	21 (6 Female)	22 (4 Female)	19 (4 Female)	10 (1 Female)	
Post Docs	4 (1 Female)	3	1	0	

SAMCoT KEY FIGURES – PUBLICATIONS	2014	2013	2012	2011	Accum. Fig.
Massmedia Communication Items (Newspapers, Radio, TV)	25	9	8	2	**43**
MSc Thesis	9	8	6	1	**24**
Key Notes and Oral Presentations	104	43	12	6	**162**
Journal and Conference Papers	62	40	18	15	**119**
PhDs Defences	3	3	1	2	**9**

SAMCoT PARTNERS 2014 AND REPRESENTATIVES TO THE GENERAL ASSEMBLY:

Engineering Challenges in the Arctic addressed by SAMCoT

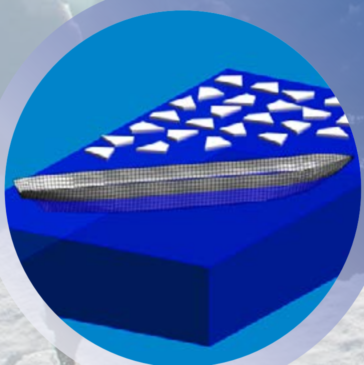
VISION:

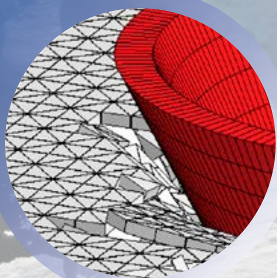
SAMCoT is a leading national and international centre for the development of robust technology necessary for sustainable exploration and exploitation of the valuable and vulnerable Arctic region.

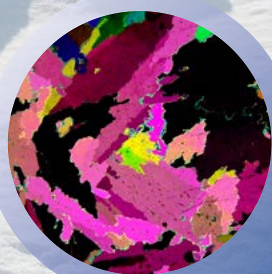
SAMCoT meets the challenges created by ice, permafrost and changing climate for the benefit of the energy sector and society.

Arctic Field development
SAMCoT Industry Partners

Model development
WPs 3, 4, 5, 6







Quantifying the Physical Environment
Ice Mechanics/
Physics

Review of SAMCoT 2014 highlights:

Dear Researchers, Professors and Partners:

In 2014, SAMCoT membership numbers grew with the addition of three Industry Partners and one Research Partner, all with great international relevance to Arctic research. These additions are proof that SAMCoT's focus on meeting key challenges in the Arctic is in line with the expectations from the industry and with the topics of research chosen by key international research institutions.

All SAMCoT partners have also made an additional effort in 2014 to meet the high standards required from the Research Council of Norway during the on-going Midway Evaluation. As a result the Centre's structure has improved, the collaboration among partners was strengthened and the research objectives have now been fine-tuned for the coming three years.

Field/Lab Work Highlights

SAMCoT is committed to building new capacity in the next generation of Arctic experts and in doing so, trains the next generation of industry thinkers. This cannot be achieved without providing proper and extensive field experience for all SAMCoT participants, both researchers and industry members. The active participation by SAMCoT members in the Centre's fieldwork is a key component in helping to develop highly qualified personnel with world-class expertise.

Field Work in the Barents Sea, Svalbard Archipelago & Russia

Barents Sea

The Barents Sea is an important location for SAMCoT's field activities. All of SAMCoT's Industry & Research Partners are interested in better understanding an area to which they are committed because of its economic and social importance. SAMCoT postdoc Aleksey Shestov was responsible for preparing the 2014 expedition to the Barents Sea on the research vessel Lance because of his expertise with both the scientific equipment and scientific planning needed for the expedition, as well as HSE and logistics.

Key international researchers with links to SAMCoT were invited to join the 2014 expedition, including Prof. Peter Sammonds from University College London; Dr. Rocky Taylor, CARD Chair in Ice Mechanics at Memorial University and researchers Drs. Eleanor Bailey and Ian Turnbull; as well as two Memorial graduate candidates, Doug Smith and Regina Sopper. SAMCoT promotes researcher mobility by providing a great platform for collaborative field activities, which in many cases are unique expeditions with the possibility of only limited participation. Field activities are one of the Centre's strengths and attract many internationally renowned researchers who understand the uniqueness of joining SAMCoT's expeditions when invited. In this way, SAMCoT stimulates knowledge exchange and helps our PhDs, researchers and participants build an ever expanding network, which over time is a positive catalyst for the creation of spin offs.

SAMCoT PhD candidate Renat Yulmetov was lucky enough to be one of the SAMCoT researchers who joined the 2014 Lance expedition. His main task was to deploy 360° cameras and collect the data from observing ice floe size changes across the ice edge. He planned to use these data as valuable input to his recently developed broken ice generator. Unfortunately extreme weather conditions in the form of a strong heat storm on the East side of Svalbard made this work impossible. Instead, he worked closely with the international group of experts on board sampling ice from an ice floe that was large enough to moor and to work on. Renat explains that "we were lucky as this was probably the only large ice floe in Storfjorden that we were going to encounter".

Van Mijen Fjord

SAMCoT PhD candidates and postdocs contribute to the course programme offered at UNIS, assisting in the supervision of master's and bachelor's candidates at different locations in the Svalbard archipelago. Their tasks are strongly linked to their own research and add to their curriculum by obtaining valuable field, lab and supervising experience.

Sveasundet is a location of great interest to SAMCoT researchers due to the physical conditions. During the winter season of 2014 (January to May) SAMCoT PhD candidate David Wrangborg made six field visits to this area to study the growth, crack formation and stress pattern in coastal sea ice around Barryneset. "We deployed eight earth pressure cells to follow the stress pattern both close to the shoreline as well at further out in the inlet. We followed the temperature in the ice using thermistor strings installed in different locations," David explains. David also followed the crack pattern and ice movements around the coastline with the help of laser scanning and total station measurements. Gaining knowledge of the ice thickness and freeboard, collecting ice samples for salinity, density and other measurements and learning more about tidal behaviour during the entire season are key parameters to reach a better understanding of coastal sea ice growth, behaviour and physical properties.

Aleksey Shestov is also conducting important research in this area, under the harsh Arctic conditions of the Svalbard archipelago. Every year, Aleksey spends a couple of weeks on the land-fast ice of van Mijen Fjord. In March 2014 with Professor A. Marchenko, Aleksey led a research expedition that included UNIS candidates, visiting researchers from Russia and Professor Erland Schulson from the USA. Professor Schulson was the 2014 Fulbright Arctic Chair. Aleksey spent most of his time studying the hydrology regime in Braganzavågen. SAMCoT's research is often linked to the construction of new infrastructure and the further development of an area. This is the case of the southern shore of Braganzavågen where the Norske

Spitsbergen Kulkompani AS is interested in possible new activities. "Hydrological information is useful for the road design," Aleksey says.

Longyearbyen Harbour

Location and cooperation are very important for research, and to this end, SAMCoT researchers work closely with the harbor of Longyearbyen. A plastic quay with 19 mooring lines to the bottom is located there to test load cells and logging forces. SAMCoT postdoc Aleksey Shestov is responsible for the research which from 2016 may be expanded to include a larger quay and a permanent marine lab.

Isdammen

SAMCoT PhD candidate Torodd Nord led a group of UNIS candidates for an Ice Mechanics course at Isdammen, an area close to Longyearbyen. Later in the year, in November, he returned to Svalbard to assist with teaching at the lab week for the master's candidates in Physical Environmental Loads on Arctic Coastal and Offshore Structures. "We installed a tactile sensor (pressure sensor) on the indentation rig for the first time, and which we tested in the lake above Mine 7. Snowfall,-15ºC air temperature and winds exceeding 10 m/s ensured good conditions for testing the tactile sensor under the Arctic climate conditions," explains Torodd. PhD candidate Renat Yulmetov was also supervising candidates at this same location during the 2014 Arctic Offshore Engineering course at UNIS. The course extends over one week, including compulsory safety training. HSE, logistics and reporting on fieldwork are all key activities offered by the course.

Vestpynten

In 2014 an international group of researchers, including SAMCoT PhD candidate Emilie Guegan, Prof. Hanne Christiansen and researcher Anatoly Sinitsyn from UNIS along with 2 PhD colleagues from University Laval in Quebec met at the Vestpynten field site. This site has been

monitored for the past two years by Emilie, who works in the Coastal Technology research area. They download data and moved a heat flux meter to the Adventdalen CALM research site. "The CALM site was chosen to calibrate the measurements of the heat flux meter because it provides meteorological data, ground temperatures as well as ground thermal properties," explains Emilie. A Coastal Technology dream team in action!

Ny-Ålesund

In February, PhD candidate Petter Norgren, whose studies are a part of the SAMCoT Ice Management research area, participated in a field campaign in Ny-Ålesund, Svalbard. His responsibility was to operate and program the NTNU REMUS autonomous underwater vehicle (AUV). This campaign was part of the UNIS course "Underwater robotics in the Arctic Polar night". "We conducted several missions with the AUV, trained candidates in the use of AUVs and remotely operated underwater vehicle (ROVs), and gathered valuable scientific data related to Arctic biology. During the seven missions, we gained valuable experiences related to operation of underwater robots in the Arctic – making this field campaign especially relevant for my work with AUVs in the Arctic," Petter said.

Russia – Varanday, Pesyakov and Medynskiy

SAMCoT and SOI, the State Oceanographic Insitute, Moscow, have collaborated closely since 2012, in an effort that is fundamental to the Coastal Technology research carried out by Centre scientists. SOI researchers collected field data in Varandey in August. Three SOI researchers, Osip Kokin, D. Kuznetsov, and Aino Kirillova, performed topographical measurements on 40 profiles recovered from Pesyakov, Varandey and Medynskiy. In addition the researchers downloaded temperature data from a polygon on Pesyakov Island, and made observations aimed for potential work on a polygon on the thermo-abrasive coast of Medynskiy sector.

Laboratory work

Many of the SAMCoT activities require extensive laboratory work. This is especially true for Anna Pustogvar, whose work is mainly based on empirical studies made in the Ice Lab. She carried out two series of tests in the spring of 2014 at the cold laboratory at NTNU. Her work relates to the research topic of Material Modelling and in particular to rubble ice. For these experiments, Anna used an Oedometer originally designed for testing the compressibility of rocks and other coarse materials. She presented the results on a conference paper at the 22nd IAHR International Symposium on Ice in Singapore. Her paper was among the 5 best papers at the conference (from a total of roughly 30 candidate papers) which indicates the importance of Anna's work and her results!

Also at NTNU, but this time using the lab of another Centre for Research-Based Innovation (SIMLab), SAMCoT PhD candidate Martin Storheim got the chance to conduct pilot test experiments on coupled ice-structure interaction at high (realistic) velocities. With the assistance of, then PhD candidate Ekaterina Kim (who is now a postdoc) and Torodd Nord, four ice bullets were produced. The experiment consisted in shooting the ice bullets, using a pendulum accelerator rig, to impact into a steel beam at 8 m/s. The candidates could observe both elastic and inelastic beam deformations and large amounts of crushed ice. "Based on the data we measured and high-speed video recordings, we can show that we achieved a coupled interaction, in which the deformations of the steel beam contributed to increased confinement of the ice, thereby increasing its strength. The transition from elastic steel response to large inelastic deformations was rapid, emphasizing the need to further study the coupled ice-structure interaction with brittle ice in the shared energy regime," Martin explains.

Martin and the group of researchers who worked on this experiment also had an unusual – and very significant – chance to share their science with the public. A team of journalists from Discovery Channel Canada came to Trondheim to film the experiment and interview Martin, Torodd and Ekaterina, among others. The programme was aired on Tuesday, 9 September, and was third place in the ratings for that night, with about 200 000 viewers. As Martin happily observed, "The experiments gave us also a good opportunity to try out the new SAMCoT jackets!"

Knuste «isfjell» for Discovery channel

- Det dere gjør her er enestående i verdenssammenheng, sier Discovery Channel-produsent Koula Bouloukos.

Other lab-based experiments at the UNIS Ice Lab provided real on-hands experience to many candidates as well as information on ice-structure interaction and uniaxial testing of ice samples. "The aim of this work was to collect data as well as to teach candidates how to operate the instruments and extract ice parameters from the data to judge the behaviour of ice and distinguish between ductile and brittle failure," said Torodd, who was responsible for supervising UNIS candidates at the Ice Lab. "Some of the experiments allowed the candidates to see the cracking in the ice and they were introduced to the problem of having fixed structures in ice-choked waters. This really gave them a sense of the severe forces acting on the structure, and they could also observe the mechanisms occurring at the interface between a structure and the ice," Torodd said with great enthusiasm.

Highlights from Theory & Design Development for Innovation

The characteristics of an SFI is high scientific quality of research and relevance. However, there should also be a high potential for innovation and value creation, and active cooperation between innovative companies and those doing the research. SAMCoT is a bridgehead for international cooperation and recruits talented researchers. The research being done provides a basis for innovation either within the Centre or within the partners.

The work of SAMCoT PhDs goes further than field and lab activities and fundamental research. As a Centre for Research-based Innovation, and with an emphasis on innovation, SAMCoT needs to provide its partners with theory and design developments that will lead the industry to develop innovative items internally. That was Marnix van den Berg's job in 2014. During the first half of the year, Marnix developed a concept for a meso-scale floating buoy for the measurement of ice forces. "We gained a lot of insights and proposed solutions for several design challenges. A meso-scale floating buoy can fill the gap between ice tank tests and full-scale measurements and can be used to verify and develop ice load prediction models," Marnix says. After six months of working for SAMCoT, it was natural for him to decide in August to continue under the centre's umbrella and take a PhD position. "During my first few months I investigated the application of a non-smooth discrete element method for the modelling of ice rubble. This is a very interesting method that can potentially speed up discrete element calculations by several orders of magnitude. The results are promising and will be presented at POAC 2015," Marnix said.

This flying start for Marnix illustrates the significance of what we name "SAMCoT Toolbox". This product is being developed at NTNU to facilitate the communication between the PhD candidates in WP4 and across the work packages. It assures us a continuous development and protects our candidates from reinventing the wheel again and again. SAMCoT Toolbox as a communication platform is also very helpful for the candidates to calibrate and validate their work. Several PhD candidates have been actively involved in this collaboration. One of these candidates is Andrei Tsarau, whose mathematical models have been implemented to simulate the fluid effects on ice. Another candidate is Renat Yulmetov from WP5, whose engagement in the SAMCoT toolbox development of was very useful to transfer knowledge from WP4 about floating structures in ice to WP5 where it was applied to simulate the towing and free drift of icebergs in ice. In return, the work of Renat to define and numerically generate an ice field with given concentration and floe-size distribution was implemented in the Toolbox and hence it was useful to all the PhD candidates in WP4.

Innovation is often linked to the very close collaboration of our PhDs with the industry. This was the case for Petter Norgren, who in the summer of 2014 conducted important testing of a custom-made sensor module for Autonomous Underwater Vehicles (AUV) based geological surveys. Statoil hired NTNU's Applied Underwater Robotics Laboratory (AUR Lab) and the Remote Environmental Monitoring Unit, an autonomous underwater vehicle (REMUS AUV) for testing. The sensor module was 1.25 metres long, which nearly doubled the length of the AUV. The tests included an analysis of AUV manoeuvrability, the tuning of controllers, and assistance during interfacing. "Since I have been working on designing and interfacing of another sensor module for the REMUS, this work was highly relevant for my research," Petter explains.

Highlights from Research Mobility, Academic Work, Scientific Conferences

SAMCoT's greatest societal impact will come from its production of people - human resources (HR), in the form of highly educated engineers with a deep knowledge of Arctic research and even more important, a real understanding of the Arctic environment. To achieve this, all SAMCoT researchers are required to take Health, Safety and Environment courses at The University Centre in Svalbard, UNIS, at 78° North and most participate intensively in field activities during their engagement. In addition, SAMCoT PhD candidates often participate in the supervision of master's candidates and in different academic programmes. The supervision of SAMCoT PhD candidates as well as the production of MSc and BSc candidates is critical to the Centre's activities. The quality of SAMCoT's researchers and professors contributes to this success. One example is Professor Andrei Metrikine, who was selected as the Best Civil Engineering teacher at Delft University of Technology. He was awarded this honour not only by Civil Engineering bachelor's candidates, but was also elected best teacher in the Civil Engineering MSc programme in Structural Engineering, as well as best teacher of the interfaculty MSc programme in Offshore and Dredging Engineering.

Face-to-face discussions often result in new ideas and help researchers advance their studies. These interactions are very beneficial for SAMCoT and for ice mechanics research in general. The Centre enables and encourages such exchanges as well as participation in conferences, dissemination of results, the production of conference and journal papers and the presentation of results at international conferences.

Research Mobility

At the end of October, PhD candidate Sergey A. Kulyakhting visited Nicolas Serré from Multiconsult in Tromsø to discuss the simulation of rubble field-structure interaction tests performed as a part of the Rubble Ice Transport on Arctic Offshore Structures (RITAS) project. "We had many fruitful discussions during my stay, especially how to set up boundary conditions correctly and which model parameters could be interesting for parametric study," explains Sergey. On a different occasion, Sergey hosted a SAMCoT colleague at NTNU, postdoc Arttu Polojarvi. Arttu explains the importance of his stay at NTNU at the end of 2014: "This research visit gave me a chance to work on the topic of homogenization of ice rubble with Sergey Kulyakhtin. Our work was initiated during the two months I worked in Trondheim, and now we are continuing it through emails and Skype calls, since I am back at Aalto University," says Arttu.

SAMCoT Industry Partners are often involved in the supervision of PhDs, as is the case with Farzad Faridafshin, whose work tries to determine whether probabilistic methods are the only coherent framework for the design of Arctic offshore structures. Farzad is looking into scenarios where the offshore structure is protected by a number of icebreakers. Fundamental developments have been necessary before moving onto real Arctic problems. In 2014 his work was supported by a number of SAMCoT Industry Partners, including DNV GL and Statoil. Farzad spent some time at the DNV GL offices in Høvik and had several rounds of interesting interactions with his supervisors.

As in previous years, several workshops and seminars were organized in 2014 to promote discussions among SAMCoT participants and strengthen the collaboration between researchers and the industry. These included two Ice Rubble workshops (organized at NTNU and Aalto) and a Scientific Seminar and a Technical Workshop organized at NTNU with the participation of all SAMCoT parties. The PhD candidates have a chance to present and discuss their results with Research and Industry Partners, which often results in changes to the research direction of the PhD candidates' work. For example, Chris Keijdener presented a model used to analyse ice-structure interaction at high speed. "A point was raised during the discussion that the

added mass of the water will play an important role. After returning to Delft we started working on incorporating the effects of hydrodynamics into our models," Chris said. PhD candidate Hayo Hendriksen also enjoyed the collaboration with international researchers, including Professor Erland Schulson from Dartmouth College, USA; Dr. Kari Kolari, from the VTT Technical Research Centre of Finland; and Dr. Devinder Sodhi, from the US Army's Cold Regions Research and Engineering Laboratory and key Industry Partners, such as Shell and TOTAL for his work on finding the key to deciphering ice induced vibrations.

22nd IAHR International Symposium on Ice

This summer SAMCoT PhD candidate Renat Nailevich Yulmetov was recognized with the best candidate paper award at the IAHR conference held in Singapore. Together with Renat many other SAMCoT PhDs candidates presented their work at IAHR, including PhD candidate Janne Ranta who started his PhD in late 2013. "During the spring of 2014, when I was writing my first conference paper on discrete element simulations, I learned many new things not only from the topic of my research, but also from ice mechanics and statistics. The conference trip itself to the IAHR ICE 14 conference was fruitful and the conference venue in Singapore fulfilled all expectations and more," explains Janne. (See dissemination list for more information regarding SAMCoT's contribution to IAHR.)

Eurodyn conference in Porto

SAMCoT's WP3, Ice Induced Vibrations, was well represented at the Eurodyn conference by Torodd S. Nord, Eliz-Mari Lourens, Andrei Metrikine and Ole Øiseth. "We were able to present our results on force identification at the conference," Torodd said.

NUMGE, WCCM and IACMAG Conferences in 2014

In 2014 PhD candidate Yared Worku Bekele reached important milestones in the development of a fully coupled Thermo-Hydro-Mechanical finite element model for frozen soil. He presented the finalized theoretical development of the governing equations of the THM model at the 8th European Conference on Numerical Methods in Geotechnical Engineering (NUMGE) in Delft. The results from the first step of the numerical implementation for groundwater flow were presented at the 11th World Congress in Computational Mechanics (WCCM), in Barcelona, Spain. The results from a test implementation for one-dimensional freezing and thawing were presented at the 14th International Conference of the International Association for Computer Methods and Advances in Geomechanics (IACMAG), in Kyoto, Japan.

International Conference on Maritime Technology (ICMT)

For Andrei Tsarau, 2014 marks the midterm milestone of his research programme as a PhD candidate. The main results of his work to date were presented at several conferences and scientific workshops during the year. Among them were the 2014 International Conference on Maritime Technology in Glasgow and the 22nd IAHR International Symposium on Ice in Singapore. "The conferences helped not only in establishing contacts with experts in marine technology and ice researchers worldwide but also gave me input for my papers for the Journal of Cold Regions Science and Technology," explains Andrei.

European Permafrost Conference (EUCOP 4th)

"A warm place for a cold topic," commented Emilie Guegan on the 4th European Permafrost Conference held in Portugal. SAMCoT was well represented with the

PhDs Defences

WENJUN LU – The completion of 51-month-long PhD journey

Wenjun Lu reached peak production in his scientific research in 2014 when he submitted three papers to different academic journals. He addressed fundamental questions in relation to the fracture of ice floes and proposed analytical solutions in relation to the development of the SAMCoT Toolbox. Because of these efforts, Wenjun managed to compile a very respectable number of articles in a single doctoral thesis. He defended his work in hash interrogations in front of top experts in the field and then enjoyed flowers, applause, a defence dinner and a well-deserved vacation back home in China. He is back in Trondheim to continue his contribution to SAMCoT as a postdoc.

EKATERINE KIM – 2014 – a year to remember three things about ice

After her promotion and the start of her postdoc in 2014, Ekaterina Kim and her SAMCoT partners uncovered unusual new facts and angles in ice science. Her mission in the coming years is to keep uncovering mysteries about ice. Here are three things that she believes are good to know:

In Ancient Greek geography, the North, covered by ice in winters, was regarded as a frame for the rest of the world.

Specific energy absorption during the ice crushing process is a scale-independent and size-invariant parameter of the ice/indenter system. Our finding indicates that this specific energy absorption can be used as an ice material parameter in numerical simulations.

By taking into account the strain-softening behaviour of ice when rapidly deformed beyond terminal failure within the regime of brittle behaviour, two effects can be explained: the decrease in pressure with increasing area (Sanderson's pressure-area relationship), and, for a given area, the increase in pressure with the increasing radius of the indenter. In the context of structure-ice interactions, this means that many parameters are hidden in the coefficients in the pressure-area relationship. Ice pressure is not just a function of contact area. There is a link between a constitutive stress-strain relationship for ice and the resulting pressure-area dependency that could be used in future mathematical models of ice crushing.

presentation of results from three research projects to the international research community through posters and oral presentations.

OMAE & PSAM

Other important conferences for SAMCoT dissemination activities in 2014 have been the International Conference on Ocean, Offshore and Arctic Engineering (OMAE) in San Francisco, US, and the Probabilistic Safety Assessment & Management conference (PSAM) held in Honolulu, Hawaii, where PhD candidate Martin Hassel presented a paper on the main challenges with the current risk model for collisions between ships and offshore installations on the Norwegian continental shelf.

A look ahead to 2015

The work done in 2014 has paved the way to exciting new research topics and activities. Here is a short summary of what we are looking forward to in 2015:

- Many new master's candidates projects are now planned that involved field and lab campaigns as well as literature studies. Working with master's candidates has resulted in very positive outcomes for SAMCoT. For example, in the autumn of 2014, one of WP3's master's candidates, Øyvind Wiig Pettersen, won the prize for the best Civil Engineering thesis with his master's thesis: "Model-based stochastic-deterministic State and Force Estimation using Kalman filtering with application to Hanko-1 Channel Marker." Øyvind's work was supervised by SAMCoT researchers Ole Øiseth, Torodd S. Nord and Professor Emeritus Mauri Määttänen, who is an expert on Finnish channel markers.

- New Experimental Lab campaigns have been launched related to different research topics. A good example is PhD candidate Anna Pustogvar, who has defined a new research topic related to the packing of ice rubble based on her results from 2014. An experimental campaign on this topic is currently being developed.

- New field campaigns are in place. Often the participation of PhD candidates in the different workshops arranged by the Centre can result in new activities. This was the case for Åse Ervik who was in contact with the head of logistics at UNIS during the SAMCoT Arctic HSE workshop. He mentioned a field project planned for the winter of 2015 in which the Norwegian Polar Institute (NPI) will freeze the research vessel RV Lance into the ice at 84 degrees north and drift south. Åse knew there must be ice ridges there. After a flurry of emails and a meeting in Tromsø with NPI, Åse will be spending the spring on Svalbard as a participant in N-ICE2015. Postdoc Aleksey Shestov will also participate in this exciting project.

- New PhD candidates – great expectations. In 2014 three new PhD candidates joined the SAMCoT team. The most recent to come on board is Hans-Martin Heyn, who hopes with his research to enable safer and more reliable offshore operations in Arctic conditions. "Operations in Arctic environments are technologically challenging and must be conducted with the greatest care in order to prevent disasters in the ecologically sensitive environment of the Arctic. Therefore, fault-tolerance of station keeping will be one of the major aspects of my research, which I started in September 2014," Hans-Martin says.

- Last but not least, we have defined some new and exciting associated projects, including the Ice-Induced Vibrations of Offshore Structures (IVOS) project leaded by HSVA and supported by seven SAMCoT Industry Partners, all of whom have agreed to increase their financial support to the Centre through this project. We take this as a strong and clear sign of the Industry interest in SAMCoT activities and spin-offs.

Thanks to everyone who made SAMCoT's progress and successes possible in 2014. We look forward to continuing another exciting year in 2015.

The View from the Industry

The Arctic is cold, dark for half of the year, and poses challenges not commonly found in other development areas. These factors demand innovative approaches and technology-driven solutions in Arctic areas. SAMCoT's industry partners say they benefit from their cooperation and exchange with the centre because it boosts company R&D and innovation – which in turn enables safe operations in the Arctic, with minimum environmental impact.

The Arctic is cold, dark for half of the year, and poses challenges not commonly found in other development areas. These factors demand innovative approaches, in part because companies cannot operate in conventional ways in Arctic areas. SAMCoT's industry partners say they benefit from their cooperation and exchange with the centre because it boosts company R&D and innovation – which in turn enables safe operations in the Arctic, with minimum environmental impact.

That industry finds SAMCoT a worthwhile partner is clear from the numbers: in 2014, the number of SAMCoT industry partners jumped by 30 per cent, from 10 to 13, with the addition of ExxonMobil, Lundin and Det Norske.

Many SAMCoT partners say the centre's structure and operation are an innovation on their own. But the new partners add that many other factors – from the ability to work with people from academia and government in a collaborative environment to the ability to develop technologies that can handle Arctic conditions – are among the reasons they have decided to sign on to SAMCoT in 2014.

The next generation of Arctic experts

ExxonMobile's Upstream Research Company decided to join SAMCoT because it saw there would be clear research benefits, said Daniel Fenz, PhD, PE, with ExxonMobil's Offshore and Environment Function, Arctic, Metocean and Structures Section.

"ExxonMobil became interested in SAMCoT's research programme due to the breadth, quality and relevance of the Centre's work," he said. "The wide range of partners from industry, academia and government allows us to leverage our research funds - and do so in a collaborative environment with diverse perspectives."

Fenz said that by joining SAMCoT, ExxonMobil anticipates being able to develop Arctic technologies from the research-based knowledge cultivated through the Centre's activities.

"The methods and models for Arctic phenomena developed with SAMCoT will provide a firm foundation for meeting our in-house research needs and providing the technology needed to support our Corporation's present and future Arctic operations," he said.

He also commented favourably on one of SAMCoT's strongest assets: its production of bright PhDs who have a cutting-edge understanding of Arctic conditions and how to work safely there.

"It has been said that 'working with smart people makes you smarter'," he said. "We expect that working with members of the current and next generation of Arctic experts will no doubt make us smarter."

Responsible operations in the Barents Sea

Det norske oljeselskap has had a presence in northern Norway since 2007 and is working in the Barents Sea, with a long-term commitment to local industries in Northern Norway and to the Arctic, said Bjarne Kristoffersen, with the company.

Kristoffersen said that SAMCoT is a cost effective way for Det norske and other industries that work in the Arctic to understand the complexities of working in this challenging environment, and to fill existing technological gaps that have been identified, especially by the RU-NO Project. The

RU-NO Project ran from 2012-2014, and was a cooperative Norwegian-Russian oil & gas industry project that assessed the gap between the technology currently available and the technology needed for extracting oil and gas resources in the Barents, Pechora and Kara Seas in an environmentally sound and safe way.

"Our expectations are that the SAMCoT programme will develop safe and reliable technical solutions based on cost effective and innovative technical solutions within relevant disciplines," Kristoffersen said.

He said Det norske was attracted by SAMCoT's broad expertise, combined with the range of industrial partners who are collected under the SAMCoT umbrella.

Developing new technologies that are specially suited to the Arctic "should be possible based on the competence collected in the different teams, and by collecting and sharing of existing knowledge in the industry," he said.

A good fit

Fenz says another advantage offered by SAMCoT is that its research programme fits will with ExxonMobil's R&D activities, and complements the company's efforts in fixed structures, floating structures, ice mechanics and ice management.

"We are confident that SAMCoT will have a sustained positive impact on the Arctic research and development efforts of our Corporation," Fenz added. "SAMCoT's research thrusts focus on addressing core Arctic science and engineering needs. With the Centre focused on these fundamentals, this allows our Company's researchers to devote additional resources addressing the technology needs specific to our operations."

Kristoffersen also commented that the recent decrease in oil prices made SAMCoT innovations even more valuable to its industry partners.

"Based on the current oil price level, all companies see the need for cost reduction, and more effective and innovative solutions for all parts of the total system," he said. "This will lead to more effective drilling operations, more standardization of subsea systems, reduced weight, and reduced transport and installation costs."


Svalbard

Health, Safety and Environment in the Arctic – A SAMCoT Priority!

The Arctic is a place where maps are not to be trusted.

Glaciers may surge one month, and grind to a halt the next. Crevasses can yawn open one week where it was safe to travel the week before. For half of the year, it is cold – very cold – and dark. And help can be far, far away.

"There are no 'road signs' in the Arctic and in Svalbard," says Fred Skancke Hansen, director of HSE and Infrastructure for UNIS, the University Centre in Svalbard. Instead, he says, you have to rely on practical knowledge refined over years of experience working in this rapidly changing place.

Developing and refining the experience needed to protect the Arctic are key goals of NTNU's Sustainable Arctic Marine and Coastal Technology centre (SAMCoT).

SAMCoT works hand-in-hand with Hansen and his colleagues at UNIS to offer safety training for SAMCoT candidates and staff, and in honing HSE practices that are used by researchers and the centre's industry partners.

Conducting research in the Arctic requires a level of awareness of risks and safety procedures that also provides valuable information to the industry – although it may not result in academic publications per se.

Photo: Ø. Buljo

"The SAMCoT industrial partners can learn from how we operate in the field, at sea, on ice and on land," SAMCoT centre director Sveinung Løset says.

"They can also learn from how we assess risks and risk levels, how we identify critical tasks, and how we handle risks in an extreme environment."

Practical and safe

As a SAMCoT academic partner, UNIS works closely with the centre to develop best practice HSE standards that address practical problems, Hansen said.

Photo: Ø. Buljo

Hansen said every field experience offers UNIS and its SAMCoT partners the chance to further refine HSE practices. Sometimes that may mean making regulations more flexible – which is often the opposite of the way large companies work.

"Often we see that strict safety regulations make things more dangerous because they set very strict limitations on what you can use and how you can use it,"

he said. "Sometimes we need to look into the practical side of things and see what is most practical in this kind of scenario while still being safe."

Environment an important part of HSE

The acronym for practices focused on health, safety and the environment – HSE –is most commonly associated with safety. But protecting the environment is also an important aspect of any HSE effort, says Statoil's Gürtner.

"When we enter into new 'frontier' areas, we want to observe the environment around us and gain knowledge about the natural environment," Gürtner said.

In the summers of 2012 and 2013, SAMCoT researchers, many of them PhD candidates, spent two weeks in the icy waters off the northeast coast of Greenland aboard the Oden. The Oden is a research vessel operated by the Swedish Polar Research Secretariat that is also an icebreaker. The waters off the northeast coast of Greenland – also called the Fram Strait – are among the least studied area in the world. One big issue facing any development in northern waters is the effect that development will have on marine mammals in the environment, like whales and polar bears. But in order to understand where the vulnerable areas are, you need to know where the animals are.

Focusing on the right hazards

Possibly the most important knowledge produced by SAMCoT is embodied in its PhDs. The centre works hard to make certain that all PhD candidates get field experience, if it is relevant to their research. That fieldwork is grounded in good safety procedures.


BEFORE
Photo: A. Shestov


AFTER.
Photo: A. Shestov

SAMCoTs Arctic HSE Workshop

UNIS offers intensive training to SAMCoT candidates along with UNIS candidates, where participants do everything from learn to shoot guns – for polar bear protection – to drive a snowmobile safely.

Participants also learn about avalanche and sea ice safety, snow physics and glaciers, Hansen said. All told, about 1300 people go through safety training at UNIS per year, in more than 120 field safety courses.

The trick is that "humans in the Arctic may not be able to recognize threats,"

Hansen said. People may be afraid of polar bears, but they are the smallest threat. "The weather is much more dangerous," Hansen said. "People tend to focus on the wrong hazards."

Weather conditions can define a clear before-after experience of how unpredictable research situations are as shown in these pictures:

Transferring knowledge

SAMCoT centre director Løset agrees that teaching the next generation of researchers is a valuable role for the centre. "It's important to transfer knowledge from experienced 'Arctic researchers' to younger generations," he says. "And SAMCoT delivers these MScs and PhDs to the industry" with all of their HSE education and experience.
Statoil's Gürtner says the industry is enthusiastic about the HSE training that SAMCoT PhDs receive, because it means both people and the environment are protected, and operations in the Arctic are thus safer. "It's important that we introduce young researchers to HSE," Statoil's Gürtner says. "We can create common ground and understanding. And once the candidates are exposed to this, it is great background for when they start working in the industry."

SAMCoT Arctic HSE Workshop in 2014 was also a clear example on how SAMCoT takes seriously its responsibility to transfer HSE related knowledge.

A special focus on innovation

As one of Norway's Centres for Research-based Innovation, SAMCoT has an important role to play in conducting the kind of research that will help bring new knowledge to the industry, which in turn can spur innovative results.

With this in mind, SAMCoT organizers created the Exploitation and Innovation Advisory Committee (EIAC) when the Centre was founded to ensure that the Centre's research delivers on these goals. The committee includes members from the Centre's industry partners, whose job is to see that SAMCoT's research has impact and is implemented in the industry.

The committee also supports the transfer of knowledge and data from industry to SAMCoT's PhD candidates and serves as the industry sounding board for the candidates. The EIAC also shows PhD candidates the practical relevance of their work, and ensures that their research results find their way back into the industry.

In 2014, EIAC set a special focus on development and innovation, to determine where and how SAMCoT research is helping industry come up with new methods, measures and techniques that can be used in the Arctic.

The committee found that SAMCoT research over its first four years has spurred a variety of innovations, including new ways of visualizing and measuring ice, the infrared sensing of marine mammals, and improving our understanding of the effect of ice loads on fixed and floating structures.

Spin-offs from R&D

One of the goals that the Research Council has for centres like SAMCoT is stimulating companies to innovate to provide solutions in the field that can be seen as spin-offs from current R&D work.

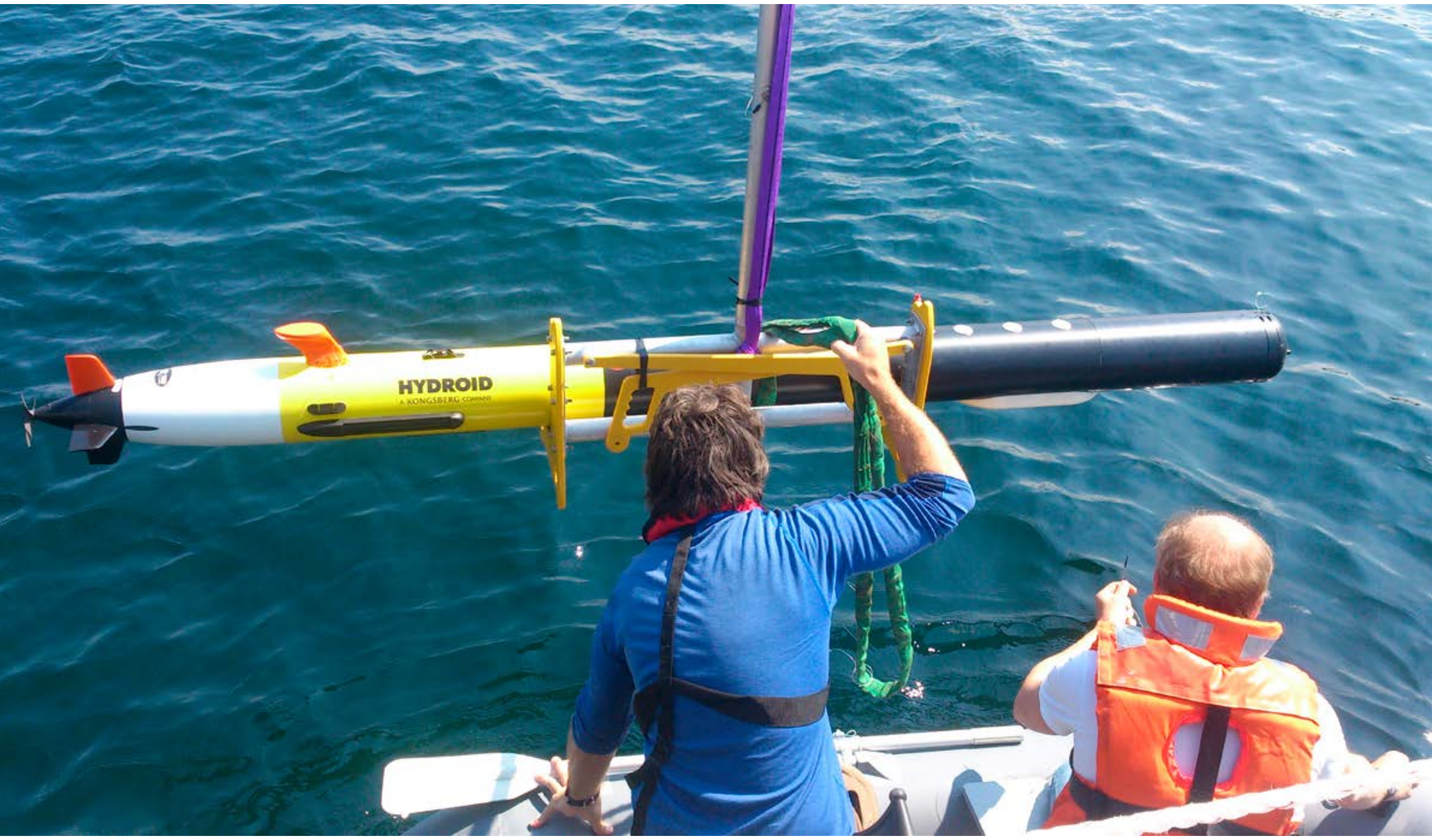
Some of the most striking examples in this area have resulted from the 2013 Oden Arctic Technology Research Cruise (OATRC), when researchers and industry representatives spent the last half of August in the ice-filled waters of the Fram Strait, off the northeast coast of Greenland.

There, researchers tested polarized marine radar to help visualize ice conditions. Researchers also used a 360° camera to provide a kind of bird's eye view of the ice conditions around the Oden icebreaker – a technology that can prove useful not only for ships and other structures out in the Arctic ice pack, but for researchers as they assess the data collected from the cruise. Being able to specifically quantify ice conditions in a 360-degree circle around the ship adds a new dimension to interpreting data and building computer models for better understanding of ice behaviour. Scientists also tested an innovative technique for the infrared sensing of sea ice and wildlife, both of which can have immediate applications in icy waters. Especially in low-light or foggy conditions – as was experienced during the Oden cruise and as can be common in ice-filled waters – it can be difficult to detect marine mammals, and infrared pictures proved a powerful tool in this context. The researchers also worked with software for recording manual ice observations.

New ideas often arise when researchers and industry experts are out in the actual conditions where a technology is going to be deployed. The EIAC found that the opportunities for fieldwork and laboratory testing offered by SAMCoT have been key to developing new concepts in surveillance technology, situational awareness and numerical software. These kinds of experiences from SAMCoT are very important in the development of robust technology for the Arctic.

Ice loads on floaters

Water depths in the Norwegian part of the Barents Sea may be 300-450 metres or more, which makes understanding the effect of ice loads on floating structures very important.



Petter Norgren during tests with the Statoil 'REMUS AUV' at NTNU's AUR-Lab

The mooring challenges in these depths differ significantly from those in shallower water. Seafloor conditions can be especially demanding, with layers of mud and soft materials. That makes the ability to predict ice loads on floating platforms a central enabler in the development of Arctic areas where fixed platforms are not feasible. The roadmap for the future involves understanding ice characteristics, improving load definitions, including taking vessel motion into account, and a validated analysis tool. In this context, R&D is important for developing standards for reliable and safe structures.

In 2014, SAMCoT researchers working with material modelling of ice characteristics (Work Package 2) were able to share their data with SAMCoT researchers working with ice loading on floating structures (WP4) to determine the load definition. These are the kinds of internal synergies that come from having a Centre for Research-based Innovation, where scientists working with different aspects of a larger puzzle can share information and fuel innovation.

Another concrete result from the centre was the development of a theory for the physical interaction between level/broken ice and the hull of a floater, which in turn was introduced into numerical tools that can predict the response of floating systems in first/multi-year ice and ice ridges.

Ice loads on fixed structures

Today's exploration and development in the Arctic has relied on the industry's ability to design and construct structures to handle the ice, as well as come up with strict HSE standards. But these efforts currently lack a fundamental understanding of underlying phenomena of the physics of ice pressures.

The Centre's unique combination of numerical studies, laboratory testing and field work as well as participant contributed measured data sets has led to the development of novel theory and algorithms for treating the physical processes related to interaction between sea ice and structures.

In this context, SAMCoT scientists are studying the effect of iceberg impacts, rubble transport and under-ice turbulence, as three examples. These methods and data are then used in the industry's development of numerical software to simulate the complex ice-structure interaction processes and the development standards for Arctic offshore projects. This is a prerequisite for the sustainable development of Arctic resources.

This year, researchers increased their understanding of ice-induced vibrations, where ice velocity around the structure combined with the natural vibration of the structure and ice behaviour was found to determine the magnitude of the ice loads. Researchers are thus able to develop numerical models to predict ice-induced vibrations that include ice properties in an explicit way. They also created practical algorithms to identify ice forces from structural response measurements.

These kinds of complex and nuanced research insights give SAMCoT industry partners the opportunities to come up with innovative structure designs.

Frank Lange, Principal Offshore Structures Engineer, GSNL-PTE/ECSO at Shell Global Solutions International bv and EIAC chairman said the understanding of ice loading and resultant ice-induced vibrations can help the industry build better and more innovative fixed structures.

"This happens through improved models that lead to improved standards for calculating loads and dynamics of offshore structures," he said. "The improvement will be evident in more cost-effective structures."

Ice drift and management

The understanding of the phenomena driving the drift of icebergs and ice fields is paramount in predicting and forecasting ice loads on structures or determining abandonment criteria. Expanding this understanding will remove an important barrier in the use of temporary or permanent floating structures in Arctic waters. SAMCoT has deployed a number of ice trackers both on icebergs and sea ice. In some cases two trackers have been deployed on the same iceberg (one at each end) and one or two on the adjacent sea ice.

These kinds of measurements enable the rotation of the iceberg in the water to be detected as well as its differential drift in relation to the sea ice. This information can be of major importance in specific circumstances, such as in evaluating the towing of icebergs in broken ice. The industry thus gets the benefit of SAMCoT's full-scale measurements and modelling technology related to load calculations and ice management operations.

The industry already has substantial experience managing icebergs now in Canada. But EIAC chairman Frank Lange says that innovations will come from how companies choose to implement their ice management programmes, based on the new knowledge provided by SAMCoT.

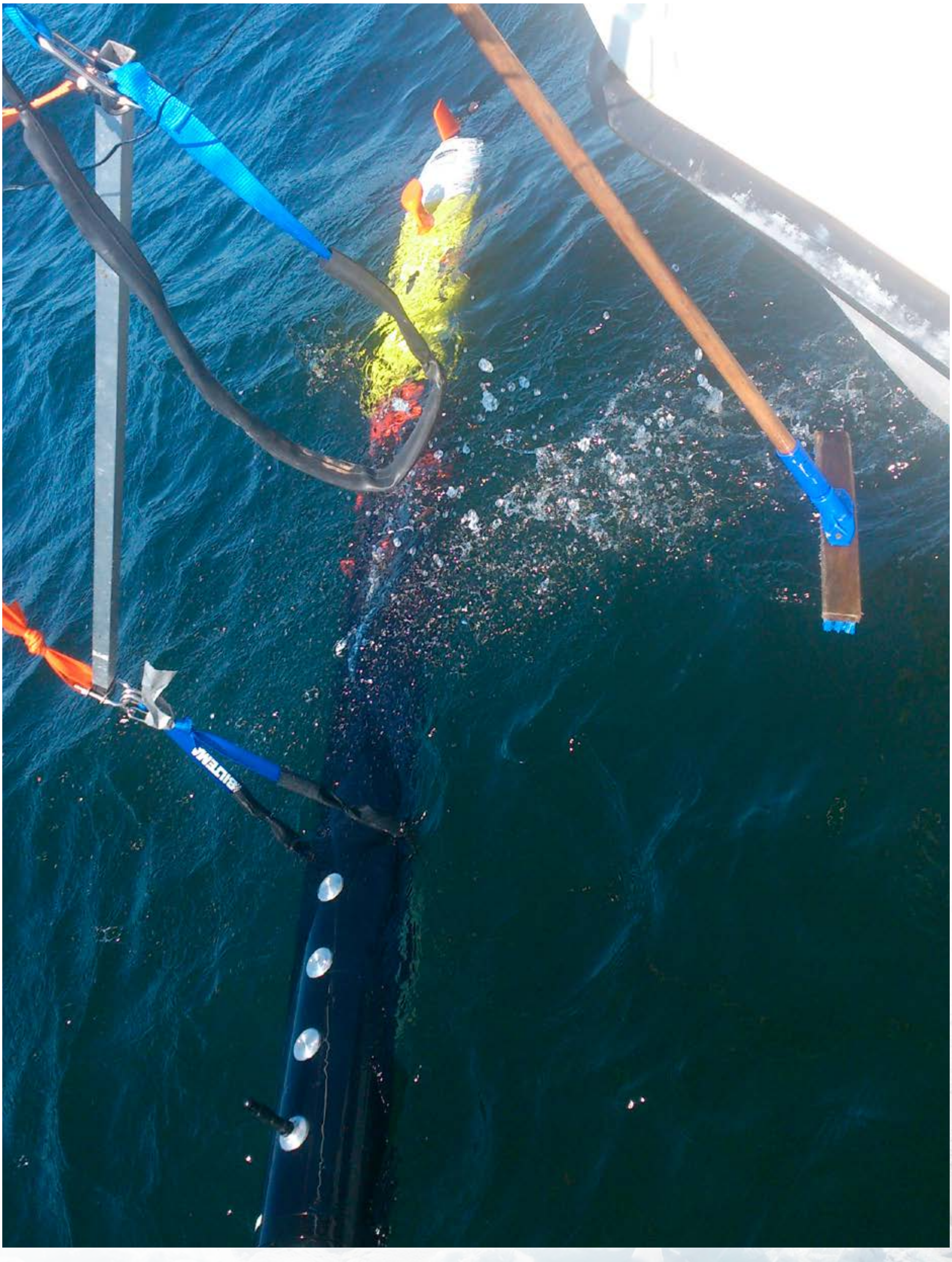
Arctic coastal structures

A large number of developments in the Arctic area do and will require structures in the shore area, where they interact with permafrost, waves and currents. Erosion in this area and the associated processes are not well understood and are increasingly influenced by global warming. These forces demand innovative approaches to building safe facilities that will protect the environment in these areas.

By obtaining an increased understanding of these processes, in future structures can be designed for the life of the fields without undue impact on the environment. Of particular value is experience from Svalbard and other relevant areas where permafrost is found in shore areas.

SAMCoT researchers have worked on mapping and describing coastal erosion processes under Arctic conditions, tested protection using geobags in Arctic areas, and studied ice loads on quay structures with respect to Arctic breakwater design, but much of this research remains at somewhat early stages.

'The innovation will be in how sustainable (given climate change) jetties and harbours (or coastal structures) can be developed," EIAC chairman Frank Lange said. "Innovations in this area will be mainly design based, but will also relate to sustainable dredging."



SAMCoT Research Structure

Data Collection and Process Modelling (Work Package 1 – WP1)
Material modelling (Work Package 2 – WP2)
Fixed structures in Ice (Work Package 3 – WP3)
Floating Structures in Ice (Work Package 4 – WP4)
Ice Management and Design Philosophy (Work Package 5 – WP5)
Coastal Technology (Work Package 6 – WP6)

The organizational structure of each Work Package supports the inter-collaboration among SAMCoT Research and Industry Partners as well as the international strategy of the Centre. The research strategy of the Centre as well as the implementation of the activities are closely monitored by the Centre Management Group, which reports to the EIAC, SAC and Board. In this section, we have furnished information on the main researchers in each WP, as well as the SAMCoT PhD candidates, Postdocs and Master candidates for each. In addition, visual examples of their research activities are provided.

KEY RESEARCHERS 2014

Name	Main research area	Affiliation	Sex M/F	Nationality
Aleksey Marchenko	Data collection and process modelling	UNIS	M	Russian
Anatoly Broushkov	Geotechnical engineering	MSU	M	Russian
Anatoly Sinitsyn	Physical-mechanical properties and extent of coastal permafrost	SINTEF	M	Russian
Andrei Metrikine	Dynamic ice action	TUDelft	M	Russian
Arne Instanes	Geotechnical engineering	External	M	Norwegian
Eliz-Mari Lourens	Offshore Engineering	TUDelft	F	South African
Ingrid Utne	Ice management/Safety	NTNU	F	Norwegian
Jan Otto Larsen	Data collection and process modelling	NIS	M	Norwegian
Jukka Tuhkuri	Discrete Element Modelling of ice rubble and ice ridges	Aalto	M	Finnish
Jørgen Amdahl	Iceberg impact on floaters	NTNU	M	Norwegian
Knut V. Høyland	Ice rubble and ice ridge action	NTNU	M	Norwegian
Maj Gøril G. Bæverfjord	Geotechnical engineering	SINTEF	F	Norwegian
Mauri Määttänen	Dynamic ice action	NTNU	M	Finnish
Nataly Marchenko	Geographic Information System (GIS)	UNIS	F	Russian
Raed Lubbad	Ice management and coastal technology	NTNU	M	Norwegian
Roger Skjetne	Ice management	NTNU	M	Norwegian
Sveinung Løset	Ice actions on floaters	NTNU	M	Norwegian

VISITING RESEARCHERS 2014

Name	Main research area	Affiliation	Sex M/F	Nationality
Alexander Sakharov	Ice mechanics	MSU	M	Russian
Ben Lishman	Ice physics	UCL	M	British
Devinder Singh Sohdi	Ice Mechanics	CRREL (Ret)	M	American USA
Erland Schulson	Ice Mechanics	TSED - FArC	M	American USA
Evgeny Karulin	Ice Mechanics	KSRC	M	Russian
Hansen Johnson	Research assistantship Biological & Scientific Journalism	BC - FS	M	American USA
Kari Kolari	FE Modelling and Dynamic ice action	VTT	M	Finish
Karl Shkhinek	Ice action on Offshore structures	St-PSPU	M	Russian
Marina Karulina	Ice Mechanics	KSRC	F	Russian
Peter Chistyakov	Ice Mechanics	MSU	M	Russian
Peter Sammonds	Const. models for ice rubble, micro-macro coupling	UCL	M	British
Stanislav Ogorodov	Coastal Erosion	MSU	M	Russian
Zygmunt Kowalik	CFD	UAF	M	American USA

NTNU	Norwegian University of Science and Technology
UNIS	The University Centre in Svalbard
SINTEF	Stiftelsen SINTEF
Aalto	Aalto University, School of Engineering
TUDelft	Delft University of Technology
VTT	Technical Research Centre of Finland
UCL	University College London
KSRC	Krylov State Research Centre
KSRC	Krylov State Research Centre
MSU	Moscow State University
CRREL	Retired from CRREL
St-PSPU	Saint-Petersburg State Polytechnical University, Institute of Civil Engineering
UAF	University of Alaska Fairbanks
UCL	University College London
MSU	Moscow State University
MSU	Moscow State University
TSED - FArC	Thayer School of Engineering at Dartmouth - Fulbright Arctic Chair
BC - FS	Bates College - Fulbright Scholar
CRREL (Ret)	Cold Regions Research and Engineering Laboratory (CRREL) - Retired

POSTDOCTORAL RESEARCHERS LINKED TO SAMCoT IN 2014

Name	Topic	Sex M/F	Nationality	Start
Aleksey Shestov*	Thermodynamic consolidation of ice ridge keels	M	Russian	2013
Arttu Polojärvi*	Discrete Element Modelling (DEM) on ice rubble	M	Finnish	2013
Ekaterina Kim**	Integrated Finite Element method in Ice – Structure; Continuum mechanics modeling of ice for analysis of abnormal ice action effects	F	Russian	2014
Wenjun Lu**	Waterline Process during sloping structures interacting with a large ice floe	M	Chinese	2014

PHD CANDIDATES LINKED TO SAMCoT IN 2014

Name	Topic	Sex M/F	Nationality	Start
Andrei Tsarau*	Modelling hydrodynamic interactions between a floater and broken ice	M	Belarus	2012
Anna Pustogvar*	Constitutive modelling of ice rubble, experiments	Female	Russian	2012
Chris Keijdener*	The effect of the contact model on the predicted breaking length of level ice	M	Dutch	2013
Daria Aleksutina**	Composition, structure and properties of sediment cores and frozen soil	Female	Russian	2012
David Wrangborg*	Ice-water actions on coastal structures	M	Swedish	2012
Ekaterina Kim**	Coupled finite element analysis of ice - structure interactions; "Design" ice model for analysis of abnormal ice action effects	Female	Russian	2010
Emilie Guegan*	Coastal erosion mechanisms	Female	French	2012
Farzad Faridafshin*	Alternative methods for quantifying the safety of offshore structures protected by Ice Management	M	Iranian	2012
Hans-Martin Heyn**	Fault-tolerant guidance, control and online parameter estimation for thruster-assisted position mooring in Arctic offshore conditions	M	German	2014
Hayo Hendrikse*	Ice-induced-vibrations, (numerical modelling)	M	Dutch	2011
Marnix van den Berg*	Actions and action effects of ice ridges on floating structures and moorings	M	Dutch	2014
Martin Hassel**	Risk and Safety of Marine Operations under Arctic conditions	M	Norwegian	2014
Martin Storheim**	Structural Resistance of Ships and Offshore Structures to Extreme Ice Loads	M	Norwegian	2011
Petter Norgren */**	Autonomous Underwater Vehicles (AUV) for operations under ice: subsurface monitoring of sea ice and icebergs	M	Norwegian	2013
Renat Yulmetov*	Iceberg drift and towing in pack-ice	M	Russian	2012
Sergey Kulyakhtin*	Constitutive models of ice rubble, Finite Element Modelling (FEM)	M	Russian	2011
Taya Sinitsyna */**	Ice field heterogeneity and probabilistic ice load analysis	F	Russian	2013
Torodd Nord*	Ice-induced-vibrations, (analysis of measured data)	M	Norwegian	2011
Wenjun Lu**	Waterline Process during sloping structures interacting with a large ice floe	M	Chinese	2010
Yared Bekele*	Thermo-Hydro-Mechanical Coupled Finite Element Modeling	M	Ethiopian	2012
Åse Ervik	Ice-ridge-fixed structure interaction modelling in FEM	F	Norwegian	2014

MASTER'S CANDIDATES LINKED TO SAMCoT IN 2014

Name	Topic	Sex M/F	Nationality	Start
Andreas Orsten	Automatic Reliability-based Control of Iceberg Towing in Open Waters	M	Norwegian	2013
Bård Blæsterdalen	Coastal ice	M	Norwegian	2013
Carl Magnus Vindegg	Coastal ice	M	Norwegian	2013
Cathrine Y Pedersen	Interfacial Study of Input Data in dynamic Ice-structure Interaction and Evaluation of Tactile Sensors Usability in Ice-related problems	F	Norwegian	2013
David Horner	Fragmentation behavior of ice masses in dependence on varying high impact stress wave propagation	M	German	2014
Ekaterina Ignatieva	Ice jams caused by shipping in navigational channels	F	Russian	2014
Ida Marie Bueide	Freeze-bond strength experiments, radially confined compression tests on saline and fresh water samples	F	Norwegian	2013
Igor Konstantinov	Thermal expansion of frozen soils and actions on foundations	M	Russian	2014
Luca Argini	Temperature variations and heat flow in coastal soils in the Arctic	M	Italian	2014
Marina Verbickaya	Experimental and numerical modeling of the intercation of ciliodric solid indenter with ice	F	Russian	2014
Martin Dons	Arctic strait crossing on soft seabed sediments/ Vurdering av geotekniske forhold for veifylling i Sveasundet, Svalbard	M	Norwegian	2013
Nicolai Greaker	Laboratory Measurements of Ice-concrete Abrasion with different Types of Ice Quality	M	Norwegian	2013
Nina Ganicheva	Engineering structures in the coastal zone in the Arctic, the example of Vestpynten, Spitsbergen	F	Russian	2013
Synnøve Kvadsheim	Iceridge keel size distributions	F	Norwegian	2012
Thor Olav Myklebust	Equipment and Production of Columnar Sea Ice Replica in NTNU Cold Lab	M	Norwegian	2013

* Salary and Operational costs from the Centre

** Operational costs from the Centre

Scientific Review 2014:

In 2014, SAMCoT came into a harvesting phase meaning that scientific and engineering achievements in the different work packages (WPs) came into use in other WPs. An example on this is the material models developed for frozen soil in WP2 that now contribute to the work in Coastal Technology (WP6). Another example is the material models for sea ice ridges developed in WP2 that now has its application in WP4 (Floating Structures in Ice). Further, WP4 gives input to Ice Management and Design Philosophy (WP5) by e.g. providing simulation models that are required by WP5.

WP1 (Data Collection and Process Modelling) is a fundamental package in the sense that it provides basic data that are need by the other packages. There has been a number of invited scientists. The most advanced field of research for WP1 has been sea ice ridges, with their fine structure, thermodynamics and mechanical properties. The content of WP1 research was in 2014 tuned to be more consistent with the SAMCOT emphasis on ice engineering. This has been achieved and the progress has been very good. From the core of sea ice ridging the research has expanded to coastal research, with land-ice interaction, and to offshore questions of drift of sea ice and icebergs.

WP2 (Material Modelling) has the dominant thrust of the mechanical behaviour of ice rubble. Included is the strength of freeze bonds between blocks of saline ice (,e.g. the effects of time, temperature and environment) and the frictional resistance during slow sliding across a freeze-bonded interface. Most of these data are being gathered from measurements in the laboratory. The studies are amongst the first of its kind, and have been performed in a careful and systematic manner. The progress in 2014 has been good.

WP3 (Fixed Structures in Ice) has a primary focus on ice-induced vibrations. Work on understanding vibrations (basin tests/analysis, numerical modeling to assist in explaining occurrences and scaling) can identify solutions to minimize dynamic ice loading. In the past year, the package has been clever on using model basins data as well a full-scale data from the offshore industry and use a network of high quality professors in Norway, Finland, the Netherlands and elsewhere in Europe. The direction of the research has generally aimed at understanding, rather than direct design.

WP4 (Floating Structures in Ice) has made major progress this last year. This is most visible in the integration of the various research topics including floe ice - structure interactions and the modelling of hydrodynamic effects in this process. Application of multibody dynamics is extensively used and models communicate through the SAMCoT Toolbox. Two PhD candidates defended their thesis and one new PhD candidate started in WP4.

WP5 (Ice Management and Design Philosophy) has also this last year been clever in mounting field and laboratory programmes with emphasis on iceberg/sea ice drift modelling and analytical risk assessment. In 2014, WP5 studied technologies and methods for sea-ice surveillance, iceberg towing, and risk and safety assessment of structures protected by ice management. One new PhD candidate started in the autumn and the progress on WP5 is good.

WP6 (Coastal Technology) has in 2014 addressed Arctic coastal erosion mechanisms with emphasis on field work, and numerical modelling of the thermo-denudation of coastal bluffs in the Arctic. Field studies have been performed both on Spitsbergen and in Northwest Russia. An increased number and level of publications based on the collected data are expected in the present year.

To summarize, SAMCoT in 2014 made significant contributions to both the production of highly qualified people and the creation of new knowledge. SAMCoT has the potential to become recognized internationally as a leader in sustainable Arctic engineering. As more journal papers appear and as the scientific and technical communities have the opportunity to use the products of SAMCoT's work, its status will become apparent.

I would like to express my thanks to all contributors, and I am looking forward to continuing another exciting year in 2015.

Sveinung Løset

WP1:

Data collection and Process Modelling

The goal of WP1 is to provide field data as required by the other WPs on
- sea ice and icebergs,
- coastal permafrost,
- characteristics of sea state.

Further, the goal is to develop models of performed experiments and observed phenomena with special focus on the region of the Barents Sea opening.

The activity of WP1 "Data collection and process modeling" focused in 2014 on the following five topics:
- Sea state and Ice conditions in the Barents Sea Opening
- Monitoring of sea ice and iceberg drift
- Mechanical properties of ice
- Sea ice actions in the coastal zone
- Applied oceanography:

The activities within each topic are described below.

Sea state and Ice conditions in the Barents Sea Opening:

- Data on sea state (CTD, ADCP), ice drift characteristics, morphological properties and structure of ice ridges were collected in yearly cruises of RV Lance in the north-west Barents Sea and Spitsbergen Bank since 2011,
- Data from ice strength tests (flexural, uniaxial, indentation, tensile) performed on land fast ice in Spitsbergen fjords and on the drifting ice in the north-west Barents Sea were collected since 2011,
- FE Model on thermodynamic consolidation of ice ridges was constructed in Comsol Multiphysics and test numerical simulations were performed,
- Models of iceberg drift under the action of wind and water drag forces and waves were constructed and test numerical simulations were performed.

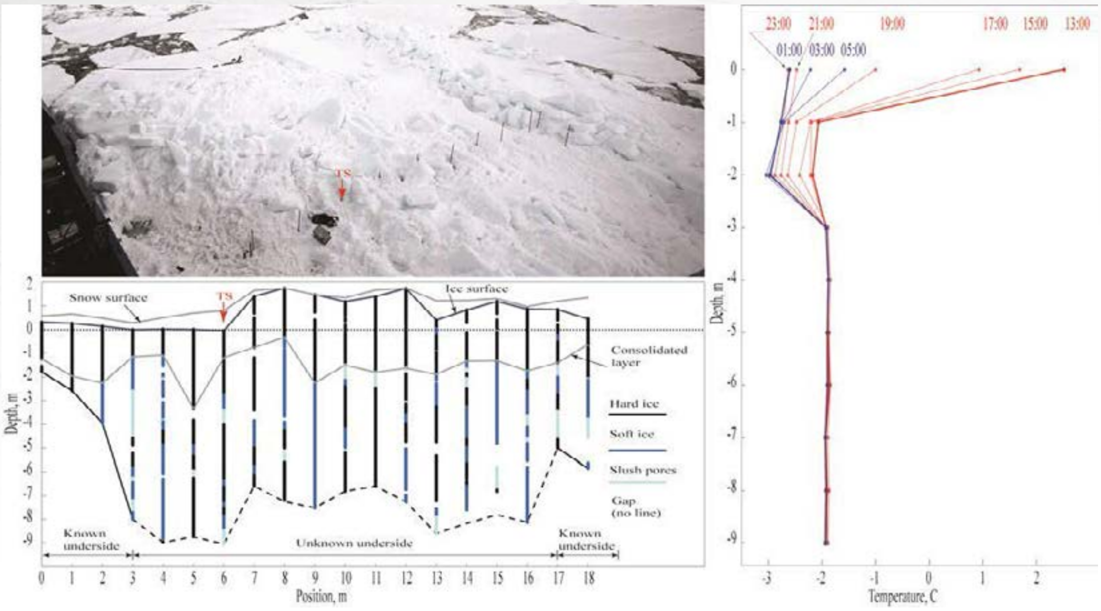


Figure 1. Monitoring of ice temperature profile through ice ridge drifting in the Barents Sea.

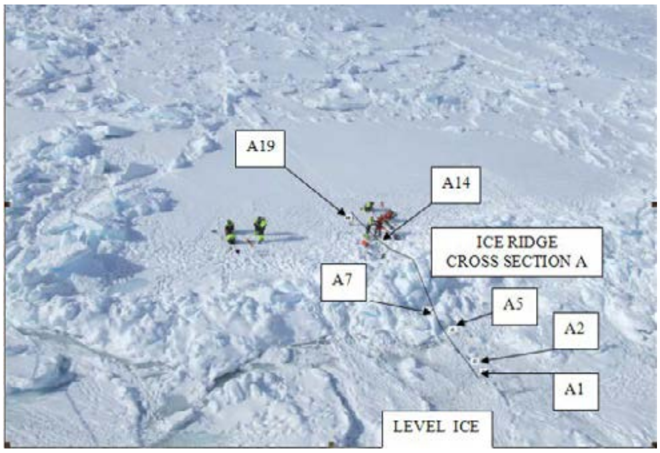


Figure 2. Locations of drilling studies of ice ridge structure.

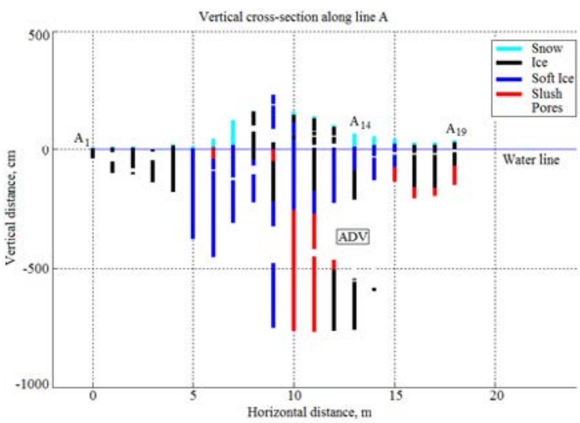


Figure 3. Ice ridge structure reconstructed by the drilling. Location of measurement of sea current velocity is marked by ADV.

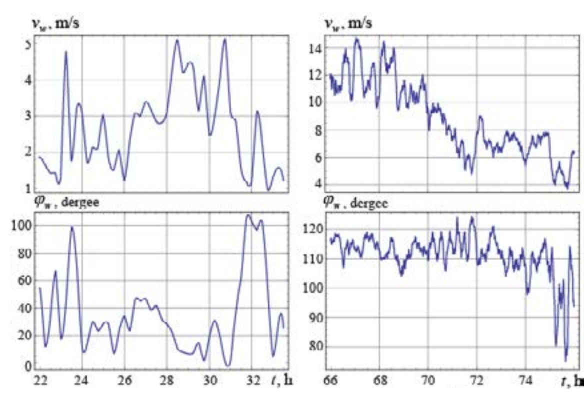


Figure 4. Absolute value and direction of sea current velocity measured below the level ice (a) and inside ridge keel (ADV point in Fig. 3) (b).

Monitoring of sea ice and iceberg drift:

- Iridium ice trackers Oceanetic Measurements were used for the monitoring of drifting ice and icebergs in the Barents and Greenland Seas since 2012,
- In 2014 a new model of ice tracker equipped by thermistor string was deployed on drifting bergy-bit and delivered operative information about temperature profile through the iceberg,
- Profiling of ice ridges sails and icebergs has been performed with Laser scanner Riegl Vz-1000.

Mechanical properties of ice:

- Original equipment for ice strength tests is designed, constructed and used for field measurements of flexural strength and indentation tests of ice (displacement rates are up to few cm/s in the tests),
- Data of compressive, flexural and indentation strength were collected in field tests (experiments were performed since 2011),
- 3D FE models of ice strength tests were constructed in Comsol Multiphysics and Ansys and numerical simulations were performed for the interpretation of experimental results,

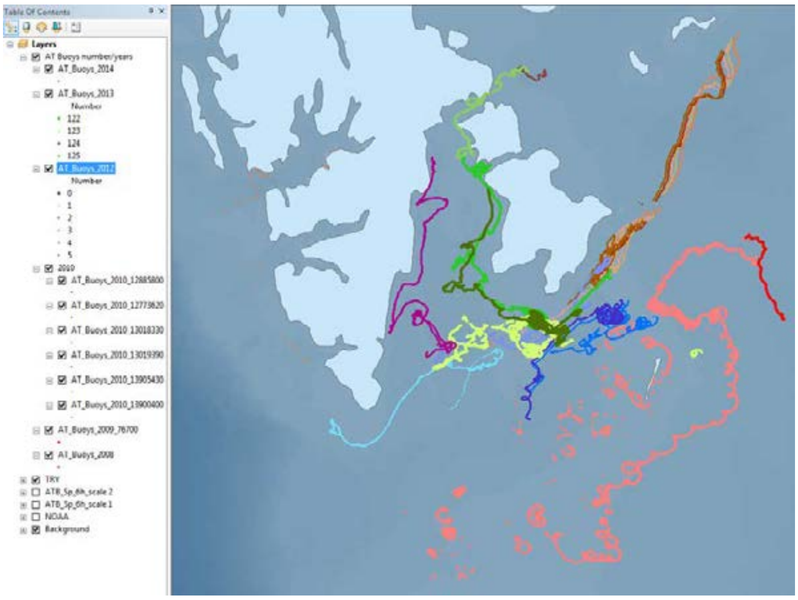
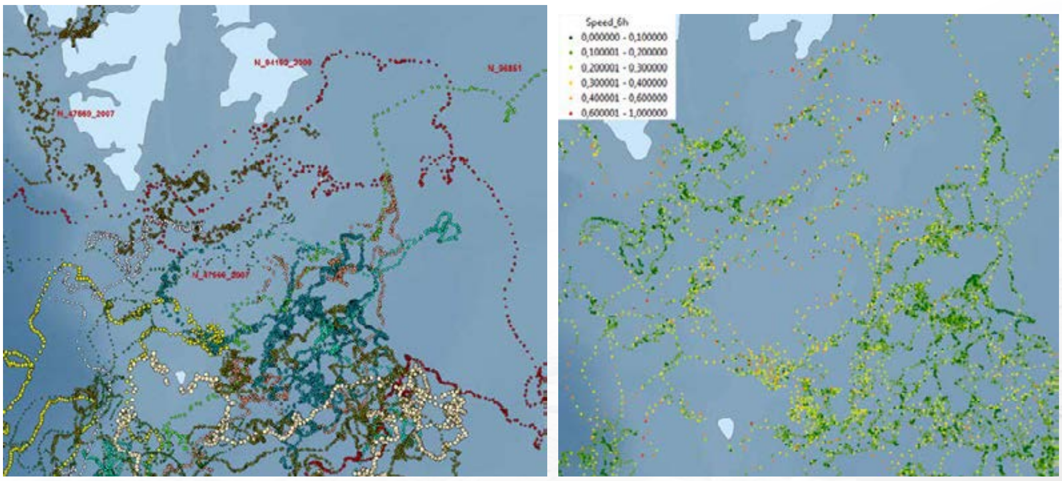
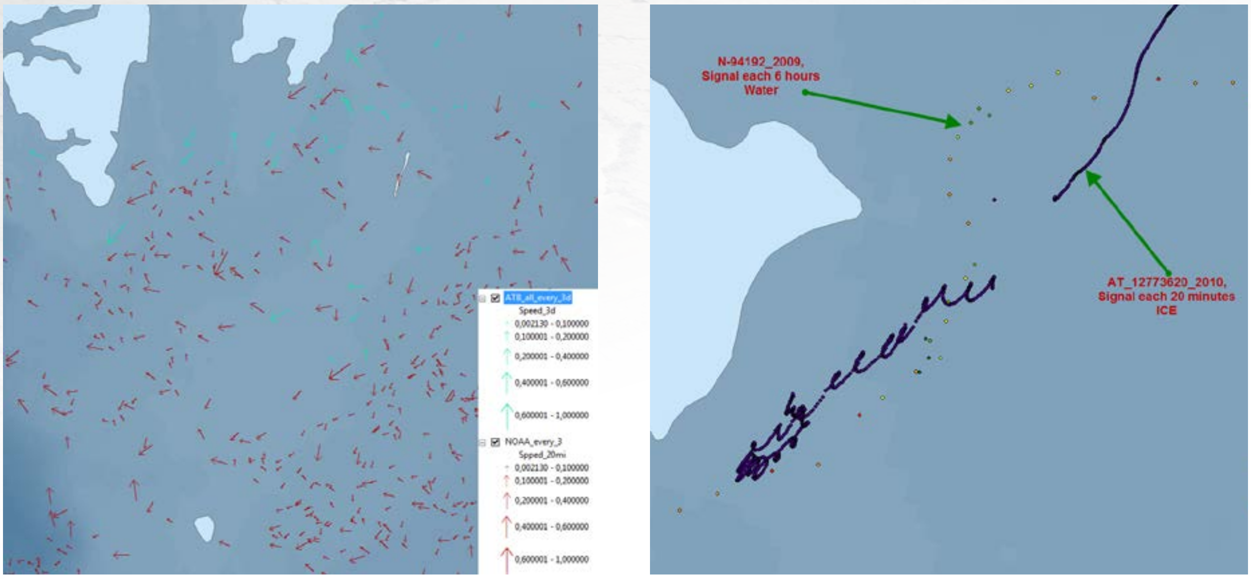


Figure 5. Trajectories of buoys, installed on sea ice by Arctic technology department of UNIS



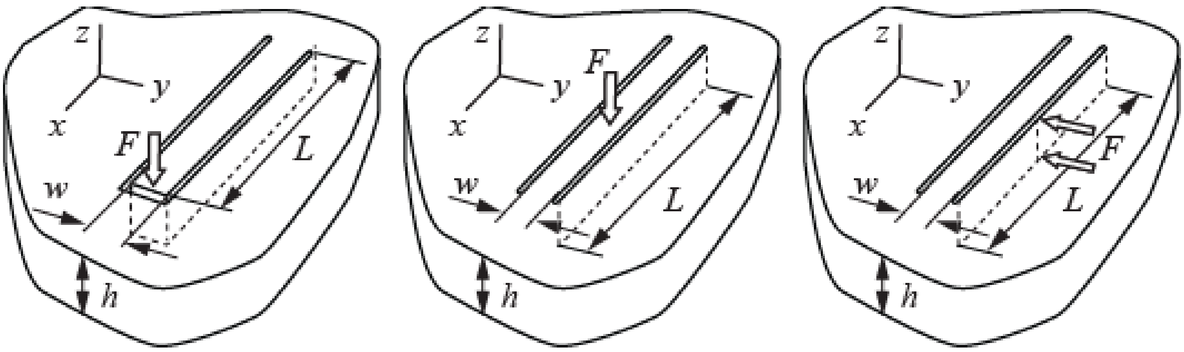
a) b)
Figure 6. Trajectories (a) and drift speed (b) of NOAA buoys in the Barents Sea opening



a) b)

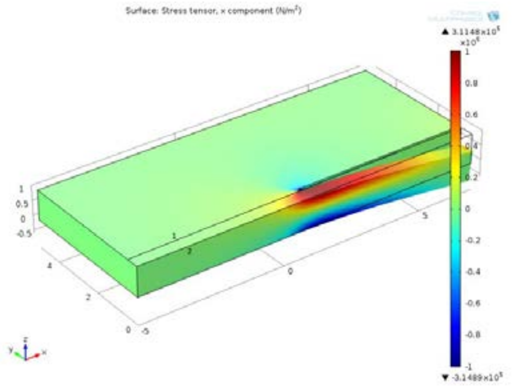
Figure 7. Vectors of drift: NOAA buoys – red arrows, AT buoys – blue arrows (a). Trajectories of drift: NOAA buoys – red points, AT buoys – blue points (b).

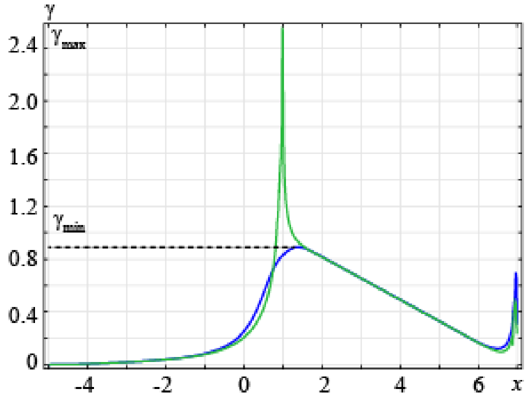
- Original system of Fiber Bragg Grating sensors for the measurements of strain and temperature at small scales is designed, constructed and used in laboratory measurements of the coefficient of thermal expansion of saline ice and frozen soils,
- Data on thermal expansion of saline ice and water saturated soils were collected in laboratory tests using original FBG temperature and strain sensors (experiments were performed since 2011),
- Method for the calculation of effective elastic modulus of floating ice deformed by waves was elaborated and approved with using of the field data.



a) b) c)

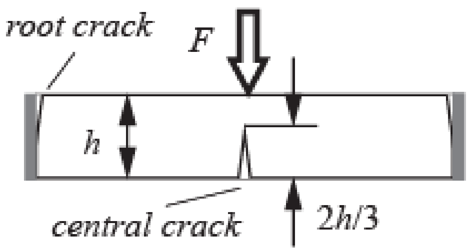
Figure 8. Tests with ice beams performed in-situ for the calculation of flexural strength (a), compressive strength of surface ice layer (b), and compressive strength averaged over ice thickness (c).

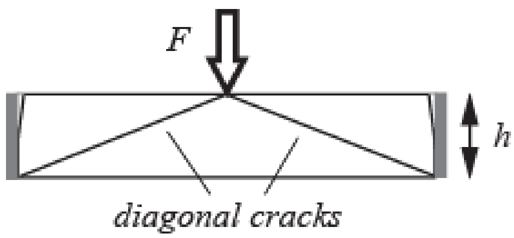




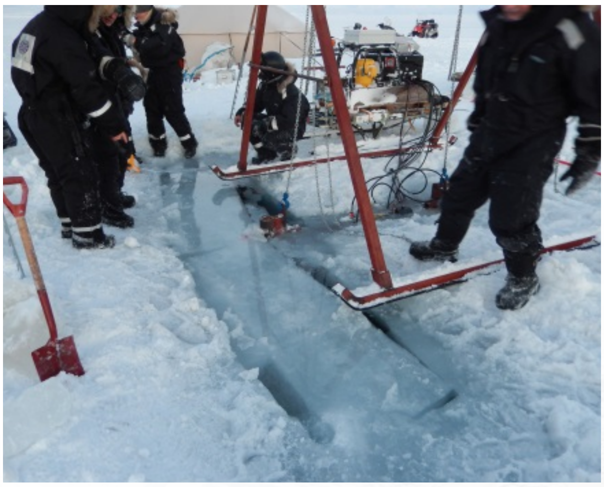
a) b)

Figure 9. Results of 3D numerical simulations of test with cantilever beam in Comsol Multiphysics (a) and reconstructed concentration of stresses on the lines 1 (green) and 2 (blue) (b).





a) b)



c) d)

Figure 10. Two main scenarios of ice failure in tests with fixed-ends beams observed in in-situ experiments: formation of central crack (a,c) and formation of diagonal cracks (b,d).

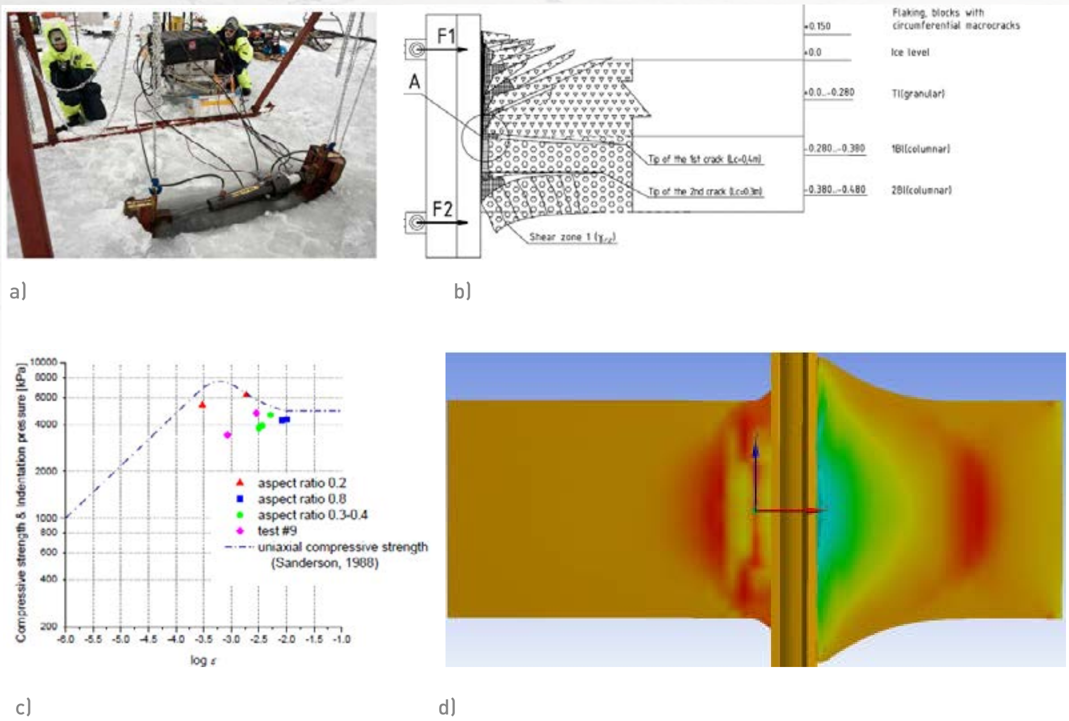


Figure 11. Indentation test (a), scheme of ice failure reconstructed from indentation test (b), indentation pressure versus strain rate (c), and vertical stresses reconstructed from numerical simulations in Ansys WorkBench (d).

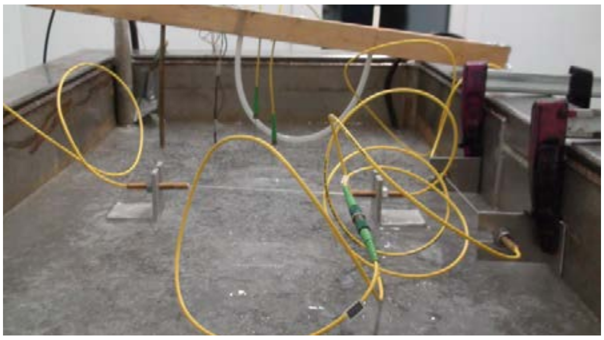
Sea ice actions in the coastal zone:

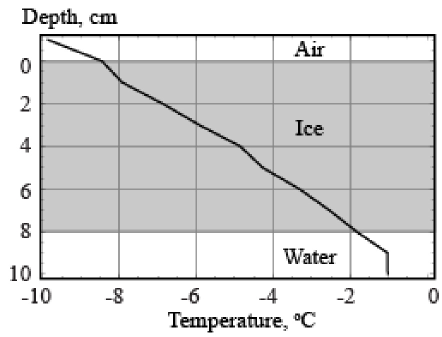
- Ice loads on shoreline and fixed quay were measured with pressure load cells Geokon in 2013-2014 and analyzed according to tide measurements,
- Monitoring of deformations of coastal ice and structural elements of fixed quay were performed with Laser scanner Riegl-VZ 1000 in 2013-2014,
- Data on soil temperature and pore pressure were collected around pipeline landfall in Longyearbyen and in coastal zone of Varandey (Pechora Sea) with thermistor-strings Geoprecision and piezometers Geotech in 2013-2014,
- Model and numerical simulations of tide induced ice loads on the shore line were performed,
- Model and numerical simulations of ice loads on cofferdam due to thermal expansion of ice were performed.

Applied oceanography:

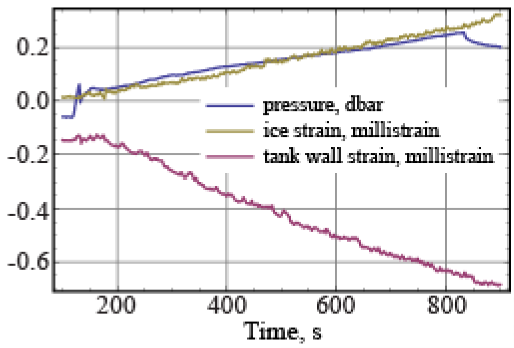
- Regular measurements of CTD profiles, ADCP profiles, waves and turbulent characteristics of ice adjacent layers are performed in the North-West Barents Sea since 2011 during cruises on RV Lance and in the Greenland Sea,
- Data on sea currents, waves and tides near research site for the monitoring of coastal erosion near Longyearbyen are collected over 2013 with ADCP AWAC Nortek mounted on the bottom frame,
- Data on surface currents in Advent fjord and Akselsundet are collected with ice drifters using AstroDog antennas,
- Model of tides in Svalbard Fjords is elaborated. Numerical simulations of tidal currents, water level elevation and natural oscillation of water in fjords are performed.

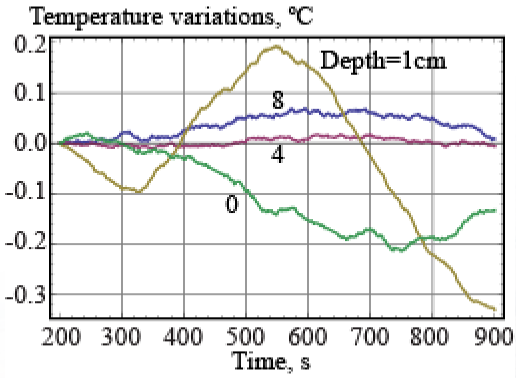
a) b)
Figure 12. Organizing of research site for the monitoring of coastal ice deformations (a), deployment of pressure load cells in the ice (b).



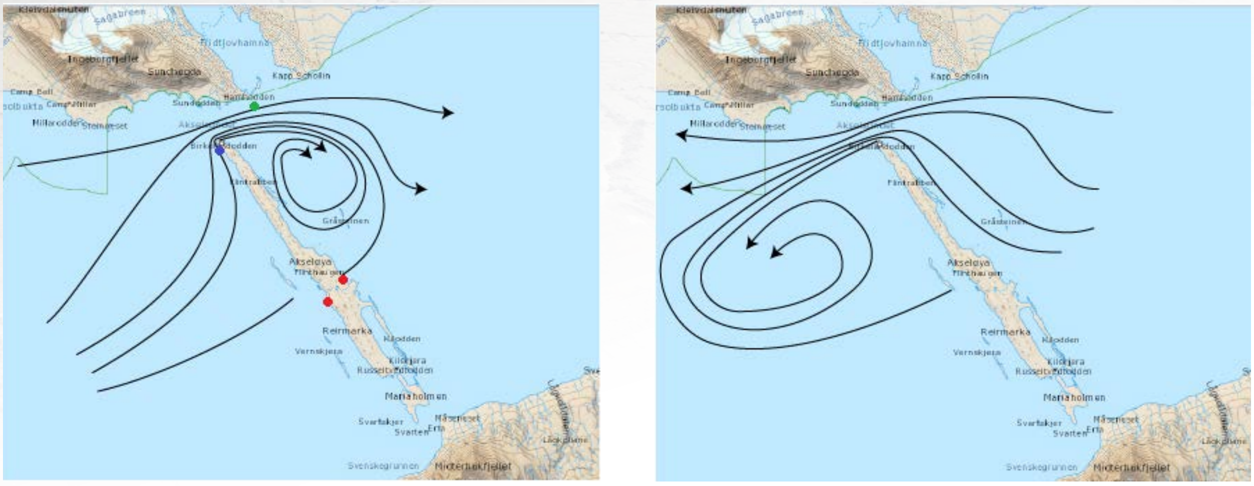


a) b)

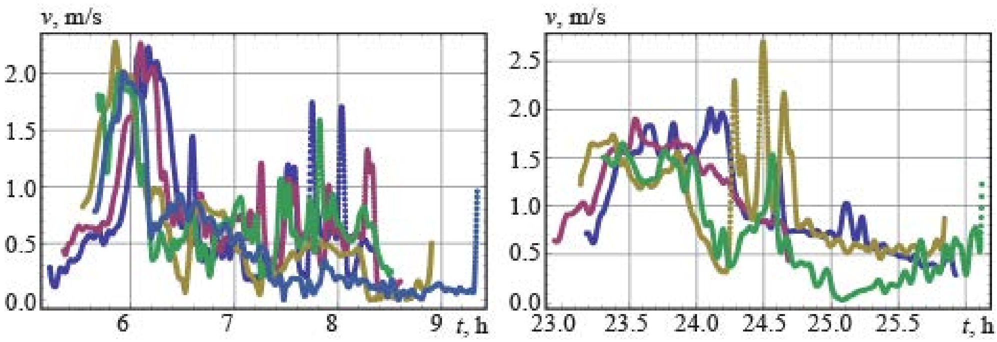




c) d)
Figure 13. Laboratory experiment in the ice tank for the investigation of ice actions on fixed quays mand cofferdams caused by tide action on confined ice (a), temperature profile in model ice measured with FBG thermistor string (b), strains in ice and tank walls induced by the increase of the water pressure below the ice (c), temporal variations of the ice temperature induced by brine migration through the ice (d).



a) b)
Figure 14. The Akseloya Island in the entrance of the Van Mijen Fjord. Qualitative scheme of flow lines in the Akselsundet strait on flood (a) and ebb (b) phases of the tide. Locations of tide measurements are shown by red, blue and green dots.



a) b)
Figure 15. Absolute velocities of jet flow in the Akselsundet strait measured by surface drifters on the flood (a) and ebb (b) tide.

WP2: Material modelling

An important part of quantifying the physical nature is to characterize the nature mathematically. In SAMCoT we particularly address material or constitutive modelling of ice rubble (=the unconsolidated layer of first-year ridges) and frozen soils. One Post-Doc and three PhD candidates address ice rubble through numerical and experimental studies, and one PhD candidate works with frozen soils numerically and theoretically.

Arttu Polojärvi is SAMCoT Post-Doc at Aalto University School of Engineering, Department of Applied Mechanics. His second year (2014) started with work with 2D DEM simulations on laboratory scale shear box experiments performed at NTNU. The simulations brought insight on experimentation on ice rubble. We showed that in a shear box experiment, one should be carefully take into account granular behaviour of the rubble. The simulations showed that force chains generated inside the shearing rubble cause high loads measured in an experiment. The work was presented in IAHR conference in Singapore. We also continued on working on the results and extended our study into a journal paper, which is now under review. During November and December Polojärvi had a two-month research visit to NTNU. During the visit he worked on the topic of ice rubble homogenization with PhD candidate Sergey Kulyakhtin. The starting point was the question of how much ice rubble one needs in order to model it as a continuum and found through the visit the opportunity to explore this further. The motivation for this study is that both Polojärvi and Kulyakhtin think that the advantages and the limits of different numerical modelling methods should be understood: one should choose a method that best fits for modelling of a current problem.

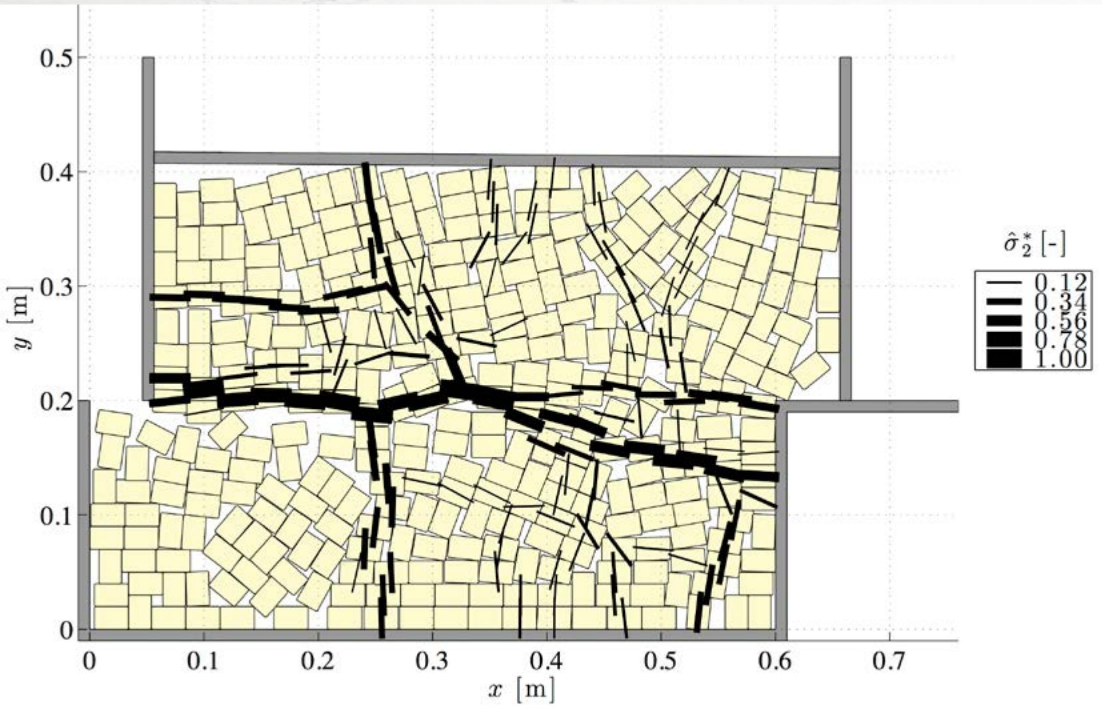


Figure 16. Snapshot from a simulation of a shear box experiment.The contact forces applied to each block are indicated by black lines with line thickness describing the value. Contact forces are normalized by the highest force acting within the rubble.

During 2014 Kulyakhtin was working mainly on two topics. The first one is the ice rubble phenomenological model, which was implemented as a user defined material subroutine in Abaqus/Explicit software during last summer - autumn. The flow rule of the model was chosen such that it conforms to the volumetric behaviour of ice rubble obtained from the reanalysis of data available in literature (paper was presented on OMAE conference in San Francisco). In addition hardening effects related to the compaction of ice rubble are taken into account using breakage mechanics concept which connects the overall material response to the underlying microstructure described by the distribution of ice block sizes and parameter related to the ice block strength. This approach is especially advantageous for ice rubble modelling due to the difficulty related to testing of representative size samples, in addition it was shown that distributions of ice blocks at least in pressure ice ridge sails from the Barents Sea, Arctic Ocean, Beaufort Sea and North Sakhalin area appeared to be almost the same when the number of measurements is around one hundred (this was presented on the 22nd IAHR International Symposium on Ice). The process of validation of the model on the data of rubble field - structure interaction model scale tests performed as a part of RITAS (Rubble Ice Transport on Arctic Offshore Structures) project is ongoing. Kulyakhtin spent two days in the end of October discussing those simulations with Dr. Nicolas Serré (Multiconsult, Tromsø) during which he received a valuable input for this research especially concerning model parameters which could be interesting for the parametric study. The second topic is obtaining equivalent continuum media by homogenizing ice rubble discrete element simulations which is investigated in close collaboration with Arttu Polojärvi from Aalto University. The work is devoted to the investigation of procedures of converting discrete quantities such as displacements and contact forces used by discrete models into the field variables such as strains and stresses required for continuum models. The importance of this research is that it can provide information about the scale over which field variable representation and thereby continuum modelling is meaningful. In addition this procedure can be directly used to derive stress - strain responses for developing ice rubble phenomenological models that undoubtedly has a great value considering cost and difficulties involved in ice physical testing of ice rubble.

Figure 17. PhD candidate Sergej Kulyakhtin preparing oedometer experiment in the NTNU cold lab.

a) b)

Figure 18. Ice-block size and gradation: a) original picture; b) analyzed by means of image processing.

PhD candidate Anna Pustogvar works on laboratory investigations of ice rubble. In spring 2014 she completed her last course 'Applied Statistics'. Tests for the mandatory project for this course were performed in the cold laboratory at NTNU. The experiments were designed to study effects of several factors on the density of saline ice. The density was measured by hydrostatic weighing in paraffin.
Earlier in the spring semester Pustogvar and Kulyakhtin performed oedometer tests on ice rubble. The tests were targeted on revealing effects of gradation and shape of ice blocks on the compressibility of ice rubble (Fig. 3). A paper presenting the results was published in the proceedings of the 22nd IAHR International Symposium on Ice. In June 2014 during the 33rd International Conference on Ocean, Offshore and Arctic Engineering Pustogvar presented results of another test campaign conducted in 2013. The conference paper summarizes all previous direct shear box tests on ice rubble and recent tests performed by the author in the aspect of effect of block to box size ratio. Summer and autumn of 2014 was spent on studying a new research topic related to packing of ice rubble. Literature review on the existing packing models of granular materials helped to build up a basis for a new experimental campaign which is about to be started in the cold laboratory at NTNU.

There have been some important milestones in 2014 regarding the development of a fully coupled Thermo-Hydro-Mechanical finite element model for frozen soil. The finalized theoretical development of the governing equations of the THM model was presented at the 8th European Conference on Numerical Methods in Geotechnical Engineering (NUMGE) in Delft, The Netherlands, 18-20th June 2014. The results from the first step of the numerical implementation concerning groundwater flow was presented at the 11th World Congress in Computational Mechanics (WCCM), 20-25 July 2014, in Barcelona, Spain. The results from a test implementation for one-dimensional freezing and thawing were presented at the 14th International Conference of the International Association for Computer Methods and Advances in Geomechanics (IACMAG), from 22-25 September 2014, in Kyoto, Japan.

WP3: Fixed structures in Ice

Fixed structures in the Arctic and other icy waters need to withstand ice actions. The structures can be vertically sided or have sloping sides in the water line. Iceberg impact, ice ridge action and ice-induced vibration from crushing of level ice are the three critical scenarios for vertical sided structures, whereas the rubble accumulation can be vital for sloping structures. In SAMCoT we have so far addressed ice-induced vibrations or dynamic ice actions, but in 2013 we also initiated sloping structures and probabilistic ice action estimation.

PhD candidate Torodd Nord works with ice –induced vibration and address specifically analysis of measurements. The simultaneous identification of the ice forces and the spatially complete response of the structure coupled with the ice-pressure measurements brought new insight to the ice-induced vibrations (Figure 19). The results we have achieved on force and state identification in WP3 was presented at the Eurodyn conference in Porto this summer. SAMCoT WP 3 was well represented at this conference by Torodd S. Nord, Eliz-Mari Lourens, Andrei Metrikine, Ole Øiseth. Their work was recently published in the journal of Cold Regions Science and Technology.

In February 2014, laboratory works were conducted in the cold labs at UNIS and field work at Isdammen close to Longyearbyen. The course was AT-211 Ice Mechanics, Loads on Structures and Instrumentation. SAMCoT participants were Aleksey Marchenko, Nataly Marchenko, Aleksey Shestov, Ben Lishman and Torodd S. Nord. The main objective with Nords laboratory experiments was to teach candidates how the ice interacts with structures and how to measure the ice strength. In the fall of 2014, one of WP3's master candidates, Øyvind Wiig Pettersen, won the price for the best Civil Engineering master thesis. Øyvind was supervised by Ole Øiseth and Torodd S. Nord

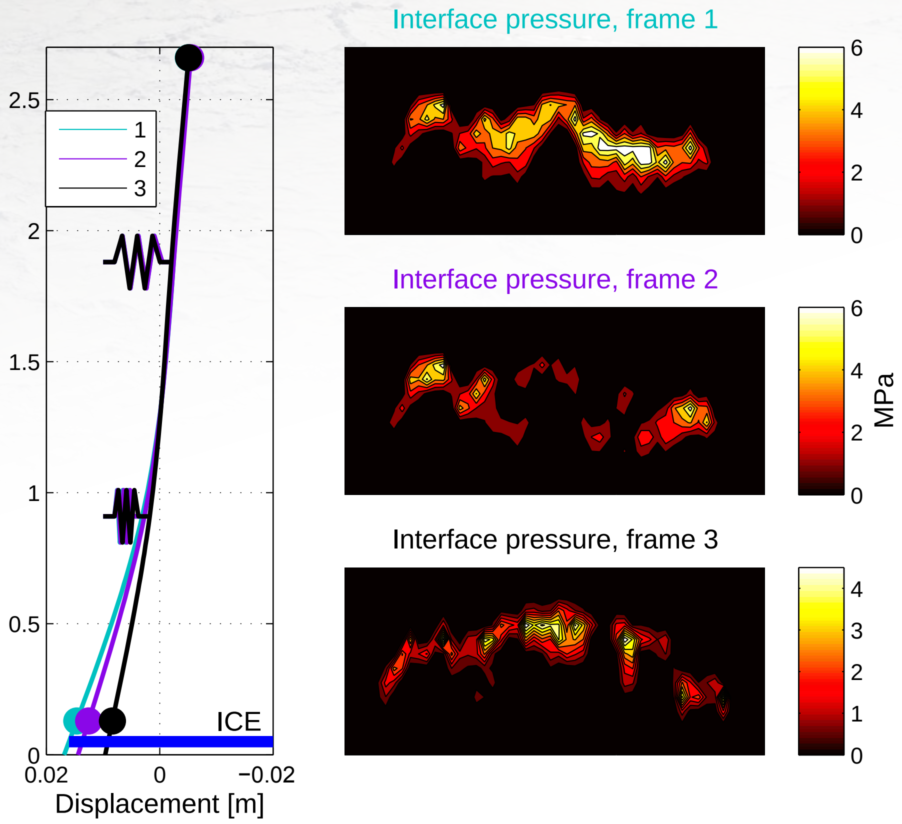


Figure 19. Identified spatially complete structural behaviour and interface pressure during at the onset of ice failure at the ice velocity 20 mm/s (intermittent crushing).

on his thesis. The title was Model-based stochastic-deterministic State and Force Estimation using Kalman filtering with application to Hanko-1 Channel Marker. The expertise on the Finnish channel markers was guided by Mauri Määttänen. We are happy to inform that Øyvind started on a PhD on bridge dynamics, supervised by Ole Øiseth and Eliz-Mari Lourens. In November Nord returned to UNIS for teaching in the labweek for the master candidates in *AT 332 - Physical Environmental Loads on Arctic Coastal and Offshore Structures*. They installed for the first time a tactile sensor (pressure sensor) on the indentation rig which they tested in the lake above Mine 7. Snowfall,-15°C air temperature and winds exceeding 10 m/s ensured good conditions for testing the tactile sensor in the Arctic climate.

PhD candidate Hayo Hendrikse at TU-Deflt is getting close to submitting his PhD. At the start of 2014 a novel approach of the dynamic ice-structure interaction problem was formulated. This new theory focusses on the development of the discrete contact between ice and structures. Based on this new theory a numerical model has been developed which shows to capture the different regimes of ice induced vibrations for different types of structures. A journal paper have been submitted to the International Journal of Solids and Structures containing an explanation of the theory and obtained results. Earlier work on ice induced vibrations of offshore wind turbines has been presented for a broad practical audience at the OMAE'14 conference in San Francisco. Further collaboration with SAMCoT partners has resulted in several in depth discussions throughout the year. The main focus of these discussions has been the crack formation in ice as well as scaling of ice-structure interaction. During the last part of 2014 a start has been made with finalizing the results in the form of a thesis which will be submitted in 2015.

PhD candidate Janne Ranta at Aalto addresses the ice action on sloping structure. He started his studies midway in 2013, and in 2014 he deepened his knowledge about discrete element simulations. But while preparing his first conference paper in his PhD he learned many new things not only from discrete element simulations but also from ice mechanics and statistics. The conference trip itself to the IAHR Ice Symposium 2014 conference was fruitful and the conference venue in Singapore fulfilled all expectations and more. A main learning so far has been that results from discrete systems shall always be considered by using statistical methods. Statistics plays an important role also in ice mechanics where one is often faced with highly varying responses. It seems that discrete element simulations are capable to produce responses with statistical characteristics of a similar kind as what can be extracted out from experimental data. Therefore, at the moment, it is an extremely interesting situation to continue to work on that subject.

Åse Ervik started her PhD study within Ice ridge interaction - numerical simulations in September 2015. She did her MSc within Ice mechanics at NTNU/UNIS and wrote and presented a paper for the 22nd IAHR Ice symposium in 2014. In the first term she has been taking courses and planning field work. The Norwegian Polar Institute (NPI) is freeze the research vessel RV Lance into the ice at 84°N and drift south where certainly ice ridges are present(http://www.npolar.no/en/projects/details?pid=b98886ce-590a-48a8-b113-4b96e98c65c8). Together with Post-Doc Aleksey Shesotv (WP1) she plans to investigate temporal development of first-year ridge properties. She is also busy with starting up a numerical model in ABAQUS. Her work is based on the material model developed by Kulyakhtin (WP2). Finally she has submitted a paper for the POAC2015 conference and will submit her paper in early 2015.

Figure 20. PhD candidates Hayo Hendrikse and Farzad Faridafshin conducting field work in the Fram Strait (OATRC 2013).

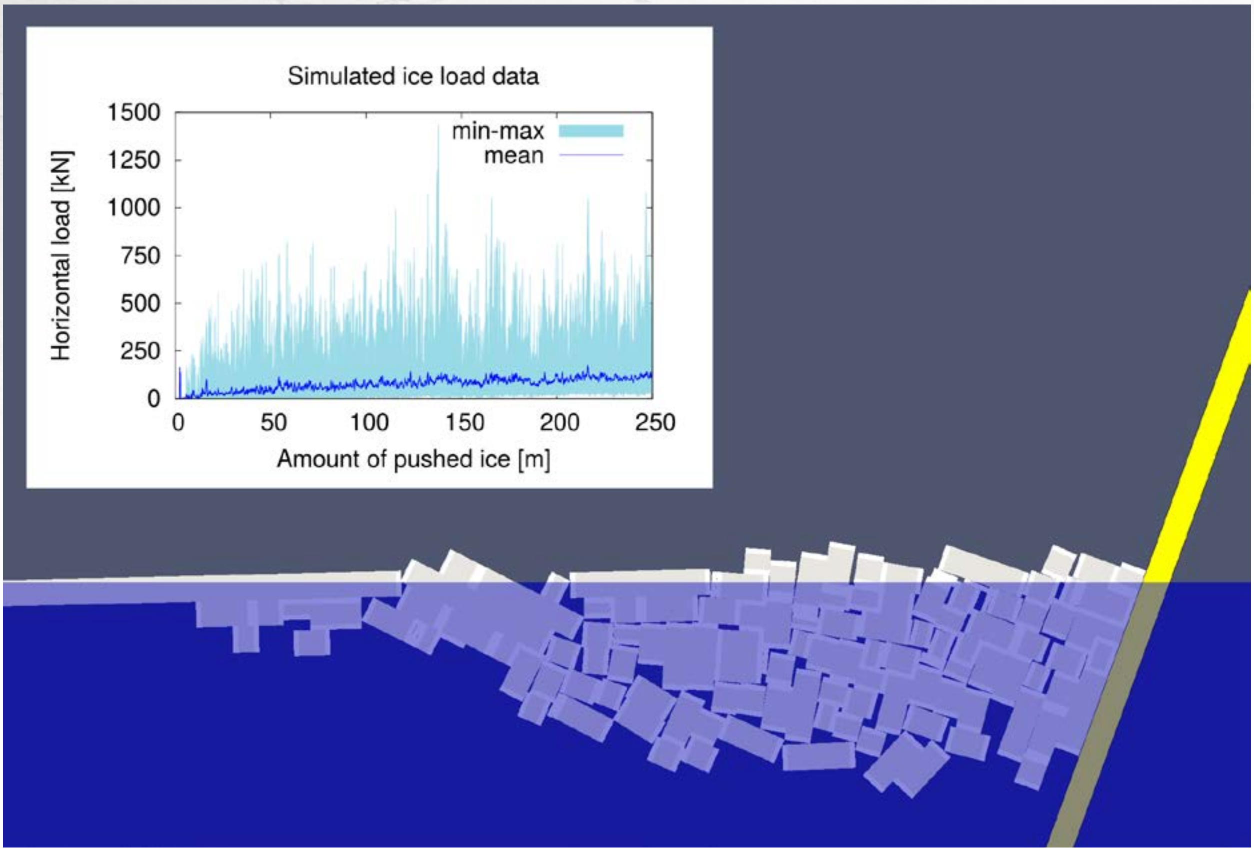


Figure21. 2D simulation of ice interaction against an inclined rigid structure. The ice thickness is 1.25m and the slope angle of the structure is 70 degrees. Associated load data is based on 35 replicate simulations.

WP4: Floating Structures in Ice

The goal of WP4 is to develop new knowledge, analytical and numerical models needed by the industry to improve the prediction of loads exerted by first/multi-year sea ice and ice ridges as well as icebergs on floating structures. This does also imply prediction of the performance of floating structures in icy waters.

To achieve this goal, 7 researchers are involved and 6 PhD candidates have been working on the different research topics below:

- Floe ice - structure interactions
- Modelling the hydrodynamic effects on floe ice – structure interactions
- Small-scale versus meso-scale experiments
- Application of multibody dynamics to model structures – floe ice and ice ridges interactions
- Accidental collisions with coupled ice mass – structure

Figure 22 illustrates these research topics.

Two of the PhD candidates defended their doctoral theses within WP4 in 2014 (both of them continue in post-doctoral positions in SAMCoT/AMOS):

- **EKATERINA KIM** defended her doctoral thesis on 9th May 2014: *Experimental and numerical studies related to the coupled behaviour of ice mass and steel structures during accidental collisions. Doctoral theses at NTNU, 2014:135, 220 p.*
- **WENJUN LU** defended his doctoral thesis on 3th December 2014: *Floe Ice – Sloping Structure Interactions. Doctoral theses at NTNU, 2014:324, 314 p.*

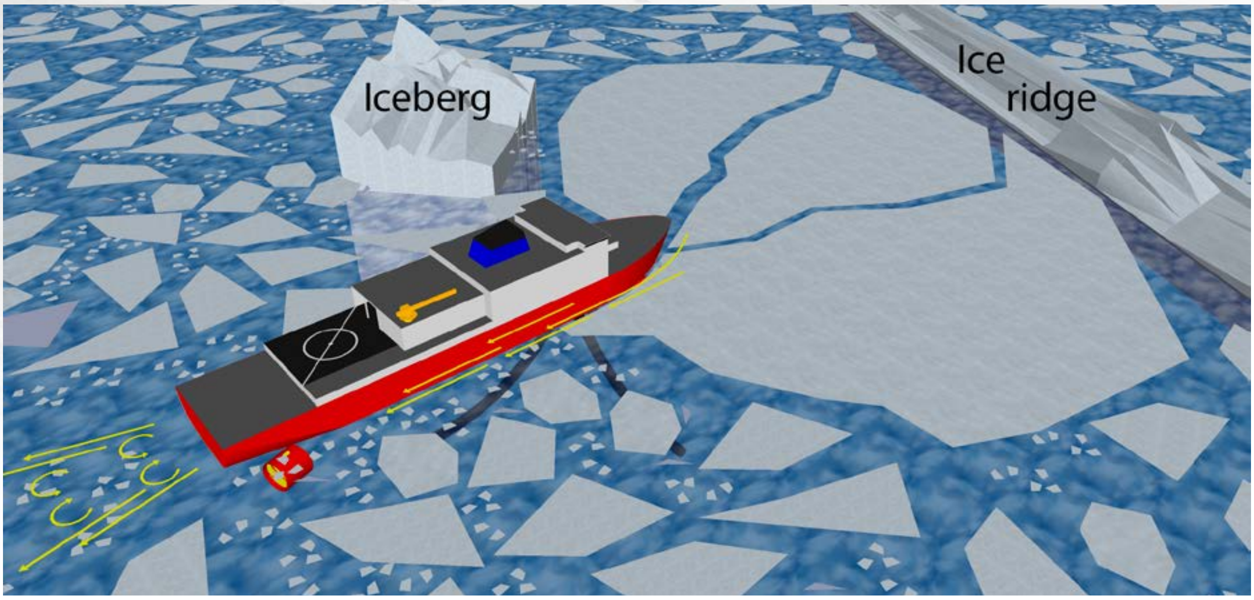


Figure 22. Illustration of research topics within WP4.

Floe Ice – Structure Interactions

Standing on the foredeck of an icebreaker sailing in the Arctic, one can easily be amazed by the rather large-scale, violent scenes and scary noises from fracturing ice floes. People (researchers and engineers) often talked about 'fractures of ice'. However, with regard to most engineering applications with the presence of ice fracturing processes (e.g., ice - sloping structure interactions), researchers/ engineers seldom use the knowledge of fracture mechanics.

There is a knowledge gap when it comes to the quantification

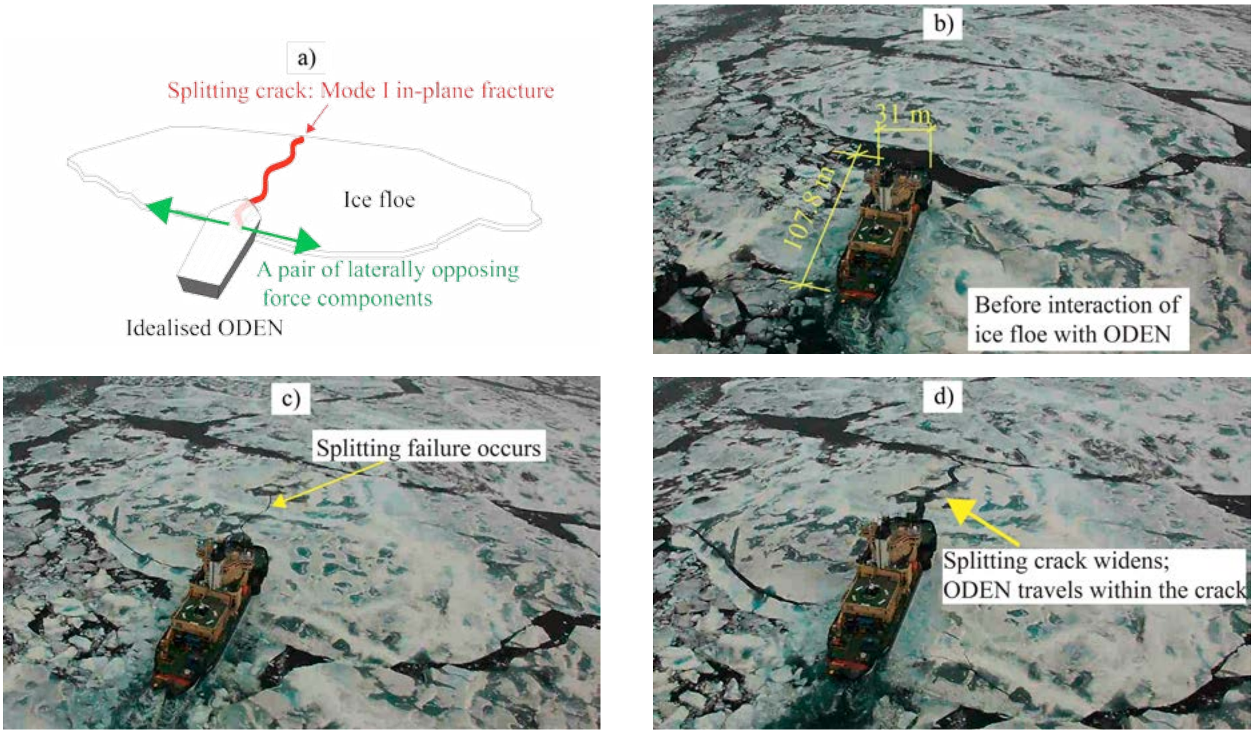


Figure 23. Splitting failure: a Mode-I in-plane fracture of an ice floe while interacting with a sloping structure.

of a border between a breakable and non-breakable ice floe. Moreover, within the breakable floe regime, how the floe boundaries influence the possible failure patterns, i.e., splitting and bending failure mode, is unknown. In SAMCoT these knowledge gaps are dealt with using approaches based on fracture mechanics. Different cracks' initiation and propagation are studied to yield a more convincing quantified border among different failure patterns.

Based on field experience, the splitting failure mode has been frequently observed while a sloping structure (i.e. an icebreaker) interacts with a finite size ice floe with little lateral confinement. For the application of 'ice - sloping structure interactions', splitting failure of an ice floe is defined as a Mode I in-plane fracture of an ice floe by a pair of laterally opposing force components that are induced by the contact between the sloping structure and the ice floe (see Figure 23).

Analytical solutions regarding different fracture patterns of a finite size ice floe have been achieved in Wenjun Lu's doctoral thesis. These analytical solutions are directly fed to the development of the numerical toolbox in SAMCoT with respect to the calculation of forces needed to fracture certain types of ice floes.

Modelling the hydrodynamic effects on floe ice – structure interactions

The work of PhD candidate Andrei Tsarau in 2014 has been focused on modelling the hydrodynamic interactions that may take place during offshore operations in ice-covered waters and are important for understanding, among others, ice loads and the dynamics of structures in ice. This research topic is closely associated with several other scientific topics summarised by A. Tsarau in Figure 24 based on their relevance for ice management (IM) and station-keeping in ice.

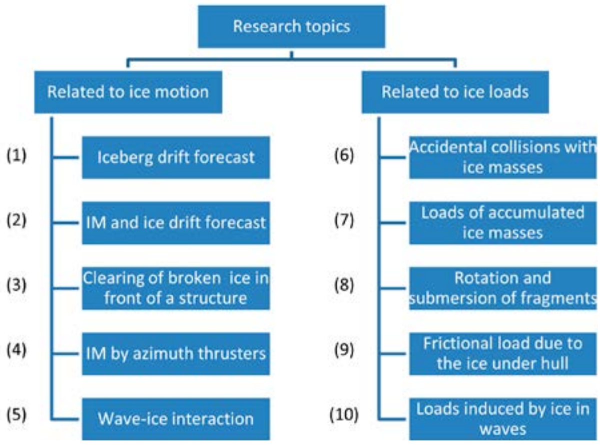


Figure 24. The ice-related research topics considered in the light of hydrodynamics.

Several of these topics were at least partly addressed in a number of publications submitted by A. Tsarau in 2014 and presented to the international scientific community. Among them are the papers for the journal of Cold Regions Science and Technology and for the International Conference on Maritime Technology (ICMT) 2014 in Glasgow, where a model for ice drift motions in front of a structure was presented. Another piece of work submitted for publication concerns the modelling of ice motions in vortical flow; e.g., in the wake of a structure (Figure 25).

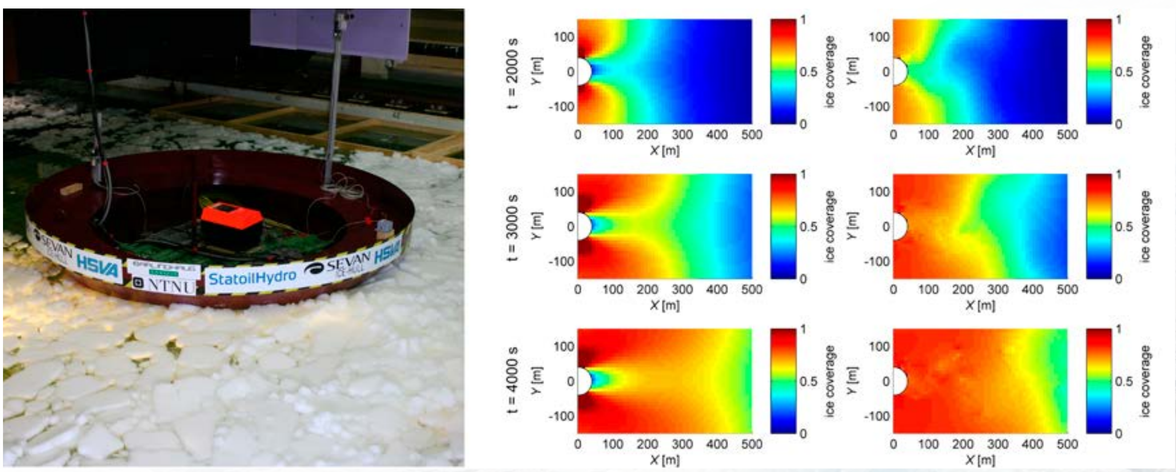


Figure 25. Modelling ice motions in the wake of a structure.

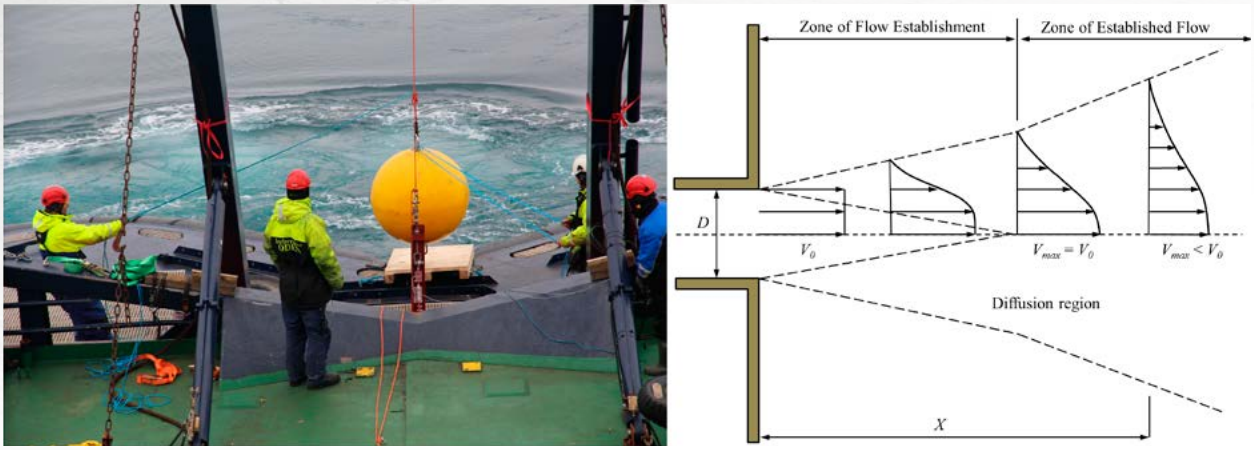


Figure 26. The experimental and analytical investigations on the propeller-wash effect on ice.

Special attention has been paid to the techniques that may help to minimise managed ice loads on a protected vessel by clearing the broken ice and preventing its accumulation against the structure. One example is the application of propeller-induced jets for ice clearing, which is also in the concept of IM by azimuth thrusters. From a scientific point of view, this problem was analytically studied by A. Tsarau based on the experimental data obtained during the Oden Arctic Technology Research Cruise in 2013 (Figure 26). The results of this work were presented at the 22nd IAHR International Symposium on Ice in Singapore.

Meanwhile there has been collaborative work on the development of a numerical toolbox that would incorporate the features of the discrete element method and the developed hydrodynamic models to allow the complete simulation of the complex ice-structure interaction problems.

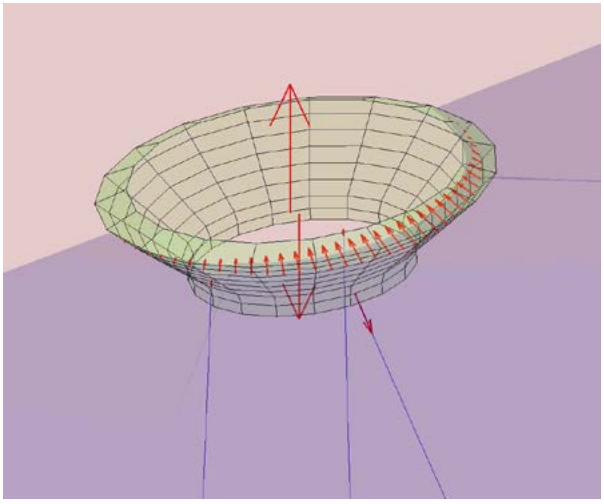


Figure 27. Meso-scale buoy numerical model.

Small-scale versus meso-scale experiments

In the first half of 2014, Marnix van den Berg has developed a design concept for a meso-scale buoy. The main purpose of the buoy would be to provide data on ice loads during downward bending failure, as well as the influence of buoy pitch and buoy dynamics on ice failure loads. Load data from such a buoy could supplement data from ice tank tests. Major findings were that the minimum size of the buoy is limited by the needed pitch stability and the buoyancy needed to carry the weight of the mooring system. Longyearbyen (Svalbard) was proposed as possible deployment location for the meso-scale buoy. A modelling example of the buoy is shown in Figure 27.

Application of multibody dynamics to model structures – floe ice and ice ridges interactions

M. van den Berg started his PhD in August 2014. His PhD topic is Actions and Action Effects of Ice Ridges on Floating Structures and Moorings. In the first months of his PhD he investigated the applicability of the novel non-smooth discrete element (NDEM) method in the modelling of ice rubble. Application of this method could potentially lead to a decrease in calculation time of several orders of magnitude compared to traditional DEM calculations. The initial results are promising; NDEM simulations show behaviour similar to traditional DEM simulations. An example is shown in Figure 28. Results also show resemblance with experimental measurements.

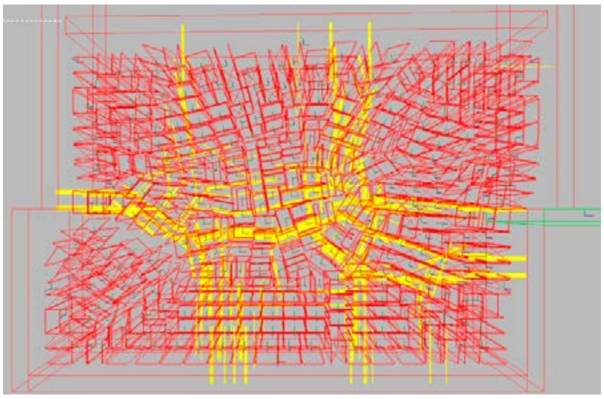


Figure 28. Force chains in shear box simulations. NDEM results compared to traditional DEM results by Polojärvi et al. (2014) (Figure 16, p. 36).

In the verification process, M. van den Berg has cooperated with Dr. Arttu Polojärvi from Aalto University, who has years of experience in the development of DEM simulations for ice rubble.

The work of M. van den Berg fits well into the collaborative efforts of WP4 to develop a numerical toolbox for design. The toolbox uses same modelling methodology, such that the ice ridge model can be easily implemented in a later stage.

Accidental collisions with coupled ice mass – structure

Low ice class vessels are designed with a design load that is well below the expected load during the service life of the vessel. Hence, permanent damage to the ship is expected. Small damages pose no problem except cost, but the probability of larger damages causing flooding, environmental pollution or loss of ship and crew should be reduced in the design stage. Typical scenarios causing such damages are impact into multi-year or glacial ice, with ice predominantly in the brittle regime due to the high impact velocities.

During 2014 we got the chance to conduct pilot test experiments on coupled ice-structure interaction at high (realistic) velocities. Granular ice bullets with a diameter of 32 cm were impacted into a steel beam at 8 m/s in the pendulum accelerator rig at the SIMLab research facilities at NTNU, with a total kinetic energy of about 24 kJ. During impact, both elastic and plastic deformations of the impacted beam were observed while at the same time most of the ice was

Figure 29. High-speed video of the ice impact experiments.

crushed (Figure 29). Impact force and displacement of the ice was measured, along with high speed video recordings at 18 kHz.

Based on the measured data and high-speed video recordings, we could show that a coupled interaction was achieved, in which the deformations of the steel beam contributed to increased confinement of the ice, thereby increasing its strength. The transition from elastic steel response to large inelastic deformations was rapid, emphasizing the need to further study the coupled ice-structure interaction with brittle ice in the shared energy regime. Conducting such experiments at the SIMLab facilities is promising; we were able to get the type of ice-structure interaction expected to occur in realistic full-scale behaviour for impacts causing large structural damage in a cost-efficient way with a good measurement system. Further improvements of the experiments are possible within the limitations of the testing apparatus and measurement system.

The experiments were also featured on the Discovery Channel's Daily Planet show in September, 2014, in which we got a chance to communicate some of the challenges ships face in ice, and how our research aims to bridge the knowledge gaps, thereby improving the safety of operations in ice (Figure 30).

Figure 30. Communicating challenges with ice collisions and how our research will help to create safer operations to the Discovery audience.

WP5:
Ice Management and Design Philosophy

In WP5 "Ice Management and Design Philosophy", the objectives are to establish a system design philosophy that ensures that safety and reliability requirements are fulfilled by the Arctic offshore structures without being overly conservative. This shall consider use of ice management means such as icebreakers, iceberg towing vessels, structure disconnection and reconnection capabilities, and a sophisticated ice surveillance system for online situational awareness of the ice management process.

In essence, the following topics have been studied in 2014:

- Technologies and methods for sea-ice surveillance.
- Broken ice studies.
- Iceberg towing.
- Risk and safety of structures protected by ice management.

Sea-ice surveillance

The 360CamSys and sea-ice image processing

In the Oden Arctic Technology and Research Cruise 2013 (OATRC'13), a 360 degree Camera System (360CamSys) was developed, installed, and successfully applied. The main objective was to establish a comprehensive and systematic photo documentation of the sea-ice condition around the vessel during its maneuvers. Figure 31 shows one of the two 360-degree camera domes used to capture images.

Relevant images from the 360CamSys was stitched and orthorectified to represent the overall image in correct scale on a flat surface. The result is a picture as shown in Figure 32, where the vessel is partly shown together with the surrounding ice environment. Such images were capture every 10 seconds during the vessel maneuvers in ice.

After the mission, work has been done to post-process the data with the aim to extract useful ice parameters from the

Figure 31: One of the 360CamSys camera domes, showing some unfortunate fogging. Courtesy: Bjørklund et al. (2013).

Figure 32: Stitched and orthorectified panorama image representing the image data in correct scale on a flat surface (Zhang and Skjetne, 2014).

images. Such data include calculation of ice concentration and identification of individual ice floes to create a floe-size distribution statistics for each image. This work is based on the methods developed by Zhang and Skjetne (2015), where closed ice floe boundaries are detected using a GVF snake algorithm, especially to separate the connected floes. The overall procedure is to first distinguish ice pixels from water pixels, then perform ice floe boundary detection using the GVF snake algorithm (with some modifications), and finally perform ice floe shape enhancement.

The result is an image as shown in Figure 33 where the individual ice floes have been identified with shape, size, and centroid position in the image. A floe size distribution is then automatically calculated and illustrated as shown by the histogram in Figure 34.

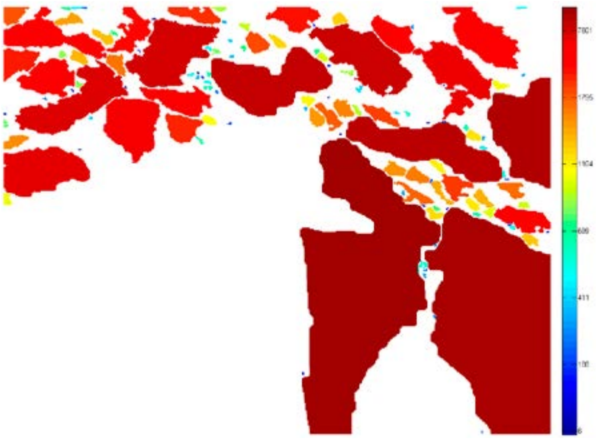


Figure 33: Identified ice floes with coloring based on floe sizes. Courtesy: Zhang and Skjetne (2014).

Since the input stitched images from the 360CamSys are sometimes highly blurred due to occasional icing/fogging on the camera dome, some manual interaction in the post image processing has been necessary. This is a time-consuming process, and work in progress is to improve this for the 360CamSys. Work in progress is also to make the post-processing algorithms fully automatic to alleviate time-consuming manual tuning.

For more details on the ice-image processing methods, see Zhang and Skjetne (2015). See also Zhang and Skjetne (2014) where the 360CamSys images are discussed in further details.

Sea-ice surveillance by autonomous underwater vehicles

Autonomous underwater vehicles (AUVs) are suitable as sensor carriers in the Arctic, as they are unaffected by

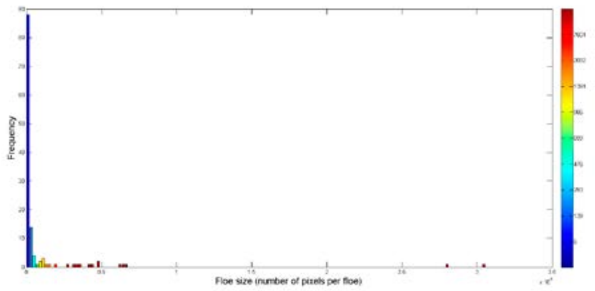


Figure 34: Histogram with floe size distribution. Courtesy: Zhang and Skjetne (2014).

harsh surface conditions, and since ice features are more dominant on the underside of the ice. An ongoing work in WP5 is the use of AUVs for subsurface mapping and monitoring of sea-ice and icebergs. The most immediate goal is to mature and qualify the necessary AUV and sensor technologies for Arctic conditions. Next, the goals are to develop AUV guidance and control algorithms, in combination with relevant sensor technologies, for continuous monitoring of drifting sea-ice and for autonomous detection and mapping of drifting ridges and icebergs frozen into the sea-ice.

The main experimental platform, available to the research, is as shown in Figure 35 the NTNU REMUS 100 AUV and an Imagenex DeltaT multibeam echo-sounder. Ongoing work includes software development and implementation, instrumentation, and field experiments with this underwater sensor platform.

Figure 35: The NTNU REMUS 100 AUV used in SAMCoT research (Norgren and Skjetne, 2014).

PhD candidate Petter Norgren is conducting this development and research work. In his research he looks at how to utilize AUVs for detection, mapping, and tracking of ice features that may pose a threat to a protected vessel in an IM operation. In the period between January 6th and February 7th 2014, he participated in a UNIS course called "Underwater robotics in the Arctic Polar night", with responsibility to operate and program the NTNU REMUS AUV. The course was a collaboration between NTNU, UiT, and UNIS, and included several international researches as well. The field campaign took place in Ny-Ålesund at Svalbard, and during this period, they conducted several missions with the AUV, trained candidates in the use of AUVs and ROVs, and gathered valuable scientific data related to Arctic marine biology in the polar night. During the seven conducted missions, they gained valuable experiences related to operation of underwater robots in the Arctic.

One of the planned routes and achieved AUV trajectories from the Ny-Ålesund campaign is shown in Figure 36. This shows how bad hydroacoustic navigation in combination with a large compass bias estimation can affect the track-following behavior of the vehicle, taking it far off the specified track. These issues are studied in combination with this work in the Centre of Excellence AMOS.

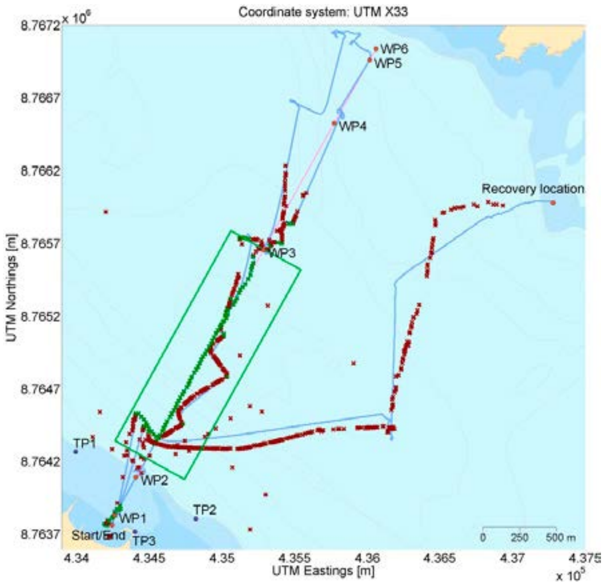


Figure 36: Planned routes and actual AUV trajectory for a cross-fjord survey outside Ny-Ålesund at Svalbard. Courtesy: Norgren and Skjetne (2014).

More details on experiences from the AUV missions at Svalbard and related technological details are provided by Norgren et al. (2014) and Norgren and Skjetne (2014).

Ice tracking drifters

During the OATRC'13 expedition in the Greenland Sea, 14 drift trackers, as seen in Figure 37, were deployed on sea-ice and icebergs. The trackers recorded GPS position and sent this information through an Iridium channel. The objectives were to study the ice drift patterns and motion characteristics in the region.

PhD candidate Renat Yulmetov was assigned this task. Three trackers were deployed as a group, with one on each end of the longer horizontal axis of an iceberg (see Figure 38) and one on an adjacent sea-ice floe. A total of three such

Figure 37: Ice drift tracker.

Figure 38: Deployment locations on iceberg.

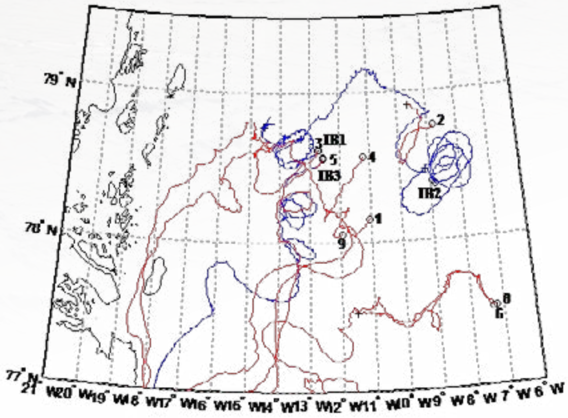


Figure 39: Drift trajectories of ice trackers (blue = icebergs; red = ice floes). Courtesy: Yulmetov and Løset (2014).

groups were deployed. This provided the ability to record both rotational and translational motion of the iceberg as well as the relative motion between the sea-ice floe and the iceberg.

The drift speed, relative drift speed, and rotation speed were analyzed to show that the sea-ice generally drifts faster than the icebergs, though the relative velocity of close objects is low (a few cm/s on average). Some of the icebergs were shown to rotate actively, with diurnal periodicity, making a full revolution in just a few hours. The overall drift patterns are depicted in Figure 39.

This work was concluded in the IAHR'14 conference paper by Yulmetov and Løset (2014), for which the main author received the "Best candidate paper award." More detailed descriptions and conclusions from this data collection activity is found in this paper.

Online ice surveillance by shipboard sensors

The newest addition to the SAMCoT WP5 family is the PhD candidate Hans-Martin Heyn, who started September 1st 2014. The objective of his research is to enable safer and more reliable stationkeeping operations by position mooring in Arctic conditions. To establish this, part of his study is to develop methods for monitoring the sea-ice loads on the vessel (global force magnitudes and angle of attack, early detection of changes in relative drift direction) through the onboard motion sensor suite used in stationkeeping, in particular posref units, gyrocompasses, and the motion sensors (IMUs). The candidate has therefore started to study relevant background knowledge, in particular methods for change detection through signal statistics (signal-based detection) and through physical models (model-based detection). Vessel motion responses due to interaction with a broken ice field are presently studied both in time-domain and frequency domain, to see if certain vessel-ice interaction processes can be recognized through specific signatures.

Broken ice studies

Highly concentrated and confined broken sea-ice can be a serious threat for an offshore floater. To predict and simulate impacts from broken sea-ice on a floater, a study by PhD candidate Renat Yulmetov and co-authors in WP5 (Yulmetov et al., 2014) has been to model the sea-ice floes as discontinuous, consisting of many independent rigid bodies. As seen in Figure 40 and Figure 41, naturally broken sea-ice may differ significantly for different areas, seasons, and environmental state. Comparing these to the artificially broken ice from IM, shown in Figure 42, indicates that a different characteristic description may be needed.

Figure 40: Naturally broken sea-ice North-East Greenland, 2012.

Figure 41: Naturally broken sea-ice by Svalbard, 2013.

Figure 42: Artificially broken sea-ice North-East Greenland, 2012.

A single sea-ice floe can be geometrically characterized by thickness, mean caliper diameter, area, roundness, etc. For broken sea-ice, it is therefore of interest to attain knowledge on the overall concentration and distributions of those characteristics over relevant offshore fields and use this as input to numerical models used for design and verification of concepts for those fields.

The study in WP5 has therefore been on developing an effective algorithm for random generation of sea-ice floes modeled as polygons. The resulting algorithm presented by Yulmetov et al. (2014) can, within a reasonable calculation time, generate given concentrations and floe-size distributions, with no overlap between floes in 2D. An example is shown in Figure 43.

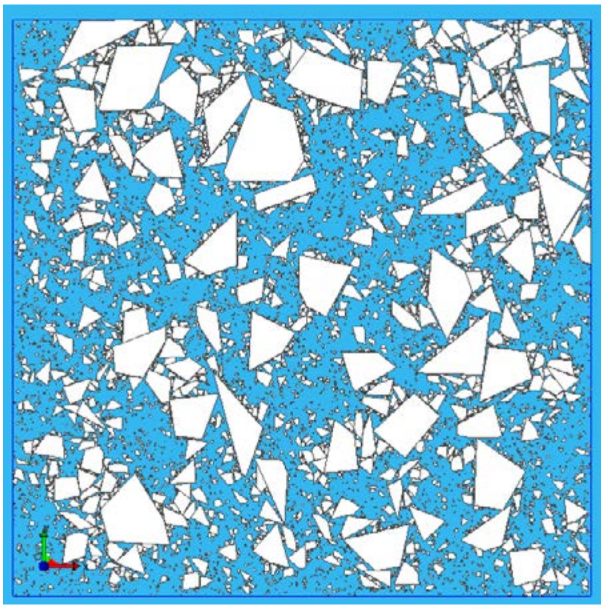


Figure 43: Numerically generated sea-ice field. Courtesy: Yulmetov et al. (2014).

Iceberg towing

Towing of icebergs is a subject investigated in WP5 through an ongoing PhD study on numerical simulation of iceberg towing in sea-ice. This is illustrated in Figure 44.

A control engineering study on how to guide and control a towing vessel to safely and efficiently tow an iceberg away from an operations area has also been conducted in the master thesis by Orsten (2014). He proposed an interesting setup for a single vessel iceberg towing operation. The research objective was to safely tow an iceberg out of an offshore field along a specified straight-line path under the influence of ocean current. This involves two subproblems:

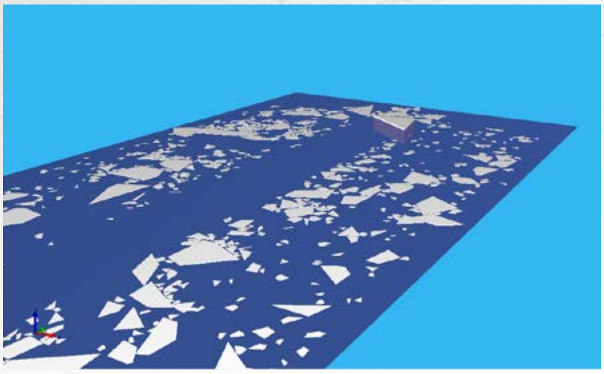


Figure 44: Numerical simulation of iceberg towing in sea-ice. Courtesy: R. Yulmetov.

1) how to make the iceberg follow the path, and 2) how to limit the tow force to avoid the failure modes of towline rupture, towline slippage, and iceberg overturning.

To make the iceberg follow the path, a so-called integral-Line-of-Sight (iLOS) algorithm was used to online calculate the direction of the towline and, consequently, the towing position of the vessel. As reported by Orsten et al. (2014) and illustrated in Figure 45, the integral action in the iLOS algorithm will automatically compensate for the ocean current by estimating the appropriate towline direction that ensures zero cross-track error. To limit the towforce, an online reliability index algorithm was embedded into the towing vessel speed control law. Based on continuous measurement of the towline tension, this continuously constrains the towing vessel speed such that the online calculated reliability index for the towline never drops below a threshold for which the mentioned failure modes are likely to occur.

Risk and safety of structures protected by ice management
Various efforts are under way in SAMCoT to evaluate the response of offshore structures, in particular floating units, in short-term ice conditions. Ensuring the safety, however, requires that the structure can perform in a long-term portfolio of ice conditions that can be encountered over design life of the structure. The research in this in WP5 is about quantifying the safety of arctic offshore structures over their lifetime. This should cater for both long- and short-term variations of loads.

To ensure a sufficiently safe structural design at the same time as reducing costs of Arctic offshore field developments, ice management operations are considered for reducing the ice severity. As discussed by Farid et al. (2014a), ice management in sea-ice will typically involve use of 1 to 4 icebreakers depending on the operating environment. The ice management fleet will protect the offshore installation by breaking the incoming ice into smaller pieces and by reducing the confinement in the ice cover. Failure of such a marine operation in the demanding Arctic environment can threaten the integrity of the offshore platforms or drilling units. Therefore, analyzing potential failure modes, understanding its causes, and obtaining knowledge of the influencing factors are of crucial importance to plan for and mitigate the risks.

Factors with an influence on the risk are called risk influencing factors (RIFs) and can be technical, organizational, and human. RIFs are identified and structured in the study

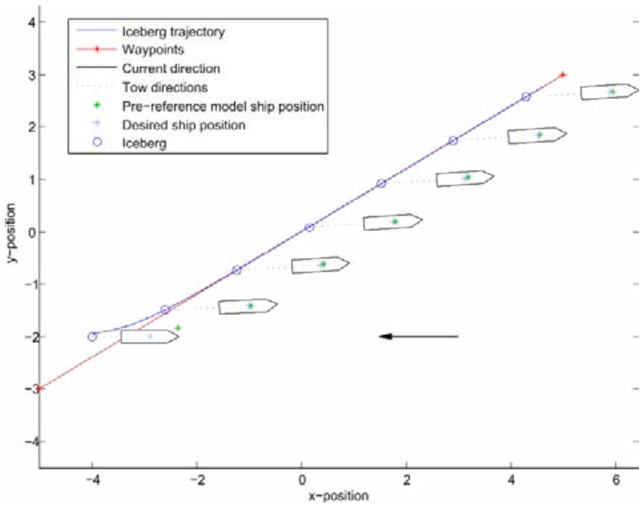


Figure 45: Simulated iceberg towing in ocean current. The blue circles are the location of the iceberg at different instants of time. The iLOS algorithm ensures that a correct towline direction is enforced. Courtesy: Orsten (2014).

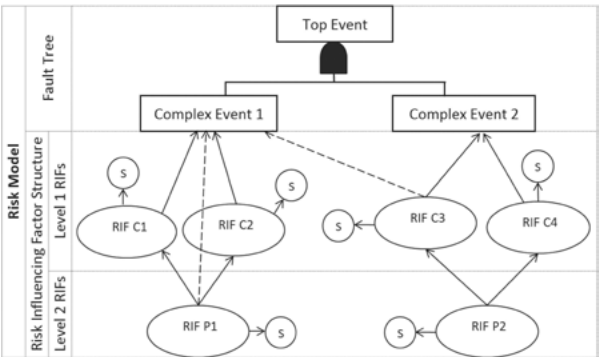


Figure 46: A simplistic risk model being a merger of a fault tree and a RIF structure. Courtesy: Farid et al. (2014a).

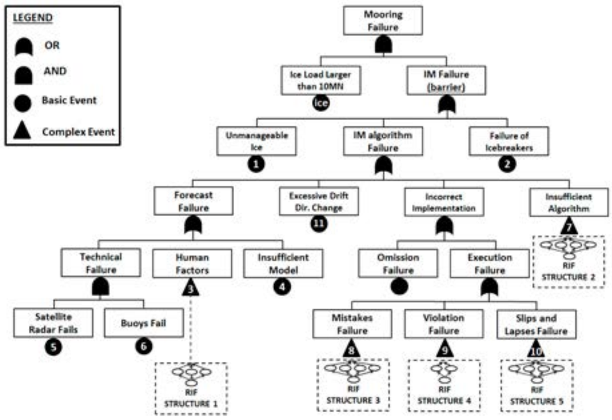


Figure 47: Fault-tree enhanced with RIF structures for safety barriers of IM. Courtesy: Farid et al. (2014a).

by Farid et al. (2014a) such that they affect the basic events of a conventional fault tree analysis and thus the total risk, where the RIFs are treated as uncertain variables.

The model is hybrid because it merges a Bayesian belief network (BBN) for the RIF structure with a conventional fault tree model; see Figure 46. The Bayesian framework provides then the opportunity to update constituents of the model as more evidence becomes available over time. Case studies have been investigated by PhD candidate Farzad Faridafshin to illustrate the methodology. One case study is the ice management operation related to the Shtockman development offshore Russia, and the corresponding fault tree is shown in Figure 47. Results show how the improvement in the status of the RIFs (better practices) can improve the reliability of the mooring lines of a floating unit and how the precision in data and other model parameters affect the results. See Farid et al. (2014a) for more details on this work.

PhD candidate Martin Hassel presented a paper at the PSAM 12 conference (Hassel et al., 2014) on the main

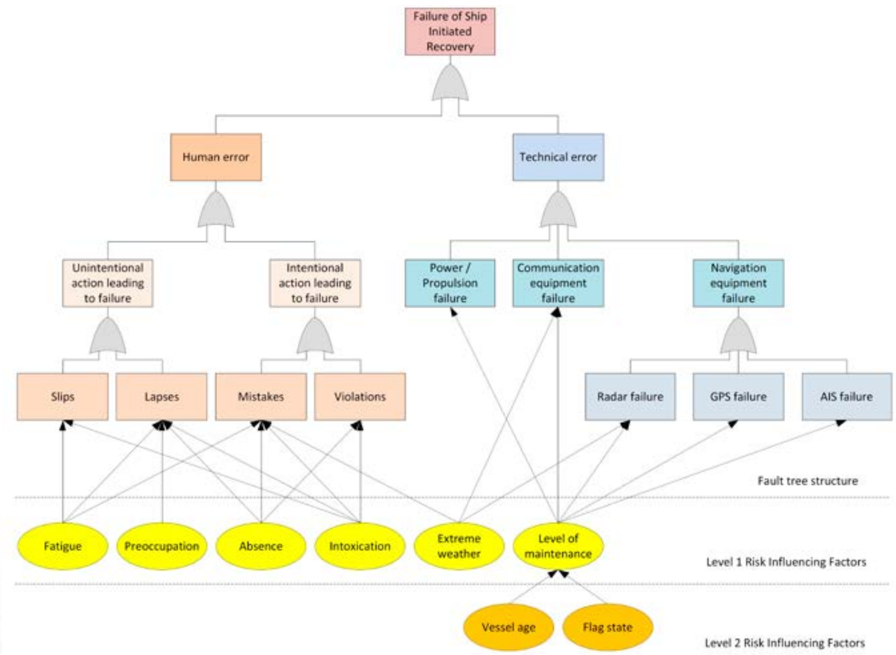


Figure 48: Example hybrid fault tree and RIF structure for PFSIR (Failure of Ship Initiated Recovery). (Hassel et al., 2014).

challenges with the current risk model for collisions between ships and offshore installations on the Norwegian continental shelf. As stated, the "COLLIDE risk model became the industry standard about 20 years ago for calculating the risk of ship collisions against offshore installations on the Norwegian Continental Shelf (NCS). The risk model is currently being revised, in order to take account for the new technology that has entered into the arena. Technological advances have significantly changed the way seafarers operate and navigate." Following up on this, Hassel et al. (2014) "presents challenges with the current industry standard COLLIDE-methodology and highlights areas where improvements and alternatives to the current model are needed"

The focus in this WP5 study is on developing the next generation risk model for ship-installation impacts, using a Bayesian Belief Network (BBN) in order to better model all relevant factors. An example is shown in Figure 18 on the risk that a vessel itself does not initiate action to avoid a collision with an installation (Failure of Ship Initiated Recovery – PFSIR). The focus of M. Hassel is on risk assessment and risk models that will also be valid for petroleum activities in the Barents Sea under Arctic conditions.

References:

Bjørklund, H., Prusakov, A., and Sinitsyn, A. (2013). 360 Degree Camera System. SFI-SAMCoT Internal report. Project OATRC'13.

Farid F., Lubbad, R., and Eik, K. (2014a). A Hybrid Bayesian Belief Network Model for Risk Modeling of Arctic Marine Operations. In Proc. ASME 33rd Int. Conf. Ocean, Offshore and Arctic Eng. (OMAE2014). San Francisco, California, USA.

Farid, F., Scibilia, F., Lubbad, R., and Løset, S. (2014b). Sea Ice Management Trials during Oden Arctic Technology Research Cruise 2013 Offshore North East Greenland. In Proc. 22nd IAHR Int. Symposium on Ice. Singapore, pp. 518–525.

Hassel, M., Utne, I. B., and Vinnem, J. E. (2014). Analysis of the Main Challenges with the Current Risk Model for Collisions Between Ships and Offshore Installations on the Norwegian Continental Shelf. In Proc. Probabilistic Safety Assessment and Management (PSAM 12). Honolulu, Hawaii.

Norgren, P., Lubbad, R., and Skjetne, R. (2014). Unmanned underwater vehicles in arctic operations. In Proc. 22nd IAHR Int. Symposium on Ice. Singapore, pp. 89–101.

Norgren, P. and Skjetne, R. (2014). Using autonomous underwater vehicles as sensor platforms for ice-monitoring. Modeling, Identification, and Control. 35(4), pp.263-277. doi:10.4173/mic.2014.4.4

Orsten, A., Norgren, P., and Skjetne, R. (2014). LOS guidance for towing an iceberg along a straight-line path. In Proc. 22nd IAHR Int. Symposium on Ice. Singapore, pp. 526–534.

Orsten, A. (2014). Automatic Reliability-based Control of Iceberg Towing in Open Waters. MSc thesis, Norwegian Univ. Science & Technology, Trondheim, Norway.

URL: http://www.diva-portal.org/smash/record.jsf?dswid=-5115&pid=diva2%3A746614

Yulmetov, R. and Løset, S. (2014). Kinematic Characteristics of Sea Ice and Iceberg Drift in the Greenland Sea. In Proc. 22nd IAHR Int. Symposium on Ice. Singapore, pp. 727–734.

Yulmetov, R., Løset, S., and Lubbad, R. (2014). An Effective Numerical Method for Generation of Broken Ice Fields, Consisting of a Large Number of Polygon-Shaped Distinct Floes. In Proc. 22nd IAHR Int. Symposium on Ice. Singapore, pp. 829–836.

Zhang, Q. and Skjetne, R. (2014). Image techniques for identifying sea-ice parameters. Modeling, Identification and Control. 35(4), pp.293-300. doi:10.4173/mic.2014.4.6

Zhang, Q. and Skjetne, R. (2015). Image processing for identification of sea-ice floes and the floe size distributions. IEEE Trans. Geoscience and Remote Sensing. 53(5), pp. 2913-2924. doi:10.1109/TGRS.2014.2366640.

WP6: Coastal Technology

Coastal zone development in the Arctic is quite demanding. The construction of Arctic roads, harbours and other facilities 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, the climate changes may result in a warmer Arctic with less sea-ice cover leading to higher wave forces 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, analytical and numerical models needed by the industry to improve the prediction of Arctic coastal erosion and the influence of climate changes. This is essential for the design of environmentally friendly and sustainable coastal structures and technologies.

In order to address these general challenges according to the industry partners needs for innovation, several research projects have been carried out, addressing:

- Arctic coastal erosion mechanisms – Field work
- Numerical modelling of the thermo-denudation of coastal bluffs in the Arctic

Arctic coastal erosion mechanisms – Field work

Field work is continuously being performed at several sites at Spitsbergen (Vestpynten) and northwest Russia (Baydaratskaya Bay and Varandey) to collect full-scale data on Arctic coastal erosion. This includes monitoring the dominant erosion mechanisms, erosion rates, extent of coastal permafrost, ground thermal regimes and the ice conditions at these locations.

The field crew visiting the CALM site in Adventdalen with from left to right: Prof. Hanne Christiansen, PhD candidate Emilie Guegan, fellow PhD candidate visiting from Lvala University, Benoit Loranger and Julie Lepage and Anatoly Sinitsyn. To the right, Anatoly Sinitsyn with the heat flux meter in Vestpynten.

March 2014, Vestpynten

August 2014, Vestpynten

August 2014, Vestpynten

August 2014, on CALM site in Adventdalen

Figure 49: Photos from field activities on Spitsbergen.

Figure 50. Topographical survey on Pesyakov Island, Varandey area. Photo: Kokin O.

Figure 51. Coastal survey in Medynskiy sector, Varandey area. Photo: Kokin O.

Figure 52. A location for a potential polygon on thermo-abrasive coast of Medynskiy segment. Photo: Kokin O.

Guegan E. and Sinitsyn A. on DUE permafrost workshop, Frascati (Rome), Italy

Sinitsyn A. presented paper "Field investigations, remote sensing and modelling approach for Arctic coastal erosion" on XXV International Coastal Conference "Coastal Zone – Future Perspectives" in Sochi, Russia. Photo: A. Sinitsyn

Figure 53: Photos showing WP6 conference attendance in 2014.

The focus of the field work this year has been on maintaining the investigation sites and analysing the data being collected, i.e. no additional field equipment were installed this year. In March, A/Prof. Sinitsyn and MSc candidates Dormoy and Ganicheva visited the Vestpynten site and downloaded temperature data from thermistor strings. Sinitsyn revisited the Vestpynten site together with PhD candidate Wrangborg and they performed Laser scanning in order to closely monitor the geomorphologic evolution of the site.

In the Vestpynten site, field investigations were also performed in August by PhD candidate Guegan, A/Prof. Sinitsyn and Finseth. The three researchers maintained the site and downloaded its data. Furthermore, they relocated the heat-flux meter to the Adventdalen CALM site run by Prof. Hanne Christiansen. The ground heat flux is currently being recorded at the CALM site where thermal ground properties are known. This will be very useful to calibrate the measurement and to test the validity of WP6 instrumentations.

The Vestpynten site highlighted the importance of the snow bank for the erosion process of such a mixed type of coast, i.e. quaternary sediments are overlying bedrock. The results and a detailed description of the erosion process for this site will be presented in a Journal paper which will promptly be submitted by Guegan & Christiansen.

In August, State Oceanographic Institute (SOI) carried out a field campaign in Varandey site and collected full-scale data according to the scope of work of WP6. SOI's team performed topographical measurements on 40 profiles on Pesyakov, Varandey and Medynskiy sectors. They downloaded temperature data from a polygon on Pesyakov Island, and made observations to choose a location for a potential polygon on thermo-abrasive coast of Medynskiy segment.

In the site at Baydaratskaya Bay, PhD candidate Aleksyutina from Moscow State University (MSU) participated in the field work at the site in June. Aleksyutina is a PhD candidate since 2012 and she is studying mainly the structural composition and behaviour of frozen soils of Ural coast of Baydaratskaya Bay. During the field work at the Baydaratskaya Bay site this June, Topographical measurements were performed, temperature data were collected, and a new thermistor string was installed.

The findings from the field work of WP6 were presented to the national and international scientific community at different occasions. The remote sensing analysis (satellite images) to evaluate the historical erosion rates at the investigation sites were presented by Guegan and Sinitsyn at the DUE permafrost conference in February 2014 at the European Space Agency in Frascati, Italy.

In June, the investigations sites discussed above were presented at the 4th European Permafrost Conference (EUCOP4) in Evora, Portugal, with both oral and poster presentations.

In October, Sinitsyn presented a paper titles "Field investigations, remote sensing and modelling approach for Arctic coastal erosion" on XXV International Coastal Conference "Coastal Zone – Future Perspectives" in Sochi, Russia.

In November, Sinitsyn hold presentation "Coastal Studies for Arctic Offshore Development in the Pechora Sea, Russia" on "A Norwegian-Russian conference on petroleum resources, energy-political cooperation and social development in the Arctic region", Lysaker (Oslo), Norway

Numerical modelling of the thermo-denudation of coastal bluffs in the Arctic

The PhD candidate, Guegan was employed in 2012 to identify and study the different mechanisms behind coastal erosion in the chosen Arctic sites. After preliminary field investigation, it appears that Thermodenudation is the dominant erosive processes both in Svalbard but also in Baydaraskaya Bay site and affecting significantly some segment of Varandey coastlines.

Guegan investigated numerically the influence of the thermodenudation processes on soil stability and discussed the material properties that are needed for such models. During July, Guegan worked intensively with Dr. Anteneh Tsegaye from WP2. They developed a sequentially coupled frozen soil model that they implemented in the Geo-studio package. Guegan tested and applied the model to WP6 investigation sites, i.e., Vestpynten (Svalbard), Baydarskaya Bay (Russia) and Varandey (Russia). The model works now and can be used, but still a lot of efforts are needed for validation and calibration. The research and modelling approach used for modelling coastal erosion was presented by Sinitsyn in the International Coastal Conference in Sochi in August 2014.

Guegan is planning to submit 3 journal papers in the first half of 2015 and hopefully to defend her thesis before Sep., 2015.

SAMCoT
"continues to make very good progress"

SAMCoT's Scientific Advisory Committee (SAC) is part of the centre's organization structure whose role is to provide scientific quality assurance. The committee is composed of Prof. Steve Bruneau, Memorial University, Canada; Prof. Anatoly Brouchkov, Moscow State University; Dr. Robert Frederking, National Research Council, Canada; Prof. Sven Knutsson, Lulea University of Technology, Sweden; Prof. Matti Läppäranta, University of Helsinki, Finland; Prof. Erland Schulson (Chair), Dartmouth College, USA; and Prof. Hayley Shen of Clarkson University, USA. All international experts in Arctic Research with profound knowledge of the different Research Areas within SAMCoT.

The Centre's overall objectives are:

(i) to provide research-based knowledge that industry will need to develop arctic technology for the energy sector of the economy and for society as a whole;

(ii) to address specifically the implications that arise from the presence of ice and permafrost, as well as to produce knowledge that will ensure sustainable exploration, safe exploitation and transport from and within the vulnerable Arctic; and

(iii) to provide the foundation for further development of environmentally adapted coastal infrastructure.

Given these objectives, SAMCoT has six work packages (WPs), summarized below, each with specific objectives. This report is the first document prepared by SAC. It covers the period 2011-2014, from the programme's beginning until the present. Since its inception, SAMCoT has made significant contributions to both the production of highly qualified people and the creation of new knowledge. This is evident in the statistics: 7 PhDs and 27 MSc degrees have been awarded, 24 journal papers have been published and 110 contributions have been made to the proceedings of technical conferences.

From this perspective alone, the programme as a whole is well on track. The only concern is the work package on coastal technology where progress appears to be slow.

Although it is too soon to make a measure, SAMCoT has the potential to become recognized internationally as a leader is sustainable arctic engineering. As more journal papers appear and the scientific and technical communities have the opportunity to use the products of SAMCoT's work, its status will become apparent. Citations to its published work will be one measure. New technology such as design guidelines, software, data sets and new models will be others. In short, SAMCoT has made and continues to make very good progress.

WP 1:
Data collection and process modelling

Objectives: To provide field data, as required by the other WPs, on sea ice and icebergs, on coastal permafrost and on characteristics of sea state.

Assessment: In 2011–2014 WP1 has produced two PhD degrees and eight journal papers that can be taken as a very good achievement. Also the number of MSc degrees (nine) is remarkable. The most advanced field of research has been sea ice ridges, with their fine structure, thermodynamics and mechanical properties. From the core of sea ice ridging the research has expanded to coastal research, with land-ice interaction and permafrost, and to offshore questions of drift of sea ice and icebergs. Progress over the past four years is very good.

WP2:
Material modelling

Objective: To develop material models to be used in advanced numerical simulations of ice rubble and frozen soils.

Assessment: The dominant thrust of WP2 is the mechanical behaviour of ice rubble, including the strength of freeze bonds between blocks of saline ice and the frictional resistance during slow sliding across a freeze-bonded interface. The work is justified largely on the basis that pressure ridges (sails and keels) are geophysical ensembles of ice blocks, the assembly of which imparts strength and other properties that depend on the degree of bonding. The study is amongst the first of its kind, and is being performed in a careful and systematic manner.

While useful data are being gathered from measurements in the laboratory, less evident is information on the actual physical mechanisms. For example, could insight, at least within the water-free environment of a ridge sail, be gained from an examination of the literature on the sintering of a snow? Progress to date is very good.

WP3:
Fixed structures in ice

Objectives: To develop models to predict ice-induced vibrations, and to simulate the ice action from first-year ice ridges on fixed structures.

Assessment: The ridge work (literature survey, field measurements, sonar analysis and physical/numerical modelling of keel loads, adoption of Aalto University's "home-made" model) can help in assessing risk and sizing/shaping offshore structures. Work on understanding vibrations (basin tests/analysis, numerical modelling to assist in explaining occurrences and scaling) can identify solutions to minimize dynamic ice loading.

The direction of the research is generally aimed at understanding, rather than direct design applications. The behaviour of ice as a material is likely to be a more significant topic as WP3 turns its attention to mitigating the effects of ridges on structures and on their dynamic response. The quality of the work is good, including the output of high quality people.

WP4:
Floating structures in ice

Objectives: To improve the prediction of loads exerted by first/multi-year ice, ridges and icebergs on floating structures, and to predict the performance of structures.

Assessment: The numbers of PhD candidates and journal papers are positive, as are the number of conference papers and MS theses. The fact that two of the PhD candidates will join the team as postdocs is also positive, by creating a vertically integrated pipeline of knowledge.

The overall quality of the outputs is difficult to judge at this point, although one indicator is the high profile, keynote lecture given by Prof. Løset at the 22nd IAHR Ice Symposium in Singapore this past summer.

Concerning future work, the SAC notes that owing to changing conditions in the Arctic it is conceivable that structures will face semi- open water more frequently. Therefore, developing in-house expertise along with collaborations with large-scale ice dynamics people at environmental prediction centers and with the remote sensing community will be very useful. Progress to date is very good.

WP5:
Ice management and design philosophy

Objectives: To establish a philosophy that ensures that the Ultimate Limit State (ULS) and Accidental Limit State (ALS) requirements are fulfilled by arctic offshore structures without being overly conservative, based on the use of icebreakers, of iceberg towing vessels, of structure disconnection/reconnection capabilities and of a sophisticated ice surveillance system for online situational awareness, and to quantify the efficiency of ice surveillance.

Assessment: WP5 appears to be meeting its obligations in some areas, primarily in iceberg management, various field trials, sea ice drift modelling and analytical risk assessment. WP5 has made clear contributions to the training of high quality personnel and, through 19 conference papers and one journal paper, significant contributions to the literature. Yet iceberg challenges prevail elsewhere, such as the east coast of Canada, and there does not appear to be a concerted effort to work with Canadian operators and researchers. Will there be some effort in this direction? On the whole, progress on WP5 is good.

WP6:
Coastal technology

Objectives: To develop new knowledge of and analytical and numerical models of coastal erosion in the Arctic.

Assessment: The development of three highly qualified people (MSc recipients) is noteworthy. However, the absence after four years of a single contribution to the peer-reviewed scientific literature via journal papers is a negative point. Progress to date appears to be significantly below progress on the five other WPs.

DISSEMINATION

A criteria for a successful SFI is high scientific quality of research. One way to control that is by publishing in well recognised journals. In 2014 SAMCoT researchers published 16 journal papers, 46 conference papers and gave 104 oral presentations.

A key event in 2014 was the 22nd IAHR International Symposium on Ice, 11–15 August 2014, Singapore where 25 persons associated with SAMCoT attended. Renat Yulmetov, a SAMCoT PhD candidate, received the award for the best candidate paper at the conference.

The partners in SAMCoT are updated on the research activities and progress through quarterly newsletters and two annual workshops for the partners. In addition SAMCoT had 25 other media coverages, where SAMCoT in Discovery Channel Canada had the highest rating with about 200 000 viewers.

SAMCoT SAC

• Prof. Anatoly Brouchkov	Moscow State University
• Prof. Erland M. Schulson	Thayer School of Engineering at Dartmouth - Chair
• Dr. Hans Bihs	NTNU
• Prof. Hayley H. Shen	Clarkson University
• Prof. Matti Leppäranta	University of Helsinki
• Dr. Robert Frederking	National Research Council of Canada
• Prof. Steve Bruneau	Memorial University of Newfoundland
• Prof. Sven Knutsson	Luleå University of Technology

Doctoral Thesis and Master Thesis (3, 9)

Dalane, O. *Some Aspects of Conical Floaters Exposed to Ice Actions.* NTNU Publication Series - Doctoral Thesis 2014:334

Kim, E. *Experimental and numerical studies related to the coupled behavior of ice mass and steel structures during accidental collisions.* NTNU Publication Series - Doctoral Thesis 2014:135

Lu, W. *Floe Ice - Sloping Structure Interactions.* NTNU Publication Series - Doctoral Thesis 2014:324

Bueide, I.M. *Freeze-bond strength experiments, radially confined compression tests on saline and fresh water samples.* NTNU Publication Series - Master Thesis 2014.

Ganicheva, N. *Engineering structures in the coastal zone in the Arctic, the example of Vestpynten, Spitsbergen.* NTNU Publication Series - Master Thesis 2014.

Greaker, N. *Laboratory Measurements of Ice-concrete Abrasion with different Types of Ice Quality.* NTNU Publication Series - Master Thesis 2014

Kvadsheim, S. *Iceridge keel size distributions.* NTNU Publication Series - Master Thesis 2014.

Myklebust, T.O. *Equipment and Production of Columnar Sea Ice Replica in NTNU Cold Lab.* NTNU Publication Series - Master Thesis 2014

Orsten, A. *Automatic Reliability-based Control of Iceberg Towing in Open Waters.* NTNU Publication Series - Master Thesis 2014.

Pedersen, C.Y. *Interfacial Study of Input Data in dynamic Ice-structure Interaction and Evaluation of Tactile Sensors Usability in Ice-related problems.* NTNU Publication Series - Master Thesis 2014.

Vindegg, C.M. *Stress measurements in landfast sea ice in Van Mijenfjorden in Svalbard.* NTNU Publication Series - Master Thesis 2014.

Østhus,V. *Robust Adaptive Control of a Surface Vessel in Managed Ice Using Hybrid Position- and Force Control.* NTNU Publication Series - Master Thesis 2014.

Published Conference Papers (46)

Aleksyutina D., Guegan E. *"A first approximation of ground thermal regime and ground ice volume in Baydaratskaya Coast, Northern Russia: an integration of field, laboratory and remote sensing analysis"*. 4th European Permafrost Conference (EUCOP4) in Evora, Portugal

Aleksyutina D. *"Pilot studies of structure and properties of frozen soil of the Ural coast of Baidarata Bay"*. MSU Conference "Lomonosov"

Bekele, Y., Kyokawa, H. *On Thermo-Hydro-Mechanically (THM) Coupled Finite Element Modeling of Ground Freezing and Thawing.* Proceedings of the 8th European Conference on Numerical Methods in Geotechnical Engineering (NUMGE) Delft, The Netherlands, 18-20 June 2014.

Ekeberg, O.-C., Høyland, K.V. Hansen, E., Tschudi, M. *Reduction in the number and draft of ridges in the Transpolar Drift in the Fram Strait during 2006-2011.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Ervin, Å., Høyland, K.V., Marchenko, A., Karulina, M., Karulin, E. *In-situ experimental investigation of the vertical stress distribution in sea ice covers; a comparison of tensile and flexural strength.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Farid-Afshin, F., Lubbad, R., Eik, K. J. *A hybrid bayesian belief network model for risk modeling of Arctic Marine Operations.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Farid-Afshin, F., Lubbad, R., Løset, S., Scibilia F. *Sea Ice Management Trials during Oden Arctic Technology Research Cruise 2013 Offshore North East Greenland.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Guegan, E., Sinitsyn, A., Nordal, S. *Field investigations, remote sensing and modelling approach for Arctic coastal erosion.* XXV International Coastal Conference "Coastal Zone – Future Perspectives" 2014.

Hassel, M., Utne, I.B., Vinnema, J.E. *Analysis Of The Main Challenges With The Current Risk Model For Collisions Between Ships and Offshore Installations On The Norwegian Continental Shelf.* Probabilistic Safety Assessment and Management PSAM 12, 2014.

Hendrikse, H., Renting, F.W., Metrikine, A. *Analysis of the fatigue life of offshore wind turbine generators under combined ice- and aerodynamic lodading.* Proceedings of the ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Høyland, K.V., Møllegaard, A. *Mechanical behaviour of laboratory made freeze-bonds as a function of submersion time, initial ice temperature and sample size.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Karulin, E., Marchenko, A., Karulina, M., Chistykov, P., Sakharov, A., Ervik, Å., Sodhi, D. *Field Indentation Tests of Vertical Semi-Cylinder on First-Year Ice.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Keijdener, C., Metrikine, A. *The effect of ice velocity on the bending length of level ice failing in downward bending.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Khilimonyuk V., Buldovich S., Brouchkov A *"Stability of permafrost for 60 years in the Northeast of the Europe"*. 4th European Permafrost Conference (EUCOP4) in Evora, Portugal

Kim, E., Høyland, K.V. *Experimental Investigations of the Energy Absorption Capacity of Ice During Crushing: Is the Specific Energy Scale Independent?* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Kim, E., Schulson E.M. *Some Secrets of the Ice Pressure-Area Curve for the Indentation of Ice.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Kim, E., Storheim, M., Amdahl, J., Løset, S. *Findings and lessons learned from implementing ice-structure impact tests in water and air.* Proceedings of the HYDRALAB IV Joint User Meeting, Lisbon, July 2014.

Kulyakhtin, S., Høyland, K.V. *Study of the Volumetric Behaviour of Ice Rubble Based on Bi-axial Compression Data.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Kulyakhtin, S. *Distribution of Ice Block Sizes in Sails of Pressure Ice Ridges.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Kyokawa, H., Bekele, Y. *Numerical simulation of thermo-hydro-mechanically coupled processes during ground freezing and thawing.* Proceedings of the 14th International Conference of the International Association for Computer Methods and Advances in Geomechanics (IACMAG), 22-25 September 2014, Kyoto, Japan, 2014.

IACMAG

Li, Z., Lubbad, R., Høyland, K.V. *Literature study: Development directions of coastal engineering in Arctic under climate changes.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Linzbach, A., Sinitsyn, A., Wrangborg, D., Ganicheva, N., Guegan, E. *Investigations of Coastal Erosion by Means of Laser Scanner VZ-1000 in Vestpynten, Spitsbergen.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Lishman. B., Marchenko, A. *An investigation of relative thermal expansion and contraction of ice and steel.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014

Lu, W., Høyland, K.V., Serré, N., Evers, K.U. *Ice load measurement by tactile sensor in model scale test in relation to rubble ice transport on Arctic offshore structures (RITAS)* Proceedings of the HYDRALAB IV Joint User Meeting, Lisbon, July 2014

Lubbad, R., Løset, S. *Time-domain analysis of managed-ice actions on offshore structures.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014

Marchenko, A. *Influence of added mass effect on rotation of a drifting iceberg in non-stationary current.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Marchenko, A., Karulin, E., Chistyakov, P., Sodhi, D., Karulina, M., Sakharov, A. *Three dimensional fracture effects in tests with cantilever and fixed ends beams.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Marchenko, N. Northern Sea Route: *Modern state and challenges.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Marchenko, N. *Floating Ice Induced Ship Casualties.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Nord, T., Lourens, E-M., Øiseth, O., Metrikine, A. *Model-based force identification in experimental ice-structure interaction by means of Kalman filtering.* Proceedings of the 9th International Conference on Structural Dynamics, EURODYN 2014, Porto, Portugal, 30 June - 2 July 2014.

Norgren, P., Lubbad, R., Skjetne, R. *Unmanned underwater vehicles in Arctic operations.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Orsten, A., Norgren, P., Skjetne, R. *LOS guidance for towing an iceberg along a straight-line path.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Polojärvi, A., Tuhkuri, J., Pustogvar, A. 2D DEM *Simulations of Model Scale Direct Shear Box Experiments.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Polojärvi, A., Tuhkuri, J. *3D DEM for Freeze Bonded Ice Rubble Consisting of Polyhedral Blocks.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Pustogvar, A., Polojärvi, A., Høyland, K.V., Bueide, I.M. *Laboratory scale direct shear box experiments on ice rubble: the effect of block to box size ratio.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.

Pustogvar, A., Kulyakhtin, S., Høyland, K.V. *Laboratory Oedometer Tests on Rubble Ice.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Ranta, J., Tuhkuri, J., Polojärvi, A., Paavilainen, J. *Statistical reconstruction of peak ice load data based on 2D combined finite-discrete element method simulations of ice interactions against inclined wall.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Saponaro, P., Sorensen, S., Rhein, S., Mahoney, A.R., Kambhamettu, C. *Reconstruction of testureless regions using structure from motion and image-based interpolation.* Proceedings of the IEEE International Conference on Image Processing, ICIP Paris 2014.

Serré, N., Høyland, K.V., Lu, W., Bonnemaire, B., Evers, K.-U. *Rubble Ice Transport on Arctic Offshore Structures (RITAS), Scale Model Investigation of Level Ice Action.* Proceedings of the HYDRALAB IV Joint User Meeting, Lisbon, July 2014.

Shestov, A. Marchenko, A. *Properties of Ice Ridge Keels and Sea Currents in their Vicinity in the Barents Sea.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

IAHR-Group

Sorsimo, A., Heinonen, J. *Modelling ice ridge punch tests with cohesive 3D discrete method.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.
Storheim, M., Amdahl, J. *Non-conservative consequences of "conservative" assumptions in ship-platform collision analysis.* Proceedings of the ASME 33rd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014. June 8-13, 2014, San Francisco, California, USA.
Tsarau, A., Løset, S. *Numerical simulations of broken ice motion in the vicinity of a floating structure.* Proceedings of the International Conference on Maritime Technology (ICMT), 7 to 9 July 2014, Glasgow, UK.
Tsarau, A., Løset, S., Grindstad, T.C., *Propeller wash by an icebreaker.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.
Tuhkuri, J., Polojärvi, A. *Preliminary Results from a Study on Full Scale Freeze Bond Geometry and Microstructure.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.
Wrangborg, D., Marchenko, A. *Stresses in Coastal Sea Ice and its Relation to Tidal Motion and Weather Data.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.
Yulmetov, R., Løset, S., Lubbad, R. *An Effective Numerical Method for Generation of Broken Ice Fields, Consisting of a Large Number of Polygon-Shaped Distinct Floes.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.
Yulmetov, R., Løset, S. *Kinematic Characteristics of Sea Ice and Iceberg Drift in the Greenland Sea.* Proceedings of the 22nd IAHR International Symposium on Ice. Singapore, August 11 to 15, 2014.

Published Journal Papers (16)

Aleksyutina D. M., Motenko R. G. (In Russian) *"Heatphysical Properties and Phase Composition of Moisture of Frozen Soil of the Ural Coast of Baydarata Bay".* Journal of Engineering geology.
Bogorodskiy, P., Marchenko, A. *Thermodynamic Effects Accompanying Freezing of Two Water Layers Separated by a Sea Ice Sheet.* Marine Physics, Oceanology, Vol. 54, No. 2, pp. 152–159, 2014.
Dalane, O. *Influence of pitch motion on level ice actions.* Cold Regions Science and Technology 108 (2014) 18–27.
Ekeberg, O.-C., Høyland, K.V., Hansen, E. *Ice ridge keel geometry and shape derived from one year of upward looking sonar data in the Fram Strait.* Cold Regions Science and Technology 109 (2014) 78-86.
Kjerstad, Ø.K., Skjetne, R. *Modeling and Control for Dynamic Positioned Marine Vessels in Drifting Managed Sea Ice.* Modeling, Identification and Control, Vol. 35, No. 4, 2014, pp. 249-262.
Lu, W., Lubbad, R., Høyland, K.V., Løset, S. *Physical model and theoretical model study of level ice and wide sloping structure interactions.* Cold Regions Science and Technology 101 (2014) 40–72.
Lu, W., Lubbad, R., Løset, S. *Simulating Ice-Sloping Structure Interactions With the Cohesive Element Method.* Journal of Offshore Mechanics and Arctic Engineering AUGUST 2014, Vol. 136 / 031501.
Lu, W., Lubbad, R., Løset, S. *In-plane fracture of an ice floe: a theoretical study on the splitting failure mode.* Cold Regions Science and Technology 110 (2015) 77–101.
Møen, E., Høiseth, K.V., Leira, B., Høyland, K.V. *Experimental study of concrete abrasion due to ice friction — Part I: Set-up, ice abrasion vs. material properties and exposure conditions.* Cold Regions Science and Technology 110 (2015) 183-201.
Norgren, P., Skjetne, R. *Using Autonomous Underwater Vehicles as Sensor Platforms for Ice-Monitoring.* Modeling, Identification and Control, Vol. 35, No. 4, 2014, pp. 263–277.
Skjetne, R., Imsland, L., Løset, S. *The Arctic DP Research Project: Effective Station keeping in Ice.* Modeling, Identification and Control, Vol. 35, No. 4, 2014, pp. 191–210.
Storheim, M., Amdahl, J. *Design of offshore structures against accidental ship collisions.* Marine Structures 37 (2014) 135–172.
Su, B., Skjetne, R. *Numerical assessment of a double-acting offshore vessel's performance in level ice with experimental comparison.* Cold Regions Science and Technology 106–107 (2014) 96–109.
Su, B. Skjetne, R. Berg, T.E. *Experimental and Numerical Investigation of a Double-Acting Offshore Vessel Performance in Level Ice.* Modeling, Identification and Control, Vol. 35, No. 4, 2014, pp. 317–332.
Sukhorukov, S., Marchenko, A. *Geometrical stick–slip between ice and steel.* Cold Regions Science and Technology 100 (2014) 8–19.
Tsarau, A., Lubbad, R., Løset, S. *A numerical model for simulation of the hydrodynamic interactions between a marine floater and fragmented sea ice.* Cold Regions Science and Technology 103 (2014) 1–14.
Zhang, Q., Skjetne, R. *Image Techniques for Identifying Sea-Ice Parameters.* Modeling, Identification and Control, Vol. 35, No. 4, 2014, pp. 293–301.

Key Note Lectures, Invited Lectures and Oral Presentations (104)

Bazilchuk, N., Storheim, M., Nord, T., Nilsen, J.A. *A Crushing Experience: When Discovery Channel came to NTNU.* NTNU Communication Division Group, Trondheim 2014.
Bekele, Y. *THM Coupled Finite Element Modeling: Ground Freezing and Thawing.* SAMCoT Scientific Seminar, Trondheim May 2014.
Berg, vd M. Meso-Scale Floater at Spitsbergen. SAMCoT Scientific Seminar, Trondheim May 2014.
Bæverfjord, M.G. *Arctic Research-based Industrial Development and Resource Management; Energy and Minerals.* Arctic Technology Transatlantic Science Week 2014, Toronto.
Dalane, O. *Ice Management. Full Scale and Model Scale Tests in Ice - Challenges and Benefits (Trial Lecture).* NTNU PhD Defence Trondheim, 2014.
Ervik, Å. *In-situ experimental investigation of the vertical stress distribution in sea ice covers; a comparison of tensile and flexural strength.* IAHR International Symposium on Ice. Singapore, August 2014.
Farid-Afshin, F. *Sea Ice Management Trials during Oden Arctic Technology Research Cruise 2013 Offshore North East Greenland.* IAHR International Symposium on Ice. Singapore, August 2014.

Nancy Bazilchuk, attending HSE course at UNIS.

Farid-Afshin, F. *A hybrid bayesian belief network model for risk modeling of Arctic Marine Operations.* International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014.

Farid-Afshin, F. *Risk Influence Modeling of Arctic Marine Operations and Its Relation to Design of Offshore Floating Units.* SAMCoT Scientific Seminar, Trondheim May 2014.

Guegan, E. *Use of Satellite Images for Coastal Erosion Studies in Varandey, Barents Sea.* DUE Permafrost 2014.

Gutierrez-Glez, M.A. *Midway Evaluation Sustainable Arctic Marine and Coastal Technology – SAMCoT.* All SAMCoT Partners 10 different meetings/locations.

Gutierrez-Glez, M.A. *Sustainable Arctic Marine and Coastal Technology – SAMCoT.* C-CORE visit of the Board of Directors to NTNU/SAMCoT.

Gutierrez-Glez, M.A. *EIAC Members.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Gutierrez-Glez, M.A. *Reporting to the RCN.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Gutierrez-Glez, M.A. *Cost-Deliverables 2014.* SAMCoT Board Meeting, Aalto, Helsinki.

Gutierrez-Glez, M.A. *SAMCoT Midway Evaluation RCN – 2014/15.* SAMCoT Board Meeting, Aalto, Helsinki.

Gutierrez-Glez, M.A. *Planning_2014-15.* SAMCoT Board Meeting, Aalto, Helsinki.

Gutierrez-Glez, M.A. *The Scientific Advisory Committee (SAC).* SAMCoT Board Meeting, NTNU, Trondheim.

Gutierrez-Glez, M.A. *SAMCoT CA Addemdum 2.* SAMCoT Board Meeting, NTNU, Trondheim.

Gutierrez-Glez, M.A. *Sustainable Arctic Marine and Coastal Technology – SAMCoT - Status & Mid Term Evaluation.* Shell Technology Norway AS, Oslo 30th May, 2014.

Hansen, F.S. *HSE at UNIS.* SAMCoT Arctic HSE Workshop, Trondheim Sep. 2014.

Hassel, M. *Analysis Of The Main Challenges With The Current Risk Model For Collisions Between Ships and Offshore Installations On The Norwegian Continental Shelf.* Probabilistic Safety Assessment and Management PSAM12, 2014.

Hedman, U. *Arctic Operations An exercise in Safety and Logistics.* SAMCoT Arctic HSE Workshop, Trondheim Sep. 2014.

Hendrikse, H. *Modelling of Ice Induced Vibrations.* SAMCoT Scientific Seminar, Trondheim May 2014.

Høyland, K.V. *WP3 Fixed Structures in Ice.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Høyland, K.V. *WP2 - Material modelling.* SAMCoT Technical Workshop, Trondheim Sep. 2014.

Høyland, K.V. *WP3 - Fixed Structures in Ice.* SAMCoT Technical Workshop, Trondheim Sep. 2014.

Indreiten, M. *Best practice of HSE in icy waters – UNIS.* SAMCoT Arctic HSE Workshop, Trondheim Sep. 2014.

Jenssen, N.A. *Presentation on dynamic positioning in ice.* DNVGL-Statoil seminar, Hamburg.

Jenssen, N.A. *Presentation on dynamic positioning in ice.* Memorial University Newfoundland Canada.

Jenssen, N.A. P*resentation on dynamic positioning in ice.* NFA-Servomøtet, Kongsberg.

Kashafutdinov, M. *Wave-induced deterioration of icebergs.* SAMCoT Scientific Seminar, Trondheim May 2014.

Keijdener, C. *Stationary dynamic regimes of icefloater.* SAMCoT Scientific Seminar, Trondheim May 2014.

Kim, E. *Experimental and numerical studies related to coupled behavior of ice-mass and steel structures during accidental collisions (Defence Presentation).* NTNU PhD Defence Trondheim (2014).

Kim, E. *An Overview of Mathematical and Numerical Modeling of Material Fracture Criteria (Trial Lecture).* NTNU PhD Defence Trondheim (2014).

Kim, E. *Coupled finite element analysis of ice – structure interactions; "Design" ice model for analysis of abnormal ice action effects.* SAMCoT Scientific Seminar, Trondheim May 2014.

Kim, E. *Findings and Lessons Learned from Implementing Ice-Structure Impact Tests in Water and in Air.* HYDRALAB IV Joint User Meeting.

Kjerstad, Ø.K. *Dynamic positioning in drifting managed ice: Modeling, simulation, and control.* Norway-Russia - cooperation and development in the High North, 2014.

Kjerstad, Ø.K. *Dynamic positioning in drifting managed ice: Modeling, simulation, and control.* SAMCoT Scientific Seminar, Trondheim May 2014.

Doctoral promotion, Ekaterina Kim.

Kulyakhtin, S. *Distribution of Ice Block Sizes in Sails of Pressure Ice Ridges.* IAHR International Symposium on Ice. Singapore, August 2014.

Kulyakhtin, S. *Continuous ice rubble model.* SAMCoT Scientific Seminar, Trondheim May 2014.

Lu, W. *Waterline Process during sloping structures interacting with a large ice floe.* SAMCoT Scientific Seminar, Trondheim May 2014.

Lubbad, R. *WP5 Ice Management and Design Philosophy.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Lubbad, R. *WP6 Coastal Technology.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Lubbad, R. *Numerical model for prediction of ice load reduction due to ice management.* Norway-Russia - cooperation and development in the High North, 2014.

Løset, S. *Opening to the Meeting.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Løset, S. *WP4 Floating Structures in Ice.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Løset, S. *SAMCoT Revision of Papers Procedure.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Løset, S. *Status On SAMCoT (2014).* SAMCoT Board Meeting, Aalto, Helsinki.

Løset, S. *Way Forward.* SAMCoT Board Meeting, Aalto, Helsinki.

Løset, S. *Status on SAMCoT.* SAMCoT Board Meeting, NTNU, Trondheim.

Løset, S. *Reporting to the Research Council of Norway.* SAMCoT Board Meeting, NTNU, Trondheim.

Løset, S. *The Arctic Ocean.* Det norske oljeselskap, Trondheim, 22nd April, 2014.

Løset, S. *Arctic Engineering, Ice Study at NTNU and UNIS.* Meeting at Far Eastern Federal University, Vladivostok, Russia.

Løset, S. *Ice-Structure Interactions (Key Note).* IAHR International Symposium on Ice. Singapore, August 2014.

Løset, S. *Technology-needs for Arctic Offshore Field Development.* Norway-Russia - cooperation and development in the High North.

Løset, S. *Floating Structures in Ice.* Norway-Russia - cooperation and development in the High North.

Løset, S. *Teknologi for Barentshavet.* NPF, Oslo, 18th March, 2014.

Løset, S. *Sustainable Arctic Marine and Coastal Technology – SAMCoT.* NTNU, Kvaerner Engineering, 14th January, 2014.

Løset, S. *Petroleumvirksomhet i Nordområdene - Holder vi hodet (is)kaldt? (Invited Lecture).* NTVA Industrielt råd årsmøte, Oslo.

Løset, S. *Purpose/Focus of the HSE Workshop.* SAMCoT Arctic HSE Workshop, Trondheim Sep. 2014.

Løset, S. *WP4 - Floating Structures in Ice.* SAMCoT Technical Workshop, Trondheim Sep. 2014.

Løset, S. *SFI SAMCoT - Impact on Technology for the Arctic (Invited Lecture).* SFI Forum, Oslo.

Løset, S. *Floating Structures in Ice.* Shell International, The Netherlands, 31st January 2014.

Løset, S. *Technology Needs for the North (Invited Lecture).* VISTA Scholar's Day, Rotvoll Trondheim.

Marchenko, A. *WP1 Data Collection and Process Modelling.* Exploitation and Innovation Advisory Committee, NTNU, Trondheim.

Marchenko, A. *WP1 Data collection and process modelling.* SAMCoT Board Meeting, NTNU, Trondheim.

Marchenko, N. *Arctic shipping challenges.* Arctic Frontiers, Tromsø January 2014.

Marchenko, N. *Monitoring of Sea Currents and Waves in Spitsbergen Fjords.* EuroGeo, Vienna, Austria.

Marchenko, N. *Floating Ice Induced Ship Casualties.* IAHR International Symposium on Ice. Singapore, August 2014.

Munkeby, I. *Welcome to SAMCoT Arctic HSE workshop.* SAMCoT Arctic HSE Workshop, Trondheim Sep. 2014.

Nord, T. *Force and state estimation in experimental ice-induced vibrations.* SAMCoT Scientific Seminar, Trondheim May 2014.

Norgren, P. *LOS control for steering an iceberg along a straight-line path.* IAHR International Symposium on Ice. Singapore, August 2014.

Norgren, P. *Unmanned underwater vehicles in Arctic operations.* IAHR International Symposium on Ice. Singapore, August 2014.

Norgren, P. *Unmanned underwater vehicles in Arctic operations.* SAMCoT Scientific Seminar, Trondheim May 2014.

UNIS delegation on EUCOP 2014.

Orsten, A. *LOS guidance for towing an iceberg along a straight-line path.* IAHR International Symposium on Ice. Singapore, August 2014.

Polojärvi, A. *DEM in modelling experimentation on ice rubble.* SAMCoT Scientific Seminar, Trondheim May 2014.

Pustogvar, A. *Laboratory Oedometer Tests on Rubble Ice.* IAHR International Symposium on Ice. Singapore, August 2014.

Pustogvar, A. *Laboratory Scale Direct Shear Box Experiments on Ice Rubble: The Effect of Block to Box Size Ratio.* International Conference on Ocean, Offshore and Arctic Engineering. OMAE2014.

Pustogvar, A. *Constitutive Modelling of Ice Rubble, Experimental Part.* SAMCoT Scientific Seminar, Trondheim May 2014.

Ranta, J. *Statistical analysis of ice-structure interaction simulations.* SAMCoT Board Meeting, Aalto, Helsinki.

Ranta, J. *2D FEM-DEM and ice pile-up process.* SAMCoT Scientific Seminar, Trondheim May 2014.

Shestov, A. *Ice ridges Properties.* SAMCoT Scientific Seminar, Trondheim May 2014.

Shestov, A. *Properties of Ice Ridge Keels and Sea Currents in their Vicinity in the Barents Sea.* IAHR International Symposium on Ice. Singapore, August 2014.

Sinitsyn, A. *Investigations of Coastal Erosion rates and mechanisms in Varandey area, Barents Sea.* 4th European Conference on Permafrost (EUCOP4).

Sinitsyn, A. *Coastal Studies for Arctic Offshore Development in the Pechora Sea, Russia.* Norway-Russia - cooperation and development in the High North 2014.

Sinitsyna, T. *Studies of Influence of Heterogeneity of Level Ice and Ice Ridges Properties in Relation to Ice Load on Offshore Structures.* SAMCoT Scientific Seminar, Trondheim May 2014.

Skjetne, R. *Part 1: The Maneuvering Control Problem; Part 2: Control and Estimation for Effective Station-keeping Operations in Sea-ice.* AuR-Lab.

Skjetne, R. *Recursive nullspace-based control allocation with strict prioritization for marine craft.* AuR-Lab.

Skjetne, R. Arctic DP: *The Arctic Offshore Project on Station keeping in Ice.* IBC Ice Class Vessels.

Skjetne, R. *Dynamic positioning in ice for offshore vessels: Results from the Arctic DP Project.* NFA-Servomøtet, Kongsberg.

Sorsimo, A. *Modelling freeze bonds with cohesive 3D discrete element.* SAMCoT Scientific Seminar, Trondheim May 2014.

Storheim, M. *Calculation of damage from ship-ice collisions.* Norway-Russia - cooperation and development in the High North 2014.

Storheim, M. *Structural Resistance of Ships and Offshore.* SAMCoT Scientific Seminar, Trondheim May 2014.

Sukhorukov, S. *Ice-Ice and Ice-Steel Friction in Field and in Laboratory (Defence Presentation).* NTNU PhD Defence Trondheim (2013).

Sukhorukov, S. *Structural Abrasion due to Ice Actions (TrialLecture).* NTNU PhD Defence Trondheim (2013).
Suyuthi, A. *SAMCoT activities in DNV GL perspective (Key Note).* SAMCoT Scientific Seminar, Trondheim May 2014.
Tsarau, A. *Modelling hydrodynamic interactions between a floater and broken ice.* SAMCoT Scientific Seminar, Trondheim May 2014.
Tuhkuri, J. *Aalto University: Arctic Marine Research and SAMCoT.* SAMCoT Board Meeting, Aalto, Helsinki.
Watn, A. *SAMCoT - Arktisk teknologi for framtidas utfordringer.* Arktisk forskningsarena, Bergen.
Wrangborg, D. *Laser Scanning for Moving Ice Objects and Ice Induced Deformations - Ice-water actions on coastal structures.* SAMCoT Scientific Seminar, Trondheim May 2014.
Yulmetov, R. *Iceberg drift and towing in pack ice. Observations and numerical simulation.* SAMCoT Scientific Seminar, Trondheim May 2014
Østlund, H.B. *Kvaerner research and development initiatives including SAMCoT presented to an international audience.* INTSOK conference in Newfoundland, Canada.
Østlund, H.B. *Kvaerner research and development initiatives including SAMCoT presented to faculty staff.* Meeting at Far Eastern Federal University, Vladivostok, Russia.
Østlund, H.B. *Kvaerner research and development initiatives including SAMCOT presented to faculty staff.* Memorial University Newfoundland Canada.

Other Media Coverage (25)

Bazilchuk, N. Celebrity Ice. Gemini.no: http://gemini.no/en/2014/06/celebrity-ice/
Bazilchuk, N. Secrets of the High North. Gemini.no: http://gemini.no/en/2014/01/secrets-of-the-high-north/
Bazilchuk, N. Crash Course. Gemini.no: http://gemini.no/en/2014/03/crash-course/
Bazilchuk, N. Celebrity Ice. ScienceNordic.no: http://sciencenordic.com/celebrity-ice
Bazilchuk, N. Celebrity Ice; Discovery Channel Filming SAMCoTs Research. https://www.youtube.com/watch?v=1_hWrYpAGQI&feature=youtu.be
Bazilchuk, N. In search of the perfect ice. http://www.ntnu.edu/web/samcot/video
Bazilchuk, N, Gutierrez-Glez, M.A. FaceBook IVT-Fakultet, SAMCoT/NTNU Research at Svea - HSE (31.March Blog). https://nb-no.facebook.com/ivt.ntnu
Bostrom, D. Promotional video Kvaerner Concrete Solutions, PIONEER. SAMCoT lab test included. - TVP Broadcast https://www.youtube.com/watch?v=kBBsgSW7w34
Bouloukos, K. Discovery Channel Production (Video owned by Discovery Channel, distribution rights)
Bjørke, C. N. Arven etter Exxon Valdez. Svalbardposten.no: http://svalbardposten.no/index.php?page=vis_nyhet&NyhetID=4629
Engås, C. Får Flere svar fra havisen. Svalbardposten, Svalbard 2014
Furberg, K. Knuste «isfjell» for Discovery channel. Universitetsavisa.no: http://www.universitetsavisa.no/forskning/article40388.ece
Gutierrez-Glez, M.A. Successful first SAMCoT Arctic HSE Workshop! SAMCoT Web: www.ntnu.edu/samcot
Gutierrez-Glez, M.A.; Nord, T.; Pustogvar, A.; Kulyakhtin, S. SAMCoT e-room blogs (19, since March 2014). https://project.ntnu.no/sites/samcot/
Johnson, H. The importance of sound for bowhead whales. ScienceNordic.no: http://sciencenordic.com/importance-sound-bowhead-whales
Løvhaug, N.R. SFI-samarbeid på Discovery Channel. Research Council of Norway site - Sentre for forskningsdrevet innovasjon.
http://www.forskningsradet.no/ Nyhetsarkiv.
Løvhaug, N.R. Se ny film fra forskningstokt. Research Council of Norway site - Sentre for forskningsdrevet innovasjon. http://www.forskningsradet.no/ Nyhetsarkiv.
Løvhaug, N.R. SFI gir store ringvirkninger. Research Council of Norway site - Sentre for forskningsdrevet innovasjon. http://www.forskningsradet.no/ Nyhetsarkiv.
Misund, O. A. Mer forskning enn Riksrevisjonen tror. Svalbardposten.no: http://svalbardposten.no/index.php?page=vis_nyhet&NyhetID=5074
Nilsen, J.A. FaceBook IVT-Fakultet, NTNU - Discovery Channel Filming SAMCoTs Research (2. June). https://nb-no.facebook.com/ivt.ntnu
Rådgivende Ingeniørers Forening (RIF). Multiconsult deltar i to nye Sentre for forskingsdrevet innovasjon. RIF.NO
Rønneberg, H. Det spirer og gror i forskning og innovasjon Bryggeindustrien. Brygg.no: http://www.bygg.no/article/1194017
SAMCoT CMG, SAMCoT Annual Report 2013. Fagtrykk, Trondheim 2014. SAMCoT Web: www.ntnu.edu/samcot
SAMCoT CMG. SAMCoT News Letters 2014 (3). SAMCoT Web: www.ntnu.edu/samcot
Seehusen, J. Byggenæringen får påfallende høyt gjennomslag hos Forskningsrådet. TUBygg: http://www.tu.no/bygg/2014/01/20/-byggenaringen-far-pafallende-hoyt-gjennomslag-hos-forskningsradet

Statement of Accounts 2014

In December 2014 the Annual Work Plan for 2015 was presented and approved by the Research Council of Norway (RCN). The RCN has the task to monitor the activities planned ensuring their compliance with the EFTA Surveillance Authority (ESA) requirements.

In addition the Cost, Time and Resource (CTR) plans for each Work Package for 2015 were presented to SAMCoT's Board and approved in November 2014. The CTR's provide a detailed description of each Work Package by defining: Objectives; Knowledge Gaps; Activities planned for the current year; dependencies, critical factors, assumptions, milestones and resource requirements.

CRI ANNUAL WORK PLAN 2014 – FUNDING (All figures in 1000 NOK)

Item	Type of Research*	RCN Grant	Host***** NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	Aker Solutions	Exxonmobile URC	GDF SUEZ	Det Norske	Lundin	Kværner	Norwegian Coastal Admin	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	Total funding
Type of partner**			R	R	R	L	L	L	L	L	L	L	L	L	L	L	L	P	R	R	R	R	R	R	
WP1	F	1 857	18		798	122	107	144	132	115		78	44	145	9	105	93								3 765
WP2	F	1 857	1 117			122	107	144	132	115		78	44	145	9	105	93					604			4 670
WP3	F	1 857	195			122	107	144	132	115	123	78	44	145	9	105	93		125	135	51				3 578
WP4	F	1 857	2 393			122	107	144	132	115	123	78	44	145	9	105	93			135					5 600
WP5	F	1 857	2 091			122	107	144	132	115	123	78	44	145	9	105	93								5 164
WP6	F	1 857	85	833		122	107	144	132	115	123	78	44	145	9	105	93	330					101		4 421
EIAC	I					122	107	144	132	115	123	78	44	145	9	105	93								1 216
Adm.		1 857	1 764	833	798																				5 252
Total budget		12 998	7 661	1 666	1 597	851	744	1 011	924	803	617	545	309	1012	66	734	648	330	125	270	51	604	101	-	33 666

* Type of Research: *F = Fundamental research **I = Industrial Research

** Type of partner: R=Non-for-profit research organisation, P=Other public, L=Large Enterprise, SME=Small and medium sized enterprise

CRI ANNUAL WORK PLAN 2014 – COST (All figures in 1000 NOK)

Item	Host***** NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	Aker Solutions	Exxonmobile URC	GDF SUEZ	Det Norske	Lundin	Kværner	Norwegian Coastal Admin	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	Total
WP1	354		3 879																				4 234
WP2	3 628							140									125			781			4 674
WP3	2 033																	135	806	781			3 754
WP4	4 328																	135	806				5 269
WP5	3 492		867			170									49								4 579
WP6	872	2 508					168														101		3 649
EIAC				175	122	170	168	140	159	23	67	115	33		49								1 222
Equipment	213		145																				359
Adm.	3 074	833	798	175	122	170	168	140	159	23	67	115	33		49								5 927
Total budget	17 995	3 341	5 690	351	244	511	505	421	317	45	133	230	66	-	148	-	125	270	1 611	1 562	101	-	33 666

ESA reporting SAMCoT 2013.

Annual Report 2014

Photos by SAMCoT members

Produksjon: www.fagtrykk.no Miljømerket trykkeri, lisensnr. 241 811

CONTACT

Sveinung Løset, Centre Director
Tel: (+47) 907 55 750

Maria Azucena Gutierrez Gonzalez, Centre Coordinator
Tel: (+47) 918 97 745

Postal address
NTNU, Department of Civil and Transport Engineering
NO-7491 Trondheim, Norway

Visiting address
NTNU, Høgskoleringen 7a, Trondheim

www.ntnu.edu/SAMCoT

sfi Centre for Research-based Innovation

NTNU – Trondheim
Norwegian University of Science and Technology