ANNUAL REPORT 2016

SUSTAINABLE ARCTIC MARINE AND COASTAL TECHNOLOGY

SAMCoT

sfi

NTNU
Norwegian University of Science and Technology

SAMCoT KEY FIGURES	2016	2015*	2014	2013	2012	2011	Accum.Fig
Turnover (in 1000NOK)	39 336	75 299	33 666	59 887	45 770	13 859	267 817
PhD Defences	4	5	3	3	1	0	16
Published Journal Papers	26	29	16	5	7	7	90
Published Conference Papers	43	52	40	40	18	15	207
MSc Thesis	6	11	6	7	8	2	40
Mass Media & Other Popular Media	36	12	24	11	8	3	94
Industry Partners	13	13	13	11	11	9	13
Research Partners	9	8	8	7	7	7	8
Public Partners	2	2	1	1	1	1	2
PhD Candidates	26 (6 Female)	26 (7 Female)	21 (6 Female)	22 (4 Female)	19 (4 Female)	10 (1 Female)	23
Post Docs	9 (2 Female)	9 (2 Female)	4 (1 Female)	3	1	0	9

*Turnover including OATRC2015

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SAMCoT PARTNERS

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

CONTENTS

Graphic Design:
NTNU Grafisk Senter

Months in the Arctic

Participation in research cruises (Different destinations: Barents Sea, Greenland Sea, Arctic Ocean, Kara Sea)

Ice ridges studied

Ice thin sections sliced

Ice samples crushed

Holes drilled in Arctic ice/permafrost*

Fractures in ice
(Several of them being the third largest samples in ice ever)

Data points processed

Ice flows cut

Wave cycles run

Steps in the North Pole

m^2 of radar frames collected

Simulations run

Soil temperature values analyzed

Number of supercomputer hours used

Length of seabed simulated

Number of breaking waves counted

Polar/Grizzly bears spotted

Has been inside a polar bear cave

2016
IN REVIEW

ADMINISTRATIVE REPORTING

In 2016 the Sustainable Arctic Marine and Costal Technology SFI (SAMCoT) continued to pursue its vision to develop key knowledge and innovative tools to promote safe, environmentally sound operations in the Arctic. SAMCoT currently counts 23 partners after adding the Swedish Polar Research Secretariat (SPRS) as a Public Partner in 2015 and the Technical University of Denmark as a Research Partner in 2016. The SPRS's contribution was fundamental to SAMCoT`s field activities in 2016.

HEALTH SAFETY AND THE ENVIRONMENT (HSE)

HSE is a key item for all SAMCoT activities, especially those carried out in the field. HSE was the special focus of the Board's meeting in April 2016. Led by Fred S. Hansen, SAMCoT Board Member and Director of HSE and infrastructure at the University Centre in Svalbard (UNIS), and Sveinung Løset, SAMCoT's Director, SAMCoT Board members and a representative from the Research Council of Norway embarked on a three-day meeting in Svalbard that encompassed field visits and an HSE-focused snowmobile trip.

All activities were designed to provide SAMCoT's Board with firsthand fieldwork experience and an important opportunity to discuss HSE-related issues.

From left to right: Astrid Vigtil (NTNU), Berit Laanke (SINTEF), Erik Schiager (ENGIE), Øystein Braathen (Statoil), Hilde Benedikte Østlund (Kværner), Erik Holtar (Aker BP), Fred S. Hansen (UNIS), Per Olav Moslet (DNV GL), Kimberly C. Mayes (observer, RCN), Ole Kristian Sollie (Shell), Sveinung Løset (Board Secretary, NTNU), Rune Teigland (Total) and Maria Azucena Gutiérrez Glez. (Board Secretary, NTNU)

SCIENTIFIC COLLABORATIONS

In addition to SAMCoT's associated project Ice-induced vibrations of Offshore Structures (IVOS), the Centre continued its extensive collaborative links with different research programmes and organizations. In particular, SAMCoT has built a reliable scientific network among other Centers funded by the Norwegian Research Council. SAMCoT's Ice Management and Design Philosophy research group is well established in its collaboration with the Centre for Autonomous Marine Operations and Systems (SFF AMOS). Currently four PhD candidates benefit from this collaboration. Another SAMCoT research group, Floating Structures, also benefits from the collaboration with a different SFI, the Center for Integrated Remote Sensing and Forecasting for Arctic Operations (SFI CIRFA). In this case the collaboration is through the research of a female PhD candidate.

In addition to its collaboration with other research Centres, SAMCoT has a strong link with Norut Narvik through the MOSIDEO project Microscale interaction of oil with sea ice for detection and environmental risk management in sustainable operations. A PhD candidate and a postdoc linked to this project are located at SAMCoT/NTNU facilities to gain knowledge of the interactions between oil and sea ice pores as well as of risk assessment and contingency planning for oil spills in sea ice covered waters.

FIELD WORK

Among the many field activities described in this annual report, the participation of three of our SAMCoT PhD candidates in Arctic Ocean 2016 deserves a special mention. Arctic Ocean 2016 was a six-week-long polar research expedition in collaboration with Canada involving two icebreakers, the Swedish icebreaker Oden (SPRS) and the Canadian icebreaker Louis S. St-Laurent. SAMCoT's PhD candidates attended in this research cruise as part of the SPRS contribution to the Centre. In addition, and before this activity, the icebreaker Oden sailed towards the ice following the west/north coast of Spitsbergen. The aim of the expedition was to make engine power and performance measurements while the ship was breaking ice. Two SAMCoT researchers joined the expedition to study ice breaking and icebreaker performance.

Another important international collaboration was SAMCoT's fieldwork on the Russian coast with the support from Moscow State University (MSU). SAMCoT performed extensive field studies at Baydaratskaya Bay in September 2016. The Russian Arctic coast is of great interest to some of our SAMCoT partners and to Arctic research on coastal technology in general.

INTERNATIONAL COLLABORATION

Professor Akihisa Konno from the Kogakuin University (Tokyo UrbanTech) was a visiting researcher in 2016 at NTNU/SAMCoT. His stay greatly contributed to the definition of the Japan-Norway Collaboration for Sustainable Development of the Arctic (JNArc) project, for which SAMCoT/NTNU applied for funding from the INTPART programme (which is jointly operated by the RCN and SIU, the Norwegian Centre for International Cooperation in Education). In addition, SAMCoT Centre Director S. Løset participated in the Japan-Norway Arctic Science & Innovation Week in June 2016.

In its effort to address a critical area in Arctic research, SAMCoT increased its participation in EU projects through Hydralab+. The grant was approved and activity was implemented in 2016, which provided a unique opportunity to advance in-depth research in the field of wave/ice interaction. This was also a great opportunity to use the unique Large Ice Model Basin equipped with a wavemaker, provided by SAMCoT's partner, the Hamburg Ship Model Basin (HSVA).

SAMCoT & PHD EDUCATION

SAMCoT's host institution NTNU has the main responsibility for higher education in technology in Norway, which clearly adds value to the Centre's research and its role in its PhD candidates' education. SAMCoT is strongly linked to NTNU Oceans, one of four strategic research areas at NTNU that aims to achieve "Knowledge for a sustainable ocean". Our PhD candidates take part in the Ocean School of Innovation, which has as its goals to create a culture for innovation, strengthen awareness and competence in innovation and increase the commercialization of research results.

DISSEMINATION

It is important for research to be disseminated in order for it to be applied. SAMCoT Work Packages (WPs) leaders made a strong communication effort in 2016 by organizing a series of WP specific workshops, where Industry and Research partners presented their strategic needs and questions. Furthermore, SAMCoT PhD candidates and postdocs presented the status and future plans for their research during the annual Scientific Seminar held in May. The SAMCoT Communication team shared news of the Centre's main research activities through the production of numerous videos and articles in popular and social media.

I would like to thank all our partners for their continuous involvement and confidence in the vision and importance of the work we all do at SAMCoT.

Sveinung Løset

Sveinung Løset
SAMCoT Centre Director

Sveinung Løset, SAMCoT Centre Director

DATA COLLECTION AND PROCESS MODELLING

WP1

'One of my tasks as supervisor, taking each of our PhDs to the Arctic. Real innovation requires field experience.'

Sveinung Løset, SAMCoT Director

DATA COLLECTION AND PROCESS MODELLING

More than 20 years of extensive experimental investigations on Svalbard, the Barents and Kara Seas regions back up the work done by this Work Package. Numerous researchers, MSc and PhD students have worked together with the aim of providing the experimental basis for PhD students over the years. Field studies in the regions of the Russian Arctic are also carried out with the cooperation of Moscow State University (MSU) and Krylov State Research Centre.

The researchers' main goal is to collect and analyze field data on sea ice, icebergs, and coastal permafrost working with these data on the necessary models for further research.

COMPARISON OF SEA ICE PRODUCTS AND DATA OF DRIFTING BUOYS IN THE BARENTS SEA

Several institutions and agencies around the world provide "Sea Ice Products", in other words data that contain valuable information on, for example, mean ice motion vectors derived from passive microwave sensors, visible and infrared sensors and other sources.

Researcher Nataly Marchenko compared Sea Ice Products data from the Barents Sea. The Barents Sea is a very interesting region for SAMCoT's research due to its location and to the presence of sea ice that is representative of sea ice trends observed widely. Sea ice is a key factor in marine operations and navigation in the Arctic. An evident decrease in the ice cover in relation to both area and thickness has been determined. The thinning of the ice cover leads to more broken ice. This broken ice is an important factor to take into account during offshore activities in these waters. How this broken ice affects these activities is not yet well-known. Furthermore, the amount of multi-year ice has reduced significantly.

The ice conditions in the Barents Sea are representative of the new trends we see in the Arctic ice, including the prevalence of glacial ice (icebergs). Thus, the Barents Sea is a good study area for SAMCoT containing all these components as well as being a prosperous area for present and future oil and gas exploitation. N. Marchenko obtained relevant data from the French Research Institute for Exploitation of the Sea (IFREMER), the Ocean and Sea Ice Satellite Application Facility (OSI SAF), the National Snow and Ice Data Center (NSIDC), the Anistiamo Space Systems Finland, and TOPAZ (Towards an Operational Prediction system for the North Atlantic European coastal Zones) for comparison with data from WP1 drifting buoys (ice trackers) deployed on sea ice over the period 2008 – 2015.

Using these data, N. Marchenko defined ice drift lines for various regions of the Barents Sea under years and time-period parameters. She analyzed 20 cases where WP1 data showed stable buoys movement. The comparison of the different data sets available for these 20 cases revealed that the Sea Ice Products mostly show similar trajectories to the buoys' data in the Arctic basin, but in marginal zones, such as the Barents Sea, important trajectory differences were found. From the different Sea Ice Products services, NSIDC showed the highest coincidence (75 % of cases).

IFREMER gave 40 % coincidence for open Barents Sea water. The worst coincidence was observed when using the regional Sea Ice Products Antistiamo and TOPAZ.

SAMCoT GEOGRAPHIC INFORMATION SYSTEM (GIS)

In addition to other activities, N. Marchenko is responsible for the WP1 data storage and GIS system. Data obtained in 2016 are now available in ArcGIS including data from two drifting buoys installed by Aleksey Marchenko during the 2016 Lance expedition. This year, for the first time since the beginning of SAMCoT, the buoys also transferred wind data.

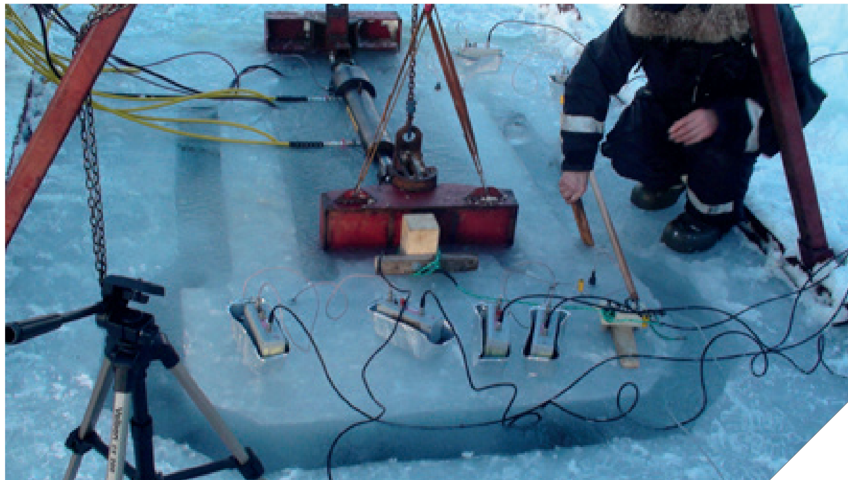
ICE STRENGTH

Among other activities, WP1 focused on the comparison of ice strength characteristics during in-situ tests of sea ice strength. Under the direction of Aleksey Marchenko, full-scale (~1m) in-situ tests on the tensile and compressive strength of saline and freshwater floating ice were performed on the land-fast ice in the Van Mijen Fjord in Spitsbergen and on the drift ice in the North-West Barents Sea.

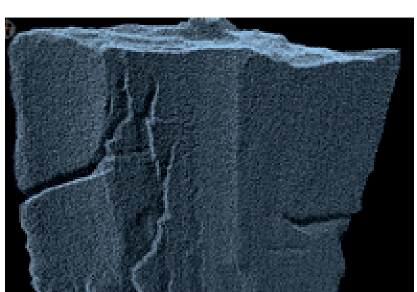
The results are directly comparable to previous small-scale tests, in which the measured tensile strength of sea ice decreases from 1 MPa to 0.2 MPa, and the measured compressive strength of sea ice decreases from 4 MPa to 2 MPa as the temperature increases from -30ºC to -2ºC. In the full-scale tests the loads were applied in the horizontal direction over the entire ice thickness to the floating ice samples in their original configuration. Full-scale tests in compression demonstrated stable failure of ice beam by central cracking parallel to the loading direction. When comparing results obtained at the full-scale compression test with those of small-scale tests, WP1 researchers discovered that the strength of ice was approximately 4 times less. Full-scale tests in tension demonstrated brittle and synchronous failure of the sample necks. In addition, the values obtained of the full-scale tensile strength tests were approximately two times smaller than the tensile strength measured in small-scale tests. The results of the full-scale tests are currently being used for the validation of mechanical models of sea ice describing ice-structure interaction and loads.

WP1 researchers, including a group of visiting researchers, also performed: small-scale tests with samples cored from sea ice in the land-fast ice in the Van-Mijen Fjord (Spitsbergen); 11 tensile and 52 compressive strength test and measurements of the acoustic emissions from each meso-scale test performed in the Van-Mijen Fjord and those performed directly on drift ice in the Barents Sea (Olga Strait).

N. Marchenko has been searching for an optimal algorithm to use when scanning ice samples to gain further knowledge on ice properties. This work started in March 2016 during the Svea expedition with the scanning of ice samples obtained from mechanical tests. She continued this line of work during the Lance cruise.



In-situ meso-scale tests on tensile strength



CONSOLIDATION OF ICE RUBBLE IN WARM WATER

Thermodynamic consolidation of ice ridges occurs due to atmospheric cooling from the surface and due to the freshening of the water trapped inside the rubble caused by the rubble melting. The latter process is very slow when the oceanic heat flux to the ice bottom is small (<10 W/m^2) and develops faster when the rubble drifts to warm water areas.

WP1 researchers studied the consolidation of ice rubble in the region of Bjørnøya. The ice drift and water surface temperature reconstructed from the data from the spectroradiometer MODIS flown on two NASA spacecraft (Terra and Aqua) show that sea ice tongues drifted several times in March 2016 from the North to the region with water surface temperature around 0 - +1ºC under the influence of Polar cyclones formed near Bjørnøya.

Oceanic heat flux to the ice bottom, estimated for these conditions with standard formulae, can reach 100 W/m^2 and higher. Numerical simulations performed with the original model of thermodynamic consolidation show that rubble ice with a macro-porosity of 20% can be completely consolidated in 1-2 months. At the same time, the rubble draft decreases due to melting. Therefore drifting ridges are transformed into relatively large consolidated sea ice features with vertical scales of several meters which are similar to "bergy bits". These ice features create potential risks for navigation near Bjørnøya. Predictions could be made using satellite information and ice maps.

WP1 researchers are very excited by these findings, and hope to further study and analyze the consolidation of ice rubble in warm waters. One example of such ice features was spotted near Edgeøya during the RV Lance expedition in May 2016. WP1 researchers have discovered that this rubble has been forming by the accumulation of ice that drifts from the North. This mass showed a concentration of 20 icebergs per km^2 with an average size of 20*40 m. N. Marchenko scanned this huge ice rubble field and processed point clouds from the scans using the RiScan and ArcGIS programs. In addition, she studied high-resolution satellite images of the same mass to obtain further information on the structure and origin of the ice rubble. She discovered that the rubble mass existed from the beginning of April to the beginning of July.

On the basis of data obtained from IFREMER and WP1 Ice trackersit was concluded that these ice features may reach Bjørnøya in two and a half months in cases when average drift applies. However, when polar cyclones and strong wind gust are observed, the drift can be much faster and these ice features or remnants of them may reach Bjørnøya in a month. Terra satellite images show that the ice tongues reaching Bjørnøya were visible every March 2015 – 2017.

Ice rubble observed near Edgeøya during the Lance cruise on 2 May 2016. Vertical wall: 3 m; average elevation above water: 2 m; width from coastal line: 8 km; stretching in N-S direction along the coast: >20 km.

ICE RUBBLE SMALL-SCALE EXPERIMENT

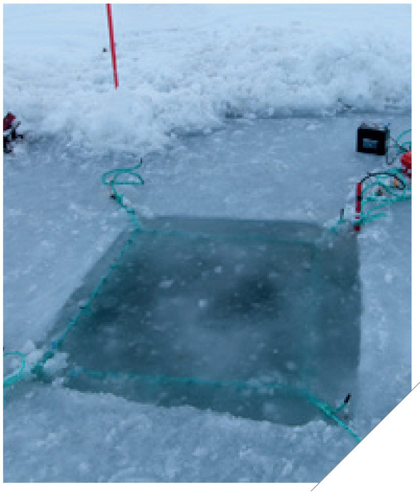
Ice ridges are key ice features both in an engineering and geophysical context.

As more of the Arctic sea ice becomes first-year ice, a larger fraction of the total volume will be first-year ridges. First-year ridges melt more easily than old ridges and therefore the Arctic ice cover as a whole becomes more sensitive to global warming. Thermodynamics of the ridges also defines their morphologic structure and therefore their mechanical properties.

The role of ice ridges in global heat and mass balance has not been studied extensively, and in particular their role in a thinning Arctic sea ice cover needs to be better quantified. SAMCoT WP1 studied ice rubble thermodynamic processes by implementing different scale experiments: laboratory size; small-scale and full-scale. During March 2016, a small-scale field experiment was performed in Svea at Lake Vallunden (Van Mijen Fjord, Spitsbergen). This lake is connected to the fjord through a strait and is therefore salt water and is covered by saline ice.

Postdoc Aleksey Shestov led the experiment searching for valuable input regarding the development of the consolidated layer and the transformation mechanisms of the ridge keel. PhD candidate Evgenii Salganik contributed to the tests. A thermistor string was deployed through the rubble field and conductivity sensors were deployed at two points inside the rubble and at one point under the rubble. Development of the consolidated layer was monitored over a period of two weeks from March 3rd.

At the end of the experiment the consolidated rubble field was lifted up and samples were taken to investigate the physical properties. Knowledge of these, together with the temperature profile, will allow us to evaluate the thermal properties and heat transfer balance.



Pictures of the small-scale field experiment in Svea at Lake Vallunden (Van Mijen Fjord, Spitsbergen).

Consolidated layer and loose rubble at the end of the experiment.

NOTABLE NUMBERS

Aleksey Shestov

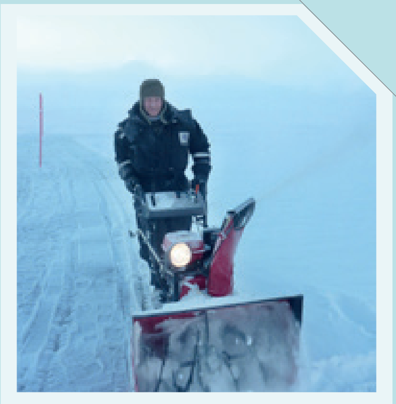
17 x 12 x 120 x 100 x 15 x 1 x 600 x

Renat Yulmetov

60 x 10 x 5 x 50 x 100 x 100 x

Evgenii Salganik

12 x 2 x 5 x 50 x 20 x



MATERIAL MODELLING

WP2

MATERIAL MODELLING

In 2016, the activities carried out by the research group on Material Modelling came to a conclusion and researchers in WPs 3, 4 & 6 have started to make use of the results provided.

Yared W. Bekele successfully defended his thesis on Isogeometric Analysis of Coupled Problems in Porous Media – Simulation of Ground Freezing on 19th May. Bekele continued as a researcher within WP6 for the second semester of 2016, collaborating in the modelling of the behaviour of unsaturated frozen soils with postdoc Seyed Ali Amiri. Together they worked on incorporating Amiri's elastic-plastic model into Bekele's THM model, this approach is currently still in progress.

PhD candidate Anna Pustogvar spent a few weeks at the beginning of the year working with assistant Professor Arttu Polojärvi at Aalto University. Pustogvar is currently working in Saint Petersburg and plans to defend her PhD in 2017.

Sergey A. Kulyakhtin has completed his PhD research and the defence will take place 21 June 2017. Kulyathkin visited Aalto during the spring of 2016 to work with Polojärvi. As a result, they presented a paper on the continuum modelling of ice rubble at the International Association of Hydro-Environment Engineering and Research (IAHR) Ice Conference. The collaboration between Kulyathkin and Polojärvi has continued, and Polojärvi reciprocated the visit and spent one week at NTNU in December 2016.

Currently Kulyathkin is working within the scope of Fixed Structures in Ice taking his research further by concentrating on the applicability and assessment of limitation of the continuum modelling of Ice Rubble.

During 2015 and parts of 2016, NTNU/SAMCoT hosted a guest PhD candidate from Dalian University of Technology (DUT) in China, Xiaodong Chen. The candidate conducted fundamental experimental research on ice consolidation, melting and heat transfer between ice and water at the ice laboratory of the Department for Civil and Environmental Engineering.

Chen designed a set-up allowing for submersion of one-dimensional pieces of fresh and saline ice in fresh and saline water. The samples were insulated from the air, so the only heat and mass transfer was that between the water and the ice. With these experiments we can study and quantify fundamental differences between saline and fresh water ice. One interesting result was that the saline ice grew 1.6 times more in volume than the fresh ice did when submerged in fresh water. Chen also designed, built and calibrated a thermistor string especially suited for measuring small temperature differences. The results have so far resulted in one paper at IAHR 2016, one accepted paper for POAC 2017 and will provide the basis for several future publications.

Hege Lindbjør-Nilsen completed her MSc in FEM-CEL simulations of full-scale and model-scale punch tests on ice rubble with the Modified Cam clay model, and started to work for Multiconsult. She addressed numerical modelling of ice rubble including volumetric properties and wrote and presented a paper for the IAHR conference in 2016. Her work was relevant to SAMCoT's ice ridge action on fixed structures research.

FIXED STRUCTURES IN ICE

WP3

'Having the field experience has made me more critical when modelling; otherwise, it is just a guessing game.'

Åse Ervik, SAMCoT PhD Candidate

FIXED STRUCTURES IN ICE

The opening of previously ice-infested waters, the dwindling supply of non-renewable resources and the demand for alternative sources of renewable clean energy have all contributed to increased economic interest in the Arctic and its natural resources in recent years.

This increased interest is reflected in the construction of numerous types of offshore structures, such as oil rigs and wind farms, within the Arctic and sub-Arctic Oceans including the Baltic Sea. Sea ice is dynamic, and when driven by winds or ocean currents it can pose a formidable hazard to these offshore structures.

If the effect of ice loads is ignored in the structural design, an ice-structure collision may result in material failure. This poses financial risk to commercial interests in the vicinity, as well as potential environmental risks to marine ecosystems and local communities. It is therefore in the interest of multiple parties to maximise understanding of the mechanical properties of sea ice and its interaction with offshore structures.

IDENTIFYING THE DYNAMIC PROPERTIES OF A STRUCTURE

Since the beginning of 2016, postdoc Torodd Nord has worked on analysing data from the Norströmsgrund lighthouse. The objectives of the research were twofold. Nord aimed to assess how modern methods in operational modal analysis work for structures in ice-infested waters and to further investigate how a system changes during ice actions.

Operational modal analysis quantifies the dynamic properties of a civil structure during operational conditions by using response measurements. The measured dynamic properties can be used to track differences between the predicted behaviour of the structure (e.g. from design) and the real behaviour. Some structures, for example wind turbines, have installations with operational requirements that rely on low disturbance from the structure. If the dynamic properties of a wind turbine structure change due to the presence of ice, these changes must be tracked to judge whether the turbine will be able to operate or not. Currently it is not known for which types of ice conditions we can expect operational modal analysis to be applicable and able to track system changes.

For his research, Nord has used an automated operational modal analysis routine on 190 time series of various types of ice actions against the Norströmsgrund lighthouse. The same methodology, now tested on the Norströmsgrund lighthouse, was first successfully applied to floating pontoon bridges. Nord will present his results at the EURODYN Conference in 2017.

Cyclic behaviour of laboratory grown sea ice

Nord's research at SAMCoT and his adjunct associate professor position at the University Centre in Svalbard (UNIS) has enabled him to supervise Niek Heijkoop, an MSc student from Delft University of Technology (TU Delft), who has attended courses at UNIS, Longyearbyen, during the winter of 2016. Heijkoop focussed on researching ice that has cyclic (regular) stresses applied to it.

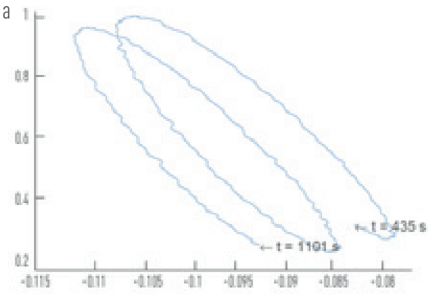
The goal is to figure out how ice affects built structures (and vice versa) under the very harsh conditions frequently encountered in the Arctic. Wind turbines in the Baltic Sea are present-day examples of the kind of structures Heijkoop is considering in his research. Understanding how ice reacts around fixed and floating installations under different conditions is key to the work done within SAMCoT.

Ice can surround a fixed structure in the far north for much of the year. A structure like this will vibrate, affect the ice and in turn be affected by it. Relatively steady wave action will cause these movements to repeat themselves again and again.Heijkoop and Nord want to study how such repetitive waves affect ice. The pressure that arises in the ice from these movements can be simulated in the lab at UNIS. Sea ice strength is sensitive to how fast loads are applied. This is also the case when applying cyclic stresses to the ice. Waves, for example, are a natural load for sea ice that repeats cyclically and with a specific frequency. It is important to examine the strength properties of sea ice for such loads. Structures can also move with a particular frequency as a result of ice being forced and crushed against the structure. In this case it helps to understand how the cyclical load applied from the structure affects the ice strength.

The challenge is to obtain results that can be compared. This means that the ice samples that are subjected to pressure must be similar enough so that the results from different tests can provide real answers. Going outdoors to fetch a random block of ice is not sufficient. Therefore, the researchers make their own ice in the UNIS lab, in order for it to be as consistent as possible from test to test.

Heijkoop's work was also supervised by associate professor Jeroen Hoving from TU Delft. Heijkoop's testing involved huge practical difficulties. David M. Cole from the Cold Regions Research and Engineering Laboratory of the US Army Corps of Engineers, a group with broad experience in laboratory testing, visited Heijkoop and Nord during the experiment and helped them solve a number of challenges related to the tests. The results will have direct influence on how we interpret and model ice that is subject to periodic loads.

a



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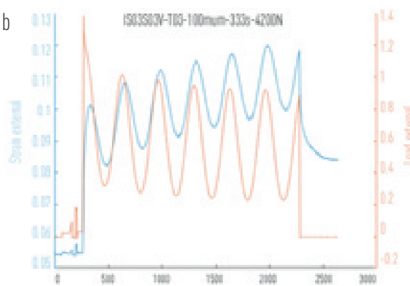


Uniaxial cyclic testing of a small sample of saline ice at the UNIS laboratory. These tests mimic the repeated wave action on an ice cover. a) Cycles of stress versus strain of a laboratory grown saline ice sample. b) Stress and strain as a function of time for a cyclic compression test on a vertical sample.

ICE-INDUCED VIBRATIONS MODEL

In the first and second quarter of 2016, PhD candidate Hayo Hendrikse from TU Delft worked on a paper on ice-induced vibrations and ice buckling which was published in November the journal in Cold Regions Science and Technology. The aim was to investigate the limiting effect of flexural deformation and bending failure resulting from buckling with respect to ice-induced vibrations. The numerical model developed earlier for the prediction of ice-induced vibrations has been expanded to include this type of failure and has been shown to be applicable to the thin ice conditions often found in model-scale testing. This work was presented to the SAMCoT partners at the annual PhD Scientific Seminar in May. During the summer, Hayo finished his PhD thesis and defended it Cum Laude in Delft on the 20th January 2017.

A summary of the results and potential for additional work within Ice Induced Vibrations was presented to SAMCoT partners at a dedicated ice-induced vibrations workshop in Trondheim in October. Following this workshop, and due to the relevance of Hendrikse's work, the SAMCoT board decided in November 2016, during the review/approval of the Cost Time and Resources (CTRs) plans for 2017, to allocate additional funds to continue the work on model validation for the 2017-2019 period.

Hendrikse continued his advisory work in the SAMCoT associated project Ice-Induced Vibrations of Offshore Structures (IVOS) and visited HSVA in December for experiments and discussion. At the same time Cody Owen, an MSc student with the European Wind Energy Master (EWEM) program in the Offshore Engineering Track at TU Delft, started his research at the ice lab at HSVA. Owen's topic of research is the comparison of cylindrical and flat vertically-sided indenters subjected to ice-induced vibrations in the frequency lock-in regime. He will be using data collected during the IVOS tests for his research under the supervision of both Hendrikse and Gesa Ziemer, the IVOS project leader. The work on ice-induced vibrations is gaining increasing interest from the wind power industry and new contacts have been made with Siemens Windpower.
After his PhD defence, Hendrikse will stay on as assistant professor in Delft and will remain part of the SAMCoT team focussing on validation of the developed model with existing full-scale data together with the data obtained from the IVOS campaign.

In addition to the activities previously described, Nord and Hendrikse are working together using Hendrikse's model to compare simulations with full-scale measurements at the Norströmsgrund lighthouse. Nord is dedicated to the analysis of the data that will be used for their study throughout 2017.

ICE-INDUCED VIBRATIONS OF OFFSHORE STRUCTURES (IVOS)

IVOS, SAMCoT associated project, has continued its course since 2015 and achieved a new set of testing and results in 2016. A new setup was used which provides higher flexibility to change structural parameters such as stiffness, geometry and natural frequency. This allowed us to create ice-induced lock-in vibrations under various conditions with different structures. Similar to the first tests, all structures were equipped with tactile sensors to monitor local ice loads.

After a successful first testing phase in 2015, IVOS conducted a second testing phase in December 2016. The local load measurements obtained from the previous test phase have already allowed interesting observations during ice-structure interactions to be made, stimulating further tests as well as review and enhancement of existing theories on ice-induced vibrations.

A completely new setup is always a challenge (with an element of risk); therefore, a "pre-test phase" was conducted in October 2016 to check its functionality, and several details have been optimized. Next to cylinders with different diameters and stiffness, a flat indenter with changing orientation was tested and set into lock-in vibrations as well.

The data obtained will be meaningful for numerical model validation, and will provide insight into the differences between ice-structure interactions on cylindrical and flat structures which are still not well understood.

Front view of Run 27010; IC @ 20mm/s
Channel after the test

CONTINUUM MODELLING OF ICE RUBBLE

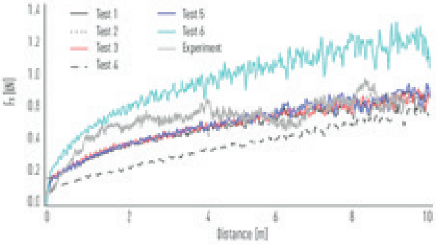
During 2016, Sergey Kulyakhtin studied the behavior of unconsolidated ice rubble. The role and behavior of ice rubble is very important in scenarios where ice ridges interact with both fixed and floating structures.

The consolidated part of an ice ridge is much stronger than the unconsolidated part, which is called ice rubble. The ice rubble, though weaker, can be 20 times larger and can therefore produce a significant load. Due to the large size of the ice rubble, its total load is difficult to measure. However, basin-scale measurements can be used to validate numerical models which can provide information for larger scale scenarios. Hence, the importance of numerical models.

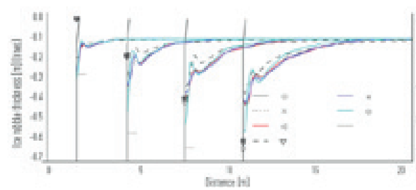
When ice rubble interacts with a structure ice fragments within the ice rubble can break. This complex behavior is difficult to incorporate into discrete models. Kulyakhtin used a continuum model, developed in WP2, to study the effect of ice breakage in ice rubble. He studied and modelled the process of ice rubble-structure interaction comparing his results to measurements obtained in lab experiments performed at the Hamburg Ship Model Basin during the RITAS project in 2012.

The most interesting result from the model predictions was that the amount of ice breakage in ice rubble had only a minor effect on the resulting load. Hence, the hardening of ice rubble due to breakage does not increase the load from floating ice rubble. This could be not the case if the ice rubble were grounded. In contrast, the accumulation of ice rubble appeared to be the decisive factor for the rubble load. The results of the study are described in a paper submitted to the Journal of Cold Regions Science and Technology.

In addition, Kulyakhtin continued his study on the uncertainties involved in approximating ice rubble by continuum models in collaboration with Arttu Polojärvi from Aalto University. They quantified the error involved in using the stress tensor instead of contact forces between blocks. This error is due to non-uniform force distribution (force chains) in the ice rubble sample. Kulyakhtin and Polojärvi also studied the effect of this error on the angle of internal friction, which is widely used to characterize ice rubble. When the sample size is increased from five block lengths to 20 block lengths, the error in the stress ratio decreases from 31% to 9%. The same increase in the sample size reduces the error in the internal angle of friction from 12% to 3%. Further information on the results of this study will be presented at the POAC17 Conference.



Ice rubble load predicted by the model with different parameter sets and measured in the ice tank. Here we see that most of the parameters show only a minor effect on the load. The strongest effect is seen in Test 6 which corresponds to the highest ice rubble accumulation.



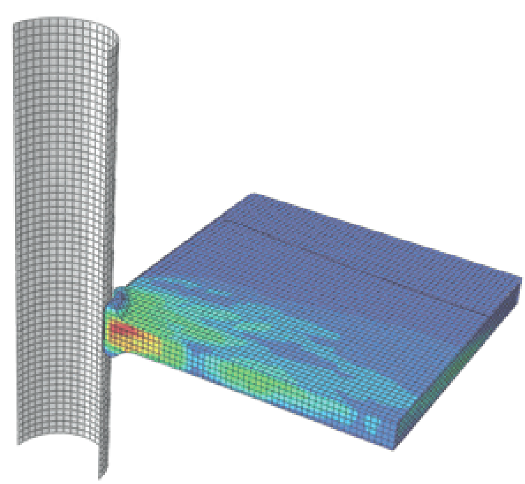
In this plot we can see that the accumulation of ice rubble in front of the structure in four time instances is as predicted by the model and measured from the underwater cameras.

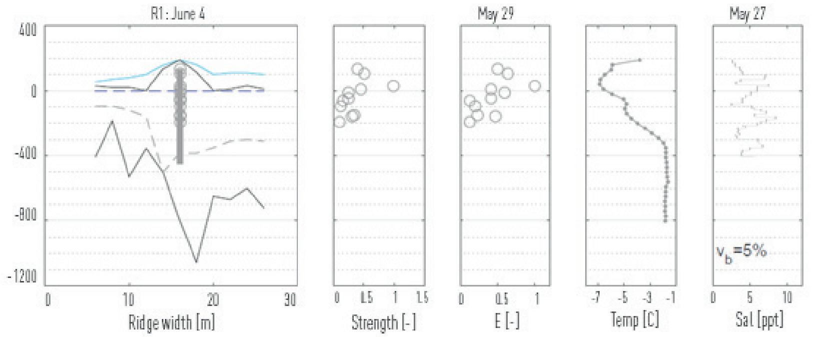
PROPERTIES OF DECAYING ARCTIC RIDGES AND MODELLING OF CONSOLIDATED ICE

During 2016, PhD candidate Åse Ervik finished analyzing the data on ice ridge measurements carried out during the N-ICE2015 expedition. By the end of 2016, Ervik and co-authors submitted two journal papers for review. Ervik studied the development of the rubble macro-porosity and the strength of the consolidated layer. The key findings were that the rubble macro-porosity continuously decreased, while the consolidated layer thickness increased, during the lifetime of a saline ridge. The strength of the consolidated layer decreased until the ice reached an isothermal state, after which the strength remained constant even when the brine volume increased. Additionally, the decaying ice exhibited ductile behaviour. The implication of these results to structures in icy waters, is that decaying ridges could cause severe loads even if the ice strength is low when compared to cold ice. The combined effect of both ductile ice and a thick consolidated layer may affect the governing failure mode and result in severe global forces.

In addition, Ervik worked on modelling the crushing failure of the consolidated layer. Ervik tested different numerical formulations and constitutive models for simulating the process of ice crushing failure against a vertical fixed structure. The results from these tests will be presented at the POAC Conference in 2017.

Numerical modelling of ice crushing. Simulation result of a large deformation continuous ice crushing experiment conducted in Svea 2003 (Moslet et al. 2004). A symmetric boundary condition was used to simulate one half of the cylinder and ice sheet. The white cylinder was considered fixed and rigid. The colours represent the Von Mises stress distribution, where the red colour shows the maximum stress and the blue is the minimum.





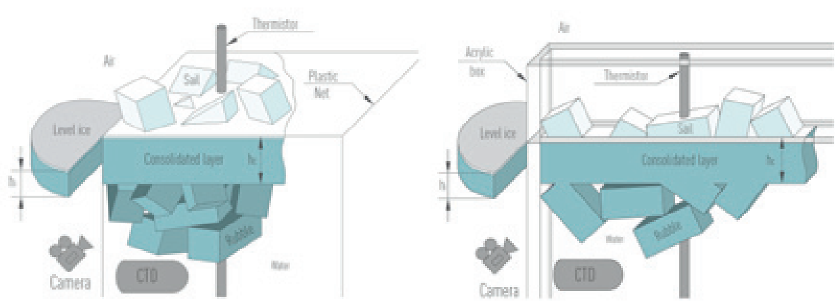
Uniaxial compressive strength compared to physical properties of ice cores in one of the ridges measured by Ervik during N-ICE2015. The left figure shows the ice ridge cross section: the light blue line is the snow surface, the dashed blue line is the freeboard, the black lines are the ice boundaries, the vertical grey line is the ice core position and the circles mark the positions of the compressed samples. The second left figure shows the strength of the samples versus depth. The middle figure shows the elastic modulus versus depth. To the right the temperature and salinity profiles versus depth are plotted.

ICE RUBBLE LABORATORY-SCALE EXPERIMENTS

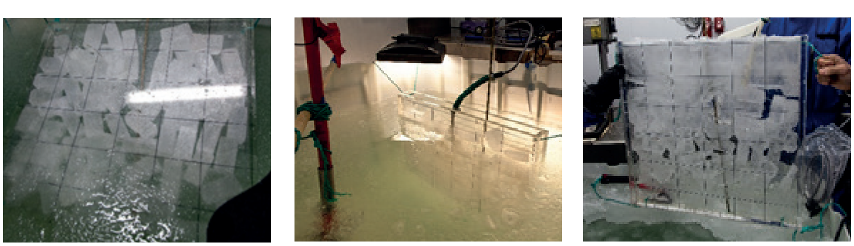
PhD candidate Evgenii Salganik, under the supervision of postdoc Aleksey Shestov, spent a period of seven months (February to August) undertaking research linked to ice rubble at the UNIS Cold Laboratory. Increasing levels of transportation and exploration in the Arctic enhance the significance of ice loads on coastal and offshore structures. Loads from ice ridges are often the highest loads. In contrast to level ice, loads from ice ridges depend on a large number of parameters that are hard to measure directly in the field. The thermodynamics of ice ridges governs two key parameters for ice ridge load value: consolidated layer thickness and its strength. According to ISO/FDIS/19906 (2010) consolidated layers of ice ridges can be modelled in a manner similar to that used for level ice with different levels of ice salinity, crystalline structure and temperature profiles.

Salganik's laboratory experiments and models aim to understand how controlled consolidation parameters (air and water temperature, initial ice temperature, dopant fraction and time) could affect the consolidated layer's thickness and salinity for laboratory-scale work.

The main goal of this study was to investigate ridge consolidation processes. Ratios of different thermal processes (conduction, convection, solidification, salt expulsion and initial rubble sensible heat at temperature T_^{0}) are different for different scales. Laboratory scale is used for basin tests and full-scale is used for collection and verification of the ice ridge thermal, mechanical and geometrical parameters.



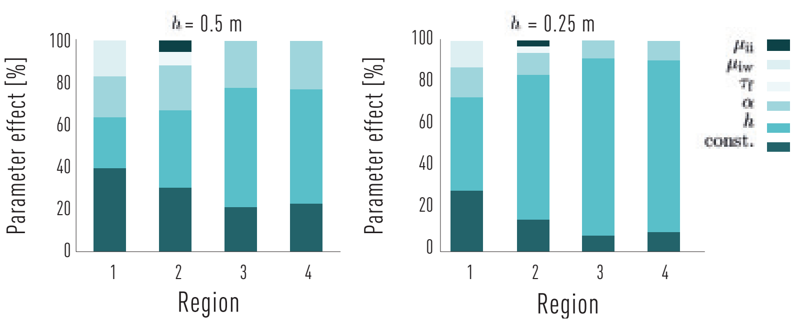
Experimental setup for 2D and 3D configurations. Thermistor strings and electrical conductivity, temperature and depth (CTD) sensors were used to measure the vertical temperature profile in air, the consolidated layer, rubble, water, and the water salinity and freezing temperature. One vertical layer of ice rubble, partly insulated from the sides and the bottom by acrylic walls, was used as the 2D configuration. A plastic net with a 30x30 cm horizontal cross-section was filled with ice rubble for the 3D configuration.



Ice rubble before, during and after consolidation experiment

NUMERICAL MODELLING OF SEA ICE MECHANICS

The Aalto University ice mechanics group has continued with their research on numerical modelling of sea ice mechanics. PhD candidate Janne Ranta has progressed with the research for his doctoral thesis on the statistics (and the mechanics behind the statistics) of ice loads. The approach is unique as the ice load statistics are based on the FEM-DEM simulations of ice-structure interaction processes. Ranta prepared three draft manuscripts for journal articles during 2016. All three manuscripts have now been submitted, and one of them was published late last year in the journal Cold Regions Science and Technology. This paper analyses peak ice load data from 2D combined finite-discrete element method simulations. In these simulations, an initially continuous ice sheet, modelled as a floating beam, breaks into smaller ice blocks as the sheet is pushed against an inclined structure. Multivariate linear regression modelling and the variable elimination method were used in the analysis of the data. The analysis gave valuable insight into the peak ice load data in a simulated ice-structure interaction process. It was found that the peak ice load data can be estimated with good accuracy using only five parameters: the ice thickness; the inclination angle of the structure; the shear strength of ice; the ice-structure and ice-ice friction coefficients. The ice thickness and the structure's inclination angle had the strongest relative effects, with their importance changing during the process. The results also showed that the stage of the ice-structure interaction process should be taken into account in ice load models. The results underline the importance of statistical analysis of ice load data and give valuable suggestions for future work. Associate professor Arttu Polojärvi and Professor Jukka Tuhkuri both actively participated in the research leading to these manuscripts. Additionally, the group presented two papers at the IAHR ice symposium last summer. One of the papers was related to the statistics of ice loads, while the other focused on a study on ice loads on shallow water structures.



The relative effects of ice thickness (h), inclination angle (α), shear strength (τ_f), ice-structure friction coefficient (μ_{iv}), and ice-ice friction coefficient (μ_{ii}) on peak ice loads. The left graph shows the effects when h = 0.5 m and the right graph when h = 1.25 m. Other parameters had fixed values: α = 70°, τf = 0.4 MPa, μ_{iw} = 0.1, and μii=0.3.

SEA ICE MECHANICS

Mark Shortt is a first-year SAMCoT PhD candidate working at the Institute for Risk and Disaster Reduction (IRDR) at the University College London (UCL). Shortt's basic area of study is sea ice mechanics. When two floes of sea ice directly collide, two possible deformation mechanisms can occur. The first is rafting, which is the overriding of one ice sheet by the other. The second is ridging, which is the breaking up of the ice sheets into an elongated pile of rubble. Both scenarios generally comprise the same basic situation; pieces of ice separated by a (relatively) thin liquid layer of seawater. Over time, the liquid layer freezes and the ice pieces gradually bond to form a coherent sea ice feature. This process of freezing and strengthening is known as consolidation. This is important as the degree of consolidation governs the strength of the ice feature.

Shortt's main research interest is investigating how the strength of thick sea ice features (ridging and rafting) changes as a function of the degree of mechanical consolidation. He will also be assessing the risk posed by these consolidated ice features to offshore structures in the Arctic. Shortt's research comprises both experimental work and mathematical modelling, and will also be supplemented by work in the field. He will devise a micromechanical model of freeze bond failure between layers of saline ice, which will be experimentally tested using UCL's Scanning Electron Microscope (SEM) facilities. Microscopic mechanical deformation tests (compressive, tensile and 3-point bending) on freeze bonds will be conducted using the Deben Microtest rig, and freeze-bond failure will be simultaneously imaged under the SEM.

For the model to be applied to the real world it must be scaled up from the micro-scale to dimensions found in nature. To investigate the effect of spatial scaling, mechanical tests on freeze bonds will be performed on the laboratory (centimetre) and field (metre) scales. Mechanical tests on the intermediate scale can be undertaken using the confined biaxial cell, which subjects ice samples to a true triaxial stress at strain rates between 10^{-4} and 10^{-8} s^{-1} and at temperatures down to -40ºC.

Image of the confined biaxial cell situated in the UCL cold rooms

Shortt conducted a review of the literature, which has helped to develop his knowledge of ice mechanics. He has learned how to grow and prepare saline ice using the facilities available in UCL's Ice Physics Laboratory and has assisted with mechanical tests on ice rubble using the uniaxial deformation cell.

NOTABLE NUMBERS

Torodd Nord

90 000 000 x

8 x

100 x

30 x

300 x

Sergey A. Kulyakhtin

16x

2 x

185 149 x

420 x

6 x

30x

1x

Åse Ervik

24x

100 x

3 x

2x

10 x

100 x

10 000 x

SAMCoT ACTIVITIES

LAB ACTIVITIES:
HSVA – Hamburg
NTNU – Trondheim
UNIS – Svalbard
UCL - London

FIELD ACTIVITIES:
Research sites Svalbard (Svea, fjords of Spitsbergen, Vestpynten)
Research sites Russian Coast (Baydara & Varandey)
Research cruise with KV Svalbard (Fram Strait)
Research cruise with RV Lance (Western Barents Sea, Fram Strait & N-ICE 2015)
Research cruise with the icebreakers Oden & Frej (82° N, 18° E)
Research cruise with the icebreaker Oden (North-East Greenland, Fram Strait & Arctic Ocean 2016 Expedition)

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Statoil Petroleum AS – Trondheim, Norway
Stiftelsen SINTEF – Trondheim, Norway
TOTAL E&P NORGE AS – Stavanger, Norway

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Aalto University, School of Engineering – Espoo, Finland
Delft University of Technology (TUDelft) – Delft, The Netherlands
Hamburg Ship Model Basin (HSVA) – Hamburg, Germany
Moscow State University (MSU) – Moscow, Russia
Norwegian University of Science and Technology (NTNU) – Trondheim, Norway
Technical Research Centre of Finland (VTT) – Espoo, Finland
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SAMCoT develops key knowledge and innovative tools to promote safe, environmentally sound operations in the Arctic
SAMCoT

FLOATING STRUCTURES IN ICE

WP4

> ‘We cut the second largest ice floe ever fractured as an experiment; it was as big as a basketball field!’
>
> Wenjun Lu, SAMCoT Postdoc

FLOATING STRUCTURES IN ICE

Since the start of SAMCoT our researchers have worked towards acquiring the necessary knowledge to develop the analytical and numerical models required by industry in the field of Floating Structures in Ice. Our team focusses on the prediction of loads exerted by first-year and multi-year level ice, ridges and icebergs as well as the performance of floating structures in ice.

Changes in the boundary conditions and new opportunities encountered along the way have determined the research path followed towards this aim. Our group is composed of seven researchers, three postdocs and three PhD candidates.

ICE ACTIONS

From an engineering point of view, ice actions can be divided between local and global ice actions on a structure.

LOCAL ICE ACTIONS

The year 2016 started with Martin Storheim successfully defending his thesis "Structural response in ship-platform and ship-ice collisions" on 19th January. He presented a novel way to separate two different mesh scale effects (termed geometric and material). He also discussed the micromechanical process of fracture and related it to macromechanical processes that can be captured with coarse shell elements.

Another of our researchers working on local ice actions, postdoc Ekaterina Kim, re-analysed the data from the indentation experiments conducted on natural iceberg ice at Pond Inlet in 1984. In collaboration with Robert Gagnon (Research Council Officer for National Research Council Canada, St John's) they found that, for three different spherically-terminated indenter sizes, the crushing specific energy of the ice shows little dependency on the volume of the displaced ice and tends towards a constant value. In addition, their results showed no apparent correlation between the crushing specific energy of the ice and indenter size, nor was there a clear consistency in the values for tests conducted with the same indenter. This means that the crushing specific energy is an important parameter in engineering models of ice impact loads and numerical simulations of ice crushing.

Within the context of local ice loads due to an abnormal ice event, our group has continued to address two effects: firstly the effect of structural deformations and secondly the effect of surrounding water. The arbitrary Lagrangian-Eulerian (ALE) and coupling algorithms have been validated through comparison with model tests of an ice-structure collision. The effect of viscosity and the equation of state for the water model within the ALE formulation are insignificant, whereas the choice of the element size has a noticeable effect on the computed contact forces and the motions of the impacted structure.

Variation of the mean value and the standard deviation (as error bars) of the crushing specific energy (MSEI) as a function of crushed volume.

GLOBAL ICE ACTIONS

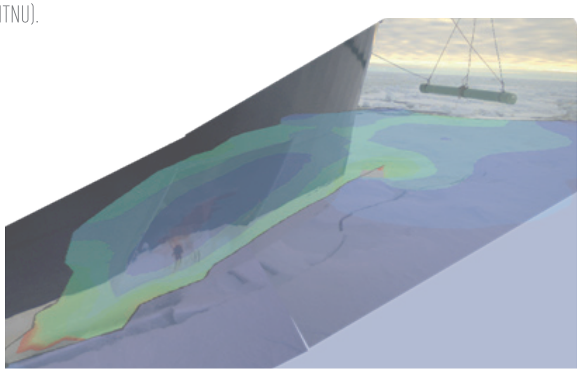
Fracturing of ice

For postdoc Wenjun Lu, 2016 was another busy and exciting year on several interesting research fronts covering field tests, theoretical and numerical studies and model tests.

Large-scale field fracture tests

Svea, Van Mijenfjord, Spitsbergen, March 2016. After extensive preparations and an impeccable implementation coordinated by Lu, the 'fracture research team' obtained valuable data and was able to observe visually, for the first time, a stable crack growth within sea ice. This is unusual, as in other test scenarios the crack propagates in an uncontrolled manner. Due to the success of the experiment and the results achieved, another field test is planned in 2017 with higher fracture loading rates. The study of fracture events is highly relevant to our industry partners. During ice management, parallel channels are created to facilitate the ice floe size reduction process and fracturing events are constantly observed. Data obtained during the Oden Arctic Technology Research Cruise in 2015 (OATRC'15) show many parallel channel fracturing events. Dr. Lu analyzed the Oden data and programmed a numerical scheme based on the Extended Finite Element Method (XFEM) to simulate the crack kinking process and to explain the observed fracture events.

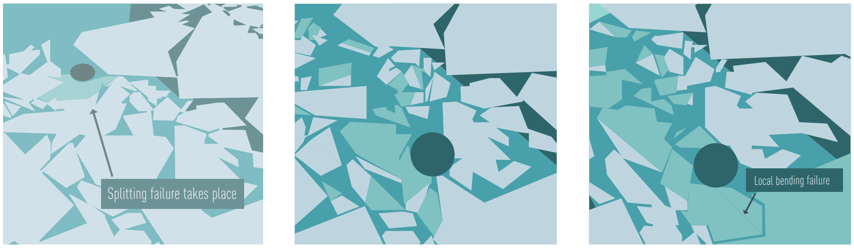
The fracture team in Svea from left to right: Petter Scharffscher (M-Tech), Aleksey Shestov (SAMCoT postdoc at UNIS & key participant), Wenjun Lu (main researcher, NTNU), Xiaodong Chen (NTNU), John Dempsey (Clarkson University, USA), Jukka Tuhkuri (Aalto University) and Sveinung Løset (NTNU).



The figure illustrates a simulation of a predicted crack path versus the crack path in reality. The exact prediction was not made, but the general trend and direction were captured.

Observed and modelled fracturing of sea ice

In 2016, researcher Hongtao Li, in collaboration with Ceetron, used Lu's analytical fracture solutions to improve the computational efficiency of Simulator of Arctic Marine Structures (SAMS). Results of the use of Wenjun Lu's analytical fracture solutions are shown here.



Towing test without fracture

Ilija Samardzija's MSc thesis focused on answering what happens if there is no fracture during the interaction between ice and a structure? Supervised by Lu (seen in the picture in the background), Samardzija (on the right) conducted a series of model tests by towing a structure in various ice conditions. Floe ice made from paraffin was used to represent ice fields of various concentrations, floe shapes and sizes. The towing force was measured together with the trajectories of each ice floe during the interaction.

MODELLING OF STRUCTURE-FLOE ICE INTERACTIONS

In 2016, PhD candidate Marnix van den Berg resolved the remaining research questions regarding the combination of lattice modelling and the non-smooth discrete element method (NDEM) to model structure-floe ice interactions. Using NDEM, compared to other discrete element methods, may lead to reduced calculation time. Accuracy is achieved by implicit time integration. van den Berg is currently in the process of validating the different components of the model with promising results.

In July, van den Berg joined the Oden icebreaker to participate in an engine trial. He used this trip to check if his modelling assumptions were realistic. Since there was no possibility to go on the ice during this trip, he used visual observations for his tasks. An important observation was that there is significant variability in ice conditions, even on relatively small spatial scales.

During most of the trip, the ice consisted of a very uneven floe field in which first year ice was mixed with some multi-year ice inclusions. A high number of ridges and rubble fields were present, as well as icebergs. The first-year ice was often very weak and 'rotten', while the multi-year ice was much stronger and much thicker. The observed variability was in line with descriptions in the existing literature. It confirms once more that full-scale Arctic summer ice conditions cannot be approximated by an assumed constant ice thickness in a numerical model.

Visual impression of a lattice-NDEM simulation showing a ship breaking through floe ice.

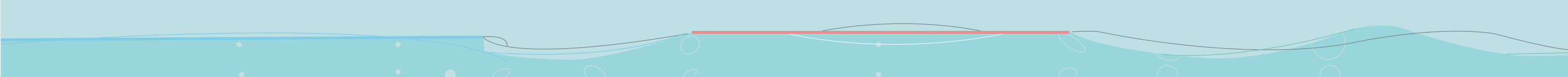
EFFECTS OF HYDRODYNAMICS ON STRUCTURE-LEVEL ICE INTERACTION

PhD candidate Chris Keijdener studies the qualitative effects of nearby level ice on the response of a floating body using a 2D model.

Below a certain onset frequency, the amplitude of the reflected waves is insignificant and consequently the body remains unaffected by the ice. This frequency is only sensitive to the ice thickness, with thinner ice resulting in a higher onset frequency. Above the onset frequency the reflected waves cause quasi-standing waves between the body and ice. For frequencies at which the surface wavelength is approximately an integer multiple of twice the gap length, the amplitude of the standing waves is greatly amplified. This can result in (anti-) resonance depending on the phasing between the reflected waves and the body's motion.

In addition, Keijdener is working on creating a model that can isolate the effects of dynamic fluid pressure on the interaction between level ice and sloping-faced structures. The ultimate aim of this work is two-fold: the first goal is to gain a qualitative understanding of how the dynamic pressure influences the interaction between level ice and a sloping structure, while the second goal is to assess for which interaction speeds the effects are negligible, hence allowing the dynamic pressure to be ignored.

The ice is located on the left, depicted by the teal line. The floating structure is depicted by the red line.



ICE IN WAVES

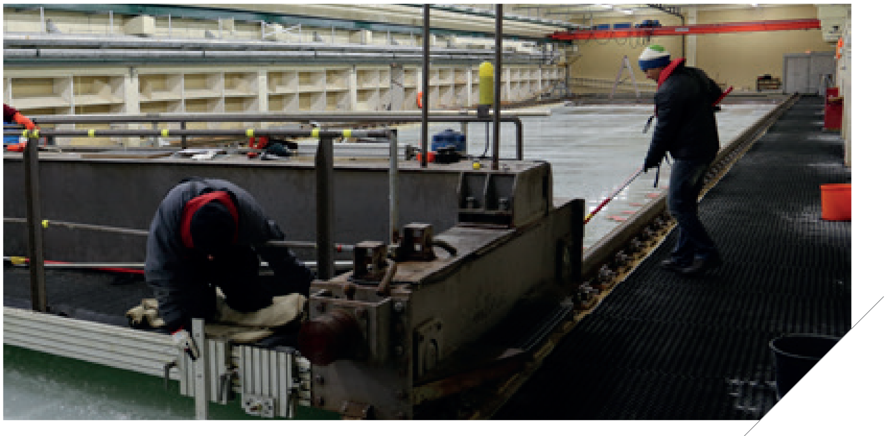
Barents Sea Ice in Waves experiment

The idea of the experiment coordinated by postdoc Andrei Tsarau was to measure simultaneously the motions of several ice floes in the field to study the process of wave attenuation in ice. The heave motion amplitudes registered by Inertial Measurement Units IMUs deployed on the ice were used to interpret the wave amplitude. The wave attenuation coefficient obtained from the comparison of the wave amplitudes at two different locations was significantly lower than the attenuation coefficients reported from previous field experiments performed in the same area in 1990. This is most likely due to the much thinner ice observed during this study compared with 1990.

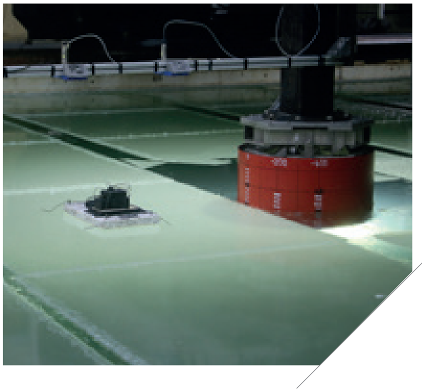
In April/May 2016 Andrei Tsarau, Aleksey Shestov and Sveinung Løset conducted an experiment in the Barents Sea Marginal Ice Zone (MIZ). One of the most challenging tasks during this experiment was to deploy, track and retrieve the equipment to and from small ice floes in high waves. Deploying sensors in the Barents Sea MIZ

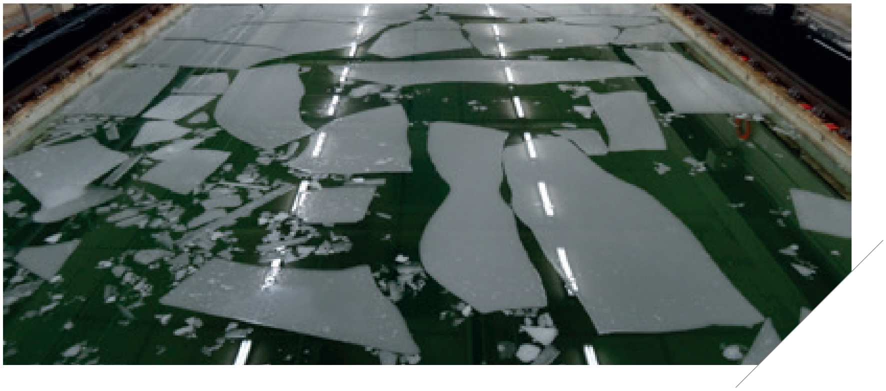
Experimental Ice in Waves campaign at HSVA

Another experimental campaign led by Tsarau was accomplished at The Hamburg Ship Model Basin (HSVA) in October/November 2016 during the Hydralab+ Transnational Access project: Loads on Structure and Waves in Ice (LS-WICE). There were three parts to this investigation: ice fracture under wave actions; wave attenuation/dispersion in broken ice covers and ice-structure interactions under wave conditions. The experiments confirmed the hypothesis that floe size strongly affects wave dispersion. It was also remarkable that in the break-up test the first crack appeared approximately in the middle of the ice cover, contrary to the expectation that progressive breaking would be observed starting from the ice edge. The first crack also had a profound influence on the subsequent development of fractures.



Cutting a continuous ice sheet into uniform size floes at HSVA during the LS-WICE project. Physical and mechanical properties were measured in the Large Ice Model Basin (LIMB) before a range of waves was passed through to obtain the attenuation/dispersion relation. Wave measurements were monitored with pressure transducers and ultrasound sensors.





USE OF REMOTE SENSING FOR ARCTIC MARINE OPERATIONS

PhD candidate Runa A. Skarbø bridges the work of SFI SAMCoT and SFI CIRFA (Centre for Integrated Remote Sensing and Forecasting for Arctic Operations). Skarbø focuses on the operational use of ice intelligence retrieved from remote sensing products such as Synthetic Aperture Radar (SAR) images, marine radar and other remote sensing technologies. Skarbø's work aims to use the ice information compiled with drift prediction in order to assess the related risks and scenarios for marine offshore operations in the Arctic.

During 2016, Skarbø used a model, developed by SAMCoT PhD candidate R. Yulmetov in 2015, to investigate the difference between iceberg drift in sea ice compared to open water. Becoming acquainted with this model was important for her research as it is linked to the topic of 'ice drift prediction'. This work provided her with useful insight. In addition, Skarbø participated in a six-week research cruise to the Arctic Ocean. The scope of Skarbø's work was to collect valuable full-scale data and to gain experience from ships travelling in sea ice and icebreaking. Skarbø collected data series of radar images while the ship was stationary, in addition to data from SAR products from Radarsat-2, ground truthing from buoy drifters, meteorological data and rheological data from the ice.

Skarbø during the Arctic Ocean 2016 research cruise on board the icebreaker Oden.

NOTABLE NUMBERS

Wenjun Lu

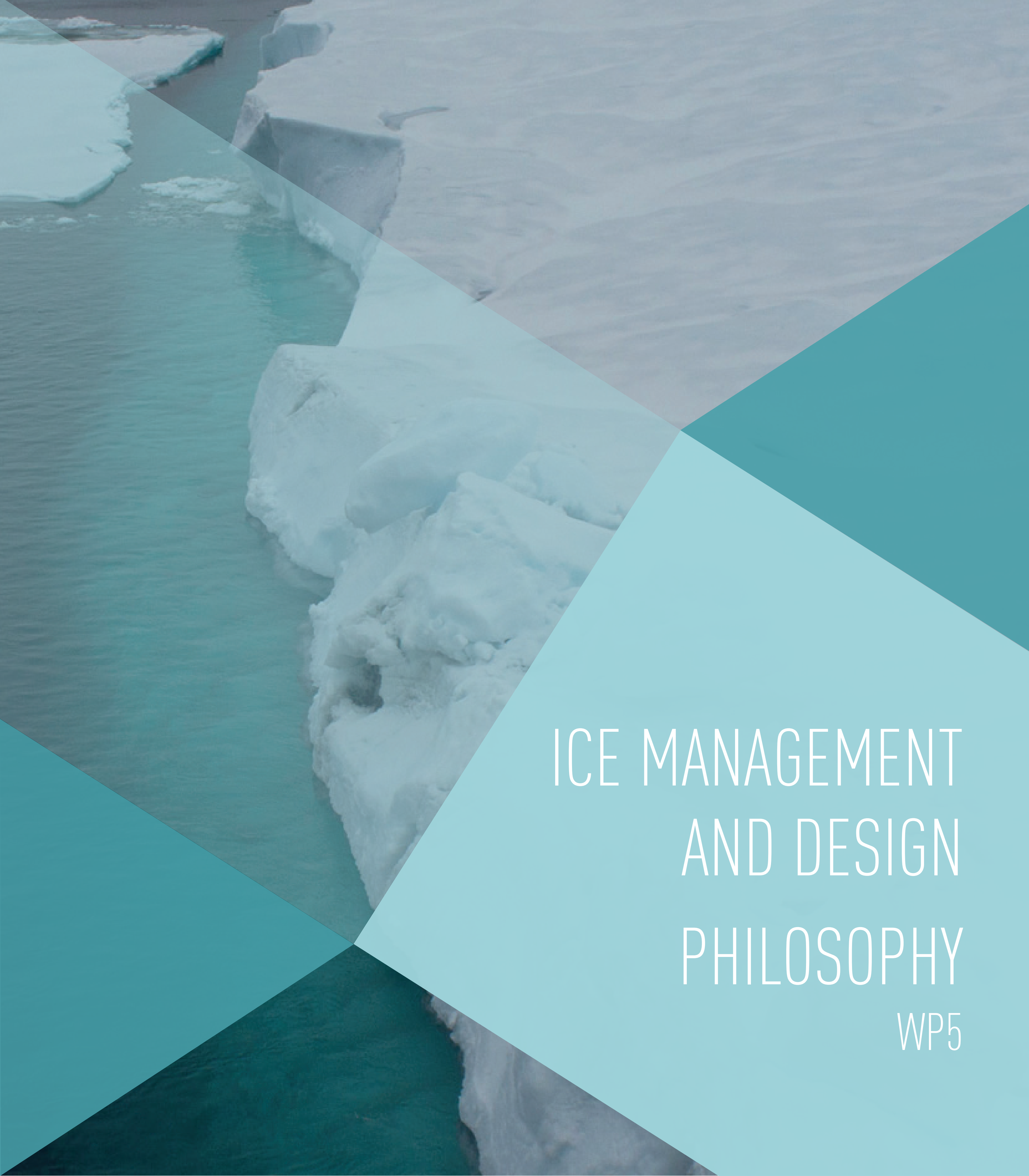
1 x 4 x 4 x 32 x 32 x

Andrei Tsarau

2 x 1 680 x 14 400 x 2 x 5 x

Runa Skarbo

2 x 2 x 1000 x 90° North 77 537 x 2 x 10 x



ICE MANAGEMENT AND DESIGN PHILOSOPHY

WP5

> 'The sound of ice scratching, the movements of the icebreaker and ice in all its force crashing against it! You can see the numbers but it's not the same.'
>
> Runa Skarbø, SAMCoT PhD Candidate

ICE MANAGEMENT AND DESIGN PHILOSOPHY

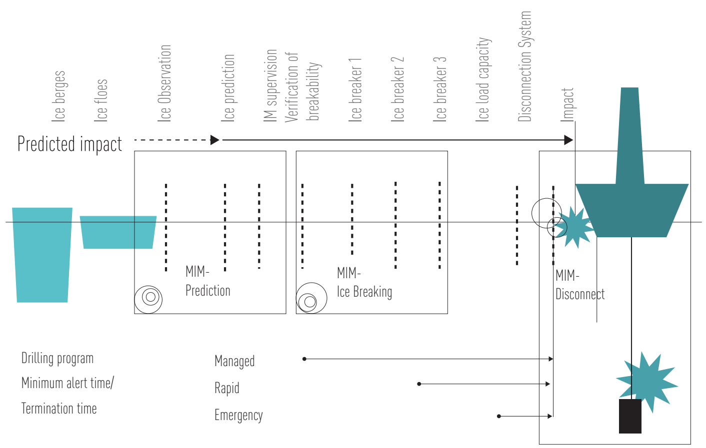
Ice management (IM) is defined as the sum of all activities carried out with the objective of mitigating hazardous situations by reducing or avoiding actions from any kind of ice feature (sea ice or glacial ice), and includes several types of barriers. The scope of IM activities is wide. It covers many aspects including technologies, equipment, systems, processes, operational procedures, etc.

METHODS FOR MODELLING ICE MANAGEMENT BARRIERS

The industry has already been involved in different IM activities for a long time and in several geographical areas. Literature refers to different types of challenges. Different companies and disciplines have different roles, responsibilities, priorities, technologies, terminologies and cultures and have different views on how to approach IM issues.

Researcher Stian Ruud started to work with these issues from the beginning of his engagement in SAMCoT in 2016. Ruud led two industry workshops in Trondheim, hosted by SAMCoT, where industry partners presented their different views on IM topics. During the workshops, participants discussed the need for modelling IM barriers. As a result, Ruud's research activity was defined. In collaboration with other WP5 researchers, he aims to provide quantitative and qualitative methods for modelling ice management (MIM) barriers, by implementing a top-down 'method for supporting IM decisions' based on aggregated quantified and qualitative information.

The modelling approach is also based on international standards like ISO/DIS 35104 on IM and the ISO/DIS 19906 standard and regulations on barrier management. The extensive work done in 2016 will enable Ruud to write a new report in 2017: 'Methods for IM barrier modelling (MIM)'. Two different case scenarios/studies will be carried out as illustrated in the figures:

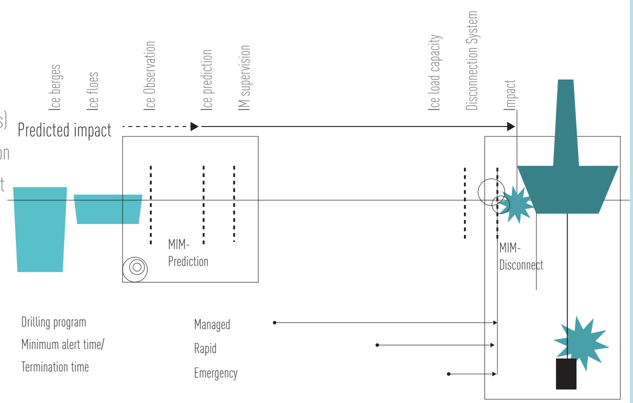


Extreme Arctic conditions with active fight IM by means of ice breakers. Vertical dotted lines illustrate ice management barriers. The overall objective of ice management is to avoid contact between ice and the protected unit (e.g. drilling rig). If the probability of ice contact is high, the protected unit shall be relocated, either by a managed, rapid, or emergency disconnection procedure.

Types of Barriers:

- Ice detection and observation
- Ice management supervision (alerting and decision)
- Physical ice management with icebreakers
- Ice prediction
- Verification of ice breakability
- Disconnection procedures and systems of the protected unit

Workable conditions with semi-active flight IM (Probability of detection (POD) of ice floes/ice bergs) The overall IM approach is based on disconnection of the protected unit if ice is detected and forecasted to be approaching. No physical ice management with icebreakers is included.



A NEW RISK MODEL BASED ON A BAYESIAN NETWORK

The Norwegian Petroleum Safety Authority (PSA) requires offshore petroleum operators on the Norwegian Continental Shelf (NCS) to perform risk assessments of impacts (allisions) between passing ships and offshore installations. These risk assessments provide a basis for defining the design of the allision accidental load on the installation. Even though the risk of allision is small, the potential consequences can be catastrophic. In a worst-case scenario, an allision may result in the total loss of an installation. The ageing industry standard allision risk model, COLLIDE, calculates the risk of impacts between passing (non-field-related) ships and installations based on Automatic Identification System (AIS) data. Both the COLLIDE risk model and a new Bayesian allision risk model currently under development are highly sensitive to variations in the vessels' passing distances, especially close proximity passings.
Allision risk assessments are typically performed during the design and development phase of an installation, which means that historical AIS data are used "as is", disregarding future changes to the traffic pattern when the new installation is placed at a location.

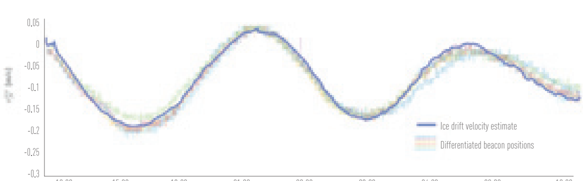
PhD candidate Martin Hassel presents, in one of his publications, an empirical study of one of the most important variables used to calculate the risk of allision from passing vessels, namely passing distance. The study shows that merchant vessels alter course to achieve a safe passing distance from new surface offshore petroleum installations. This indicates that the results of current allision risk assessments are overly conservative.
Hassel also proposes a new risk model based on a Bayesian Network that can replace the old COLLIDE model. Hassel reviewed the background knowledge and presented the theoretical foundation of existing risk models used on the NCS as the basis for his new model. The new risk model incorporates a wider range of risk influencing factors (RIFs) and enables a holistic and detailed analysis of risk factors and dependencies. It is more transparent and provides a better understanding of the mechanisms behind allision risk calculations. An expert panel has quantified key RIFs in the model, and the results from the new model are aligned with industry expectations, indicating a satisfactory performance.

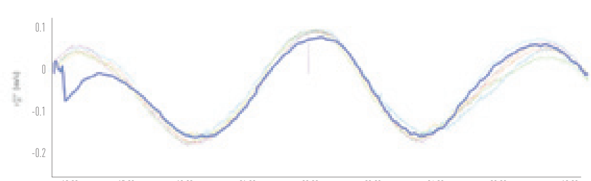
Photo of the MS Reint – H7 allision, taken by the crew on the nearby standby vessel.

ICE MANAGEMENT ONBOARD DECISION SUPPORT SYSTEMS

As a rule, the captain of a ship involved in a station keeping operation in the Arctic has a support advisory group at his or her assistance. This group, a so-called "ice management team", can consist of meteorologists, ice experts, and others with knowledge about ice or who have experience with similar operations. In many cases it is an entire fleet of ships that has to cooperate to achieve the operation objective. In such situations it is highly important that all ships have the necessary information about the weather, ice conditions and potential hazards in the area.
Postdoc Øivind K. Kjerstad does his research on one of the key challenges of IM: monitoring of ice. Kjerstad defended his PhD with the topic "Dynamic Positioning of Marine Vessels in Ice" on May 3 2016 at the NTNU. Ice motion is difficult to measure and predict accurately, making risk management challenging. To date no reliable and robust systems exist to provide real-time information on ice movement or the loads induced on the ship. The captain must therefore rely on their own or others' experience to operate vessels in ice-covered waters. At present, a set of position sensors physically placed on the ice by helicopter is used to monitor ice. The position sensors must be collected when they run out of the operation area for environmental reasons, making this method quite demanding in terms of logistics and costs. In bad weather, when the need to know how ice moves is highest, helicopter use also entails the greatest risk or is not possible at all. Kjerstad and other researchers in the IM team focus on developing other monitoring systems that provide the necessary information using only on-board sensors. Kjerstad is investigating a load monitoring system. It consists of a set of inertial measurement sensors to record the accelerations and rotational rates of the ship. Fusing these signals with conventional on-board sensors, including mooring tension sensors if available, allows the global load acting on the vessel to be estimated in real-time. In addition, this system monitors the incoming direction of the loads and rapidly detects changes in the load direction. This is important for risk monitoring and consequence analysis, and improves station-keeping capabilities as it achieves better accuracy in the load compensation calculated by the station-keeping control system.

A result from the ice velocity estimation algorithm using radar and ship motion sensors compared to the ice velocity recorded by sensors placed on the ice cover.





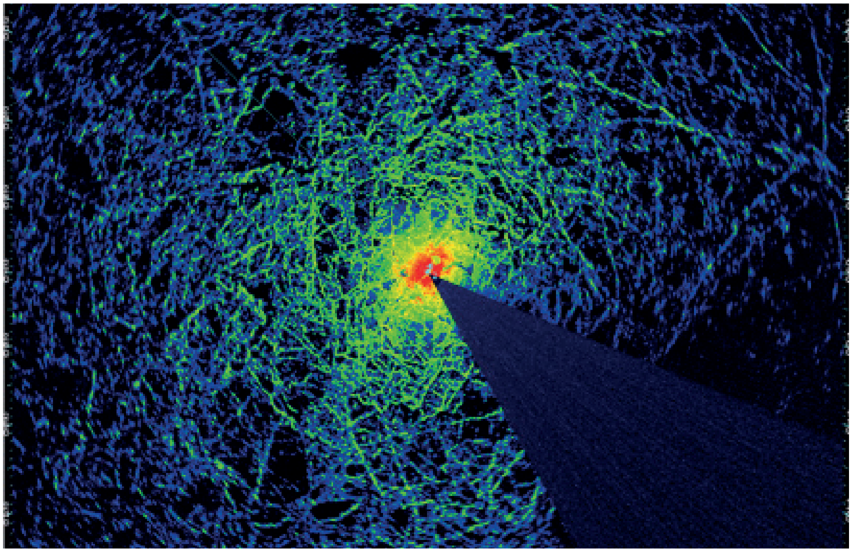
ARCTIC OCEAN 2016 EXPEDITION

Three PhD candidates linked to SAMCoT have visited the North Pole on board a research cruise to improve their understanding of the use of ice surveillance techniques for IM. The six-week-long research cruise was conducted as a collaboration between the Swedish Polar Research Secretariat (SPRS, a SAMCoT member since 2015), the Canadian government and the icebreaker Louis S. St-Laurent. The icebreaker Oden departed from Longyearbyen, Svalbard, on August 8 to meet up with the Canadian icebreaker Louis S. St-Laurent and subsequently launch the expedition. During the six-week expedition, the vessels operated in the Amundsen Basin and in areas around the underwater mountain ranges Lomonosov Ridge and Alpha Ridge. The primary goal was to allow the Canadian government to collect information about the seafloor in the Arctic Ocean in support of the country's application to the United Nations (UN) to extend the limits of its Continental Shelf. This included mapping of the seafloor using seismic surveys, dredging, scanning by multibeam echo sounder, taking sediment core samples and more.

SAMCoT PhD candidates Jon Bjørnø, Runa Skarbø and Hans-Martin Heyn (Skarbø and Heyn linked respectively to the Centre for Research-based Innovation CIRFA – Centre for Integrated Remote Sensing and Forecasting for Arctic Operations and SFF AMOS – Centre for Autonomous Marine Operations and Systems) joined the expedition to perform sea-ice data acquisition related to IM and ice surveillance. Their work aims to improve autonomy in Arctic marine operations through the development of algorithms for the online or real-time tracking and prediction of important ice parameters such as sea-ice drift and loads on vessels, ice concentration and floe size distribution.

During the expedition, the team tested a system to monitor ice drift around the SPRS Icebreaker Oden, as well as a camera system that monitored ice conditions and thicknesses around the ship and a system that measured vibrations in Oden caused by its passage through the ice.

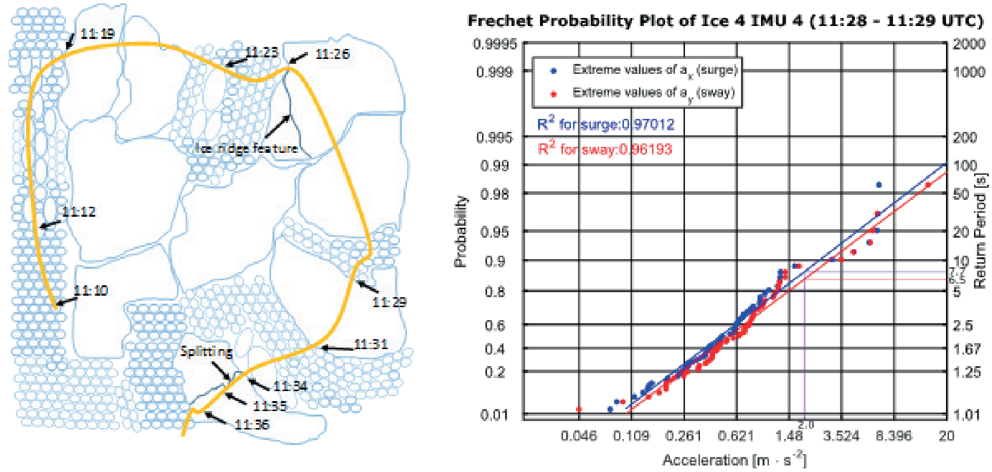
As part of her work, Skarbø collected screenshots of the radar operator station at selected locations when the vessel was stationary or drifting for more than four hours. A sequence of such radar screenshots combined with ship position reference and gyro-compass measurements can be fused with a computer vision algorithm to estimate accurately the sea-ice drift pattern in a range of 0.5 to 6 nautical miles around the vessel. This function, previously only achieved by manually deploying GPS trackers onto the sea-ice, is very important for safe and efficient IM operations where understanding ice drift and especially changes in ice drift is a critical monitoring parameter.



Example of a radar screenshot (resolution of 1920x1200 pixels, sampled at 1 Hz) in an ice management operation.

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

To facilitate Heyn's research, four inertial measurement units (IMUs) were mounted on different locations in the vessel to monitor the ice-induced accelerations of the icebreaker hull during both station-keeping operations and transit through the sea-ice. The IMU motion data were also supported by a system of 11 cameras that continuously monitored the ice conditions and icebreaking processes 360 degrees around, and especially ahead of the vessel. The conjecture here is that the acceleration measurement of the IMUs will contain information on the ice loads acting on the ship's hull similar to that which could be obtained from strain gauges. SAMCoT's research attempts to use the IMUs, cameras and radar data for the online tracking and short-term prediction of the extreme ice loads acting on the vessel, estimation of local ice drift velocity and direction relative to the vessel and real-time estimation of global ice loads on the vessel. In addition to functioning as an important image documentation system for validation purposes, the camera images are further used to estimate the local ice concentration and floe size distribution and possibly to identify ice features such as ridges and melt ponds.



Example track of the Icebreaker Oden through various ice regimes, reconstructed from the camera images, and the corresponding extreme load distribution fit for a part of the track.

INTEGRATED AUTONOMOUS OPERATIONS

In April 2016 SAMCoT PhD candidate Petter Norgren participated in an experiment to explore the possibility of combining R/V Gunnerus, the autonomous underwater vehicle (AUV) Hugin, the unmanned aerial vehicle (UAV) X8, and the unmanned surface vehicle (USV) Mariner in a network of heterogeneous unmanned vehicles. Different institutions participated, among them NTNU, the Norwegian Defence Research Establishment (Forsvarets forskningsinstitutt, FFI), Kongsberg Seatex, the Laboratório de Sistemas e Tecnologia Subaquática (LSTS) at the University of Porto and Maritime Robotics. Communication, maneuvering, onboard processing, and operational complexity are essential components in such networks. The Kongsberg marine broadband radio (MBR) system was used for communication. Norgren was involved with the AUV operation and on the processing of the data collected.

The participants defined a scenario with seabed mapping and target recognition to show the capabilities of the proposed system. The experiment made it apparent that these networks have the potential to save significant data collection costs in marine research and management by reducing ship time. To unlock fully the potential of networks of heterogeneous unmanned vehicles, the objectives of each individual vehicle will need to be better integrated into the overall mission.

Autonomous Tethering of AUVs using the USV Jetyak

A standard AUV survey requiring high-accuracy navigation currently requires a ship to follow the AUV and provide position updates. Moving this task to an USV, that autonomously follows the AUV, could potentially save significant ship time. Autonomous tethering of AUVs using a USV can also provide a real-time communication link between an operator station and an AUV, which is often a desired feature for monitoring progress and status. To prepare for research on autonomous tethering, the NTNU/UiT USV Jetyak was equipped with a range of new sensors.

Norgren extended the hardware of the USV Jetyak control system to allow logging and control of the new sensors through a Kongsberg MBR 144. The main goal of the new hardware interface on the Jetyak was to allow acoustic communication, as well as Wi-fi connectivity, with the Light AUVs (LAUVs) through the MBR. The upgrade of the Jetyak control system also allowed inclusion of several new sensors, and to extend the feasible operating area for the Jetyak in the Arctic polar night, Norgren also equipped the Jetyak with a SIMRAD 4G radar and an infrared IP camera. The scientific payload of the Jetyak was also extended to include a Norbit multibeam sonar, in addition to the old payload consisting of sidescan sonar and an acoustic zooplankton and fish profiler (AZFP).

AUV expedition with students from the UNIS course AT334 in Longyearbyen, August 2016


ODEN
ODEN

NOTABLE NUMBERS

Øyvind K. Kjerstad

6 x | 24 x | 10 x | 9 000 x | 9 000 x | 100 x

Hans-Martin Heyn

3 x | 3 x | 259200000 x | 1000 x 90° North | 4 x | 20 x | 20 x

Petter Norgren

10 x | 4 x | 3 x | 100 x | 5 x

COASTAL TECHNOLOGY

WP6

'SAMCoT PhD candidates know what they are talking about, they have been in the Arctic and they have tested their own theories. This makes them more confident, and adds crucial value to their work in the Industry.'

Sveinung Løset, SAMCoT Director

COASTAL TECHNOLOGY

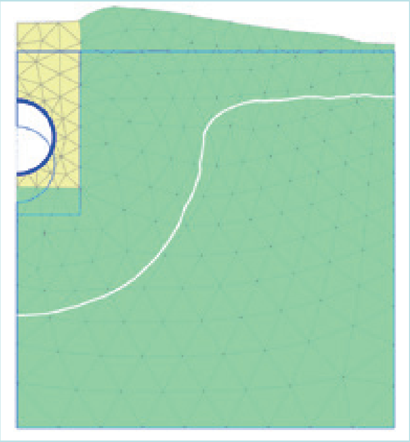
Coastal zone development in the Arctic is quite demanding. The construction of roads, harbours and other facilities in the Arctic faces several challenges, e.g. exposure to the combined action of waves, currents and ice, high coastal erosion rates, building on permafrost soils, remoteness and the lack of local material suitable for construction purposes. Moreover, 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. Different research projects address these general challenges in response to SAMCoT's industry partners' needs for innovation.

The goal of WP6 is to develop new knowledge, and 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.

THERMO-HYDRO-MECHANICAL (THM) CONSTITUTIVE MODELS

In 2016 postdoc Seyed Ali Amiri and PhD candidate Mehdi Kadivar worked to develop Thermo-Hydro-Mechanical (THM) constitutive models to simulate the behaviour of frozen soils. They have developed an elastic-plastic constitutive model for simulating the mechanical behaviour of saturated frozen soils and have published the theoretical foundation of the model in the Canadian Geotechnical Journal. The model was later implemented in PLAXIS and the beta version of the model, together with a user manual, was released by PLAXIS towards the end of 2016. In November 2016, Amiri and others from NTNU visited the PLAXIS office in Delft and conducted an introductory workshop about the model.

Considering the time-dependent behaviour of frozen soil, Amiri upgraded the elastic-plastic model to an elastic-viscoplastic version. The new model is also implemented in PLAXIS and can be used by other researchers upon request. The theoretical basis of the elastic-viscoplastic model has been published in the European Journal of Environmental and Civil Engineering.

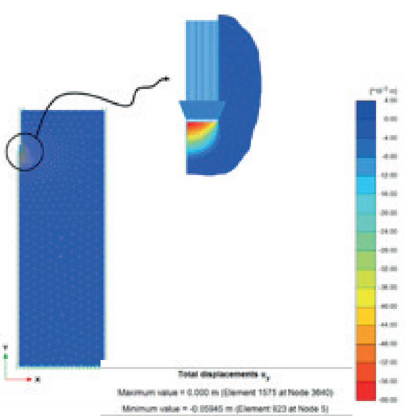


The simulation considers a chilled pipeline buried in a cold region. The cooled fluid in the pipeline has a temperature of -20º C, and the air temperature has dropped from +20º C to -5º C. This decreases the ground temperature and freezing will start. Freezing may result in frost heave which is defined as the ground expansion caused by water migration that supplied growing ice lenses. Predicting the frost penetration and frost heave is important in the design and safety of structures in, or on, frost-susceptible soils. The figure shows the simulation results for the ground deformation and frost penetration (white line) after 210 days.

MODELLING THE BEHAVIOUR OF UNSATURATED FROZEN SOILS

Both the elastic-plastic and the elastic-viscoplastic models mentioned above are restricted to saturated frozen soils. However, soils in the Arctic are mostly unsaturated. Modelling the behaviour of unsaturated frozen soils is a new field of research and substantial theoretical development will be required to reach this goal. To facilitate this research path, Amiri and his team at NTNU adopted the THM model developed by Yared Bekele in WP2 and further developed it into an in-house THM finite-element code similar to PLAXIS. Bekele defended his PhD thesis, Isogeometric Analysis of Coupled Problems in Porous Media - Simulation of Ground Freezing, on 19 May 2016.

During his PhD study, Bekele incorporated a simple non-linear thermo-elastic material model and successfully applied it to the simulation of frost heave problems. After defending his PhD thesis, Bekele worked for 6 months as a researcher trying to incorporate Amiri's elastic-plastic model into his THM model. The theoretical nature of Amiri's elastic-plastic model required significant modifications to the governing equations of Bekele's original THM model. The modifications of Bekele's code are now completed and the implementation of the elastic-plastic model is still progressing.



Long-term settlements due to creep phenomena are of great importance in cold region engineering. Creep settlements are highly influenced by the applied stress level and the temperature. The second simulation shows the effect of changing applied stress and temperature on the creep settlements of a foundation over 8 years. As shown in the graph, creep rate is increasing with increasing stress level and temperature. As expected, the creep rate of frozen soil in summer time is more critical than in winter time.

CHARACTERIZATION OF SEA ICE EFFECTS ON COASTAL WAVES

Rapid coastal erosion threatens Arctic coastal infrastructure, including communities and industrial installations. Coastal erosion in the Arctic is a function of numerous processes, including nearshore hydrodynamics, thermal and mechanical behaviour of frozen and unfrozen soil, atmospheric forcing, and the presence of sea ice. In particular, surface waves play an important role as they force circulation, which can lead to erosion. The interaction between surface waves and sea ice is quite complex. On the one hand, sea ice suppresses waves by scattering and dissipating wave energy, but on the other hand, the waves can break up the ice. Sea ice also determines the available fetch and duration for wave generation and evolution.

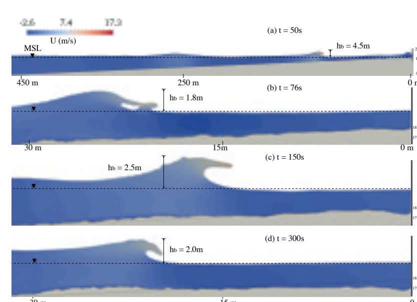
As development increases in northern regions, there is an increased need to understand and predict coastal erosion in those areas. This means, among other things, that we need to improve the existing wave models to take into account the effects of sea ice.

Hongtao Li started as a PhD candidate in September 2016. The main task for Li is to investigate the different physical processes associated with the interaction between waves and sea ice. Li's study will contribute to the theoretical development of waves-in-ice models, which will eventually improve our ability to predict coastal erosion in the Arctic. In addition to the theoretical work, Li's PhD study will put an emphasis on observations and field data collected using in-situ and remote sensing measurements. This is very important in order to understand the governing mechanisms and dominating physical processes, as well as to validate the theoretical models under development.

In October 2016, Li participated in experiments on waves-ice interactions conducted in the ice tank at Hamburg Ship Model Basin (HSVA) under the EU Hydralab+ programme. Li gained valuable lab experience and is currently working with the data, examining the portion of the wave energy that dissipated due to colliding floes.

NUMERICAL MODELLING OF SEDIMENT TRANSPORT - CFD MODEL REEF3D

PhD candidate Nadeem Ahmad is working on numerical modelling of sediment transport in the Arctic environment. Ahmad uses the open-source Computational Fluid Dynamics (CFD) code REEF3D for his research, based on three-dimensional (3D) Navier-Stokes equations. The level set method for the free surface along with the turbulence model is implemented in the code, which solves complex free surface flows such as wave breaking, standing waves and flow around hydraulic structures. In the sediment transport module of the code, the simulated hydrodynamics is coupled with the 3D morphological model to capture the erosion process. The model simulates the erosion and deposition, including the development of bed shear stresses, bed load and suspended load. In addition, the morphological calculations are based on sediment properties such as median sediment size, sediment density, sediment porosity and the Shields parameter. This makes the morphological model more robust and efficient when simulating the erosion process for different morphologies. Ahmad's contribution to WP6 is appreciable. Recently, a paper about the numerical modelling of the Bjørdalen-Isfjorden coastline in Svalbard, where significant coastal erosion was observed during a storm event in September 2015, was submitted to the ISOPE-2017 conference in San-Francisco, USA.

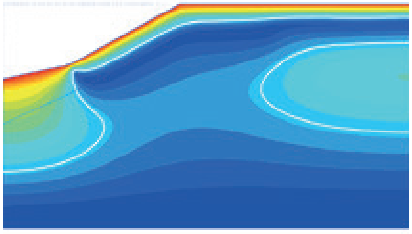


Numerical modelling of the Bjørndalen-Isfjorden coastline at Spitsbergen, where significant coastal erosion was observed during a storm event in September 2015. The observations showed that the coastlines with gentle slopes were severely affected due to the erosion.

ARCTIC COASTAL EROSION PROTECTION MEASURES

Ivan Depina, researcher at SINTEF Building and Infrastructure, focused on Arctic coastal erosion protection measures, thermal modelling of Arctic coasts and the wave-induced response of buried pipelines during 2016. A report on Arctic coastal erosion protection measures was prepared by Depina investigating the applicability of different erosion protection measures to Arctic conditions and highlighting Arctic-specific design challenges.

Thermal modelling of Arctic coasts is an important element in ensuring long-term stability of erosion protection measures. Depina's research on thermal modelling included the application of inverse modelling for the interpretation of soil thermal properties from field measurements, and the application of passive cooling systems for the preservation of permafrost. In addition to changing thermal conditions, the stability of erosion protection structures needs to be evaluated with respect to wave-induced response. As a part of these activities, the floatation potential of buried pipelines in different wave and soil conditions was examined with a model that can capture the wave-induced response of soil.



Thermal modelling of Arctic coasts: this figure illustrates the potential effects of a passive cooling system on the ground temperatures in a coastal slope. Passive cooling systems can provide prolonged periods of frozen ground, as illustrated by the blue colour below the coastal slope, thus reducing the risk of coastal slope failure and erosion.

CLIMATE-WARMING SCENARIOS IN COASTAL PERMAFROST ENGINEERING DESIGN

In 2016 Arne Instanes published a paper in the journal Cold Regions Science and Technology discussing how to incorporate climate-warming scenarios in coastal permafrost engineering design. He presented case studies from Svalbard and northwest Russia.

Instanes continues to develop his model, aiming to perform probabilistic analysis utilising the newly developed THM models and taking into account the most recent climate-warming scenarios.

The results of this study will be summarised and presented in a journal paper that is expected to be submitted before the summer of 2017.

COASTAL TECHNOLOGY GUIDELINES

Anatoly Sinitsyn, researcher at SINTEF Building and Infrastructure, continues his work on the guidelines for the design of environmentally friendly and sustainable coastal structures and technology. Within the Guidelines report, Sinitsyn worked on the chapter "Introduction and Generalities" and suggested an outline for three further chapters namely, "Prospective Stage", "Design Stage" and "Monitoring Stage".

During 2016 Sinitsyn participated in three key conferences of great relevance to the topics of permafrost and coastal dynamics in Postdam, St. Petersburg, and Oxford. Further developments and discussions resulting from attending these conferences have been used to develop the Guidelines report. Furthermore, Sinitsyn in collaboration with former postdoc Emilie Guegan, contributed to the organisation of a side meeting on "Coastal Permafrost in Transition (CPiT)" during the 11th International Conference on Permafrost (ICOP2016) in Potsdam, Germany. This side meeting gathered world-leading experts in the field of Arctic coastal dynamics and included sessions on coastal monitoring, modelling, database development and key sites for the study of Arctic coastal dynamics.

In addition, Sinitsyn continued to collect field data from the Vestpynten test site and, together with Magne Wold, examined the consequences of a severe storm in November 2016 on the Vestpynten site. This storm significantly eroded part of the coastal section next to a SAMCoT Coastal Erosion field site. However, the shoreline at the SAMCoT site was largely unaffected by the storm due to a snowbank. This shows how sediment transport is affected by the local coast characteristics, in this case the existence of a snowbank within one of the sites.

SAMCoT researchers will use the conclusions drawn from these observations to define key elements in the design of shore protection structures.

Vestpynten site after a severe storm in November 2016.

FIELDWORK AT BAYDARATSKAYA BAY

With support from SAMCoT/WP6, Moscow State University (MSU) performed extensive fieldwork at Baydaratskaya Bay in September 2016. The test site is situated on the west coast of the Baydara Gulf of the Kara Sea.

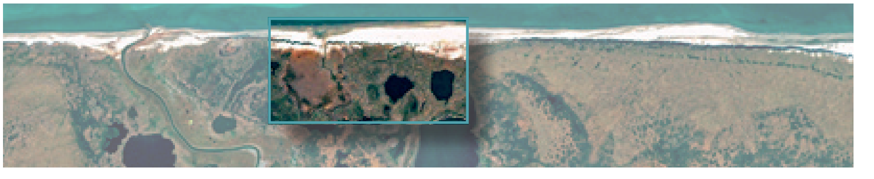
The fieldwork was conducted in order to:

1) Study the processes and mechanisms behind coastline retreat
2) Investigate the properties of permafrost in the area of interest
3) Examine the interaction between permafrost and existing engineering structures (e.g. cofferdam, pipelines)
4) Prepare for in-situ validation of some elements of MSU's thermal abrasion modelling

This year's survey is the fifth fieldwork campaign in the area. MSU researchers visited Baydaratskaya Bay site for the first time in 2012, just at the start of the SAMCoT Coastal Technology activities.

Over the years valuable full-scale data have been gathered and made available to SAMCoT researchers. These include mapping, measuring coastline retreat rate and observing the underlying physical processes, time-lapse photography of slope degradation processes, continuous temperature measurements of the soil at two typical coastal sites, etc. The compiled Baydaratskaya Bay site data are currently being used by Depina to define a case study for Arctic coastal erosion protection measures. In addition, Mohammad Saud Afzal, a new SAMCoT postdoc from 1st January 2017, will use the data. Saud aims to develop an integrated system model and a roadmap to assess coastal erosion in the Arctic.

Low coast of Baydaratskaya Bay with ice-wedge. An MSU student participating in the expedition is sampling the frost grounds for further laboratory research.



Using remote sensing data MSU researchers have tracked the retreat of the coastline in Baydara in different occasions from June 2013 to September 2016. The observed coastal cliff is shown amplified.

EXPERIMENTAL WORK ON SEDIMENT TRANSPORT IN PERMAFROST AREA

Currently there is no widely accepted approach for the quantitative assessment of soil erosion resistance and potential erosion rates for clay-rich or "cohesive" soils. Permafrost soils are considered cohesive due to both the high amount of fines and the presence of ice adding cohesion. In order to improve our knowledge of sediment transport in permafrost areas, a study on the variation of the critical shear stress versus temperature is needed. This part of the investigations will be carried out by Julie Malenfant-Lepage, PhD candidate at Laval University in Canada, who started collaborating with SAMCoT in September 2016.

Malefant-Lepage will develop laboratory and field test procedures using the cohesive strength meter to determine the critical shear stress of thawing sediments. In particular, she intends to develop a method to assess the maximum quantity of water that can be concentrated in one channel in order to control the heat transfer to permafrost as well as the erosion of soils. The use of the erosion meter system will be an important asset for Malefant-Lepage's PhD.

Malefant-Lepage will work in close collaboration with Bonoit Loranger, a PhD candidate financed by the Norwegian Research Council through the project "Frost Protection of Roads and Railways (FROST)". FROST started in 2015 and is designed to tie together knowledge from cold regions engineering, thermodynamics, geology and mineralogy. It involves researchers from both Norway and Canada. Loranger's research focuses on frost heave and on the frost susceptibility characteristics of frozen soils and crushed rock materials used in road construction. Elena Kuznetsova, a researcher at NTNU and project manager on the FROST project, will supervise the work of both candidates. Kuznetsova and the PhD candidates will work on finding a connection linking Loranger's research on the segregation potential of soils, which has numerous applications in the design of cold region constructions, and Malefant-Lepage's results on soil sensitivity to erosion. The results obtained from the connection between both topics will eventually be applied as an input to erosion/sedimentation models developed by SAMCoT's Coastal Technology team.

NOTABLE NUMBERS

Marnix van den Berg

1 x | 2 x | 9 000 x | 9 000 x | 10 x | 10 x

Julie Malenfant-Lepage

32 x | 20 x | 1,3 mil. x | 3 x | 500 000 x

Nadeem Ahmad

247 128 x | 500 x | 500 x | 100 000 x | 10 000 x

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Clarkson
Granular mechanics and sea ice dynamics

JOHN DEMPSEY
Clarkson
Effects of scale on the strength and fracture properties of structural materials

AKIHISA KONNO
Kogakuin
Fluid Engineering

ARTTU POLOJÄRVI
Aalto
Discrete element modelling of ice rubble

XIAODONG CHEN
DUT
Ice consolidation

KSRC - Krylov State Research Centre, Russia

TSED - Thayer School of Engineering at Dartmouth, USA

UCL - University College London, UK

MSU - Moscow State University, Russia

P.P. Shirshov Institute of Oceanology, Russia

DUT - Dalian University of Technology, China

NTNU - Norwegian University of Science and Technology, Norway

Aalto - Aalto University, School of Engineering, Finland

UNIS - University Centre in Svalbard, Norway

Clarkson - Clarkson University, USA

TU Delft - Delft University of Technology, The Netherlands

Kogakuin - Kogakuin University, Tokyo, Japan

PHD CANDIDATES

JULIE MALENFANT-LEPAGE
The critical shear stress of frozen soils

CHRIS KEIJDENER
Stationary dynamic regimes of ice-floater interaction

HAYO HENDRIKSE
Ice-induced vibrations – numerical modelling

MARNIX VAN DEN BERG
NDEM of ice-structure interaction

ÅSE ERVIK
Ice ridge actions, modelling of consolidated ice

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

MARTIN HASSEL
Risk and Safety of Marine Operations under Arctic Conditions

MARTIN STORHEIM
Structural Resistance of Ships and Off-shore Structures to Extreme Ice Loads

PETTER NORGREN
Autonomous Underwater Vehicles for operations under ice

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

ANNA PUSTOGVAR
Const. models for ice rubble, experimental

DARIA ALEKSUTINA
Composition, structure and properties of sediment cores and frozen soil

RENAT YULMETOV
Observations and Numerical Simulation of Iceberg Free Drift and Towing In Broken Ice

SERGEY KULYAKHTIN
Constitutive modelling of ice rubble, FEM

EVGENII SALGANIK
Thermodynamics and consolidation of ice ridges for different scales

TAYA SINITSYNA
Ice field heterogeneity and ice loads

FARZAD FARIDAFSHIN
Alternative methods for quantifying safety

MEHDI KADIVAR
THM Engineering model (Elastic-Plastic-Creep)

HONGTAO LI
Wave energy dissipation due to ice floes collisions

DAVID WRANGBORG
Ice-water actions on coastal structures

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

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

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

YARED BEKELE
THM coupled finite element modelling of frozen soil

JANNE RANTA
Ice rubble pile-up, statistical analysis of DEM simulations

POSTDOCTORAL RESEARCHERS

ALEKSEY SHESTOV
Ice ridges properties

EKATERINA KIM
Integrated Finite Element method in Ice – Structure

TORODD NORD
Ice-induced vibrations – analysis of measurements

ØIVIND K. KJERSTAD
Arctic Marine Cybernetics

MOHAMMAD SAUD AFZAL
Numerical Modelling of Coastal Waves in the Arctic

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

EMILIE GUEGAN
Coastal Technology

WENJUN LU
Numerical modelling of ice-structure interaction

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

MSC STUDENTS

JON BJØRNØ
Thruster-assisted position mooring of C/S Inocean Cat I Drillship

BENEDICTE T. BORGERSEN
Numerical Modelling of Arctic Coastal Hydrodynamics and Sediment Transport

PREBEN FREDERICH
Constrained Optimal Thrust Allocation for C/S Inocean Cat I Drillship

HUBERT KONKOL
Expansion of the port in Ustka. Simulation of wave conditions

WIKTOR M. WICKLAND
Expansion of the port in Ustka. Simulation of wave conditions

ANDRII O. MURDZA
Investigation of Sea Ice Strength properties: meso-scale tests and numerical modelling

ILIJA SAMARDZIJA
Model Scale Test of Towing Operations in Managed Sea Ice

JOB KRAMERS
Global ice ridge ramming loads based on full scale data and specific energy approach

DISSEMINATION

SAMCoT's Scientific Advisory Committee (SAC), comprising leading international academics under the leadership of Professor Erland M. Schulson, provides the Centre with the necessary quality assurance to support high scientific research. SAMCoT International Research Partners: Aalto University, School of Engineering; Delft University of Technology (TUDelft); Hamburg Ship Model Basin (HSVA); Moscow State University (MSU); Norwegian University of Science and Technology (NTNU); Technical Research Centre of Finland (VTT); Technical University of Denmark (DTU); University College London (UCL) and the University Centre in Svalbard (UNIS) greatly contribute to the Centre scientific dissemination goals.

DARIA ALEKSYUTINA

Daria Aleksyutina finished writing her doctoral thesis 'Regularities in destruction of shores composed of fine-grained rocks depending on their composition, structure and properties - East coast of Baydaratskaya Bay' in 2016. The highlight for her was the successful public defence of her thesis discussing the characterizationof permafrost at MSU on December 2.

YARED BEKELE

Yared Worku Bekele submitted his thesis 'Isogeometric Analysis of Coupled Problems in Porous Media - Simulation of Ground Freezing' in 2016 and defended it successfully in May 19 at NTNU.
Bekele's contribution to SAMCoT's research continued throughout the year as a research fellow within Coastal Technology.

MARTIN STORHEIM

On 19 January 2016 Martin Storheim successfully defended his PhD thesis 'Structural Response in Ship-Platform and Ship-Ice Collisions'. A series of experiments led by Storheim to simulate what happens when a ship slams into an iceberg were featured by Discovery Channel's Daily Planet Canada.

ØIVIND K. KJERSTAD

Øivind Kjerstad's broad field experience in the Arctic is fundamental to the results achieved during his PhD and current Postdoc position at SAMCoT (UNIS/NTNU). He defended his thesis on 'Dynamic Positioning of Marine Vessels in Ice' at NTNU on May 31, 2016. Kjerstad has participated in 6 different Research Cruises.

PhD Defences (4)

Aleksyutina, D.
Regularities in destruction of shores composed of fine-grained rocks depending on their composition, structure and properties (based on the east coast of Baydaratskaya Bay). Specialisation 25.00.08 - Engineering geology, frozen grounds and geological-mineralogical sciences, Moscow – 2016. MSU Doctoral Theses

Bekele, Y. - Isogeometric Analysis of Coupled Problems in Porous Media Simulation of Ground Freezing. NTNU Doctoral Theses 2016:140

Kjerstad, Ø. K.- Dynamic Positioning of Marine Vessels in Ice. NTNU Doctoral Theses 2016:168

Storheim, M. - Structural Response in Ship-Platform and Ship-Ice Collisions. NTNU Doctoral Theses 2016:14

Published International Refereed Journal Papers (26)

Aleksyutina, D. and Motenko, R.- The Effect of Soil Salinity and the Organic Matter Content on the Thermal Properties and Unfrozen Water Content of Frozen Soils at the West Coast of Baydarata Bay. Vestnik Moskovskogo Universiteta

Amiri, A.G., Grimstad, G., Kadivar, M., Nordal, S. - Constitutive model for rate-independent behavior of saturated frozen soils. European Journal of Environmental and Civil Engineering

Amiri, A.G., Grimstad, G. and Jørgensen, and Kadivar, M. - U. An elastic-viscoplastic model for saturated frozen soils. European Journal of Environmental and Civil Engineering

Depina, I., Le, T.M.H., Fenton, G. and Eiksund, G. - Reliability analysis with Metamodel Line Sampling. Journal Structural Safety

Guegan, E. and Christiansen, H.H. - Seasonal Arctic Coastal Bluff Dynamics in Adventfjorden, Svalbard. Journal Permafrost and Periglacial Processes (PPP)

Guegan, E., Sinitsyn, A. Kokin, O. and Ogorodov, S. - Coastal Geomorphology and Ground Thermal Regime of the Varandey Area, Northern Russia. Journal of Coastal Research

Hassel, M., Utne, I.B. and Vinnem, J.E.- Allision Risk Analysis of Offshore Petroleum Installations on the Norwegian Continental Shelf – An Empirical Study of Vessel Traffic Patterns. WMU J Marit Affairs.

Hendrikse, H. and Metrikine, A. - Edge indentation of ice with a displacement-controlled oscillating cylindrical structure. Journal of Cold Regions Science and Technology

Hendrikse, H. and Metrikine, A. - Ice-induced vibrations and ice buckling. Journal of Cold Regions Science and Technology

Instanes, A. - Incorporating climate warming scenarios in coastal permafrost engineering design-Case studies from Svalbard and northwest Russia. Journal of Cold Regions Science and Technology

Kim, E., Storheim, M. Amdahl, J. and Løset, S., von Bock und Polach, R.U.F. - Laboratory experiments on shared-energy collisions between freshwater ice blocks and a floating steel structure. Journal Ships and Offshore Structures

Kim, E. and Amdahl, J. - Discussion of assumptions behind rule-based ice loads due to crushing. Journal Ocean Engineering

Kjerstad, Ø.K. and Skjetne, R. Disturbance rejection by acceleration feedforward for marine surface vessels. Journal IEEE Access

Lu, W., Lubbad, R., Løset, S. and Kashafutdinov, M. - Fracture of an ice floe: Local out-of-plane flexural failures versus global in-plane splitting failure. Journal of Cold Regions Science and Technology

Marchenko, A., Lishman, B., Wrangborg, D. and Thiel, T. - Thermal Expansion Measurements in Fresh and Saline Ice Using Fiber Optic Strain Gauges and Multipoint Temperature Sensors Based on Bragg Gratings. Journal of Sensors

Marchenko, A. and Morozov,E. - Surface manifestations of the waves in the ocean covered with ice. Russian Journal of Earth Sciences

Nord, T., Øiseth, O. and Lourens, E-M. - Ice force identification on the Nordströmsgrund lighthouse. Journal Computers & Structures

Nuijten, A. D.W. and Høyland, K.V. - Comparison of melting processes of dry uncompressed and compressed snow on heated pavements. Journal of Cold Regions Science and Technology

Pustogvar, A. and Kulyakhtin,A. - Sea ice density measurements. Methods and uncertainties. Journal of Cold Regions Science and Technology

Ranta, J., Polojärvi, A. and Tuhkuri, J. - The statistical analysis of peak ice loads in a simulated ice-structure interaction process. Journal of Cold Regions Science and Technology

Shestov, A. and Marchenko, A. - Thermodynamic consolidation of ice ridge keels in water at varying freezing points. Journal of Cold Regions Science and Technology

Shestov, A. and Marchenko, A. - The consolidation of saline ice blocks in water of varying freezing points: Laboratory experiments and computer simulations. Journal of Cold Regions Science and Technology

Song, M., Kim, E., Amdahl, J., Ma, J. and Huang, Y.
A comparative analysis of the fluid-structure interaction method and the constant added mass method for ice-structure collisions. Journal of Marine Structures

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

Yulmetov, R., Marchenko, A. and Løset, S. - Iceberg and sea ice drift tracking and analysis off northeast Greenland. Journal Ocean Engineering

Yulmetov, R., Lubbad, R. and Løset, S. - Planar multi-body model of iceberg free drift and towing in broken ice. Journal of Cold Regions Science and Technology

Published International Conference Papers (43)

Ahmad, N., Bihs, H., Kamath, A. and Arntsen, Ø.A. - 3D Numerical modelling of pile scour with free surface profile under waves and current using the level set method in model REEF3D. Proceedings - International Conference on Scour and Erosion

Berg, vd M. - A 3-D Random Lattice Model of Sea Ice. C - Arctic Technology (ATC)

Bjerkås, M. and Nord, T. - Ice action on Swedish lighthouses revisited. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Blæsterdalen, B., Wrangborg, D., Marchenko, A. and Høyland, K.V. - Geometry and Thermo-Mechanical Properties of Coastal Ice in a Micro-Tidal Climate in Svalbard, Part I, Permeability and Geometry. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Chen, X. and Høyland, K.V. - Laboratory Work on Heat Transfer in Submerged Ice, Theory, Experimental Setup and Results. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Chistyakov, P., Karulin, E., Marchenko, A., Sakharov, A. and Lishman, B. - The tensile strength of saline and freshwater ice in field tests. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Ervik, Å. and Shestov, A. - Studies of Drifting Ice Ridges in the Arctic Ocean during May-June 2015 Part I. An overview of measurements Åse Ervik. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Ervik, Å. and Shestov, A. - Studies of Drifting Ice Ridges in the Arctic Ocean during May-June 2015 Part III. Evolution in morphology. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Hansen, E., Borge, J. and Høyland, K.V. - Effects of the observational footprint on the ice thickness distribution. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Heinonen, J.- CEL-Analysis of Punch Shear Tests to Evaluate Mechanical Properties of Ice Rubble. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Heyn, H-M. and Skjetne, R. - A system for measuring ice-induced accelerations and identifying ice actions on the CCGS Amundsen and a Swedish Atle-class icebreaker. C - International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Karulina, M., Marchenko, A., Sakharov, A., Karulin, E. and Chistyakov, P. - Experimental Studies of Fracture Mechanics for Various Ice Types. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Kim, E. - A Preliminary Analysis of the Crushing Specific Energy of Iceberg Ice under Rapid Compressive Loading. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Kim, E., Song, M. and Amdahl, J. - On ice model validation and calibration strategies for damage assessment of structures subjected to impact actions. C - International Conference on Collision and Grounding of Ships and Offshore Structures (ICCGS)

Kjerstad, Ø.K., Værnø, S.A.T. and Skjetne, R. - A Robust Dynamic Positioning Tracking Control Law Mitigating Integral Windup. C - IFAC Conf. Control Applications in Marine Systems (CAMS)

Kolari, K. - Strain-Rate Softening of Granular Ice in Brittle Regime: Fact or Artifact? C - International Association for Hydro-Environment Engineering and Research (IAHR)

Konstantinova, M., Marchenko, A., Karulina, M. Sakharov, A., Karulin, E. and Chistyakov, P. - In-situ investigations of ice deformations and loads in indentation tests. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Kulyakhtin, S. and Polojärvi, A. Ice Rubble Stress in Virtual Experiments for Assessing Continuum Approach. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Le, T.M.H., Gallipoli, D., Sanchez, M. and Wheeler, S.- Characteristics of failure mass and safety factor during rainfall of an unsaturated slope. C - European Conference on Unsaturated Soils (EUCUS)

Le, T.M.H., Bæverfjord, M.G. and Wold, M. - Challenges with sampling coarse-grained permafrost: an experience in Svalbard.C - ISC5

Li, H., Bjerkås, M., Høyland, K.V. and Nord, T. - Panel loads and weather conditions at Norströmsgrund lighthouse 2000-2003. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Lindbjør-Nilsen, H. and Høyland, K.V. - FEM-CEL simulations of full scale and model scale punch tests on ice rubble with the Modified Cam clay model. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Lu, W., Lubbad, R., Løset, S. and Skjetne, R. - Parallel Channel Tests during Ice Management Operations in the Arctic C - Arctic Technology (ATC)

Lu, W., Lubbad, R., Løset, S. and Skjetne, R. - Parallel Channel Tests during Ice Management Operations in the Arctic Ocean. C - Arctic Technology (ATC)

Lu, W., Zhang, Q., Lubbad, R., Løset, S. and Skjetne, R.- A Shipborne Measurement System to Acquire Sea Ice Thickness and Concentration at Engineering Scale. C - Arctic Technology (ATC)

Lubbad, R., Løset, S., Hedman, U., Holub, C. and Matskevitch, D. Oden Arctic Technology Research Cruise 2015. C - Arctic Technology (ATC)

Ludvigsen, M.et al. - Network of heterogeneous autonomous vehicles for marine research and management. OCEANS 2016 MTS/IEEE Monterey.

Marchenko, A., Murdza, A. and Lishman, B. - The influence of ice structure on thermo-elastic waves in saline ice. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Physical mechanisms limiting sizes of pressure ice ridges and model of ice rubble formation. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A., Diansky, N., Fomin, Y.V., Marchenko, N. and Ksenofontova, D. - Consolidation of Drifting Ice Rubble in the North-West Barents Sea. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko A.V., Diansky N.A., Onishchenko D.A., Chumakov M.M., Nikitin M.A., Fomin V.V. and Marchenko N.A. - Studies of ice drift and ridge consolidated layer evolution in the North-West Barents Sea. C - Proceedings of the Hydrometcentre of Russia

Marchenko, N. - Comparison of Sea Ice Products and data of drifting buoys. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Murdza, A., Marchenko, A., Sakharov, A., Chistyakov, P., Karulin, E. and Karulin, M. - Test with L-shaped cantilever beam for complex shear and bending strength. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Pearson, S., Lubbad, R. and Le, T.M.H. - Thermomechanical Erosion Modelling of Baydaratskaya Bay, Russia with COSMOS. C - ICSE

Petersen, Ø.W., Øiseth, O., Nord, T. and Lourens, E-M. - Response estimation for a floating bridge using acceleration output only. C - ISMA

Polojärvi, A., Tuhkuri, J., Häsä, R. and Schneider, S. - 2D FEM-DEM Study on Ice Loads on Shallow Water Structure. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Ranta, J., Polojärvi, A. and Tuhkuri, J. - A simulation based statistical study on evolution of ice-structure interaction process. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Shestov, A. and Ervik, Å. - Studies of Drifting Ice Ridges in the Arctic Ocean during May-June 2015. Part II. Thermodynamic properties and melting rate. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Sinitsyn, A., Sinitsyna, T. and Hendrikse, H. - Ice Station for Ramming Test on OATRC 2013. C -International Association for Hydro-Environment Engineering and Research (IAHR)

Skarbø, R., Yulmetov, R. and Løset, S. - Modelling iceberg drift in pack ice off North-East Greenland. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Song, M., Kim, E., Amdahl, J., Greco, M. and Souli, M. - Numerical Investigation of Fluid-Ice-Structure Interaction during Collision by an Arbitrary Lagrangian Eulerian Method. C - International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Tsarau, A. - Hydrodynamic forces on ice floes in the propeller wash of a ship – full-scale experimental study. C - International Association for Hydro-Environment Engineering and Research (IAHR)

Wrangborg, D., Vindegg, C.M., Marchenko, A., Blæsterdalen, B. and Høyland, K.V. - Geometry and thermo-mechanical properties of coastal ice in a micro-tidal climate in Svalbard, Part II, in-situ stresses. C - International Association for Hydro-Environment Engineering and Research (IAHR)

MSc Theses (6)

Bjørnø, J. - Thruster-assisted position mooring of C/S Inocean Cat I Drillship. NTNU MSc Theses

Borgersen, B.T. - Numerical Modelling of Arctic Coastal Hydrodynamics and Sediment Transport. NTNU MSc Theses

Frederich, P. - Constrained Optimal Thrust Allocation for C/S Inocean Cat I Drillship. NTNU MSc Theses

Kramers, J. - Global ice ridge ramming loads based on full scale data and specific energy approach. TU Delft MSc Theses

Murdza A. O. - Investigation of Sea Ice Strength properties: meso-scale tests and numerical modelling. Moscow Institute of Physics and Technology (State University)

Samardzija, I. - Model Scale Test of Towing Operations in Managed Sea Ice. NTNU MSc Theses

Key Notes and Oral Presentations (117)

Ahmad, N. - Numerical Modelling of sediment transport in the coastal environment using REEF3D. SAMCoT Scientific Seminar

Ahmad, N. - Numerical Modelling of Arctic Coastal Erosion using REEF3D. Workshops Other

Amiri, A.G. - Constitutive Modelling of Frozen Soil. SAMCoT Scientific Seminar & Workshops Other (2)

Amiri, A.G.- THM Boundary Value Problems in PLAXIS. Workshops Other

Andersson, L.E. - Iceberg Drift Forecast based on Estimation - Current and iceberg estimates for use in iceberg forecast. SAMCoT Scientific Seminar

Bekele, Y. - Computational Methods for Debonding between Soil and Structural Components. Trial Lecture, Thesis for the degree of Philosophia Doctor

Bekele, Y. - Isogeometric Analysis of Coupled Problems in Porous Media Simulation of Ground Freezing. Presentation, Thesis for the degree of Philosophia Doctor

Berg, vd M. - Contact force modelling in the Non-smooth discrete element framework. SAMCoT Scientific Seminar

Berg, vd M. - NDEM with non-rigid contacts, fracture and ridges. Workshops Other

Bridges, R. - Challenges of Ice Management. Workshops Other

Cauquil, E. - Guideline for arctic coastal erosion management. Workshops Other

Chen, X. and Høyland, K.V. - Laboratory Work on Heat Transfer in Submerged Ice, Theory, Experimental Setup and Results Effect of ice salinity. International Association for Hydro-Environment Engineering and Research (IAHR)

Chistyakov, P., Karulin, E., Marchenko, A., Sakharov, A. and Lishman, B.- The tensile strength of saline and freshwater ice in field tests. International Association for Hydro-Environment Engineering and Research (IAHR)

Depina, I. - Arctic Coastal Erosion Protection Measures. Workshops Other

Depina, I. - Interpretation of thermal properties of soil from temperature measurements and stabilization of Arctic coasts with thermosyphons. Workshops Other

Depina, I. - Wave-induced response of seabed. Workshops Other

Eik, K. J. - Redundancy and barrier management in ice management. Workshops Other

Eik, K. J. - Relevant locations for Arctic offshore studies. Workshops Other

Eik, K. J. - Modelling reliability of an Ice Management System. Workshops Other

Ervik, Å., Shestov, A. and Høyland, K.V. - Studies of drifting ice ridges in the Arctic Ocean during May-June 2016. International Association for Hydro-Environment Engineering and Research (IAHR)

Ervik, Å. - Simulating Continuous Failure of Consolidated Ice. SAMCoT Scientific Seminar

Farid Afshin, F. - Alternative Philosophies for Design -with a focus on design of Arctic Offshore Structures Protected by Ice Management. SAMCoT Scientific Seminar

Farid Afshin, F. - Risk Modeling in Relation to Ice Management. Workshops Other

Fenz, D. - EMURC - Aligning the Needs of Floating Drilling and the Capabilities of Ice Management. Workshops Other

Guegan, E. - Arctic Coastal Erosion – Protection. SAMCoT Scientific Seminar

Guegan, E. - What's next? Erodibility of cohesive sediment. Critical shear stress & erodibility coefficient. Workshops Other

Gutierrez-Gonzalez, M.A. - SAMCoT, PhD education aiming innovation. Workshops Other

Gutierrez-Gonzalez, M.A. - (CMG) SAMCoT Scientific Seminar Programme. SAMCoT Scientific Seminar

Gutierrez-Gonzalez, M.A - (CMG) SAMCoT Technical Workshop 2016. SAMCoT Technical Workshop

Hedman, U. and Rohlen, Å Arctic Marine Solutions. Establishing a common understanding of Ice Management. Workshops Other

Hedman, U. - Business case on comparison of an open water operation and an optimized Arctic ice operation. Workshops Other

Hedman, U. - Ice Management - the need for a quantification tool. Workshops Other

Hendrikse, H. - Ice Induce Vibrations. SAMCoT Scientific Seminar

Heyn, H-M. and Skjetne, R. - Identifying ice-actions with the help of spectral analysis. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Heyn, H-M. - Identifying ice-actions with the help of spectral analysis. SAMCoT Scientific Seminar

Heyn, H-M. - Measurement of ice induced accelerations on Icebreaker Oden. Workshops Other

Høyland, K.V. - WP2-Material modelling (2011-2016). SAMCoT Scientific Seminar

Høyland, K.V. - WP3-Fixed Structures. SAMCoT Scientific Seminar

Instanes, A. - Incorporating climate warming scenarios in coastal permafrost engineering design – Case studies from Svalbard and northwest Russia. Workshops Other

Instanes, A. - Incorporating climate warming scenarios in coastal permafrost engineering design. Workshops Other

Isaev, V. - Baydara engineer-geocryological fieldwork 2016. Workshops Other

Kadivar, M. - Frost susceptibility of Clay. SAMCoT Scientific Seminar

Keijdener, C. - (Simplified) modeling of hydrodynamics for ice-floater interaction. SAMCoT Scientific Seminar

Keijdener, C. - Modeling of hydro-dynamics for ice-floater interaction. Workshops Other

Kim, E. - On ice model validation... SAMCoT Scientific Seminar

Kim, E. - Local Ice loads overview and deliverables. Workshops Other

Kjerstad, Ø. K. - Dynamic Positioning of Marine Vessels in Ice. Presentation, Thesis for the degree of Philosophia Doctor

Kjerstad, Ø.K. - A Robust Dynamic Positioning Tracking Control Law Mitigating Integral Windup. IFAC Conf. Control Applications in Marine Systems (CAMS)

Kjerstad, Ø.K. - Estimation and prediction of local ice motion from a maneuvering vessel in drifting sea ice using radar. SAMCoT Scientific Seminar

Komarov, I. - Forecast of thermoabrasion of up-water part of coast (in the reference to the European (Asian) part of Baidaratskaia Bay). Workshops Other

Konstantinova, M., Marchenko, A., Karulina, M. Sakharov, A., Karulin, E. and Chistyakov, P. - In-situ investigations of ice deformations and loads in indentation tests. International Association for Hydro-Environment Engineering and Research (IAHR)

Konstantinova, M. - Ice failure

patterns in 3D interaction of solid indeter with ice. SAMCoT Scientific Seminar

Kulyakhtin, S. - Continuum modelling of unconsolidated Ice Rubble. SAMCoT Scientific Seminar

Lande, R.H. - An introduction to non-probabilistic methods for assessing reliability. SAMCoT Scientific Seminar

Leira, F.S. - Using UAVs for Ice Management Situation Awareness and Surveillance. SAMCoT Scientific Seminar

Lindbjør-Nilsen, H. and Høyland, K.V. FEM-CEL simulations of full scale and model scale punch tests on ice rubble with the Modified Cam Clay model. International Association for Hydro-Environment Engineering and Research (IAHR)

Lu, W., Lubbad, R., Løset, S. and Skjetne, R. - Parallel Channel Tests during Ice Management Operations in the Arctic Ocean. Arctic Technology (ATC)

Lu, W., Zhang, Q., Lubbad, R., Løset, S. and Skjetne, R. A Shipborne Measurement System to Acquire Sea Ice Thickness and Concentration at Engineering Scale. Arctic Technology (ATC)

Lu, W. - Large scale sea ice fracture tests. SAMCoT Scientific Seminar

Lu, W.Løset, S. - Floe-ice fracturing. Workshops Other

Lubbad, R. - WP6 – Coastal Technology. SAMCoT Scientific Seminar & Technical Workshop (2)

Lubbad, R. - Simulation-based assessment of planned IM operations. Workshops Other

Løset, S. - Sustainable Arctic Marine and Coastal Technology – SAMCoT. OeD Temadag, Framsenteret, Tromsø

Løset, S. - Overview WP4. SAMCoT Scientific Seminar

Løset, S. - WP4 - Floating Structures in Ice. SAMCoT Technical Workshop & Workshops Other (2)

Løset, S. - Sustainable Arctic Marine Technology – SAMCoT. Workshops Other

Løset, S. - Status Meeting Rectorat-SAMCoT. Workshops Other

Løset, S.- Impact by SAMCoT on Marine Operations in the Arctic. Japan-Norway Arctic Science and Innovation Week, Tokyo,

Løset, S. - Impact by SAMCoT on Marine Operations in the Arctic. Japan-Norway Arctic Science and Innovation Week, Follow-up,

Løset, S. - Experience with Clustering of Norwegian-Russian projects. Russian-Norwegian Workshop St. Petersburg

Løset, S. - Knowledge and Innovative Tools to Promote Safe, Environmentally Sound Operations in the Arctic. WOC Sustainable Ocean Summit, Rotterdam,

Løset, S. - SAMCoT Activities and Innovations. GoNorth Workshop, Trondheim

Marchenko, A. Marchenko, N. Fomin, Y.V. and Ksenofontova,D. - Consolidation of Drifting Ice Rubble in the North-West Barents Sea. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Physical mechanisms limiting sizes of pressure ice ridges and model of ice rubble formation. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Thermo-mechanical properties of saline ice. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Overview WP1. SAMCoT Scientific Seminar Marchenko, A. WP1 – Data collection and process modeling. SAMCoT Technical Workshop

Marchenko, N. - Comparison of sea ice product and data of drifting buoys. International Association for Hydro-Environment Engineering and Research (IAHR)

Marchenko, A. - Passive turn of turret moored vessel in drift ice. Wave-ice interaction in ice infested waters. International Conference on Arctic vision (ICAV) Busan, Korea

Moslet, P.O. - Using theoretical predictions of ice management efficiency for reducing design loads – are we there yet? SAMCoT Technical Workshop

Blæsterdalen, B., Wrangborg, D., Marchenko, A., Høyland, K.V. and Vindegg, C.M. - Geometry and Thermo-Mechanical Properties of Coastal Ice in a Micro-Tidal climate in Svalbard. International Association for Hydro-Environment Engineering and Research (IAHR)

Nord, T. - Panel loads and weather conditions at Nordstromsgrund lighthouse 2000-2003. SAMCoT Scientific Seminar

Norgren, P. - A preliminary study on a SLAM approach to iceberg and sea-ice mapping using AUV. SAMCoT Scientific Seminar

Olofsson, J. - Large Scale Ice Management through Sensor Fusion and Multi-target Tracking. SAMCoT Scientific Seminar

Onshus, T. - Some Safety Requirements to Ice Management. Workshops Other

Payo, A. - Modelling coastal morphological change at decadal and longer time scales: iCOAST approaches. Workshops Other

Polojärvi, A., Tuhkuri, J. - 2D FEM-DEM Study on Ice Loads on Shallow Water Structure. International Association for Hydro-Environment Engineering and Research (IAHR)

Ranta, J., Polojärvi, A. and Tuhkuri, J. - A simulation based statistical study on evolution of ice-structure interaction process. International Association for Hydro-Environment Engineering and Research (IAHR)

Ranta, J. - Statistics of Simulated Ice Loads. SAMCoT Scientific Seminar

Reed, I. - Arctic shipping, oil exploration and production offshore Sakhalin Island - What kind of vessels are required for operations? Workshops Other

Ruud, S. and Skjetne, R. - Agenda SAMCot WP5 Workshop on Redundancy and barrier management in ice management. Workshops Other

Ruud, S. and Skjetne, R. - Redundancy and barrier management in ice management. Workshops Other

Ruud, S. - Agenda for workshop 2 WP5.2, Workshops Other

Ruud, S. - Redundancy and barrier management in ice management. Workshops Other

Ruud, S. - Plans, CTR 2017 for 5.2.2 Barrier management. Workshops Other

Ruud, S. - Minutes of Meeting. Summary of actions from Workshop 2. Workshops Other

Salganik, E. - Ice ridges thermodynamics for different scales (Loads from scale-model ridges on fixed structures). SAMCoT Scientific Seminar

Shestov, A. - Thermodynamic processes in ice rubble. SAMCoT Scientific Seminar

Sinitsyn, A., Sinitsyna, T. and Hendrikse, H. - Ice Station for Ramming Test on OATRC 2013. International Association for Hydro-Environment Engineering and Research (IAHR)

Sinitsyn, A. - Guidelines development in WP6 – Status and Plans. SAMCoT Technical Workshop

Sinitsyn, A. and Guegan, E. - Field site "Vestpynten" – overview and some results. Workshops Other

Sinitsyn, A. - Guidelines development in WP6 Presentation of the progress since meeting on Feb 1st, 2016. Workshops Other

Sinitsyn, A. - Guidelines development in WP6. Workshops Other (2)

Skarbø, R., Yulmetov, R. and Løset, S. - Modelling iceberg drift in pack ice off North-East Greenland. International Association for Hydro-Environment Engineering and Research (IAHR)

Skarbø, R. - Ice drift prediction for Arctic marine operations using images from SAR and marine radar. SAMCoT Scientific Seminar

Skjetne, R. - WP5 - Ice Management and Design Philosophy. SAMCoT Technical Workshop

Skjetne, R. - WP5 Roadmap – Ice Management and Design Philosophy. Workshops Other

Stanilovskaya, Y. - Investigation on Permafrost-Related Issues at TOTAL. SAMCoT Scientific Seminar

Storheim, M. - Structural Response in Ship-Platform and Ship-Ice Collisions. Presentation, Thesis for the degree of Philosophia Doctor

Storheim, M. - Environmental considerations related to decommissioning ships and offshore structures. Trial Lecture, Thesis for the degree of Philosophia Doctor

Tsarau, A. - Hydrodynamic forces on ice floes in the propeller wash of a ship – full-scale experimental study. International Association for Hydro-Environment Engineering and Research (IAHR)

Tsarau, A. - Ice in waves. SAMCoT Scientific Seminar

Tsarau, A. - Floe ice Actions – Hydrodynamics. Workshops Other

Mass Media & Other Popular Media (36)

Bazilchuk, N. - Arktis er viktig for både Norge og Japan. GEMINI

Bazilchuk, N. - Der kysten faller i sjøen. GEMINI

Bazilchuk, N. Keeping Arctic villages, infrastructure from falling into the sea. GEMINI

Bazilchuk, N. - Japan-Norway Arctic Science and Innovation Week. GEMINI

Bazilchuk, N. - Three Arctic researchers at North Pole. GEMINI

Bazilchuk, N. - Arctic Safety Centre (Video). www.ntnu.edu/samcot

Bazilchuk, N. - Lazarus ice (Video). www.ntnu.edu/samcot

Bazilchuk, N. - Keeping Arctic villages, infrastructure from falling into the sea (Video). www.ntnu.edu/samcot

Bazilchuk, N. - A peek under Arctic ice (Video). www.ntnu.edu/samcot

Bazilchuk, N.; Gutierrez Glez, M.A. - Different posts related to SAMCoT on NTNU Social Media. www.ntnu.edu/samcot & SAMCoT e-room (15)

Fellmann, T. - Utenriksstudenten på Svalbard. Hallo P3-spalten Utenriksstudentene, NRKP3-11.10.16

Fellmann, T. - Runa er snart på Nordpolen. Hallo P3-spalten Utenriksstudentene, NRKP3-22.08.16

Furberg, K. - NTNU-stipendiater reiser til Nordpolen på forskningstokt. Universitetsavisa

Gutierrez Glez, M.A. & SAMCoT CMG. - SAMCoT Annual Report 2015. Fagtrykk Trondheim AS

Herrmann, V. - Coastal Erosion and Thawing Permafrost: A Dangerous Duo. High North News

Lunde Andersen, R. and Sørheim Bjørkås, T. - Reiser til Nordpolen for å forske på isen. NRK.no

Løset, S. and Lu, W. - Helikopter lander på isbryter i Arktis (Video). www.ntnu.edu/samcot

Rislå Andersen, S. - Drar til Nordpolen for å finne ut hvordan skip kan takle isen. Maritime.no

Rislå Andersen, S. - Runa (28) skal knekke iskoden. Bergens Tidende, tirsdag 02.08.16

Skarbø, R. - Follow me to the North Pole – Online Blogg. Blogg on Field Work

Skarbø, R. - Follow me to the North Pole Blog post. NTNU TechZone

Skarbø, R. - Morning radio interview. Radio Trondheim 04.08.2016

FIGURES 2016

In November 2016, SAMCoT's Centre Management Group (CMG) presented the Cost, Time and Resources (CTR) plans for 2017. SAMCoT's Board approved them. In December, the Research Council of Norway (RCN) approved SAMCoT's CTRs for 2016 and 2017. The tables below show, following the European Free Trade Association (EFTA) Surveillance Authority (ESA) reporting format, the funding and incurred costs for 2016 as reported by the Centre on January 20, 2017 to the RCN.

SFI Annual Work Plan 2016 - Costs (All figures in 1000 NOK)

Item	Host NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	Aker Solutions	Exxonmobile URC	ENGIE	AkerBP	Lundin	Kværner	Norwegian Coastal Admin	Swedish Polar Research Secretariat	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	Total cost
WP1			3 751	73	99	55	59	64	28		4	45	2		51									4 231
WP2	532			73	99	55	59	64	28		4	45	2		51									1 011
WP3 & IVOS	5 784			73	99	55	59	64	28		4	45	2		51				1 826	1 057	1 057	208	519	11 450
WP4	6 308			73	99	55	59	64	28		4	45	2		51		2 103							8 890
WP5	1 251			73	99	55	59	64	28		4	45	2		51		2 103							3 833
WP6	2 564	3 000		73	99	55	59	64	28		4	45	2		51									6 043
SFI Equipment	371																		293			26		690
SFI Administration	1 991	417	780																					3 188
Total budget	18 800	3 417	435	435	592	332			166	0	24	270	13	0	304	0	4 206	0	2 119	1 057	1 057	234	519	39 336

SFI Annual Work Plan 2016 - Funding (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	Swedish Polar Research Secretariat	UCL	HSVA	TUDelft	Aalto University	MSU	VTT	RCN Grant	Total funding
WP1			390	245	271	228	232	164	78	83	176	217	174	172	134									1 105	3 670
WP2	82			245	271	228	232	164	78	83	176	217	174	172	134									1 105	3 361
WP3 & IVOS	3 558			245	271	228	232	164	78	83	176	217	174	172	134				845	1 057	1 366	123	432	1 105	10 661
WP4	3 054			245	271	228	232	164	78	83	176	217	174	172	134		2 103							1 105	8 437
WP5	188			245	271	228	232	164	78	83	176	217	174	172	134		2 103							1 105	5 571
WP6	368	200		245	271	228	232	164	78	83	176	217	174	172	134	330								1 105	4 178
SFI Equipment																			293			26			319
SFI Administration	1427	217	390																					1 105	3 139
Total budget	8 678	417	780	1 470	1 626	1 366	1 390	984	466	500	1 058	1304	1 047	1 034	804	330	4 206	0	1 138	1 057	1 3667	149	432	7 734	39 336


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