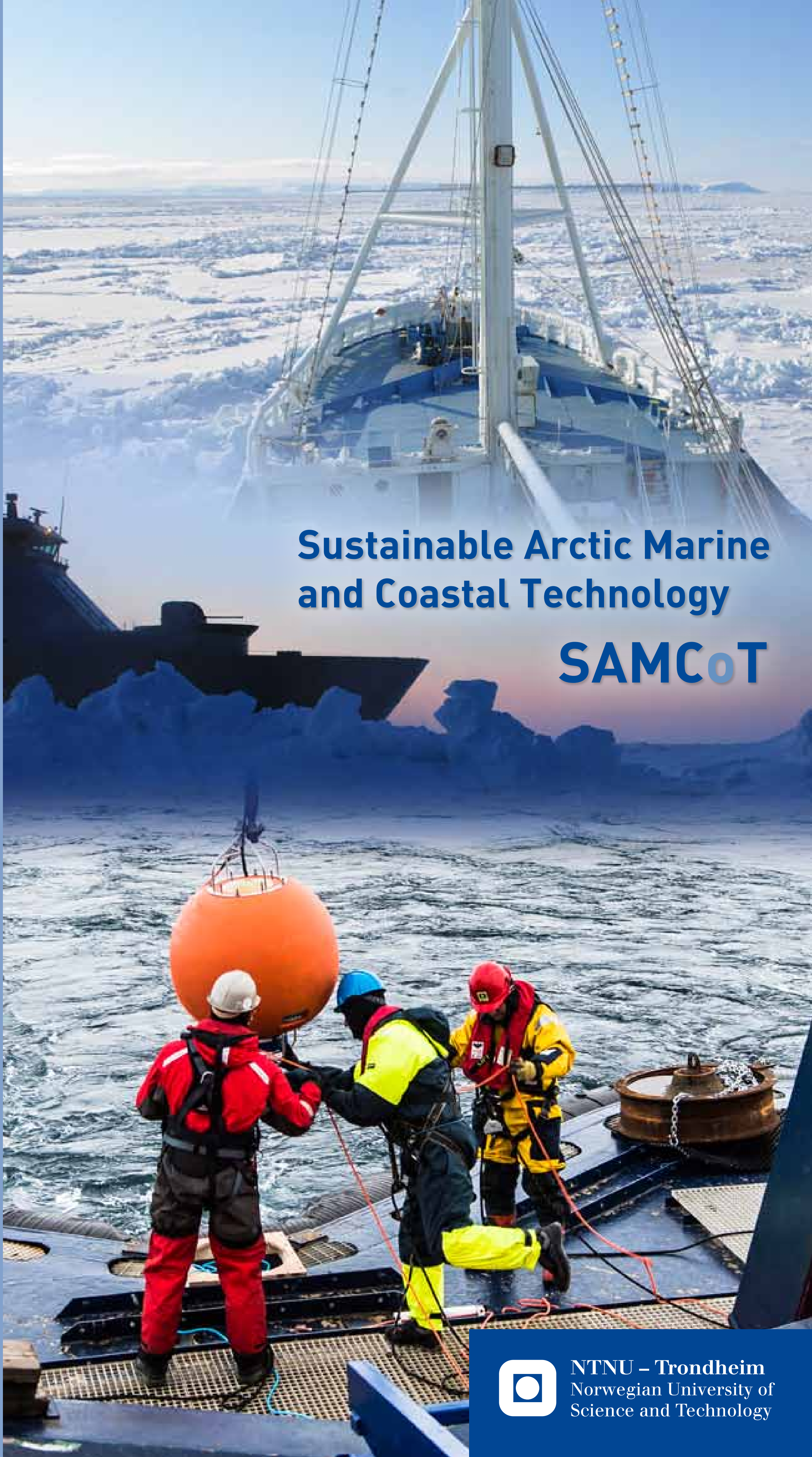
Annual Report 2012



Sustainable Arctic Marine and Coastal Technology

SAMCoT

Centre for Research-based Innovation

NTNU – Trondheim
Norwegian University of Science and Technology

Vision:

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

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

SAMCoT KEY FIGURES	2012	2011	Accum. Fig.
Turnover (in 1000NOK)	45 770	13 859	59 629
Industry Partners	10	8	10
Research Partners	8	8	8
Public Partners	1	1	1
PhD Candidates	19 (5 female)	10 (2 female)	19 (5 female)
Post Docs	1	0	1
PhD Defences	1	0	1
Published Journal Papers	7	7	14
Published Conference Papers	18	15	33
MSc Thesis	8	2	10

SAMCoT ACTIVITIES IN 2012:

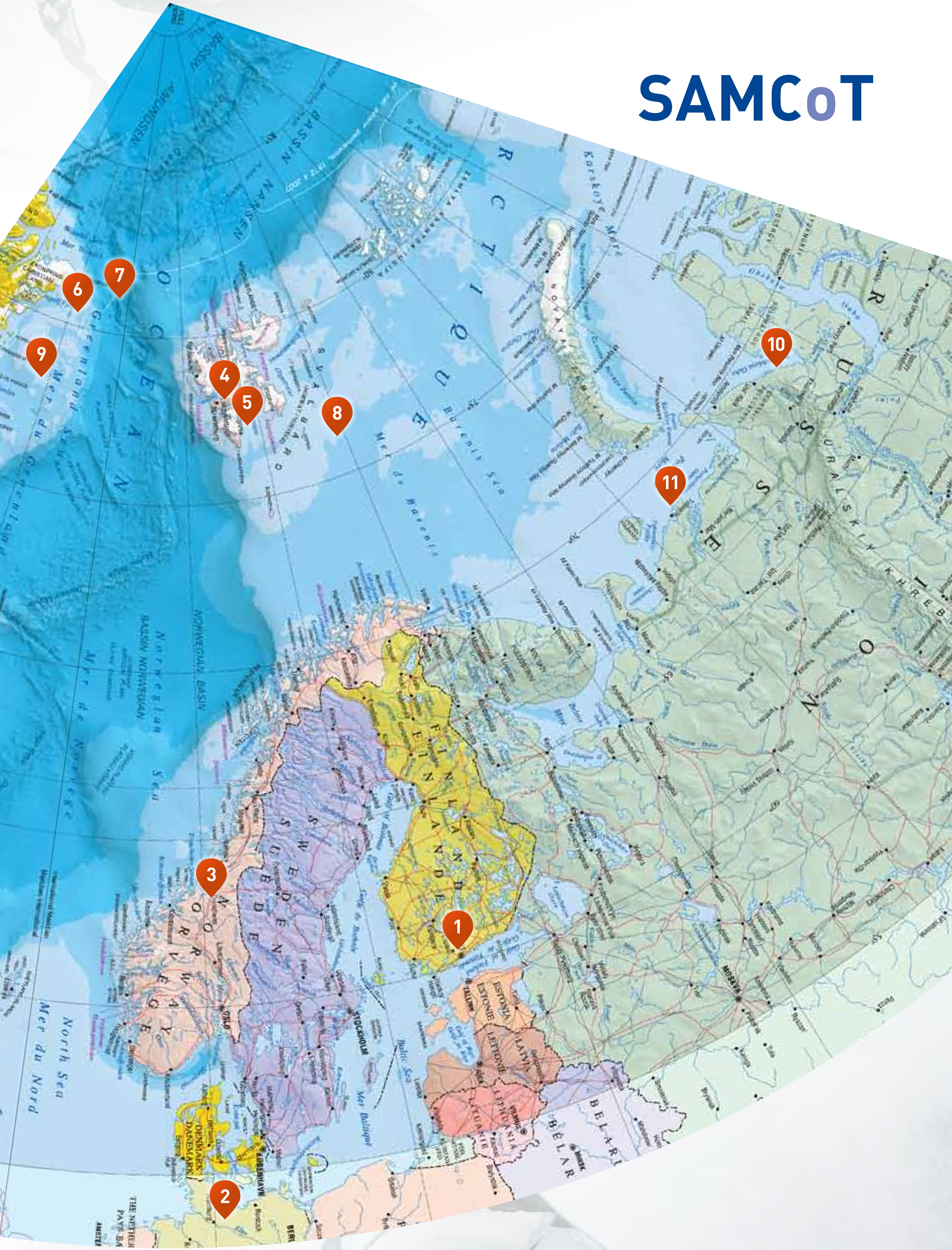
LAB ACTIVITIES:

1. Aalto University – Helsinki.
2. HSVA – Hamburg.
3. NTNU – Trondheim.
4. UNIS – Svalbard.

FIELD ACTIVITIES:

5. Research site Vestpynten, and site studies in the fjords of Spitsbergen, Svalbard.
6. Research cruise with KV Svalbard (Fram Strait).
7. Research cruise with RV Lance (Fram Strait).
8. Research cruise with RV Lance (Western Barents Sea).
9. Research cruise with the icebreaker Oden (North-East Greenland).
10. Research Site Baydara, Russia.
11. Research Site Varandey, Russia.

SAMCoT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NORWAY
SWEDEN
FINLAND
North Sea
Mer du Nord
Norwegian Sea
Barents Sea
ESTONIA
LATVIA
LITHUANIA
STOCKHOLM
MOSKVA

SAMCoT's 1st International PhD Workshop

Every year SAMCoT hosts two international workshops: one related to the different Research Groups and their yearly activities and long term research strategy, and a more specific one that focuses on the individual research topic of each and every SAMCoT PhD candidate.

Photo: Ole Morten Melgård

Objectives

- To provide the research based knowledge necessary in order for the industry to develop Arctic technology for the energy sector in particular and for society as a whole.
- To specifically address the implications of the presence of ice and permafrost, as well as to produce knowledge that will ensure sustainable exploration, safe exploitation and transport from and within the vulnerable Arctic region.
- To provide the foundation for further development of environmentally adapted coastal infrastructure.

SAMCoT Decision and Advisory Bodies

- The General Assembly (GA)
- The Board
- The Centre Management Group (CMG)
- The Scientific Advisory Committee (SAC)
- The Exploitation and Innovation Advisory Committee (EIAC)

SAMCoT PARTNERS 2012 AND REPRESENTATIVES TO THE GENERAL ASSEMBLY:

SAMCoT – The Year 2012 in Review

Dear Researchers, Professors and Partners:
The research at SAMCoT focuses predominantly on advancing understanding and theoretical descriptions of physical processes that occur in extreme environments, where man-made structures interact with oceans and ice. This research contributes to safe exploration, exploitation and transport of resources from and within the vulnerable Arctic region.

During the year 2012, SAMCoT researchers recorded a number of achievements, including five major field expeditions. SAMCoT is quickly becoming a global Arctic technology hub; we added three new members in 2012 and now total 19 partners worldwide. In addition, other international collaborators strengthened our research team: The University College of London, The State Oceanographic Institute of Roshydromet and the Krylov Shipbuilding Institute.

The year started with HSE courses at UNIS for those persons planning or directly involved in field activities either onshore at Spitsbergen or in northwestern Russia, as well as through ship-based research cruises.

In late January/early February, we arranged a workshop in Trondheim for all Work Packages (WPs), with about 60 people attending. The purpose of the Workshop was to discuss the roadmap and priorities for the research in each SAMCoT WP. The Workshop concluded with clear recommendations and priorities for each of the Research Activities. These recommendations were supported and supervised by the Exploitation and Innovation Advisory Committee (EIAC) , which monitors Project Results with respect to potential for commercial exploitation.

Photos: Ole Morten Melgård

SAMCoT's 1st International PhD Workshop

EIAC members are key representatives within SAMCoT Industry Partners. The EIAC acts as an advisory body to the SAMCoT Board, proposing further development in separate spin-off innovation projects, EU-projects or pre-competitive projects. These decisions and recommendations influence the research strategy of the Centre, keeping innovation as the ultimate goal to the overall activities at SAMCoT.

A second workshop for everyone involved in SAMCoT was arranged on the 4th and 5th of September. The main purpose of this PhD workshop was to provide exposure for the PhD candidates among the SAMCoT partners and to discuss their work and progress. At the same time, the workshop turned out to be a very useful communications arena between SAMCoT's 19 PhD candidates and Post Docs, who otherwise work in different locations in Europe and Russia.

SAMCoT EIAC Members

- Annie Audibert-Hayet (TOTAL)
- Arne Gürtner (Statoil)
- Arnstein Watn (SINTEF)
- Basile Bonnemaire (Multiconsult)
- Bård E. Bjørnsen (SMSC)
- Erik Schiager (GDF Suez E&P)
- Guido Kuiper (Shell) - Chairperson
- Hilde Benedikte Østlund (Kvaerner)
- Nils Albert Jenssen (Kongsberg Maritime)
- Per Kristian Bruun (Aker Solutions)
- Rolf Lande (DNV)
- Sveinung Løset (NTNU)

The workshop was followed by the annual site visit (7th of September) from the Research Council of Norway (RCN). The representatives from RCN concluded that "SAMCoT is well set and has a good progress with all PhD candidates in place according to plan. There is enthusiasm at the Centre and it has a high priority within the research strategy of NTNU. We do also observe that excellence attracts excellence".


Photo: Ole Morten Melgård

Site Visit from the Research Council of Norway to the SFI SAMCoT, September 2012. Front row: RCN representatives, SAMCoT Board representatives and furthest right a representative from the Rector´s office (NTNU)
Middle row: SAMCoT SAC, EIAC and CMG representatives.
Back row: SAMCoT PhD Candidates.

The following sections briefly summarise SAMCoT's activities during 2012, with emphasis on our scientific accomplishments.

Quantifying the Physical Environment

Safe and secure structures and infrastructure designed to operate in the Arctic requires substantial knowledge about the physical environment in which the structures will operate. The interactions between various ice features and the structure are termed ice actions. The shape and size of the structure, the ice conditions and the environmental actions driving the ice can influence a number of different interaction scenarios and failure modes that result from ice actions. Factors that can influence these diverse scenarios are illustrated in Fig. 1.

Most of the work in SAMCoT relating to Quantifying the Physical Environment is summarised in the grey-shaded areas in Fig. 1. To collect and later analyse such data, a number of expeditions were conducted by SAMCoT in the fjords of Spitsbergen, the Barents Sea, the Fram Strait and the ocean area northeast of Greenland. More detailed investigations were conducted in several laboratories at NTNU, HSVA, UNIS and Aalto.

This approach using both full-scale and laboratory research was also applied to our investigations of coastal permafrost, e.g., understanding effects of small changes in temperature as global warming may bring.

Floating Structures in Ice

Offshore drilling and production activities in ice-covered waters date back to the 1960s, when offshore platforms were deployed in Cook Inlet, Alaska. There, the sea surface routinely froze for a couple of months each winter. Gradually, this offshore drilling and production activity expanded to waters with more severe ice conditions, such as the Beaufort Sea. The latest drilling and production developments extend even further into deeper waters, where floating structures are a must.

SAMCoT has a strong focus on floating structures in ice. Its research focuses on establishing a better understanding of the interaction processes between structures and ice. This research includes studies and modelling of waterline processes on the upstream side of the structure, bending failure, ventilation and backfill effects. Further, this research entails multibody dynamics and hydrodynamic effects on the interaction process. Also, accidental collisions with ice masses are focused upon. The work on this topic has also included friction studies between sea ice and steel and sea ice on sea ice, as well as ice actions on a floating jetty in moving ice.

Each of these fundamental research topics are studied at SAMCoT based on development of novel theory, numerical modelling, and model and full-scale data.

Ice Management and Design Philosophy

To ensure station-keeping of floating structures in ice, whether by mooring or dynamic positioning (DP), ice management may be needed. Ice management is defined as the sum of all activities where the objective is to reduce or avoid actions from any kind of ice features. Here, the research at SAMCoT is directed towards establishing a design philosophy for floating structures protected by ice management, which ensures the fulfilment of standard design requirements without being overly conservative.

In this context, SAMCoT researchers are exploring a number of methods to quantify the safety of offshore structures protected by ice management. In particular, probabilistic and non-probabilistic methods (e.g., conventional reliability analyses and formal measures of possibility) are being investigated. The ultimate goal is to develop a mathematical tool capable of assisting the concept selection for Arctic offshore field developments. Iceberg drift and iceberg towing, especially in pack ice, are also important research topics at SAMCoT. Considerable amounts of full-scale data, useful for these topics, were collected by SAMCoT researchers during the research surveys off northeast Greenland and in the Barents Sea. Two PhD candidates are actively working on analysing the data, understanding the physical processes and developing numerical models for iceberg drift and towing in scattered ice.

Ice-Induced Vibrations

It is well known that bottom founded offshore structures occasionally experience sustained ice-induced vibrations. This vibration causes operational problems and may be a risk for structural safety. The ice-induced vibration research at SAMCoT concerns developing an understanding of the processes that cause these vibrations. From these data, it should be possible to generate designs that mitigate these problems.

In 2011, SAMCoT performed experiments in the Hamburg Ice Basin (HSVA) to provoke ice-induced vibrations. A major effort in 2012 was to carefully analyse these data and use it as one of several inputs for

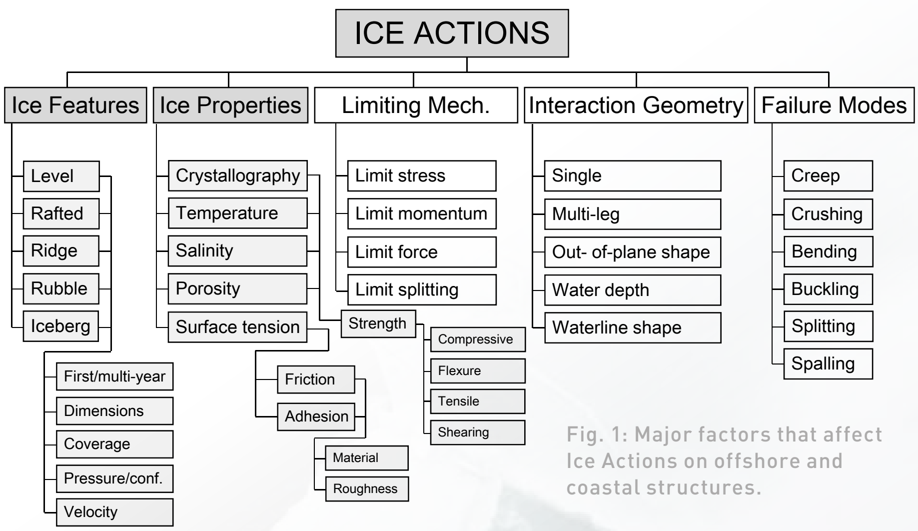


Fig. 1: Major factors that affect Ice Actions on offshore and coastal structures.

OATRC2012, Sveinung Løset on his way to deploy a drift tracker (ITD) on an iceberg.

development of a 1D lattice model. The 1D model development confirmed that the chosen approach can lead to a model capable of predicting intermittent crushing, frequency lock-in and continuous brittle crushing. This model is now being further developed into a 2D model.

The research has also pursued an analogy with other fields of dynamic flow-structure interaction as well as the velocity-effect of ice-induced vibrations.

Coastal Technology

Coastal erosion is a severe and complex condition observed in many places in the Arctic. To understand the processes behind this erosion, SAMCoT participated in field studies of seven coastal permafrost sites, including Spitsbergen and northwest Russia. These registrations are mainly based on yearly DGPS measurements and aerial photography. Soil properties have been investigated by installation of onshore data collectors, including piezometers and thermistor strings.

At one site, Vestpynten at Spitsbergen, studies of how snowdrift in the coastal zone affects the temperature regime in the coastal permafrost is studied and, the effect this snowdrift may have on erosion rates. Observations related to the presence of fjord ice clearly indicate that extremely long periods of ice-free seas cause substantially increased erosion rates. Geosynthetic tubes and bags using local soil as filling material have been developed and are now being tested for shoreline protection.

In-situ testing and laboratory testing are also required to understand the behaviour of permafrost from an engineering perspective. Thus, equipment has been developed for high quality soil sampling.

Associated Projects

Associated Projects are separate projects initiated by one or several SAMCoT partners. These projects benefit from existing know-how acquired through SAMCoT activities and build on the involvement of SAMCoT staff.

Two Associated Projects were conducted in 2012:

- Oden Arctic Technology Research Cruise 2012 (OATRC2012), headed by NTNU in cooperation with the Swedish Polar Research Secretariat (SPRS), The University Centre in Svalbard (UNIS) and Statoil.
- EU HYDRALAB – IV Project "Rubble Ice Transport on Arctic Structures" (RITAS), a project headed by Multiconsult and supported by HSVA, Statoil and NTNU.

A Thank You to All Our Contributors

I would like to take this opportunity to thank everyone who joined us in 2012 for their contributions to SAMCoT's progress and successes during the year. We should all remember that a Centre for Research-based Innovation (SFI) should include the industry partners and ensure quality and relevance of the research being done. To keep this vital interaction intact is demanding and it is best achieved through the devotion demonstrated by SAMCoT's working committees, review processes and workshops, as well as the co-supervision support the PhD candidates receive from our partners.

The year 2012 was SAMCoT's first full year and a number of new PhD candidates began it with mandatory courses before continuing with academic work. Already we now see the first fruits of this seeding phase, manifested in a number of publications being disseminated in 2013.

Once again, thanks to each of you. I look forward to continuing another exciting year in 2013.

Sveinung Løset
Director of SAMCoT

From fundamental research to technological innovation: **SAMCoT**'s Vision

The frozen reaches of the Arctic contain much as 20 percent of the world's undiscovered conventional petroleum resources – a fact that anyone in the oil and gas industry knows by heart.

But Arctic is full of challenges, too, including sea ice, icebergs and marine icing, winter darkness, remoteness and lack of infrastructure. Those are all reasons why SAMCoT's fundamental research and newly minted PhDs are key to helping the industry develop the Arctic technology it needs, says Morton Karlsen, Head of Research Going North at Statoil and SAMCoT's chairperson of the SAMCoT Board.

"Activities in this region will put new demands on our industry," Karlsen says. "We need to meet these challenges proactively, by developing the highest standards for Health, Safety and the Environment and operational quality. SAMCoT is a very important initiative to increase our knowledge about the Arctic, promote the development of innovative technical solutions and educate people for future jobs in the oil and gas industry."

PhDs: the main product

As one of NTNU's four Centres for Research-based Innovation, SAMCoT is composed of experienced researchers, PhD and master's students, along with its industry partners. Centre director Sveinung Løset sees SAMCoT as an Arctic marine technology hub, but for Karlsen and other SAMCoT industry partners, the centre is also a place where the next generation of industry thinkers is being trained.

"The main deliverables from SAMCoT are the people who are being educated, not necessarily a specific technology," Karlsen says. "Those technologies are going to be different for different industry partners. What is important for all of us is the high quality of education that people get at SAMCoT, and of course the people themselves."

Karlsen's colleague at Statoil, Arne Gürtner, who is principal researcher in Arctic technology, also sees the centre as an academic powerhouse.

"SAMCoT is a main vehicle for increased knowledge and research on Arctic technology in academia worldwide," he says.

Health and safety top priority

In May 2012, the SAMCoT Board followed an introductory HSE course at UNIS where they experienced first-hand the high HSE standards followed by SAMCoT.

UNIS, as one of SAMCoT`s research partners, also plays an important role in developing and implementing SAMCoT's HSE strategy.

Kværner Engineering AS, a specialized worldwide engineering, procurement and construction company,

Photo: Nataliya Marchenko

SAMCoT Board at a HSE exercise, Svalbard May 2012.

is one of the newest SAMCoT industry partners. Hilde Benedikte Østlund, Vice President Research & Development – Kvaerner Concrete Solutions, says the company views SAMCoT as a way to help build their expertise in a demanding environment.

KV Svalbard 2012: Raed Lubbad and Stig R. Søberg deploying an ITD on an ice floe.

"The Arctic is becoming increasingly important in securing energy supplies for the future while balancing economic, environmental and social challenges," Østlund says. "Arctic oil and natural gas resource exploration and development are demanding and the Arctic physical environment presents special challenges not experienced elsewhere in the world. Special solutions and experience will be required."

The polar regions pose both familiar and entirely new responsibilities in exploration and exploitation, Østlund says. Some, such as emergency preparedness and protection of a vulnerable environment, are familiar because they are important for natural-resource based companies no matter where they operate.

But the Arctic adds another layer of complexity, with winter dark, remoteness and lack of infrastructure, Karlsen adds. "These present challenges with respect to the safety and health of our personnel," he says. Working with SAMCoT has "reinforced our understanding of close collaboration between the industry, academia and research institutes to meet future operational and HSE standards and mitigate the risks."

Handling the ice

Then there's the issue of Arctic ice. Ice poses multifaceted questions for businesses and researchers alike. Ice will put pressure on permanent and floating structures, but what is the best way to manage those stresses?

Østlund says Kværner is very interested in knowing more about how ice should play into the design of structures. For example, should structures be designed and built using traditional approaches and using the information that SAMCoT gathers about ice loads?

Or would it be better to use information about how ice can be managed to lessen the loads on structures, which would then require different design criteria? The 2012 Oden cruise to the northeast coast of Greenland, where old ice prevails, is one of many ways that SAMCoT is collecting the data that will help answer these questions.

That fundamental information, and its ability to shape the way the industry works in the north, is one important reason why GDF Suez E&P Norway AS, another new SAMCoT partner, is enthusiastic about the Centre's work.

"We expect that SAMCoT will provide state-of-the-art technology and methodology for the sustainable exploitation of oil and gas resources in the high north," GDF Suez's Tom Steinskog and Erik Schiager say. Steinskog is leader, Technology and Development for GDF Suez E&P Norway AS, while Schiager is advisor, asset management for the company.

SAMCoT Board Members

- Arnor Jensen (Multiconsult)
- Berit Laanke (SINTEF)
- Gina Ytteborg (Shell)
- Helen Flå (UNIS)
- Ingvald Strømmen (NTNU)
- Morten Karlsen (Statoil)
- Per Olav Moslet (DNV)
- Rune Teigland (TOTAL)
- Tom Steinskog (GDF Suez)
- Kimberly Mayes (Observer, RCN)
- Sveinung Løset (Secretary to the Board, NTNU).

Fundamental research drives innovation

Karlsen says that the kind of fundamental research conducted by SAMCoT is the very foundation for progress in the industry.

"There are so many gaps when it comes to what we need, we see that there is a need for this platform," he says. The industry can then take fundamental information generated by SAMCoT to develop specific technologies to meet their needs.

"We (the industry) are able to build on results from the fundamental research and we are also able to take the PhD candidates and offer them a job in the industry," he says. "They can then do research in applied sciences here."

For SMSC, the Ship Modelling and Simulation Centre, SAMCoT is also an important arena for bringing together highly competent researchers who can share their understanding of the complexities of the Arctic.

"SAMCoT represents a project/meeting place where SMSC can get added knowledge about the Arctic, ice and ice modelling," says Bård E. Bjørnsen, Manager, projects and business development for the company.

The focus on top-notch research is also a big plus for SAMCoT partners such as UNIS, the University Centre in Svalbard, because the best research attracts the best researchers. "Cooperating with the best scientists and industry partners within this research area will give our researchers new knowledge, inspiration and prestige in their own special fields," says Helen Flå, assistant director of UNIS.

Relevance for industry

Oil and gas development in the Arctic is only in its beginning stages. Some areas of the Arctic are already open to exploitation, such as the Barents Sea, but moving beyond today's established areas requires "incremental innovation in the development and production stages," Karlsen says.

For example, Statoil is not currently exploring in ice-covered waters, but sees that this will be increasingly feasible with new technologies developed based on

Photo: Øyvind Hagen, Statoil

OATRC2012 cruise members deploying Ice Profiling Sonar (IPS) and Acoustic Doppler Current Profiler (ADCP) mooring.

SAMCoT research. "The findings from SAMCoT will be very important from this perspective, particularly after 2020," he says.

"SAMCoT is a great vehicle for increased knowledge when it comes to offshore design and coastal technology," he adds. "In these areas, we expect SAMCoT to significantly contribute to establish best practice within the industry."

Østlund says Kværner is excited about the SAMCoT partnership, because the company can contribute by assessing industry requirements, and ensuring that SAMCoT's focus, priorities and research outcomes are relevant to the industry.

"Field development in Arctic areas will be the core business for Kvaerner Concrete Solutions in the years to come," she says. "There will be major field developments during the next 20-30 years. Expanding our knowledge through research will be extremely important to ensure the possibility of safe and economic development of these areas."

Photo: Nataliya Marchenko

SAMCoT Board at a HSE exercise, Svalbard May 2012.

Engineering Challenges in the Arctic addressed by SAMCoT

COASTAL TECHNOLOGY

Research Questions in 2012

- Understanding Coastal Erosion
- Permafrost Soil Properties
- Sustainable Erosion Protection Systems

Type of Experiments

Full-scale: drilling and penetration tests, soil sampling and testing of physical and mechanical properties, temperature and thermal properties of permafrost soils, topographical measurements, observations of geocryological structures on thermo-abraded slopes

Location of Experiments

- Vestpynten, the Fjords at Spitsbergen (Norway)
- Baydara, Varandey Island, Pesyakov Island and the Medynsky Zavorot Peninsula (Russia)

Number of Researchers involved: 9

QUANTIFYING THE PHYSICAL ENVIRONMENT

Research Questions in 2012

- How strong is ice?
- How strong is an ice ridge?
- How does sea ice expand?
- How to model warming permafrost?

Type of Experiments

- Full-scale: in-situ tests, cantilever beam tests, small-scale uniaxial compression tests, small-scale indentation tests (bore hole jack tests) and dynamic test of elastic properties.
- Scale-model: simulations of scale-model ice rubble tests, shear box tests

Location of Experiments

- Fjords at Spitsbergen (Norway)
- Barents Sea and Northeast Greenland waters (KV Svalbard + RV Lance + Oden cruises)
- HSVA (Germany)
- NTNU (Norway)

Number of Researchers involved: 21

ICE-INDUCED VIBRATIONS

Research Questions in 2012

- How to estimate forces from measured structural displacements (system identification)
- How to simulate the structural behaviour during ice-induced vibrations (software development)

Main Activity

- Analyses of experiments carried out in 2011 and development of numerical models.

Number of Researchers involved: 6

Floating Structures in ice, Ice Management and Design Philosophy

FLOATING STRUCTURES IN ICE

Research Questions in 2012

- Waterline processes during the inter-action between ice and structures
- The interaction between ice, fluid and structures
- Accidental collisions between ice masses and structures
- Sea-ice friction

Type of Experiments

- Full-scale: ice friction experiments, monitoring floating jetty
- Scale-model: collision experiments , ice interaction with sloping structure experiments

Location of Experiments

- Fjords at Spitsbergen (Norway)
- Barents Sea and Northeast Greenland waters (KV Svalbard + RV Lance + Oden cruises)
- Aalto University ice basin (Finland)
- HSVA (Germany)

Number of Researchers involved: 10

ICE MANAGEMENT AND DESIGN PHILOSOPHY

Research Questions in 2012

- Quantifying safety of offshore structures protected by ice management
- Modelling of iceberg drift and towing

Type of Experiments

- Full-scale: ice management and ship manoeuvring experiments, iceberg experi-ments, e.g. scanning of the 3D geometry, deployment of ice tracking drifters on icebergs and sea-ice and measurements of sea-currents near drifting icebergs

Location of Experiments

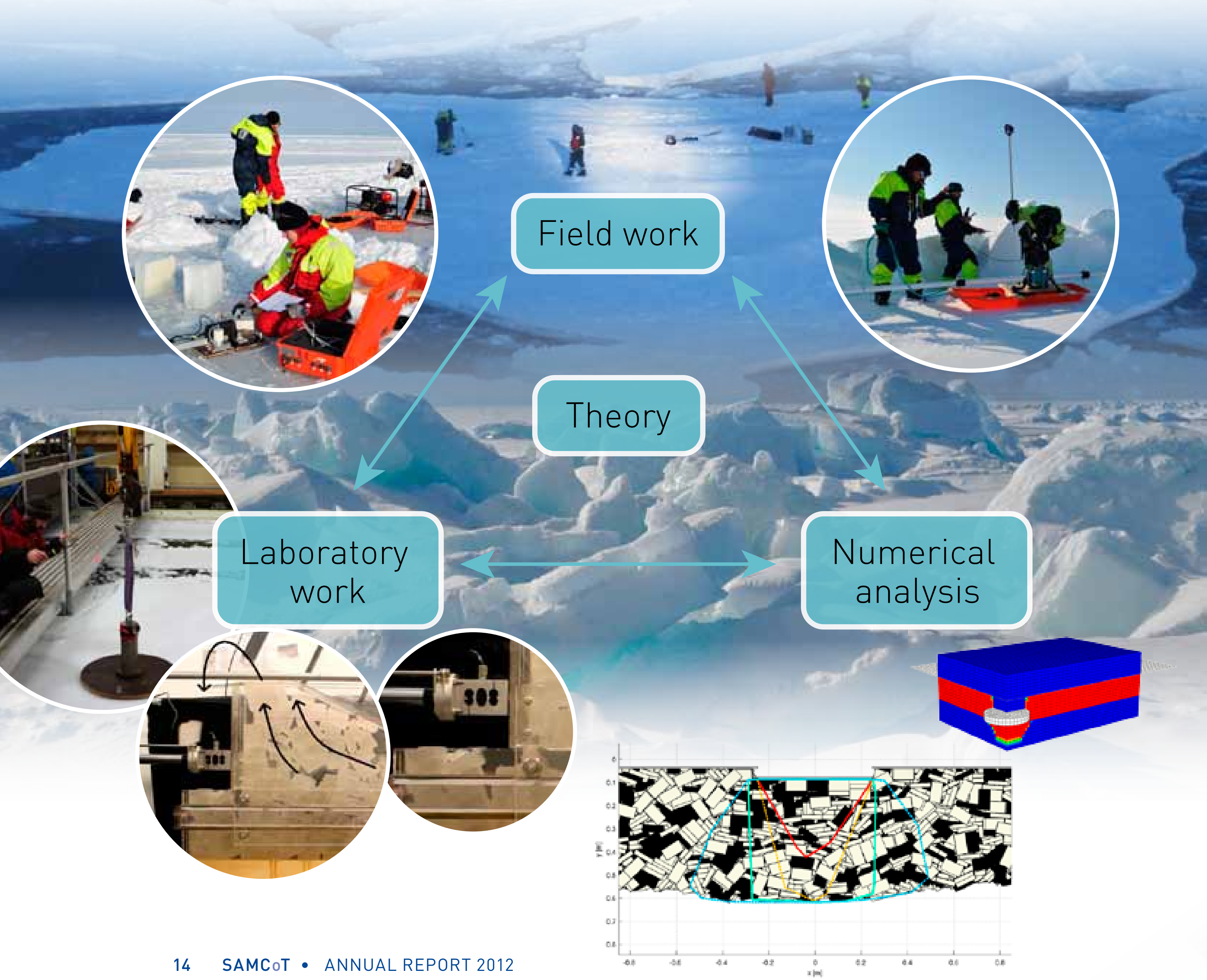
- Barents Sea and Northeast Greenland waters (KV Svalbard + RV Lance + Oden cruises)

Number of Researchers involved: 5

Quantifying the Physical Environment

Reliable designs of Arctic offshore and coastal structures require a proper quantification of the physical environment. The relevant properties of ice, soil, water and other environmental characteristics must be described in a mechanical and statistical sense. This competence represents the backbone of SAMCoT.

The researchers at SAMCoT address these challenges with a combined approach that utilizes experimental, theoretical and numerical techniques. We establish our starting point through theory and field study; subsequent detailed laboratory analysis provides us the opportunity to tune our numerical models.



How strong is ice?

Ice properties are required for simple engineering formulas, numerical simulations and when performing scale-mode experiments. In each estimate of how ice will interact with a structure, one needs a quantification of the mechanical behaviour of the ice: in short, its strength.

The mechanical behaviour of sea ice depends strongly on its temperature and its brine and gas fraction. The temperature and the brine and gas fraction change substantially throughout the seasons, so it is important to carry out in-situ experiments under different conditions to capture the variations in ice mechanical properties.

The research team carried out in-situ tests of both first-year sea ice (at Spitsbergen and the Barents Sea) and old ice (in the Fram Strait). Our researchers performed cantilever beam tests, small-scale uniaxial compression tests, small-scale indentation tests (borehole jack tests) and dynamic tests of elastic properties.

The 2012 SAMCoT specialized research team consisted of Professor Aleksey Marchenko, Aleksey Shestov, David Wrangborg and Joar Aspenes Justad. UNIS students from the AT-211:

Ice Mechanics, Loads on Structures and Instrumentation, and AT-332: Physical Environmental Loads on Arctic Coastal and Offshore Structures, courses also participated in the field work. In addition, international researchers Evgeni Karulin and Marina Karulina from Krylov Shipbuilding Research Institute in St. Petersburg, Russia, contributed to the work as guest researchers.

The beam tests represent the failures in bending when ice collides with a sloping structure. This failure is typical of ice interaction with ships and with moored or fixed structures with sloping water lines. The uniaxial compression tests and the indentation tests are more representative for cases when ice hits a vertical faced structure.

The bending strength cantilever beam tests can easily be accomplished in both full and small scales. Crushing strength measures are often difficult to compare, as uniaxial compression tests are difficult to perform on scale-model ice.

In basin tests, the crushing strength is often determined

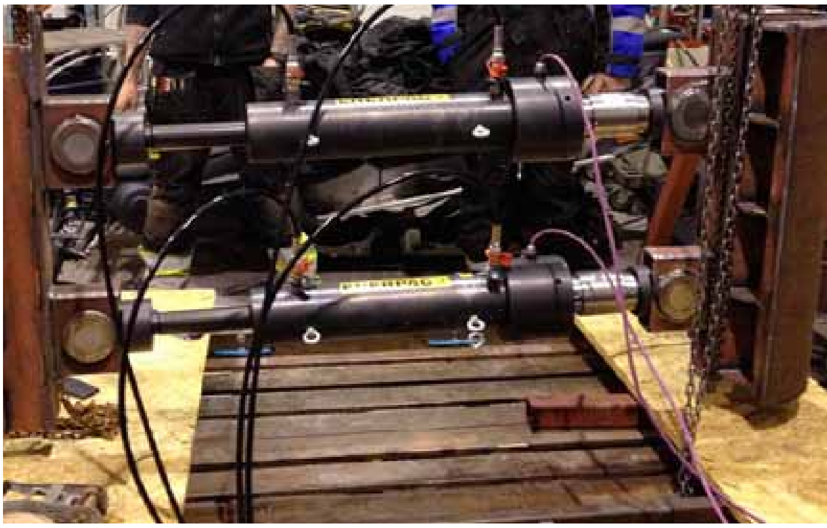


Fig. 2: The new indentation rig for in-situ ice testing.

Fig. 3: Students in AT-332 perform an in-situ beam test in Svalbard.

by indentation measures, but few comparable full-scale indentation experiments are available. SAMCoT developed a rig for in-situ indentation tests so that a reliable full-scale comparison with scale-model ice properties can be completed (see Fig. 2). The rig was tested in dry conditions in 2012 and is scheduled for field testing in 2013.

Several series of small-scale indentation experiments (borehole jack) were carried out in different ice

Fig. 4a: The beam test ready to be performed.
Fig. 4b: Thin section showing the vertical ice texture in the beam.

conditions and an improved scheme for classification of these tests has been suggested to the ice engineering community. SAMCoT has also suggested that ice strength depends on ice confinement and indentation velocity, as well as ice temperature. Beam tests of level saline and fresh water ice were conducted and numerical simulations were initiated to examine the effect of deformations on surrounding level ice and of varying ice properties vertically through level ice.

How strong is an ice ridge?

SAMCoT researchers aim to develop physically based numerical models of ice ridge action on structures by quantifying micro-macro coupling of ice rubble behaviour.

An ice ridge consists of a sail and a keel. The sail is above the water line, has minimal volume and is often relatively weak. Therefore, it has limited effect on the action of the ice ridge.

In a first-year ridge, the keel consists of an upper refrozen or consolidated layer, which is similar to level ice, but often less than four metres thick. A large ridge can be more than 30 metres thick. The larger part of the keel volume in large ridges is unconsolidated, i.e., rubble.

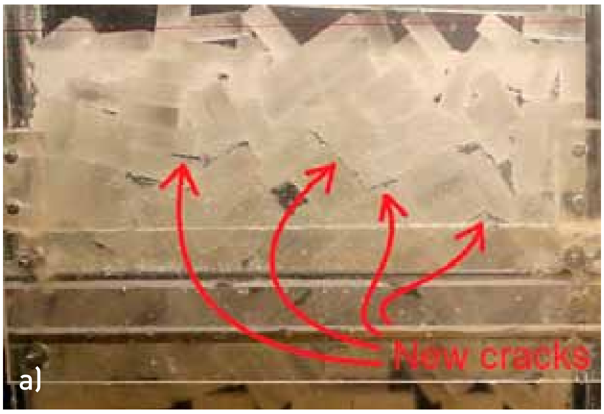
The rubble consists of broken ice pieces partly refrozen to each other through freeze-bonds and pockets of water/slush. Although the rubble is significantly weaker than the consolidated layer, it may account for more than 90% of the keel volume and contribute significantly to the total ice ridge action on a structure. When rubble deforms, the freeze-bonds may break and the resulting blocks can rotate and break apart or crush other rubble. It behaves like a granular material, not unlike some soils, but the rubble particles are much weaker than is typical for soils.

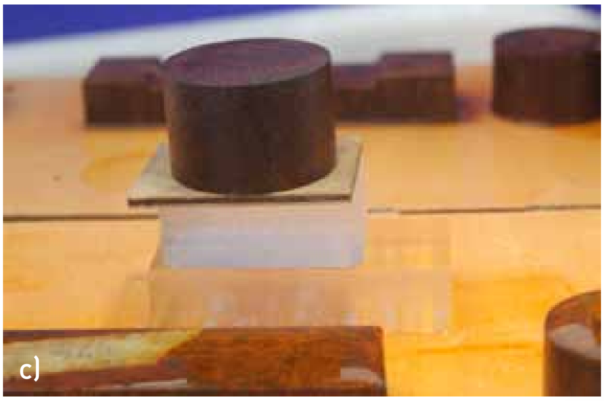
The model development strategy is to combine in-situ investigations, laboratory experiments and numerical simulations with finite elements, discrete elements and numerical simulations of the heat and mass transfer.

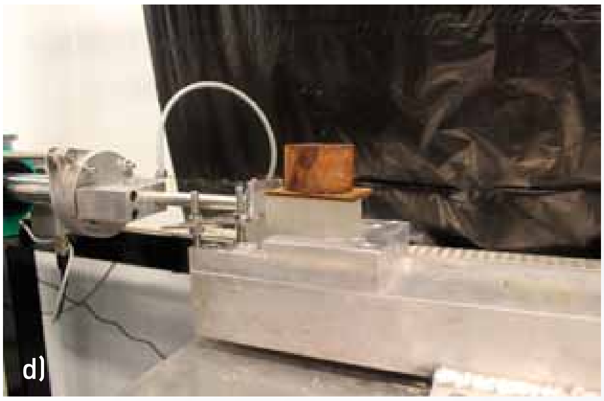
The SAMCoT specialized research group in 2012 consisted of Sergey Kulyakhtin, Anna Pustogvar, Professor Knut V. Høyland, Professor Aleksey Marchenko, Anders Møllegaard, Henning Helgøy and Oda Skog-Astrup from NTNU/UNIS, Professor Jukka Tuhkuri from Aalto, Dr. Jaakko Heinonen and Dr. Kari Kolari from VTT and Professor Peter Sammonds from UCL. In January 2013, Stanislav Pavlov began his PhD studies at UCL and Arttu Polojärvi started his post-doc at Aalto.

The RITAS Associated Project facilitated our research team to carry out and analyse scale-model experiments in the Hamburg Ship Model Basin (HSVA) in Germany. Scale-model experiments about ice rubble properties were completed and the analysis appears to confirm that scale-model ice rubble is substantially weaker than full-scale rubble.

Dr. Heinonen spent three month at NTNU as a SAMCoT Guest Researcher and carried out numerous simulations of scale-model ice rubble tests with the Finite Element Model. His goal was to quantify the different material properties of full-scale and scale-model ridges and to establish what consequences these characteristics







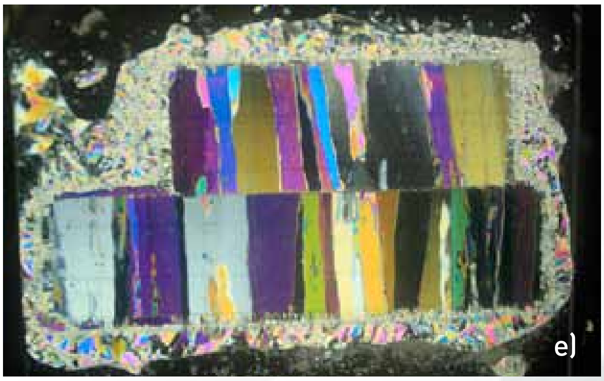


Fig. 5a: Freeze-bond breaking during the first phase of the shear box test.

Fig. 5b-e: Individual freeze-bonds
b) Putting two pieces together.
c) Confinement added and freeze-bond ready for testing.
d) Testing of freeze-bond strength.
e) Thin section showing the ice texture of the two ice blocks and the freeze-bond.

have on the observed ice rubble failure modes in scale-model experiments of ice ridge-structure interaction.

Dr. Heinone's analysis also argues that scale-model rubble is substantially weaker than full-scale rubble and that scale-model rubble has a greater tendency to compact than full-scale rubble. This finding is important, as it demonstrates how rubble accumulates in front of a structure and how it flows around and below it.

In addition, two rounds of shear box tests in the NTNU ice laboratory showed a clear connection between strength of the individual freeze-bonds between ice blocks and the mechanical behaviour of the shear box. These tests were conducted in the spring of 2012 by Master's students Oda Skog-Astrup and Henning Helgøy, and by PhD candidate Anna Pustogvar in the autumn of 2012.

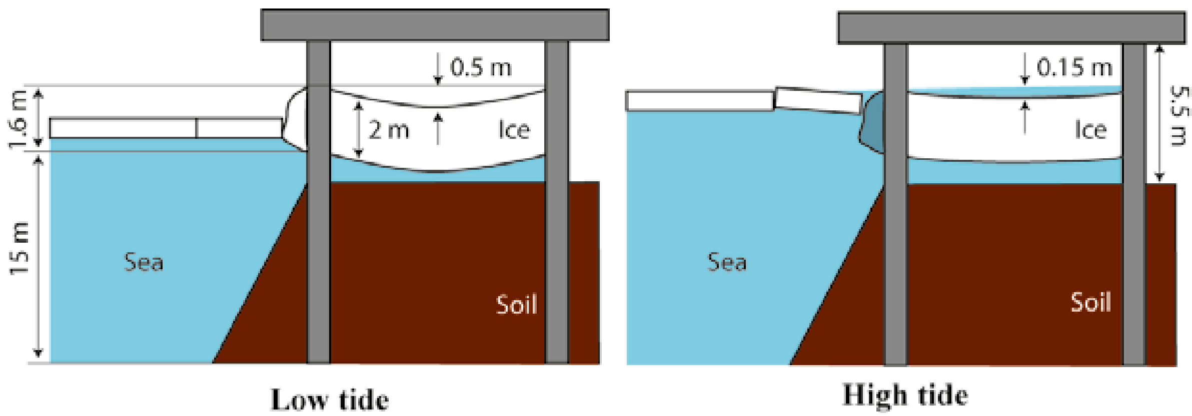
How does sea ice expand?

Fresh water ice expands when it is heated, as do most other materials. In sea ice, brine volume rises as temperatures increase.

Because the density of brine is higher than the density of pure ice, the increasing brine content should decrease the volume, thereby countering the effect of thermal expansion of pure ice. However, brine may also drain from the ice, in turn reducing the effect of higher brine volume with increasing temperature.

The unpredictable variations of thermal expansion of sea ice are often more complicated but at the same time less critical than fresh water ice. However, in situations where sea ice is physically confined and exposed to tides and large temperature variations, thermal expansion can be critical.

Fig. 6a and b: The deformation of the sheet-pile wall in the main coal harbour at Spitsbergen (Kapp Amsterdam, Svea). Above: a) Local deformation. Below: b) Sketch of ice and water at respectively high and low tides.



An example of this effect has been identified at the sheet-pile wall of the Kapp Amsterdam quay at Spitsbergen. Experts theorize that the deformation of the sheet-pile wall has resulted from a combined effect of thermal expansion and tide. The combination of brine drainage and increasing brine volume at higher temperatures has been deemed as key.

A team of UNIS researchers – Professor Aleksey Marchenko and his students from UNIS – have measured the conditions over a period of several years and in 2012 SAMCoT researchers installed load cells inside the sheet-pile wall to quantify the pressure from the ice. Laboratory experiments with fibre-optic sensors have been used to quantify the thermal expansion of sea ice as a function of salinity and temperature.

Professor Marchenko gave an overview of the topic in an invited lecture at the International Ice Symposium (IAHR) in Dalian China in June 2012. Whereas two conflicting models of the problem have been published, Prof. Marchenko explains in his findings that it makes sense to combine the two approaches.

How to model warming permafrost?

Frozen soil contains pure ice, soil particles, liquids with dissolved salts and gasses. As permafrost deforms (especially warming and melting permafrost), vital thermal, hydrological and mechanical processes occur.

The different phases of deformation are in thermal equilibrium and warming permafrost in particular is sensitive to small changes in temperature. In order to describe the deformations of permafrost mathematically, SAMCoT researchers needed to study the coupled Thermo-Hydro-Mechanical (THM) process.

Professor Thomas Benz and PhD candidate Yared Bekele were active in 2012. Bekele conducted a state-of-the-art report about THM modelling of frozen soils and also started the creation of his own numerical solution. His first step focuses on effective formulation of governing and constitutive equations of frozen soil as a porous medium.

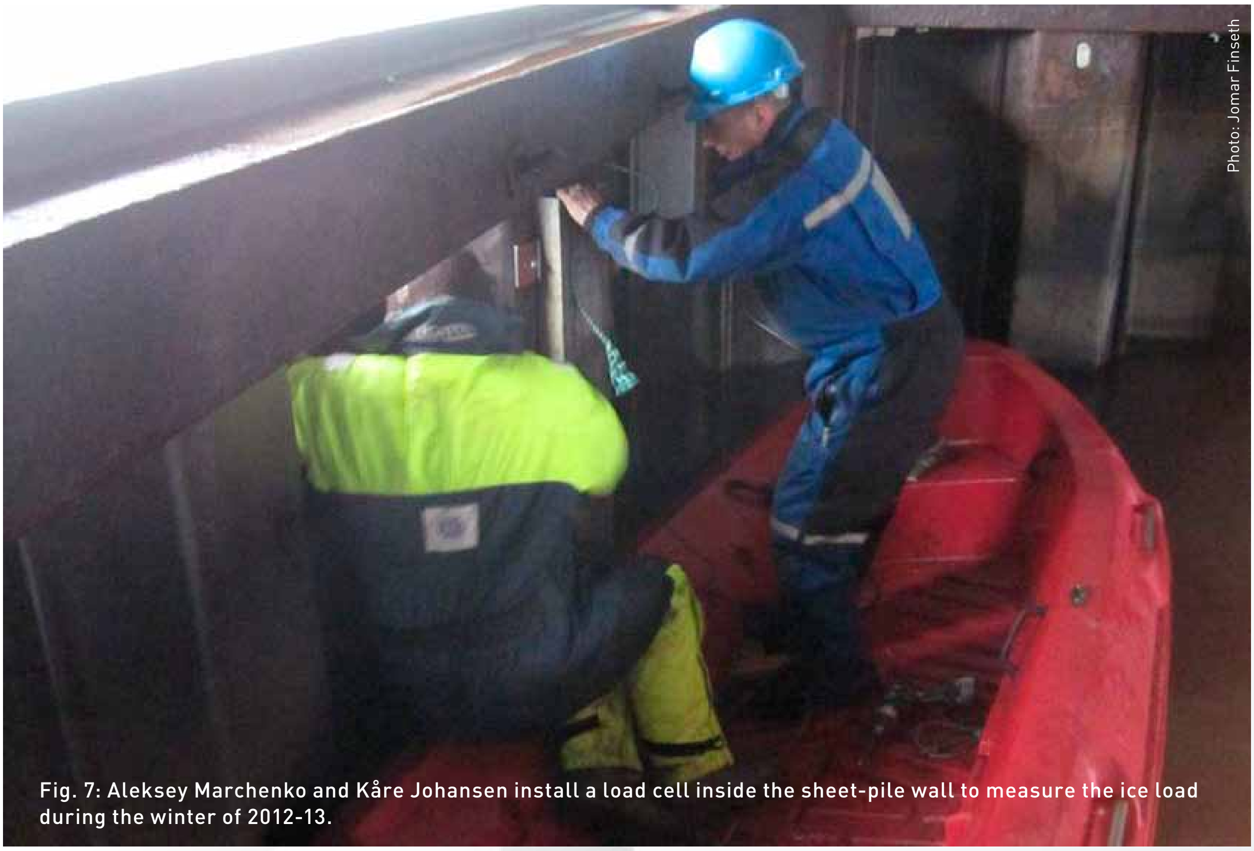


Photo: Jomar Finseth

Fig. 7: Aleksey Marchenko and Kåre Johansen install a load cell inside the sheet-pile wall to measure the ice load during the winter of 2012-13.

Floating Structures in Ice

Remote and deep water hydrocarbon fields require floating structures to facilitate both drilling and production.

Several means of station-keeping can be utilized, including mooring- and dynamic positioning. A dynamic positioning solution can be especially attractive for drilling, since drilling is a short-term operation and costly moorings and anchor handling can be avoided. Mooring, which is most often used for production platforms, must frequently be combined with ice management.

SAMCoT research focuses on better understanding the interaction processes between structures and ice. This research entails multibody dynamics and hydrodynamic effects on the interaction process.

Waterline Processes

Fracture of ice at different scales is frequently observed during the interaction between ice and offshore structures. On large scale, we may observe the splitting of ice floes, while locally at smaller scale, the bending failure of ice is constantly taking place (see Fig. 8).

Furthermore, after the bending failure of ice, the broken ice rotates downward. The ice rotating process is coupled with the fluid, which represents the so-called ventilation and backfill effects (see Fig. 9). Each of the aforementioned processes take place at the waterline. Doctoral student Wenjun Lu is making large achievements in modelling the waterline processes and to more precisely predict the ice load and rubble generation at the waterline. "I am modelling the bending failure of ice in the bow area and also the splitting of floes that interact with the floater," says Lu.

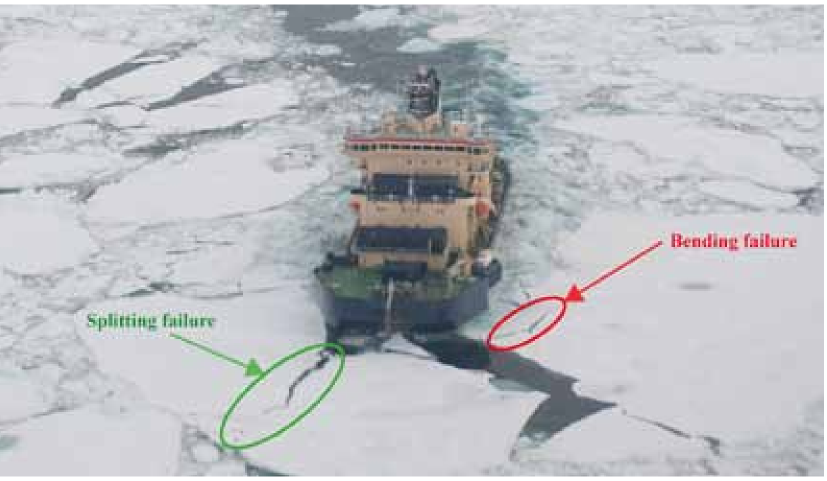


Fig. 8. Splitting of ice floes by the icebreaker Oden (OATRC2012)

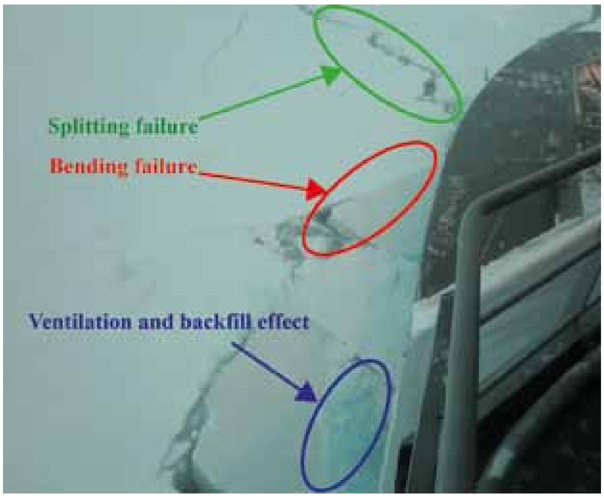


Fig. 9. Waterline processes (splitting, bending and ventilation effects).

Bending Failure

Lu is striving to model the bending failure of ice as a progressive failure process. He has initially created several different numerical methods to model the fracture and fragmentation process (see Fig. 10).

Based on the experiments he conducted at the Hamburg Ship Model Basin (HSVA) in April 2012 (further details and visual aids under Associated Projects on pages 44-47), he proposed a theoretical model to capture the important interaction mechanisms as shown in Fig. 11. In this experimental and theoretical model

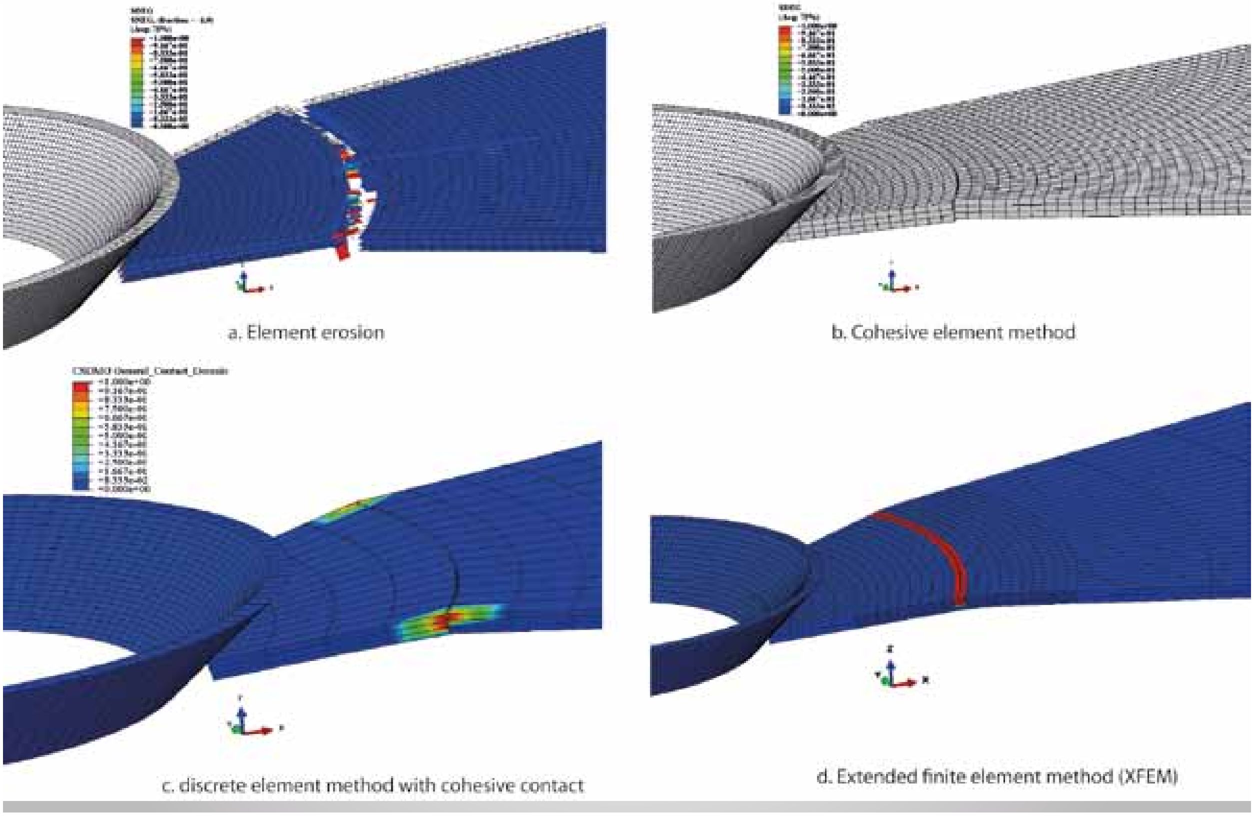


Fig. 10. Different numerical methods used to model the bending failure of ice as a progressive failure process. After investigating each of these numerical methods, Lu has built his competence in simulating the progressive failure of ice. In his next step, he theoretically and experimentally investigated the mechanisms of level ice interacting with sloping structures.

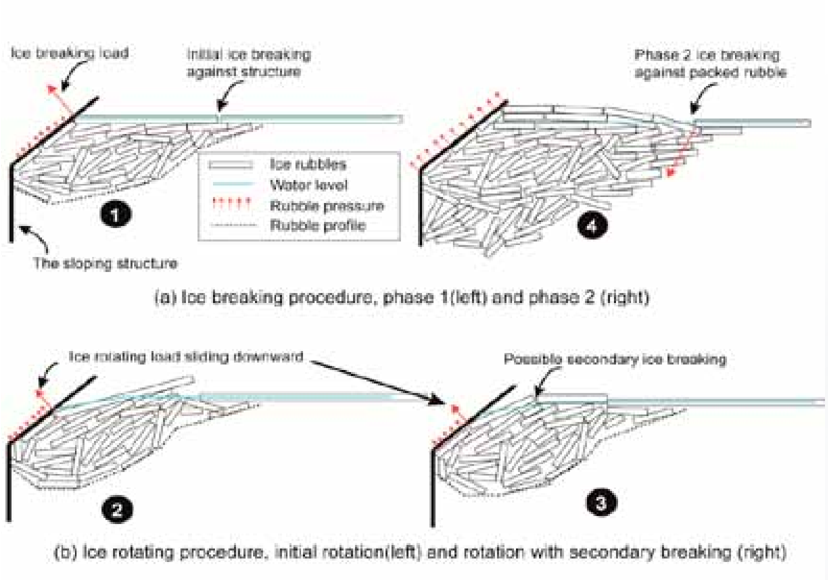


Fig. 11. The proposed interaction mechanisms of level ice that interacts with sloping structures with the presence of rubble accumulation.

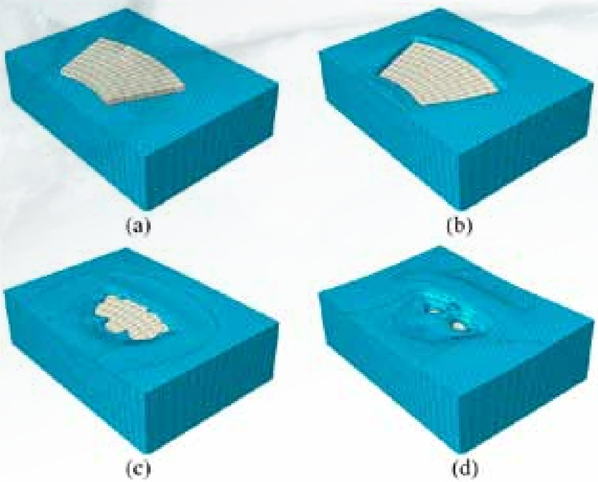


Fig. 12. Different submergence stages of a broken ice floe simulation.

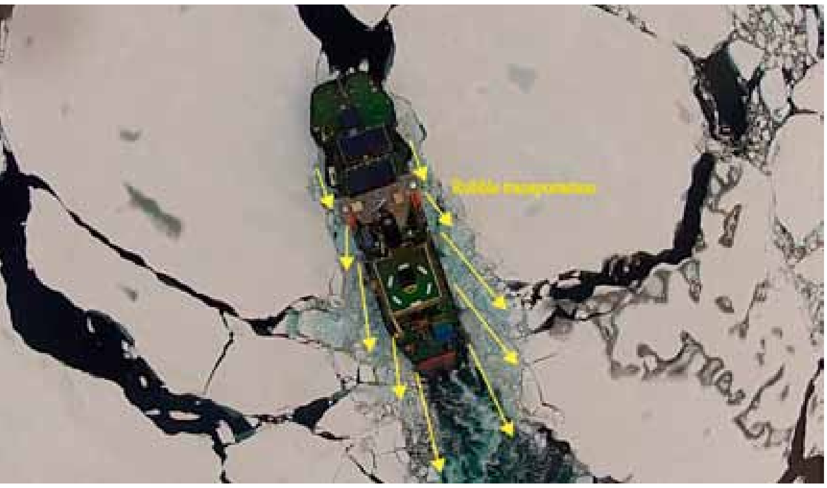


Fig. 13. Bird's-eye view of the icebreaker Oden and the transport of broken ice, indicated by yellow arrows.

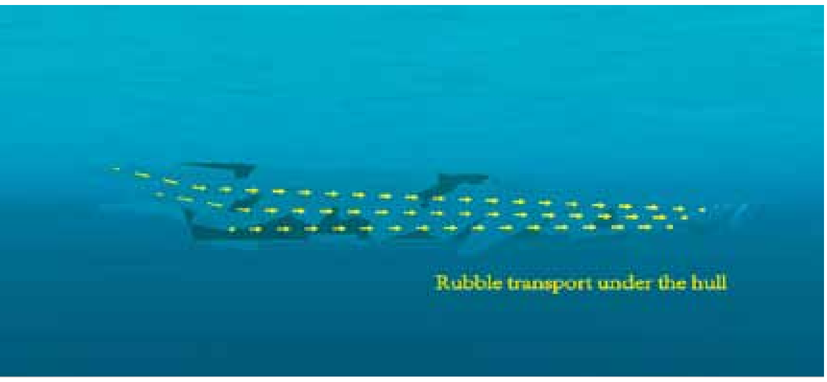


Fig. 14. Subsurface transport of broken floes and rubble along the hull.

study, Lu stressed the importance of rubble accumulation to influence the whole interaction mechanism. These influences include ice bending failure, secondary ice breaking and ventilation effects.

Ventilation and Backfill Effects

After the initial bending failure of level ice, the resulting broken ice is pushed downward below the waterline. Conventionally, when considering this process, the 'full ventilation' or 'no ventilation' assumptions are usually considered. However, depending on the interaction speed and ice concentration, the ventilation effect together with the so-called backfill effect compete to add additional ice rotating load to the global ice resistance. Lu investigated this process with the Coupled Eulerian and Lagrangian (CEL) method (Fig. 12).

The CEL method allows simulating of the fluid's backfill process during submergence of the ice floe. When integrating the pressures on the upper and lower surfaces of the rotating ice floe, the net force required is available in different speed ranges in contrast with the traditional assumptions of 'full ventilation' and 'no ventilation'.

This research result highlights the importance of taking into account the backfill effect at the specified interaction speed range (i.e. floating structure in ice).

Ice-structure and Fluid-structure Interaction Processes

Operations in icy waters produce different physical processes due to the simultaneous interaction between water with ice, hulls, risers, mooring lines, propellers, rudders and other marine systems.

Numerical modelling of the interaction between broken ice and floating offshore structures requires new and efficient methods capable of predicting both ice-structure and fluid-structure interaction processes. In general, fluid-structure interaction (FSI) problems are extremely complex and cannot be solved analytically but often can be analyzed by means of experiments or numerical simulations. Furthermore, state-of-the-art FSI techniques become hardly applicable to multi-body systems when contact interactions are involved and the computational time is of importance. Doctoral candidate Andrei Tsarau is developing a numerical simulation concept and methodology for a floater in ice coupled fluid-solid system.

In Tsarau's model, a floating structure and ice pieces are assumed to be rigid bodies with six degrees of freedom. The fluid medium is modelled under the assumptions of potential flow theory. A boundary element method is employed to calculate water flow induced by the hull and moving ice. Rigid-body equations of motion are solved using the fourth-order Runge-Kutta integration method.

Numerical methods for FSI usually combine computational fluid dynamics (CFD) and computational structural dynamics, considering both problems together. Regarding FSI in ice-related problems, many authors admit the importance of the hydrodynamic effect of water on ice and floaters dynamics, e.g. the phenomena shown in Figs. 13 and 14.

In such situations, the motion of the floater and the ice floe will determine the unsteady flow pattern in the vicinity of the hull, accelerating the water around it and thus increasing the added mass effect on the ice dynamics. Some representative values of the size of the zone surrounding the floater, where the fluid inertia force can be dominant, were obtained using the developed numerical model for a conical structure in broken ice (Fig. 15).

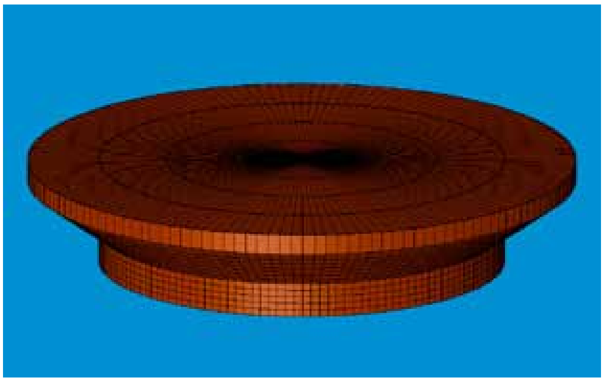
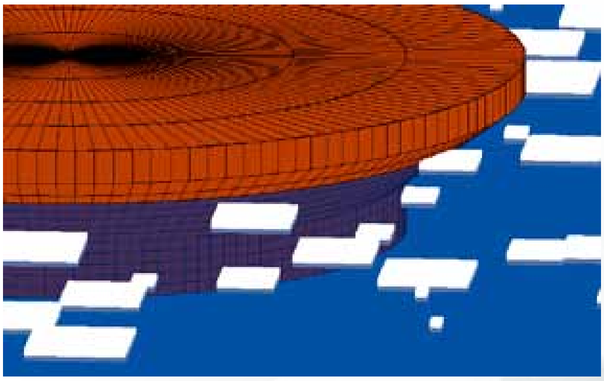


Fig. 15. Model of a conical floater in a randomly generated ice field.



The implemented potential flow method provides a hydrodynamic coupling between all the bodies in the ice-floater system and can be used in a wide range of practical problems related to operations in ice covered waters for dynamic simulations and further analysis. However, for accurate rubble transport predictions, especially when the propeller flow is considered, the mathematical model has to account for the viscosity effects also.

In many cases such as DP or ice washing processes, the induced water flow is often strongly unsteady and thus empirical formulas for the viscous drag are hardly applicable in such cases. The current research is aimed to overcome these difficulties in order to generalize the approach.

Accidental Collisions with Ice Masses

Arctic conditions will challenge the limits of technology. Accidents cannot be completely avoided and absolute safety does not exist. The possibility of accidental collision between potential ice features and ships or offshore installations has drawn considerable attention since the RMS Titanic struck an iceberg and sank on April 15th 1912.

Although the topic of iceberg/structure collision is not novel and has been investigated by many researchers, challenges still remain. Focus has to a large extent been concentrated on load assessment, used with Ultimate Limit State (ULS) design methods.

Damage-tolerant design procedures (Accidental Limit State, ALS) should be used to perform a safe design for vessels with low ice classes. With a ULS approach, operational conditions that minimize serious damage to the vessel could be established.

With an ALS approach, adequate precautions against scenarios outside of the ice class requirements can be provided for both ships and offshore structures, i.e. ensure that the consequences of an accidental event does not lead to progressive collapse or severe environmental damages.

Knowledge on the coupled behaviour of ice and the impacted structure is required to accomplish a damage-tolerant design.

Doctoral students Ekaterina Kim and Martin Storheim performed laboratory experiments on simultaneous deformations of ice and a structure to learn more about mechanisms of ice/structure interaction during a collision. These laboratory experiments were conducted at a scale approaching a full-scale ice impact scenario; laboratory-grown granular freshwater ice was used together with steel models of sizes that could produce a realistic damage as in full-scale interaction. The tests were conducted using structures of varying rigidity and several different ice masses. The focus was on ice features that are sufficiently large to represent a threat to a vessel or an offshore structure and that are appropriately small to escape a detection and management system.

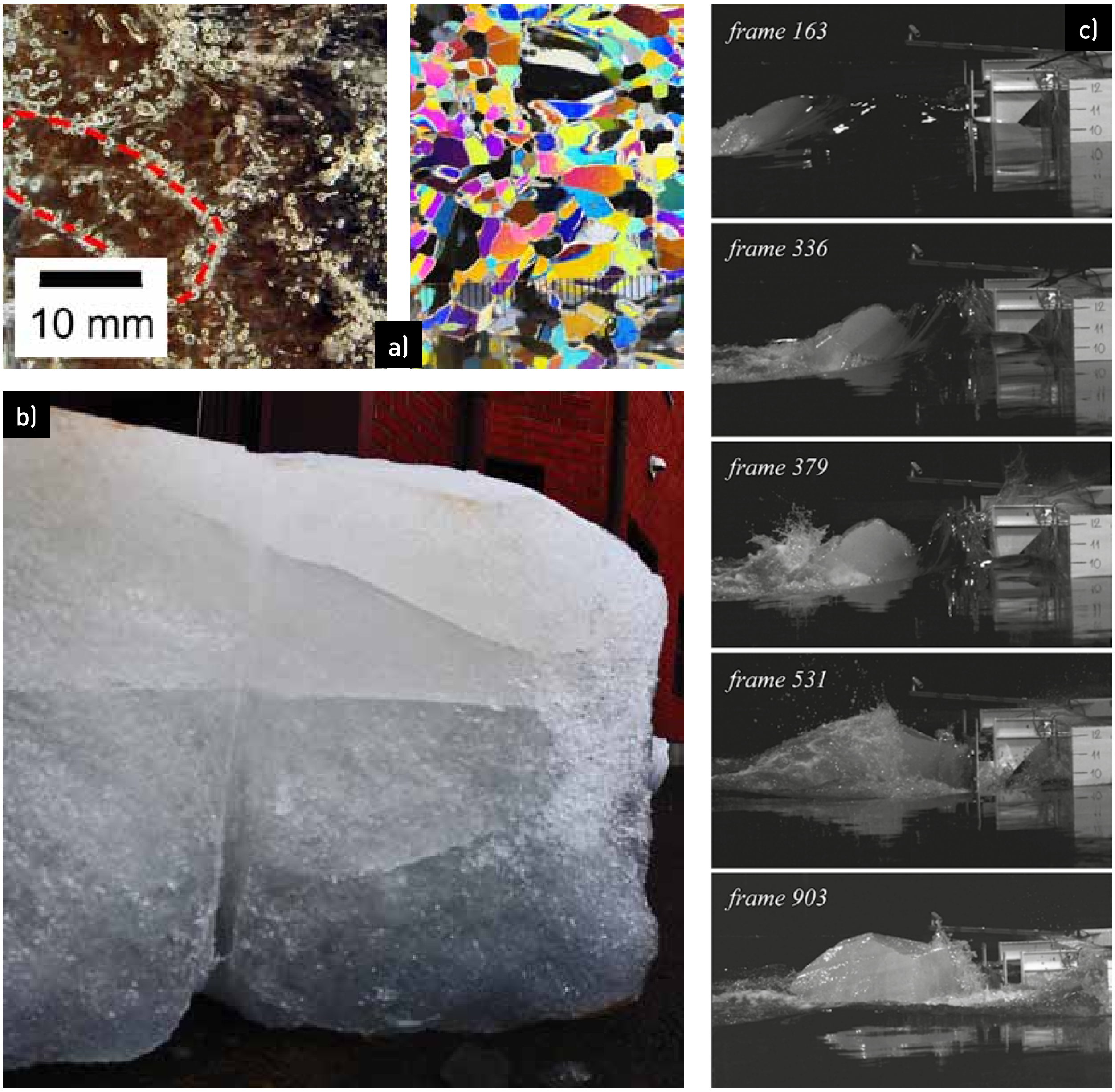


Fig. 16. a) – ice structure; b) – ice damage zone; c) – sequence of images extracted from high-speed video recordings showing a typical impact test.

The tests were conducted in the ice basin at Aalto University, Finland, where ice masses were towed into a moored structure with a deformable panel mounted in the impact zone.

Both the ice and the structure experienced notable deformations during impact. The characteristics of the ice impact zone and panel deformations compared fairly well with the data from full-scale observations (see Fig. 17).

Fig. 17. Damage to the steel structure caused by the ice: a) at full-scale (S. Hänninen), b) in laboratory.

We believe these experiments are the first to focus exclusively on the coupled damage behaviour of both ice and steel, with our findings demonstrating realistic damage to the steel plates. However, more damage to the steel structures, including stiffening systems, would further enhance the knowledge of this complex coupled deformation process. Based on the knowledge learned during the Aalto experiments, new experiments are planned in 2013/2014 with a focus on obtaining more data on ice-steel interactions producing larger deformations than achieved in the Aalto experiments.

Friction of Sea Ice on Sea Ice

Knowledge of ice friction plays an important role in a number of Arctic engineering applications. For instance, it affects the designs of icebreakers and their performance in ice and it is necessary for the calculation of ice loads on sloping offshore structure constructions.

Additionally, friction is a fundamental process during the brittle compressive deformation of cold ice. Friction is the largest sink of energy during the rafting and ridging processes of sea ice. Therefore, the results of the numerical simulations describing these processes are significantly affected by the choice of the input for the friction coefficient.

"During my field study with first-year ice (Barents Sea and fjords at Spitsbergen) and second-year ice (Northeast Greenland), I did tests where ice blocks were slid along tracks using a pulling mechanism, a linear actuator," says Sergiy Sukhorukov, a SAMCoT doctoral student.

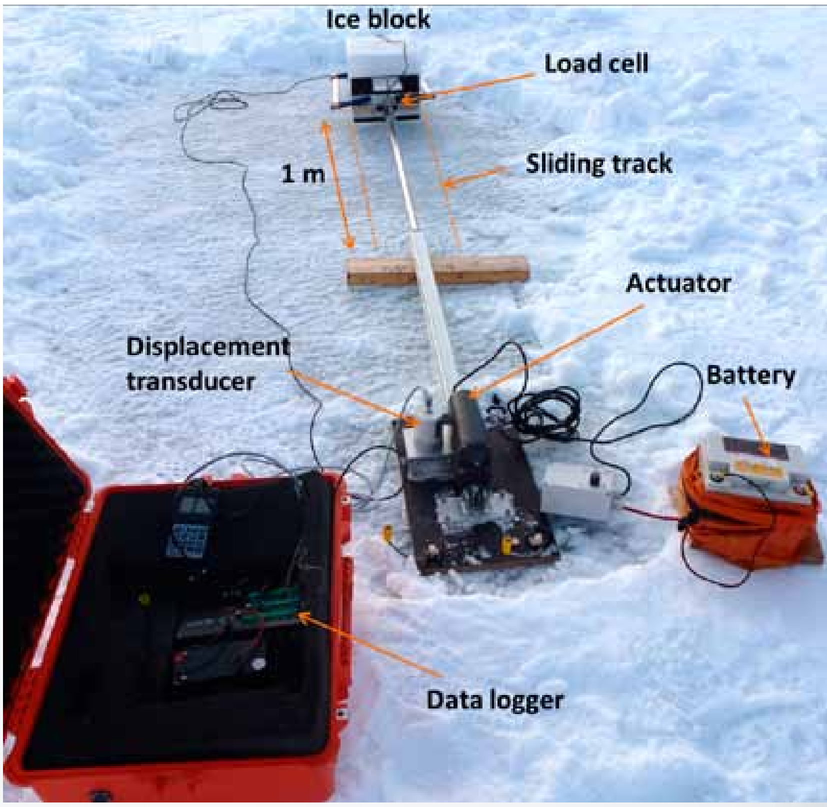


Fig. 18. Experiment set-up for friction tests.

The effects of the sliding velocity (6 mm/s to 105 mm/s), air temperatures (-2°C to -20°C), normal load (300 N to 2,000 N), presence of sea water in the interface, and ice grain orientation with respect to the sliding direction on the friction coefficient were investigated.

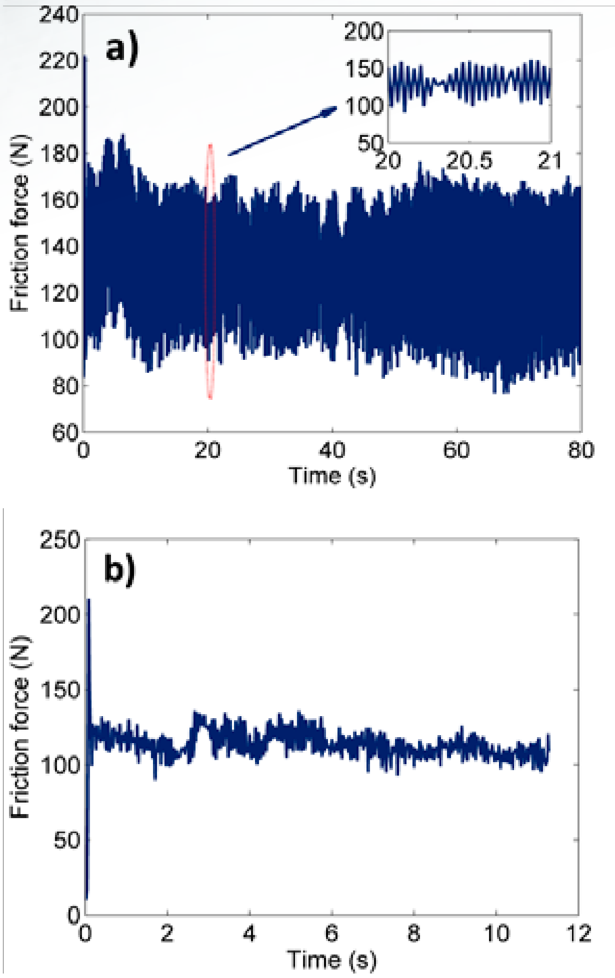


Fig. 19. Temporal variations of the frictional force in stick-slip regime a) and steady sliding regime b).
The test parameters:
a) the normal force was 242.4 N, the apparent contact area Sa = 0.101 m², the sliding velocity v = 5.4 mm/s, Tair = -10.6°C, Ttrack = -5.5°C, and Tice block = -4.4°C;
b) the normal force was Fn = 276.8 N, Sa = 0.0714 m², v = 87.7 mm/s, Tair = -2°C, Ttrack=-2.9°C, and Tice block=-2.3°C.

"The major findings from the tests are as follows", says Sukhorukov:

- Ice surface roughness is the key parameter that determines the value of the friction coefficient. Repeated sliding over the same track led to surface polishing and decreased the kinetic friction coefficient from 0.48 to 0.05.
- The friction coefficient was found to be independent of the sliding velocity (6 mm/s to 105 mm/s) when sliding occurs between natural ice surfaces. As the contacting surfaces become smoother, the kinetic friction coefficient started to depend on the velocity, as predicted by existing ice friction models, i.e. $\mu \sim v^{-0.5}$.
- The effect of the air temperature on the kinetic friction coefficient was not detected. Both very high (~0.5) and low (~0.05) kinetic friction coefficients were obtained in the tests performed at high (-2°C) and low (-20°C) air temperatures. Significant scatter in the data was observed because of the difference in the ice surface roughness.
- The frictional force (both static and dynamic) was linearly related to the normal load.
- The presence of sea water in the sliding interface has very little effect on the static and kinetic friction coefficients.

Ice Actions on a Floating Jetty

Floating structures may also be used close to shore. In 2008, the Port of Longyearbyen decided to increase their harbour facilities by launching a Floating Jetty (Fig. 20). The jetty consists of two sections, each 20×5 m, linked together in such a way that the jetty is 42 m long. Basically 30 mm thick PE100 is used as material in the jetty.

Fig. 20. Location of the floating jetty and direction of sea current and ice drift.

Fig. 21. One section of the floating jetty.

Fig. 22. Deployment of two load gauges on the mooring (31.10.2012).

Fig. 21 depicts one section of the jetty that is moored by 12 mooring lines.

In the late autumn of 2012, Professor Aleksey Marchenko and master students at UNIS deployed two load gauges to monitor the actions on the jetty and in this way provide useful full-scale data from ice-structure interaction (Fig. 22).

Another part of the study was to gain long-term experience and assess the durability of such a floating structure in the prevailing harsh environment (Fig. 23).

Fig. 23. The floating jetty in heavy first-year ice, May 2011.

Ice Management and Design Philosophy

The expansion of the petroleum industry towards the Arctic offshore presents new challenges. The search for hydrocarbons in the deep Arctic waters requires the use of drill ships and floating production units. Typically, these units require protection by using ice management, i.e., the sum of all activities where the objective is to reduce or avoid actions from any kind of ice features. Here, the research in SAMCoT is directed toward establishing a design philosophy for floating structures protected by ice management, which ensures the fulfillment of standard design requirements without being overly conservative.

Alternative Methods for Quantifying the Safety of Offshore Structures Protected by Ice Management

Establishing sound design concepts for offshore structures as development moves further north requires innovation. Existing concepts need adaptation and enhancement due to the greater uncertainties and the harsher environment of the Arctic and subarctic regions. Additional measures, such as ice management, may play a crucial role in the design of Arctic offshore structures. For instance, there are historical examples in which ice management has been an enabling technology and without which exploration drillings could not have been possible. The other concern of oil companies is how to reduce the cost of Arctic offshore developments and how to make more projects feasible as more resources are being discovered further north. Selecting an optimal concept defeating all the environmental, technological and cost barriers is not a trivial exercise.
The aim of Farzad Farid-Afshin's PhD study is to explore different methods of including ice management in a systematic manner in the design of Arctic offshore structures and to potentially prepare the basis for a mathematical tool assisting the concept selection. The main focus is on the production phase, which typically lasts for many years (e.g. 25 years), which makes it very different from short-term exploratory drilling and shallow coring activities.

In this context, linking a marine operation to a structural design is a unique yet a challenging task never tried before. What matters is to study the elements of this system, which includes both the structure and the operation under the large uncertainties involved. When it comes to the overall safety of the design concept, risks and failures involved in both the structural system and the marine operation should be evaluated. Various factors, including technical and human factors, can influence the total safety and thus illustrate a complex picture.

In this respect, alternative methods will be investigated. In particular, the investigation will explore the use of (i) probabilistic analyses, which include conventional reliability analyses, and (ii) non-probabilistic analyses, which may include formal measures of possibility, plausibility, belief, and ignorance (depending on method) and other potential approaches.

The first set of methods represents an established approach in offshore engineering, but their application to design assessments taking into account ice management operations is a subject of ongoing research, and further work is needed. The second set of methods represents alternative formal methods for addressing uncertainty, and it is of interest to explore the use of such non-probabilistic methods within the context of design of Arctic offshore structures supported by ice management operations.

Since Farid-Afshin began his PhD work in August 2012, he has studied the topic through taking relevant courses, shaped the initial scope of his research through meetings with industry professionals, and conducted a literature review. This work resulted in two project reports, which serve as the basis for the core of his research, theoretical studies of the alternative methods of uncertainty quantification.

In addition, he has initiated a study to address the failure probability of a particular ice management operation as a result of environmental uncertainties and ship manoeuvrability restrictions. Failure in this context relates to the possibility of the protected vessel (PV) or offshore installation to drift away and fall off the managed ice channel or to larger outgoing ice floe sizes than anticipated. Farid-Afshin is developing a toolbox to address these concerns. The developed toolbox builds upon superposed kinematics of icebreakers and a global ice plate or floes at each discretized time increment during the total duration of an operation. However, some effort is also put into understanding and deriving the physics of the problem in closed form rather than sticking to the typically more convenient numerical solution (see Fig. 24 below where trajectory and ice channel functions ψ and Φ as illustrated are derived under varying ice drift heading and speeds, linear and nonlinear change). The relationship for estimating the maximum outgoing floe size of a particular ice management operation is also deducted. The toolbox is under progress and additional features are being incorporated.

He is additionally planning to implement a structural analysis toolbox to evaluate the response of moored floaters in level and broken ice. This will serve as a vehicle to investigate various mathematical methods of uncertainty quantification.

Modelling of Iceberg Drift and Towing

In the Arctic Ocean, collisions between and iceberg and an offshore structure can produce extreme loads on the impacted structure. To estimate probability of impact by an iceberg, an accurate forecast of the iceberg's drift is a prerequisite. Once a collision is designated unavoidable, operators must then decide either to disconnect and temporarily relocate the structure or to apply physical iceberg management, e.g., iceberg towing.

Considering iceberg drift models are normally highly sensitive to weather forecasts and sea current, the simulation results are only as reliable as the weather forecasts themselves. The computational time is also important, as an iceberg can travel up to 2.7 km per hour. This relatively rapid drift means that the calculation procedures to determine the path of the iceberg must be fast enough to make a reliable prediction within a limited time.

Iceberg drift involves many different physical processes that make drift simulation a complex task. Both mechanical and thermodynamic effects influence not only the iceberg itself but also the ice floes and water around it. Iceberg drift simulation is usually based on equation of motion, which includes several terms corresponding to different forces acting on an iceberg simultaneously. Such models treat an iceberg as a point mass with zero moment of inertia but having surface area as a numerical property. This simplification is useful in prediction of an iceberg drift in open water under

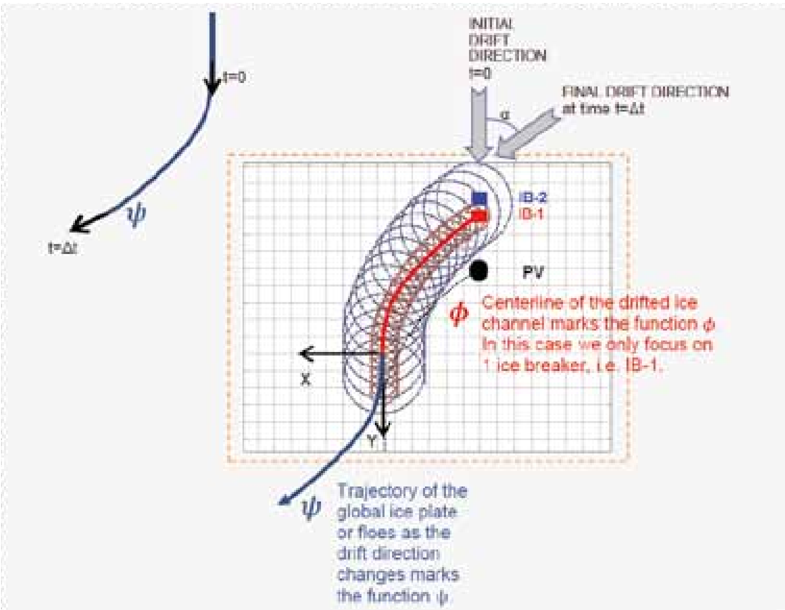


Fig. 24. Schematic of the trajectory of the global drifting ice plate or floes (ψ), together with the broken ice management channel (ϕ). The exterior rectangle illustrates the global boundary of the ice plate. The dashed orange area illustrates the region where the protected vessel is located and the ice management operation is established.

the sea current drag force, wind drag force, Coriolis force and wave force.

To model iceberg drift in broken ice, SAMCoT PhD candidates Renat Yulmetov and (others) are introducing additional terms related to ice force acting on an iceberg. These complex calculation procedures require more sophisticated models that will incorporate interaction between ice floes and an iceberg. Ice floes and icebergs will be treated as distinct rigid bodies having their own shape and moments of inertia. The interaction between them is integrated for each time step in the model. By analysing the positions of all ice floes, we should be able to apply special algorithms to determine which of the icebergs are on a collision course with a structure. To those that are predicted to collide we apply additional contact forces, depending on their rheology, relative velocity and positions (Fig. 25).

Contact detection is performed by a special research module, which is an open source project. Contact integration is performed separately by researchers at Matlab. After calculating contact forces on the iceberg, we apply that data together with other force data to calculate iceberg motion for every time step.

Full-scale data is very important for the current study to validate the numerical models. In this regard, the SAMCoT specialized research team has deployed several Ice Tracking Drifters on ice floes and icebergs in the Barents and Greenland seas (Fig. 26). The trackers determine and save their GPS position six times per hour and then send the coordinates through the Iridium network for analysis. The drift analysis predicts trajectories, velocities, curvature of trajectory, and

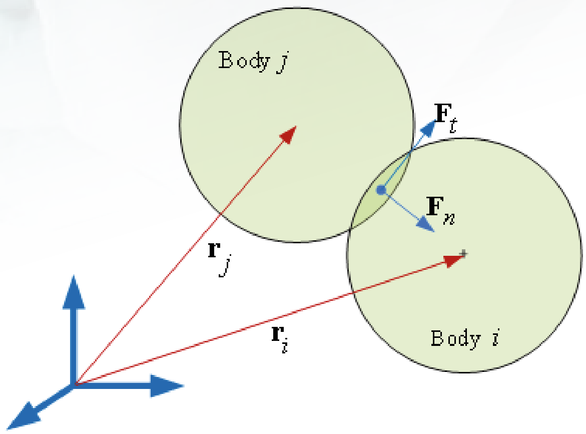
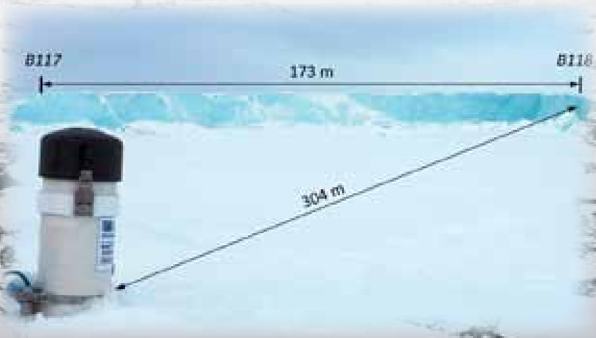


Fig. 25. Schematic presentation of the contact forces between an iceberg and a circular ice floe.

drift velocity spectrum of the icebergs hosting the Ice Tracking Drifters.

Two trackers were deployed on one iceberg and an additional tracker was deployed on an adjacent ice floe to compare the drift of the iceberg and the sea ice. We analyzed the rotation of the iceberg and the relative motion of the broken ice field. The relative motion was proven to be very slow, having relative drift speed. The relative motion occurred repulsively, during changes in the drag force direction.

Fig. 26. Icebergs in the waters northeast of Greenland during the Oden cruise 2012: Left) iceberg drifting in broken ice; Right) Deployment of trackers; two trackrs (B117, B118) were deployed 173 m apart on a single iceberg and tracker B119 was deployed on an adjacent ice floe 304 m away from B118.



Ice-Induced Vibrations

Bottom founded offshore structures occasionally experience sustained ice-induced vibrations. This vibration causes operational problems and may be a risk for structural safety.

These ice-induced vibrations are often characterized into three regimes, depending on the incoming ice velocity (for more information, see the recent ISO standard Arctic Offshore Structures): a) Intermittent crushing taking place at the lowest ice velocities; b) Frequency lock-in for intermediate ice velocities and; c) Continuous brittle crushing occurring when the ice velocity is high.

Insufficient experimental data exists, both full-scale and laboratory-scale, to explain the physical reasons for these vibrations. As the phenomena are not well understood, none of the present numerical models capture the measured forces and accelerations from experiments.

In order to make reliable predictions of ice-induced vibrations, a numerical model based on experimental data needs to be developed. In August 2011, a series of experiments were carried out in the large ice basin at the Hamburg Ship Model Basin (HSVA) through the EU HYDRLAB-IV facilities. In 2012, the SAMCoT specialized research team analysed this data and has continued the development of a numerical model.

An international ice load survey carried out by Timco and Croasdale (2006) shows that there is considerable uncertainty in prediction of ice loads on structures. Laboratory experiments are one of the ways that we can control to some extent both structure and ice conditions. Different laboratory studies on compliant structures use different techniques and measurement setups to derive the ice forces.

Many of the test setups use direct measurement of the global ice force with load cells and dynamometers, while others use indirect calculations of force from structural response. The dynamometers give easy access to forces, still the added mass from water and model mass have to be dealt with. Load cells built into the indentor, together with an accelerometer, are possible in the laboratory, but scarcely applicable on full-scale offshore structures.

Inverse force identification is a research topic adopted into structural dynamics and applied on systems where the forces are difficult to measure directly. For civil engineering purposes, bridges, piers, lighthouses and offshore structures interacting with ice are all examples where the ice force is difficult to quantify. In ice, available works on inverse force and system identification is limited and restricted to deterministic frequency domain methods.

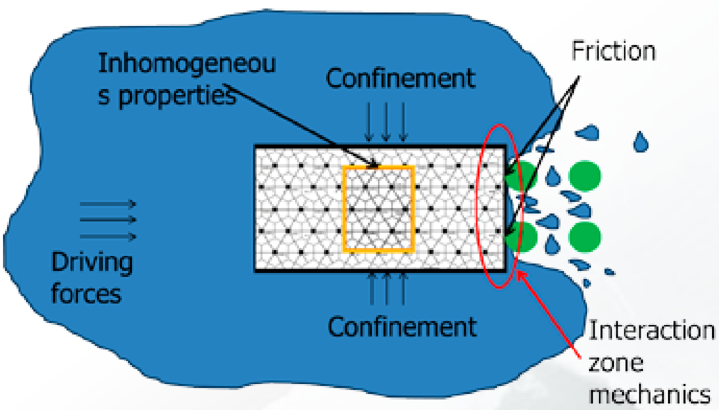
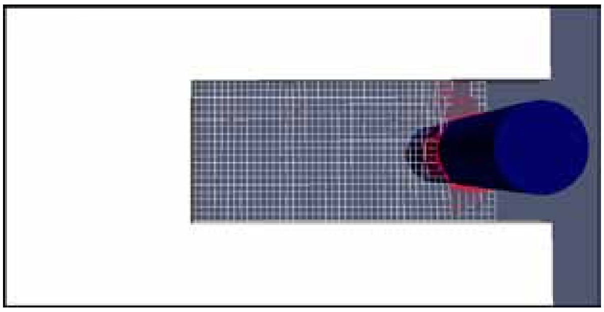


Fig. 27. Sketch of the numerical model. In green, a four-legged offshore structure is shown. In blue, the ice sheet is divided into a lattice near the structure and into a continuum at a distance from the structure. Important aspects of the interaction are characterised as: confinement, driving force, inhomogeneous ice property, friction at the ice-structure interface and interaction zone mechanics.

Numerical Modelling of Ice-Induced Vibrations

After careful analysis of the model data, SAMCoT WP3 was chosen to develop a new numerical model for the prediction of dynamic ice-structure interaction.

The aim of the project, initiated in 2012, was to incorporate several phenomena in a 2D lattice model (Fig. 27). The ice near the structure is divided in several nodes, which take into account the natural inhomogeneous character of ice. These nodes incorporate the driving forces, confinement and friction at the ice-structure interface and the interaction zone to predictively model these regimes of an ice-structure interaction. These good expectations are based on a 1D development and confirmed that the chosen approach can lead to a model capable of predicting all three regimes (Fig. 28).



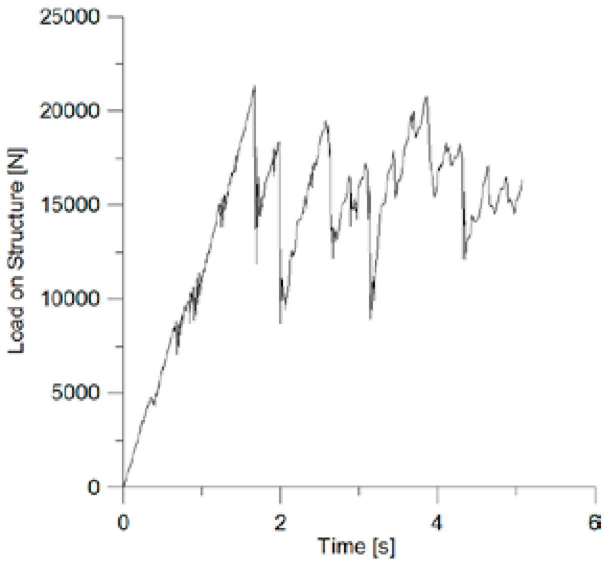


Fig. 28. A 1D numerical model has been developed to simulate a dynamic ice-structure interaction. Left: A graphical representation of the model, where a lattice grid of ice nodes interacts with a cylindrical structure. The red areas represent failed ice zones. Right: A typical result obtained for the ice load in the intermittent crushing regime. The characteristic saw-tooth pattern is clearly observed.

Fig. 29. Illustration of the analogies among different fields. Left: A typical vortex shedding pattern when a flow moves around a cylindrical structure. The oscillating forces interact with the structure, causing it to start oscillating. Right: An ice floe moving around an offshore structure known to give rise to interaction and oscillation of the structure. Could there be some similarity between the two? And what can we learn from the experience in the field of VIV?

VIV Analogy

In the search for a physical explanation of the observed phenomena that occurs during ice-structure interaction, analogies with different fields of dynamic flow-structure interaction have been pursued. In 2012, a comparison of the similarity between vortex-induced-vibrations (VIV), a phenomenon well known in the field of fluid-structure interaction, and ice-induced vibrations (Fig. 29) was completed. In fluid-structure interaction, steady-state vibrations occur at a specific range of flow velocities for cylindrical submerged pipes. When ice interacts with a structure, an interaction occurs that seems to have characteristics similar to the range of velocities during which frequency lock-in is obtained.

In the field of VIV, use has been made of forced vibration experiments to obtain characteristic information about interaction forces. During the large ice basin tests at HSVA in 2011, forced vibration tests were applied for the first time for ice-structure interaction (Fig. 30).

The results of these tests revealed new information about the interaction process and largely contributed to increasing the knowledge on how these types of tests and the analogies with the VIV process could be used to decipher the ice induced vibrations phenomenon. In 2013, the team will continue to follow this path with a proposal for a new test campaign.

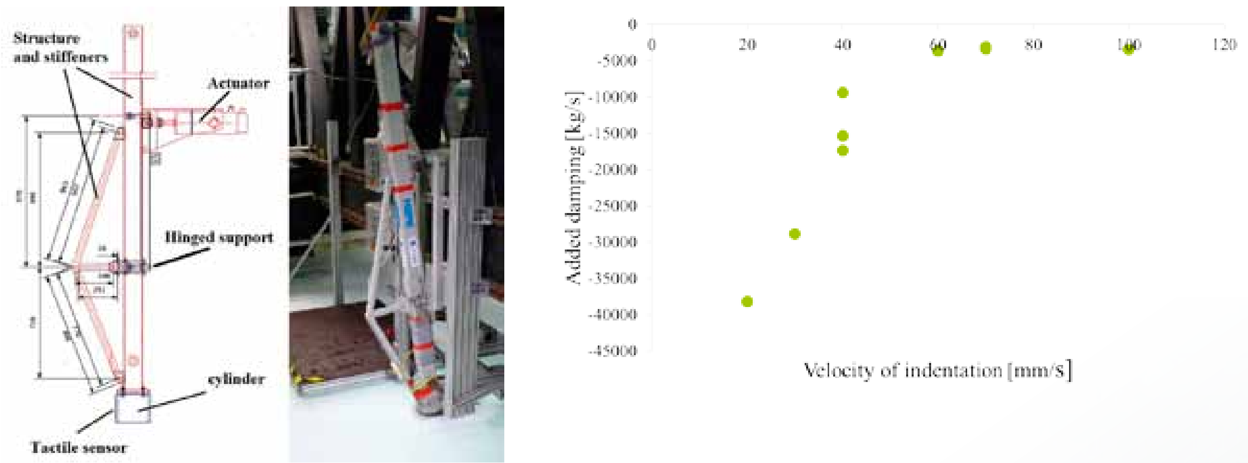


Fig. 30. Left: The test setup used for the novel forced vibration experiments at HSVA. An actuator was used to force the test structure into a harmonic motion. While being pushed through the ice, ice forces were measured. Results will be used in further analysis. Right: Example of new results obtained with the test. The added damping of the ice load was calculated, showing to be negative over a range of velocities. This result could contain the explanation of the frequency lock-in occurrence. More data points are needed to draw further conclusions.

Structural and Ice Load Identification

The main activity in this topic was to study the velocity effects of ice-induced vibrations based on the data provided from the DIIV test campaign. Fig. 31 shows the set-up. The ice force was not measured directly and a main challenge in the analysis of the DIIV tests is to identify the forces.

The ice force and response of the structure changed with increasing velocity. Fig. 32 shows detailed plotting of how the derived ice force developed and the structure's response in one of the tests. At certain velocities, the forces are significantly increased. We can also observe that the structural response frequencies change. The horizontal red lines indicate the natural frequencies of the structure, so that any indication of vibrations at those frequencies could be investigated more thoroughly.

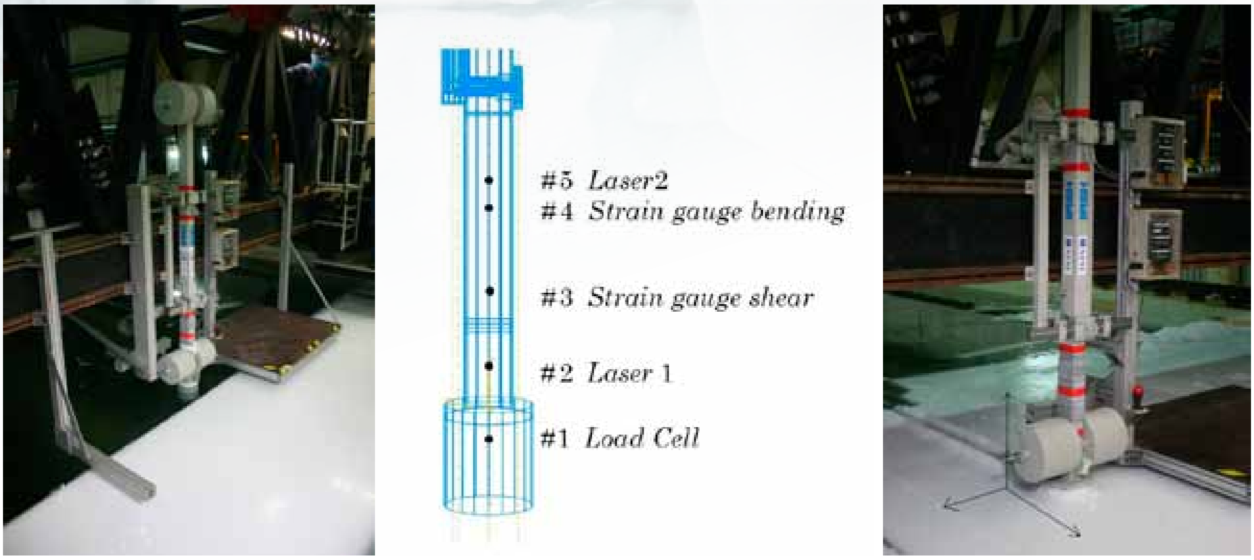
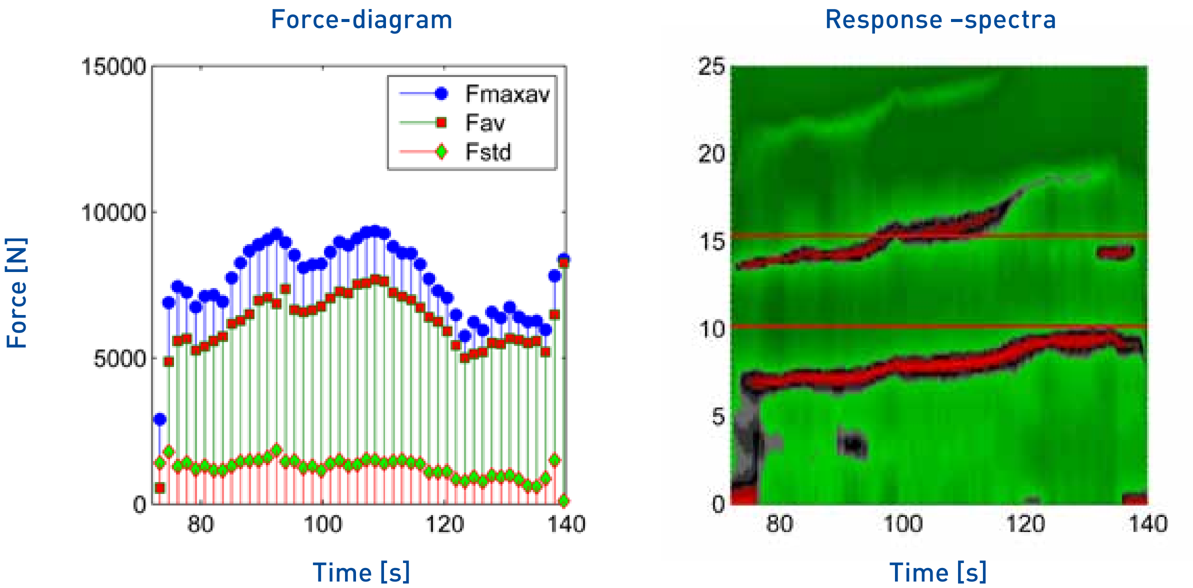


Fig. 31. The multi-degree of freedom structure from the DIIV test campaign, with adjustable masses and stiffness of the test rig, enabled the researchers to capture a range of natural frequencies to be configured. Vibrations were measured by the sensors deployed on the lower part of the structure.



Ice forces identified inversely from measured response. The velocity was gradually increased for both tests

Fig. 32. The ice force and response of the structure change with increasing velocity. At certain velocities, the forces are severely increased. Researchers also observed that the structural response frequencies change. The horizontal red lines indicate the natural frequencies of the structure, so that any indication of vibrations at those frequencies could be investigated more thoroughly.

Coastal Technology

In 2012, Arctic coast erosion rates were measured and erosion mechanisms investigated at selected sites on Svalbard, including Vestpynten, Fredheim, Damesbukta and Hiorthamn. Also two field sites in northwestern Russia, Baydaratskaya Bay and Pesyakov Island, were included in the monitoring programme.

The aim of our selection of these Arctic coast test sites is to cover different types of conditions and erosion mechanisms. Just as importantly, the investigation of coastal erosion on Svalbard is relevant not only for this group of islands, but could be considered model experimental sites based on the ease of accessibility and proximity to research infrastructure.

Annual erosion rates have been estimated at several sites on Svalbard based mainly on reviews of annual Differential Global Positioning Satellite (DGPS) measurements and aerial photography. Soil properties have been investigated by installation of onshore data collectors, including piezometers and thermistor strings. Core sampling with a rig has been tested in Vestpynten, close to Longyearbyen, in relation to testing of equipment and installation of the data collectors, while sediment sampling by hand have been preferred at protected sites, such as Fredheim. Undisturbed frozen core samples were collected at Baydaratskaya and underwent laboratory testing. The collected data has been processed for further research.

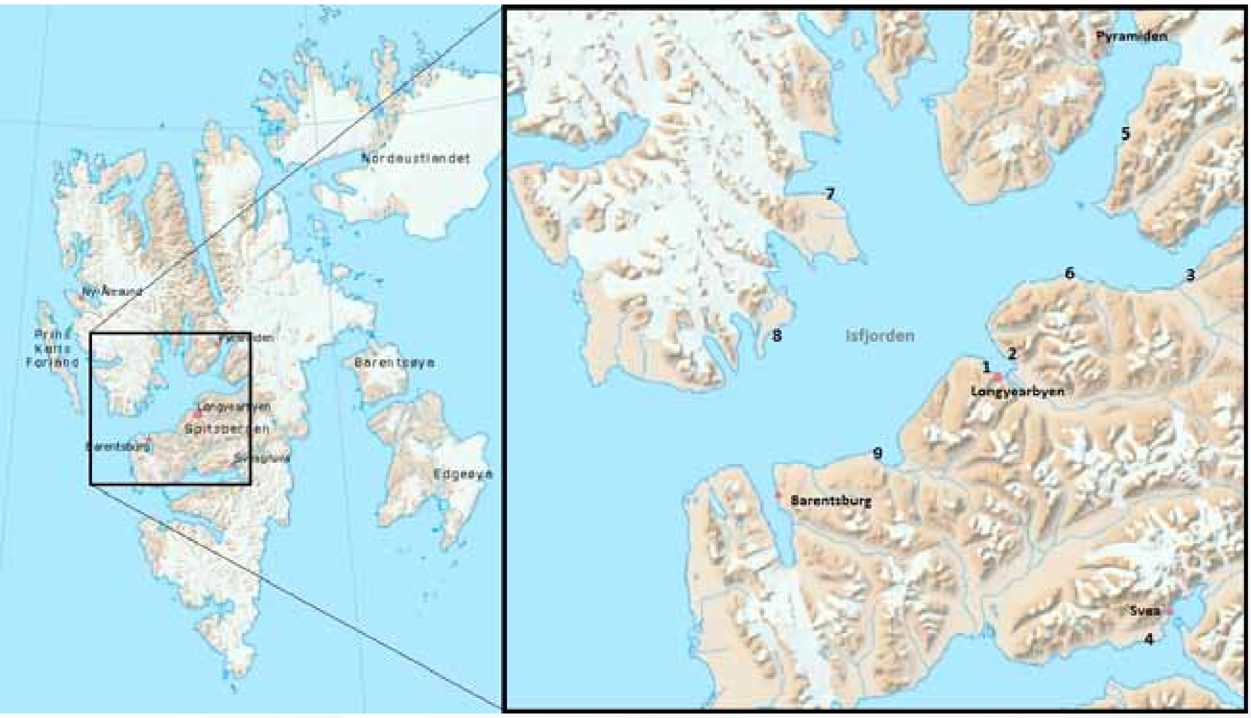


Fig. 33. Investigated sites in 2012 in central Spitsbergen, Svalbard: 1) Vestpynten, 2) Hiorthamn, 3) Fredheim, 4) Damesbukta and Barryneset, Svea, 5) Kapp Ekholm, 6) Diabasodden, 7) Bohemanflya, 8) Flytangen, and 9) Kapp Laila.

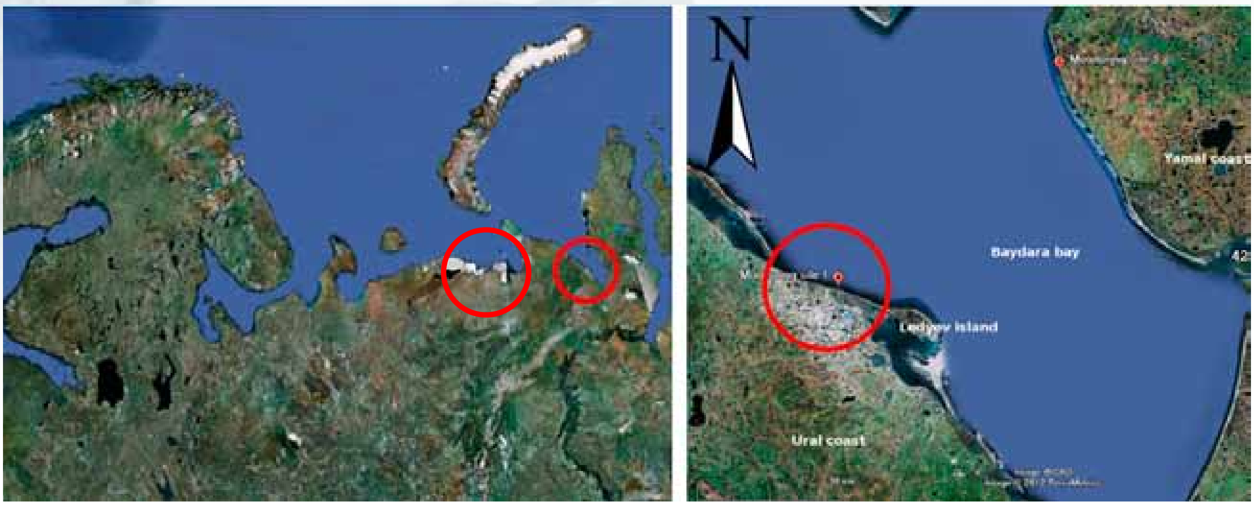


Fig. 34. Maps indicating test sites at Pesyakov and in Baydaratskaya Bay (source: Google maps).

Fig. 35. Photos shot with a time lapse digital camera at Vestpynten. The photo to the left was taken on 23 May 2012, while the photo to the right was taken 12 July 2012. The orange line represents the edge line position in July (from the work of PhD candidate Emilie Guegan).

Vestpynten is located on the south side in the outer part of the Adventfjord, close to the Longyearbyen airport and just 7 km away from UNIS. Based on preliminary studies using aerial photos, an approximation of the erosion rate was estimated to be 0.5 m per year at this particular part of the coastline. It is now instrumented with six thermistor strings at a depth of 10 m. They are placed along a profile perpendicular to the coastline. The temperature regime in the area is well documented. There are also shallow thermistors in the bluff to closer investigate the thermal processes of the degrading permafrost. The soil conditions have also been evaluated based on grain size distribution tests from bag samples collected with an auger during the spring of 2012.

Thermistors were placed in steel tubes, which were sealed on top to prevent thermal influence from internal convection and precipitation. Fig. 36 shows temperature data from one point in Vestpynten. Studies of how snowdrift in the coastal zone affects the temperature regime in the coastal permafrost, and thus affects erosion rates are ongoing in Emilie Guegan's PhD study.

Grain size distribution curves indicate that the soil consists of a well-graded material with particles between gravel and silt. This grain size distribution might deviate from the real situation due to some crushing of rocks during the sampling. The material is very dry with a water content ranging between 9.6% and 25%. Fredheim is situated in the outlet of the Sassendalen valley in the southern part of the Temple fjord, approximately 33 km northeast of Longyearbyen. The annual erosion rates in Fredheim in the period 2010-2012 has been estimated based on DGPS data and to some degree

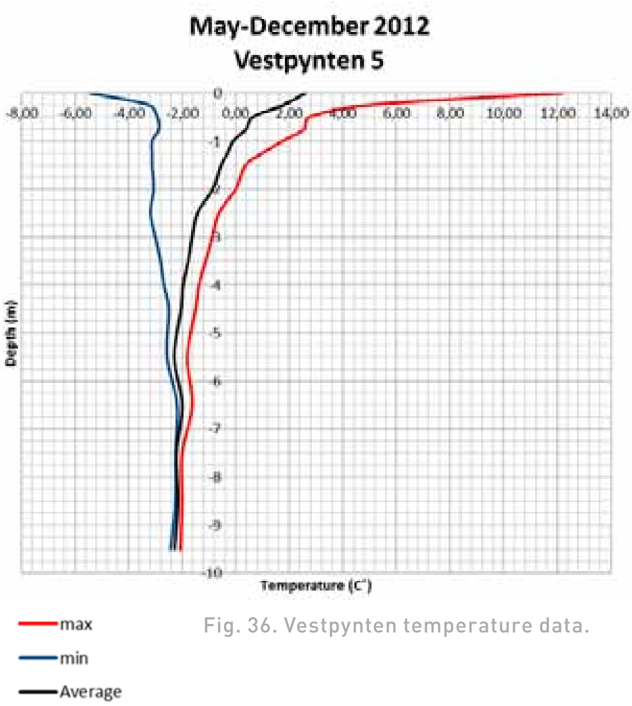


Fig. 36. Vestpynten temperature data.

Fig. 37. Stratification observed in the front of the bluff at Vestpynten.

Fig. 38. Presentation of DGPS measurements, 2010, 2011 and 2012 (Tangen and Justad, 2012).

Fig. 39. Zone with water channels and leached soil

by manual measurements. The retreats of the bluff in Fredheim vary widely from season to season in some parts, while the retreat has been steady in other areas.

The coastal retreat at the site has been monitored (not continuously) since 1986 and the retreat rate has varied from year to year. Erosion rates are calculated based on the manual measurements from three different studies. In 2012, the expected lifetime for the houses threatened by erosion hazard was estimated based on the calculated erosion rates on the coastal line.

Between 2011 and 2012, the erosion rate was approximately 30 cm. The study shows that there are variations in erosion rates between the erosion edge and the individual houses. This can largely address the erosion mechanisms of Fredheim. Previously, it was believed that the erosion was strongly linked to wave erosion, but the recent findings indicate that this might not be the case. Waves are a contributing factor, essentially as a carrier of already eroded soils. The main erosion process is melting and sliding of permafrost soil blended with local water (Fig. 39). In these channels, fine grains are washed out by the local water, causing the bluff and coastline to become more unstable in this area. This process also contributes to instability in the area between channels due to reduced lateral support.

The erosion rates vary significantly from year to year. This variation can be seen in comparisons related to air temperature, precipitation and the length of the ice-free season, which changes from year to year. Regarding annual variations, erosion rates have only been measured from one year to the next during 2010-2011 and 2011-2012. For these measurements, there is a change in the erosion rate when the erosion rate in

2012, is only 1/7th of the rate measured in 2011. These changes in erosion rates are interesting in relation to the average summer temperature of Spitsbergen. In the summer of 2012, the air temperature was lower than the average summer temperature in 2011. Observations related to the presence of fjord ice between the summer 2011 and summer 2012 show extremely long periods of ice-free sea, thereby leading to increased erosion activity at Fredheim.

The work related to the Svalbard field sites has been done by Jomar Finseth, Magne Wold, Håkon Tangen, Maj Gøril Bæverfjord and Arne Instanes from SINTEF, Emilie Guegan and Lars Grande from NTNU and Anatoly Sinitsyn, Evangeline Sessford and David Wrangborg from UNIS.

The Baydaratskaya Bay field site was established by scientific SAMCoT partner Moscow State University (MSU) in June 2012 as joint activity with SINTEF. The field work was carried out with the following participants from MSU: Prof. Vanda Khilimonyuk, Prof. Sergey Buldovich, PhD candidate Daria Aleksyutina, PhD candidate Alexey Usov, Vladislav Isaev and Sergey Grebenkin. The 2012 study of Baydaratskaya included:

- Manual drilling of three boreholes, sampling of frozen soils (undisturbed cores) and installation of the thermistors strings
- Profiles for erosion rate monitoring
- Thermal conductivity measurements in the erosion slope
- Laboratory tests of the physical properties of soils (water content, density, grain size) both thawed and frozen (performed in Moscow).

The field investigation shows that the abrasion (thermo abrasion) mechanism is only a secondary factor of the terrace bench destruction. Most of the destruction seems to be due to thermo denudation and gravitational processes. In 2012, PhD candidate Daria Aleksuytina studied the thermal properties of the Baydaratskaya permafrost soils, while PhD candidate Aleksey Usov began studying the mechanical properties of thawing permafrost soils. (Further details and visual aids under Arctic Coastal Surveys on pages 49-51).

Understanding permafrost soil behaviour in an engineering perspective requires in-situ testing and also laboratory testing on high quality soil samples. This requires development of equipment able to perform such sampling. For permafrost soil sampling on Spitsbergen the SINTEF permafrost corers are used. The corers consist of a cutting bit attached to a thick-walled, hollow-core collecting auger, much like a modified CRREL core barrel. This type of corer has proven to be efficient in collecting cores in fine grained frozen soils. The permafrost corers ensure penetration in most materials due to the use of poly-crystalline diamond composite (PCD) bit inserts. These inserts are very durable and can even cut cores in rock. These coring barrels are used without drilling fluids, a big advantage when operating in cold climates where environmentally unfriendly additives have to be used in order to prevent the liquids from freezing. Frozen hoses and pumps become a major concern when working in below-zero temperatures.

Fig. 40. The SINTEF Permafrost Corer.

In the field work at Pesyakov and Varandey, coastal studies were performed as a survey together with the State Oceanographic Institute (SOI, Moscow) where SAMCoT was represented by Post Doc Anatoly Sinitsyn from UNIS. The summer survey lasted three weeks, wherein approximately 50 erosion rate profiles were

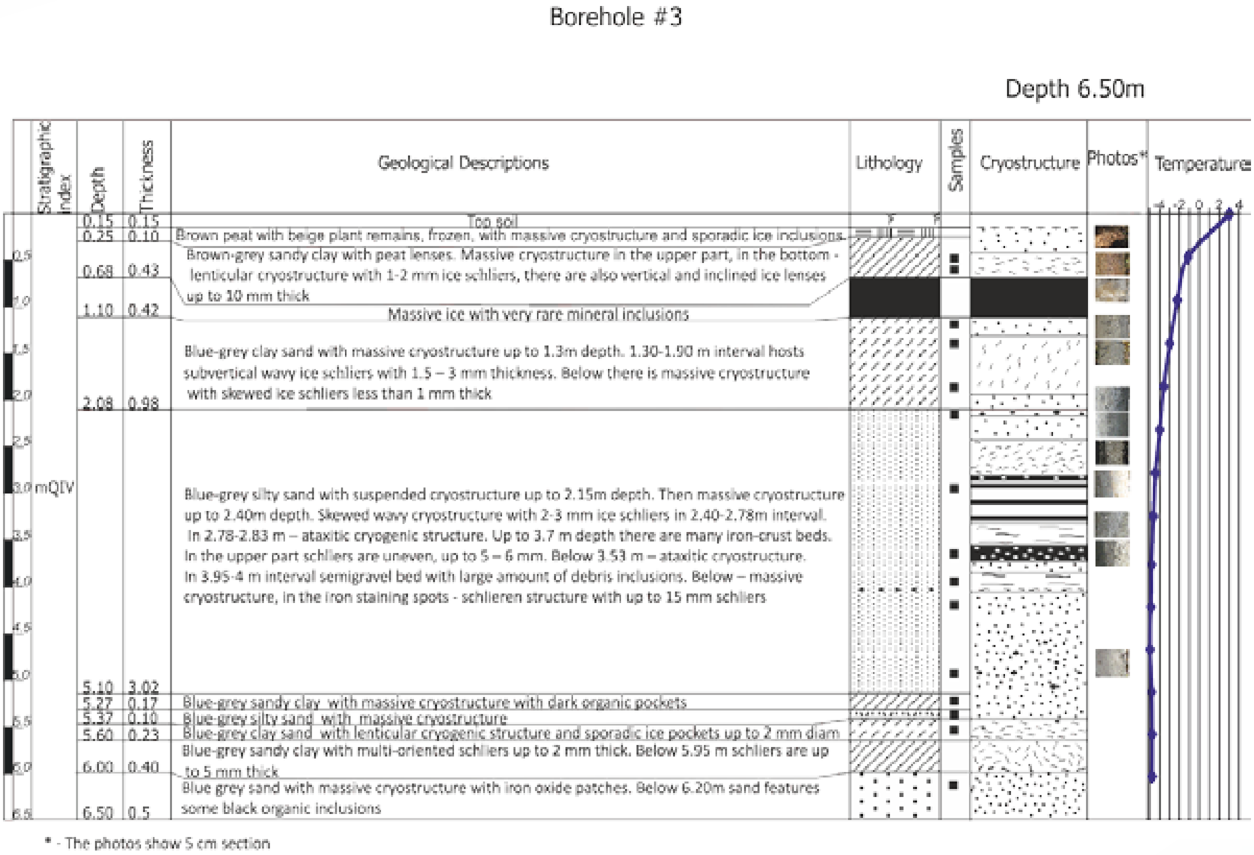


Fig. 41. Profile of Baydaratskaya Bay

established along the coastline and thermistors were installed to continuously log the soil temperature. Manual drillings were made to obtain soil samples for index testing. (Further details and visual aids under Arctic Coastal Surveys on pages 49-51).

How to Make Sustainable Erosion Protection Systems in the Arctic?

Considering the critical geotechnical conditions of some Arctic coastal and riverside areas and the rising attention on the impact of climate change in vulnerable regions, the need for innovative, sustainable and environmentally friendly construction methods for erosion protection is becoming an issue of increasing interest. Construction solutions become an even more challenging topic when considering erosion protection in geographical areas where no armor rocks or concrete blocks are easily available. Soil improvement and innovative materials used together with local soils are therefore a promising solution. For instance, geosynthetic tubes and bags using local soil as filling material have been developed and are now used in some test projects in Svea (Fig. 42). The behaviour and durability of these structures were monitored continuously during 2012.

Fig. 42. Erosion protection using geosynthetic containers filled with local soil.

SAMCoT Research Structure

SAMCoT's research groups are divided into six different Work Packages (WPs):
WP1 – Data Collection and Process Modelling;
WP2 – Material Modelling;
WP3 – Fixed Structures in Ice;
WP4 – Floating Structures in Ice;
WP5 – Ice Management and Design Philosophy;
WP6 – Coastal Technology.

SAMCoT CMG

- Aleksey Marchenko (UNIS)
- Arnstein Watn (SINTEF)
- Knut Høyland (NTNU)
- Maj Gøril Glåmen Bæverfjord (SINTEF)
- Mª Azucena Gutierrez Glez. (NTNU)
- Nataly Marchenko (UNIS)
- Raed Khalil Lubbad (NTNU)
- Sveinung Løset (NTNU)

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

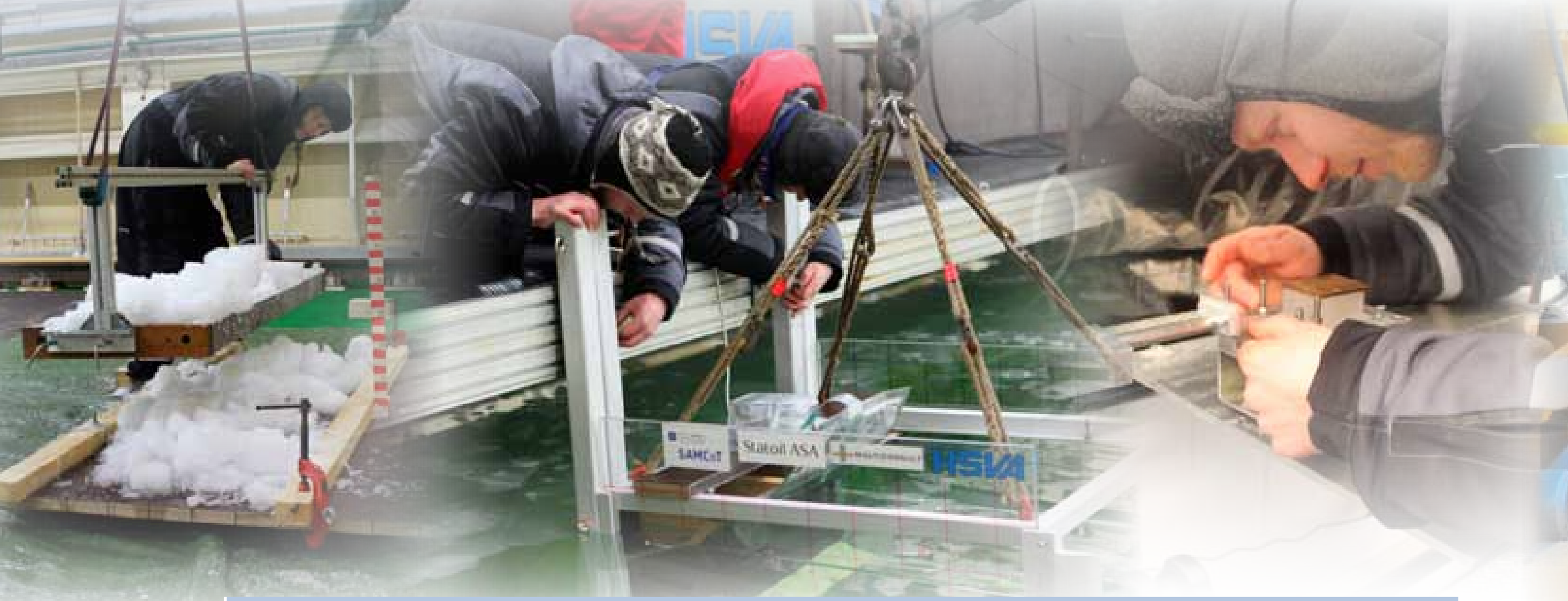
KEY RESEARCHERS

Name	Main research area	SAMCoT Research Position – Affiliation	Male/ Female	Nationality
Aleksey Marchenko	Data collection and process modelling	Leader WP1 - UNIS	Male	Russian
Jan Otto Larsen	Data collection and process modelling	Deputy Leader WP1 - UNIS	Male	Norwegian
Nataly Marchenko	Geographic Information System (GIS)	Researcher WP1 - UNIS	Female	Russian
Knut V. Høyland	Ice rubble and ice ridge action	Leader WP 2 & 3 - NTNU	Male	Norwegian
Thomas Benz	FE Modelling of frozen soils	Deputy Leader WP2 - NTNU	Male	German
Jukka Tuhkuri	Discrete Element Modelling of ice rubble and ice ridges	Researcher WP2 - Aalto	Male	Finish
Andrei Metrikine	Dynamic ice action	Deputy Leader WP3 - NTNU/ TUDelft	Male	Russian
Mauri Maattanen	Dynamic ice action	Researcher WP3- NTNU/Aalto	Male	Finish
Sveinung Løset	Ice actions on floaters	Leader WP 4 - NTNU	Male	Norwegian
Jørgen Amdahl	Iceberg impact on floaters	Deputy Leader WP4 - NTNU	Male	Norwegian
Raed Lubbad	Ice Management and Coastal Technology	Leader WP 5 - NTNU	Male	Norwegian
Roger Skjetne	Ice Management	Deputy Leader WP5 - NTNU	Male	Norwegian
Maj Gøril G. Bæverfjord	Geotechnical engineering	Leader WP 6 - SINTEF	Female	Norwegian
Jomar Finseth	Geotechnical engineering	Deputy Leader WP6 - SINTEF	Male	Norwegian
Arne Instanes	Geotechnical engineering	Researcher WP6 - External	Male	Norwegian
Anatoly Broushkov	Reporting field work	Researcher WP6 - MSU	Male	Russian

Aalto	Aalto University, School of Engineering
KSI	Krylov Shipbuilding Institute
MSU	Moscow State University
NTNU	Norwegian University of Science and Technology
SINTEF	Stiftelsen SINTEF
TUDelft	Delft University of Technology
UCL	University College London
UNIS	The University Centre in Svalbard
VTT	Technical Research Centre of Finland

VISITING RESEARCHERS

Name	Main research area	SAMCoT Research Position – Affiliation	Male/ Female	Nationality
Evgeny Karulin	Ice mechanics	Visiting Researcher WP1 - KSI	Male	Russian
Jaakko Heinonen	FE Modelling of ice rubble	Visiting Researcher WP2 - VTT	Male	Finish
Marina Karulina	Ice mechanics	Visiting Researcher WP1 - KSI	Female	Russian
Peter Sammonds	Const. models for ice rubble, micro-macro coupling	Visiting Researcher WP2 - UCL	Male	British
Stanislav Ogorodov	Coastal erosion	Visiting Researcher WP1 - MSU	Male	Russian



POSTDOCTORAL RESEARCHERS LINKED TO SAMCoT IN 2012

Name	Topic	Male/ Female	Nationality	Start
Anatoly Sinitsyn*	Physical-mechanical properties and extent of coastal permafrost	Male	Russian	2011

PHD CANDIDATES LINKED TO SAMCoT IN 2012

Name	Topic	Male/ Female	Nationality	Start
David Wrangborg*	Coastal ice	Male	Swedish	2012
Sergey Kulyakhtin*	Const. models for ice rubble, FEM	Male	Russian	2011
Anna Pustogvar*	Constitutive modelling of ice rubble , Experiments	Female	Russian	2012
Yared Bekele*	Constitutive modelling of frozen soil, FEM	Male	Ethiopian	2012
Torodd Nord*	Ice-induced-vibrations, (analysis of measured data)	Male	Norwegian	2011
Hayo Hendrikse*	Ice-induced-vibrations, (numerical modelling)	Male	Dutch	2011
Andrei Tsarau*	Floater-level ice interaction, hydrodynamics	Male	Russian	2012
Renat Yulmetov*	Iceberg drift and towing in packice	Male	Russian	2012
Farzad Faridafshin*	Alternative methods to evaluate safety of floating systems	Male	Iranian	2012
Emilie Guegan*	Coastal erosion mechanisms	Female	French	2012
Daria Aleksutina**	Composition, structure and properties of sediment cores and frozen soil	Female	Russian	2012
Alexey Usov**	Quick phenomena in seasonally thawing silty soils of Arctic coasts	Male	Russian	2012
Aleksey Shestov**	Ice ridges properties	Male	Russian	2007
Ekaterina Kim**	An integrated finite element analysis of iceberg-structure interaction	Female	Russian	2010
Martin Storheim**	Vessel response to extreme ice events	Male	Norwegian	2011
Wenjun Lu**	Floater-level ice int eraction, waterline processes	Male	Chinesse	2010
Sergiy Sukhorukov**	Sea ice friction	Male	Russian	2009
Marat Kashafutdinov**	Multi-scale modelling of iceberg drift and its application to IM	Male	Russian	2010
Lucie Strub-Klein**	Field measurements and analysis of the morphological, physical and mechanical properties of level ice and sea ice ridges	Female	French	2009-2012

MASTER'S STUDENTS LINKED TO SAMCoT IN 2012

Name	Topic	Male/ Female	Nationality	Year
Oda Skog Astrup**	Freeze-bonds and ice rubble properties	Female	Norwegian	2012
Henning Helgøy**	Freeze-bonds and ice rubble properties	Male	Norwegian	2012
Joar Justad**	Spatial variation of borehole jack testing in sea ice	Male	Norwegian	2012
Karsten Meyer**	Accurate and reliable temperature measurements in sea ice	Male	Norwegian	2012
Maxim Yazarov**	Dynamic ice action	Male	Russian	2012
Anne Hovland**	Ice actions on floaters	Female	Norwegian	2012
Anders Møllegaard**	Freeze-bonds properties	Male	Norwegian	2012
Gesa Onken**	Design of a physical analogous model for the study of dynamic ice-structure interaction	Female	German	2012

* Salary and Operational costs from the Centre
** Operational costs from the Centre

SAMCoT INTERNATIONAL ACTIVITIES

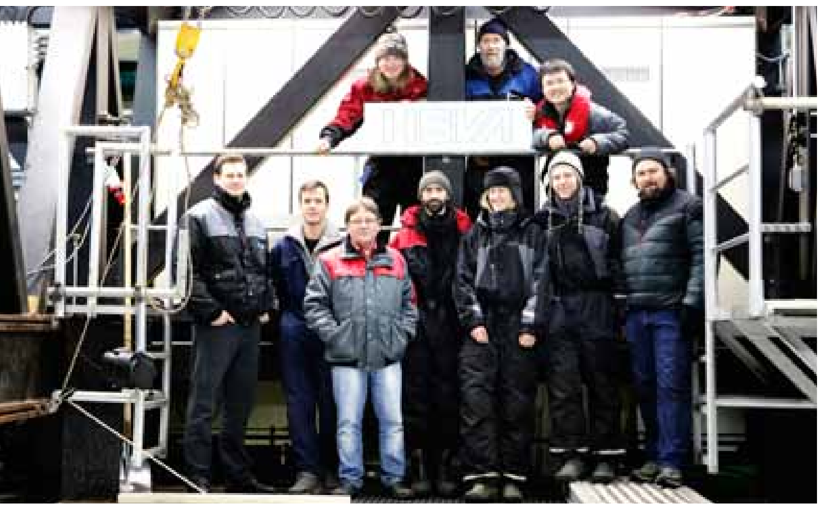
Norwegian research groups designated with the Centre for Research-based Innovation (SFI) work in close collaboration with innovative industry participants and public enterprise partners to strengthen the quality of Norwegian research. Spinoff activities in the form of Associated Projects are a key component of this objective. Both SAMCoT Associated Projects as well as the SAMCoT field activities in Russia are clear examples of the collaboration partnerships SAMCoT has created among its research and industry partners. Furthermore, SAMCoT activities stretch well beyond the country's boarders, signifying the growing international reach of SAMCoT activities.

As an example, OATRC2012 is the first Norwegian/Swedish expedition with the Oden icebreaker. This expedition was established under the umbrella of the memorandum of understanding "Nordic Cooperation in Polar Research" signed on January 29, 2010.

Likewise, SAMCoT's international collaboration is clearly evident in the RITAS project, which was established under the 7th EC Framework Programme through a grant to the Integrated Infrastructure Initiative HYDRALAB-IV, Contract No. 261520.

Collaboration with scientists and research institutions in Russia is a key element to the new Polar Research programme (POLARPROG) from the Research Council of Norway.

SAMCoT's field research activities in the summer of 2012 are two examples of SAMCoT's contribution to the aim of strengthening research cooperation with Russia, in consideration of our collaborations with the Moscow State University, with Krylov Shipbuilding Institute and the Arctic coastal studies in Varandey and Baydaratskaya Bay.



Group of researchers and companies representatives.
RITAS project 2012.

SAMCoT ASSOCIATED PROJECTS

RITAS: EU HYDRALAB - IV Project "Rubble Ice Transport on Arctic Structures"

Building Understanding of Ice-Structure Interaction
Future extraction of petroleum resources available below Arctic waters will face environmental safety challenges due to the influence of surface ice on offshore structures. Concerns related to ice actions on

floating structures are relevant to any location where sea ice represents the major design feature and there are a number of oil and gas development projects in new frontiers where such sea ice conditions apply.

Karl-Ulrich Evers, Senior Project Manager in Arctic Technology Department at Germany's Hamburg Ship Model Basin (HSVA), confirms. "Exploration and industrialisation activities in the Arctic are increasing and only a few full-scale data regarding ice interaction with offshore structures have been collected. Therefore, it is necessary to combine several approaches in order to develop a design methodology for offshore structures operating in ice-covered regions," he said.

In Spring 2012, SAMCoT Masters and PhDs candidates participated in an HSVA lab-based study to further knowledge and understanding of the effects of sub-surface rubble ice on offshore structures. Designated RITAS (Rubble Ice Transport on Arctic Structures), the research project utilized HSVA's expansive hydrodynamic research resource, the Large Ice Model Basin.

Nicolas Serre, Arctic Marine Technology leader for Multiconsult, which headed the project, said, "This is the first time that the ice breaking process has been monitored in the vertical plane below the waterline and related to measured ice breaking loads. It gave valuable insight into understanding the different components of the ice action on Arctic structures."

RITAS gave the participants a unique opportunity to design a research campaign targeting specific needs of the industry and to enhance the technology levels, while also pointing out needs for further developments and services needed by the industry. SAMCoT provided key competence to the project, creating a cooperation and meeting point among international actors, including major industry companies, research institutions, oil companies and suppliers. Moreover, Dr. Serré stated that cooperation within the SAMCoT project revealed there is a lack of comprehension on the mechanical processes linked to the level ice interaction with Arctic offshore structures.

"The tests confirmed that ice density has important effects on the magnitude of the ice breaking load. The tests gave us some surprises in terms of how steady state ice breaking loads are correlated to broken ice accumulation on the structure faces. This result may be in contrary to current ice breaking load theories," said Dr. Serré.

The project was initiated, planned and led by Multiconsult in Tromsø. NTNU and HSVA provided additional expertise and support for the planning, performance and analysis of the tests. "Statoil acknowledged the project as an important research topic and contributed with additional funds, which is highly appreciated because the tests results are available to everyone," said Dr. Serre.

The HSVA facility is ideally suited to experiments concerning transport system and ship technology research in open water and ice environments. The HSVA's 78m x 10m x 2.5m ice basin generates air temperatures as low as -20°C, with properties of the model ice scaled to simulate natural icebreaking processes. A computer-controlled, x-y motion (planar motion) carriage simulates ice drift scenarios with slow or rapid ice drift direction changes against offshore structures or floating vessels.

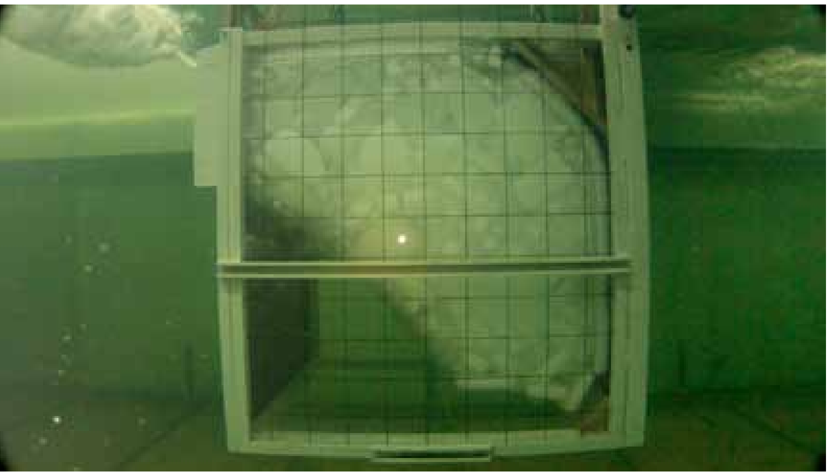
A model specially designed by Multiconsult for the RITAS project was built by the researchers at the Hamburg location. The model features an inclined slope at (and below) the waterline and is outfitted with sensors to measure forces and movements induced by ice.

This sloping waterline model built by SAMCoT and HSVA researchers at the HSVA Arctic basin venue is outfitted with sensory scales to measure ice force and movement generated by ice failure.

Sophisticated video camera systems for above and underwater image capture documented the ice rubble behaviour. The analyses done by image processing software validate the trajectories of the ice rubble after failure. In addition, the researchers used a buoyancy box to monitor ice rubble behaviour and its mechanical properties, e.g., cohesion and internal angle of friction.

Wenjun Lu, a PhD candidate at SAMCoT, joined the project to study the ice-sloping structure interaction and is determined to find solutions that address concerns for safety and reliability of vessels and structures operating in the Arctic.

Buoyancy box used to measure ice parameters and video capture ice behaviour characteristics.



"I was lucky to participate in the study," he said. "The aim of my work is to develop an integrated ice-sloping structure interaction model which permits modelling the fracturing of ice. I want to capture the fracture and fragmentation of ice with the cohesive zone theory."

To demonstrate his point, Lu relays a realistic scenario: "Imagine you're drilling in the Arctic and an ice sheet closes in on your structure. What do you do? How will the structure and ice behave if they meet? What influences the behaviour and, more precisely, what role do fluids play? How important is the fluid when the structure breaks the ice?"

Oda Skog Astrup also participated in the RITAS project. Her SAMCoT Master's thesis, Experimental Investigations and Analytical Analysis of Ice Rubble - Shear Box and Pile Testing, obliges her to establish that previous HSVA freeze-bond strength test results could be replicated and proved consistent with results from the lab at NTNU. Skog Astrup also applied the Mohr-Coulomb theory in model pile-up stability tests of ice rubble used in the RITAS project, as well as evaluated the test method.

Henning Helgøy, a Master's student at SAMCoT, found his participation in RITAS both fun and interesting. "My experiments aimed at investigating the strength of individual freeze-bonds under similar conditions and with equal ice properties as in experiments previously performed at HSVA, and to investigate the reproducibility of these experiments," he said.

"I was particularly interested in the opportunity to perform experiments demonstrating known and reproducible properties. However, collaborating with the other participants and gaining valuable experience planning and performing large scale experiments is also an important point I would highlight as something vital to our work at the HSVA," he continued.

Helgøy used a variety of equipment to perform his freeze-bond experiments: band-saw, hydraulic piston, force measurement system and a microtome to make thin sections, in addition to a trolley, a winch, and a buoyancy box. "Because of my access to so many useful tools during the RITAS project, I can demonstrate how the freeze-bond strength varied with the contact area, contact surfaces and time–temperature history of the freeze-bonding ice-blocks, in addition to results of comparing our experiments to the freeze-bond experiments earlier performed at HSVA", Henning said.

Sergey A. Kulyakhtin, a PhD candidate at SAMCoT, joined the RITAS project with a goal to observe how ice rubble behaviour in submerged state differs from its behaviour in dry conditions.

"All participants were definitely helpful and collaborative. From the HSVA staff I have learned a lot about model basin testing in general and model ice in particular. Also, they showed me different procedures for measuring level ice properties in the model basin, such as ice bending strength and ice density. Multiconsult shared their experience about mechanisms in level ice rubble fields, namely structure interaction processes and some general ideas concerning study of ice rubble. My colleagues from NTNU were helpful as well, especially in overcoming challenges which arose during the testing campaign," he said.

"While I learned some important information pertaining to my research, such as repose angle of rubble keel and the critical angle of rubble keel, I have to conclude that the most important input from the RITAS project to my own research is the experience of model scale testing. In the future, when I work again with model scale data, model ice that is, I will be aware of specific features inherent to it," said Kulyakhtin.

Overlooking his own contributions to the study, Dr. Evers said, "The experiments conducted during the RITAS project present important 2D underwater results on the ice bending failure and buoyancy measurements. The tactile sensor measurements correlate the local ice load to the ice breaking process, demonstrating how ice parameters affect ice failure and ice load in a basin setting. A lower density, higher thickness ice sheet causes greater rubble buoyancy and rubble volume under the ice sheet, thus changing the ice load. Study participants noted similar effects on velocity. "

Analysis of the experiment data and their results are destined for future Arctic Technology MSc and PhD studies. Two SAMCoT Master's candidates who participated in the RITAS project published their findings in November 2012: Oda Skog Astrup published Experimental Investigations and Analytical Analysis of Ice Rubble - Shear Box and Pile Testing; and Henning Helgøy published Experimental Investigations of Freeze-Bonds Between Saline Ice-Blocks.

In addition, to date five RITAS-related project papers were submitted to the Proceedings of the 22nd International Conference on Port and Ocean Engineering under Arctic Conditions (POAC'13) scheduled for June 2013 in Helsinki, Finland.

OATRC2012

The researchers attending OARTC2012.

In September 2012, NTNU's SAMCoT conducted its Oden Arctic Technology Research Cruise 2012 (OATRC2012) in cooperation with the Swedish Polar Research Secretariat (SPRS). The University Centre in Svalbard (UNIS) and Statoil were also instrumental in the success of the Oden expedition.

Dr. Sveinung Løset, a professor of Arctic technology at NTNU and SAMCoT Centre Director, served as cruise leader for the 10-day study in the Arctic waters northeast of Greenland, where the presence of icebergs and drifting multi-year ice impose challenges to safely and efficiently develop the region as a new energy province similar to the North Sea.

"Without doubt, the energy resources in the Arctic regions will be exploited. However, exploration and exploitation of these resources pose significant challenges for industry, especially in the assessment and management of risks along the whole production chain, avoidance of disruptions arising from potentially manageable accidents, and the need to minimise costs arising from adverse environmental impacts," said Dr. Løset.

Dr. Løset indicated that the work of SAMCoT researchers emphasizes reduction of risk, while increasing

reliability and optimizing design of structures operating in polar ice environments "We depend on full-scale experiences with real structures to obtain satisfactory sources of knowledge," he said.

The SPRS supports polar research into the Arctic and Antarctic regions. In 2012, NTNU and SPRS established the "Nordic Cooperation in Polar Research".

Photo: Øyvind Hagen, Statoil

Ice station during OATRC2012

"We acted swiftly when presented with the opportunity to conduct our study aboard the Oden. It makes its way through ice two metres thick, allowing access to otherwise unreachable areas," said Raed Lubbad, project leader on OATRC2012 and an associate professor at NTNU's Department of Civil Engineering.

The Oden, a 9,438 gross tonnage icebreaker commissioned by the Swedish Maritime Administration in 1988, was more recently re-commissioned as a research vessel for independent expeditions into polar ice packs. It was the first non-nuclear surface vessel to reach the North Pole in 1991 alongside the Polarstern, a German ice breaker.

The expedition was vital for educational purposes, said Dr. Lubbad: "After taking part in such a field trip, students come back with a more realistic view of the Arctic and a better understanding of their research topics. In other words, they become grown-ups."

The research programme focused on 10 distinct goals and its 27 researchers, primarily PhD candidates from SAMCoT, adhered to a meticulous activity plan mindfully established to study the properties of the ice and the metocean conditions, as well as to analyse the ship performance in different ice management scenarios.

"During the operation, we moored Oden in the ice to establish ice stations and measured sea-ice strength, friction and drift. Ice ridges were also studied using drilling strings and underwater cameras. We used upward looking sonars to provide statistics on ice thickness and ice drift speeds. We also used electromagnetic antennas and a system of video cameras to monitor the ice and study the ice-ship interaction. In addition, we used modern technologies to deploy ice drift trackers on icebergs and sea ice to observe drift patterns, speed and how they behave in ocean currents. Further, multibeam sonar was used to map the seabed. Also of considerable importance, we applied acoustic measurers to establish the degree of noise at varying distances when an icebreaker breaks up an ice sheet. This information can be interpreted for instance in the study of exploration's impact on whales," Dr. Lubbad said.

"Our scientists at SAMCoT will continue to evaluate our findings and monitor sonars placed at four different locations on the seabed, giving us profiles of the ice drifting over them. This information will reveal to us

Photo: Øyvind Hagen, Statoil

A grounded Iceberg North East of Greenland.

especially thick ice and help decide the loads one might have on marine structures in the area," Dr. Lubbad continued.

"A prerequisite to the success of this research cruise was the avoidance of accidents during operations. Therefore, the issues of Health, Safety and Environment (HSE) were high on our agenda throughout the project planning and execution phases. An early risk assessment mapped high risk circumstances inherent in a research cruise of this nature: remote location, extremely cold climate, operations on sea ice and icebergs, handling of weapons (polarbear guards) and long distance medical evacuation transport," said Dr. Lubbad.

The wording "perform a safe cruise" was a priority included in the overall cruise objective. Although all partners in the project have the same ultimate zero accident philosophy, HSE framework and HSE requirements differ due to the different backgrounds of the partners which participated in the project, i.e., academic, governmental and commercial. Nonetheless, alignment of the HSE framework and HSE requirements for this operation and reducing HSE risks to acceptable level was imperative.

Through an open dialogue, definition of clear roles and responsibilities, acknowledgement of the different backgrounds and focusing on reaching the final HSE objective, a pragmatic approach was found. Risk assessments at different levels, understanding the specific Arctic nature of this project, played a key role herein. On the other hand the diversity in backgrounds brought different highly relevant expertise into the project, for example SPRS and SMA with long marine operational experience in Arctic waters, NTNU and UNIS with extensive research activities on sea ice and icebergs experience, and Statoil with offshore marine operations and risk assessment competence. The open dialogue atmosphere created a fruitful collaboration, learning from each other and building on each other's strong points.

From a HSE perspective the cruise succeeded without a single accident.

"Statoil's financial support in the research expedition, of course, proved vital to the study's success and we also appreciate the scientific contribution both Statoil and UNIS provided to SAMCoT as valuable members of our scientific team," said Dr. Lubbad. We are as greatly appreciative for the logistical support from UNIS.

"We look forward to sharing our findings from the Oden Arctic Technology Cruise into the future and to new expeditions that will further expand our knowledge of polar ice behaviour," said Dr. Løset.

Arctic Coastal Surveys – Varandey and Baydaratskaya Bay

In the Arctic seas, declining ice levels are contributing to increased shipping activity and increased exploitation of oil and gas reserves. It stands to reason that there will inevitably be increased activity on shores in the region as well. However, an effect of the retreating ice cover is Arctic shorelines being exposed to wave erosion for a longer period of the year. Global warming may also cause thawing of shoreline permafrost and thus contribute to increased erosion.

In 2012, researchers participated in two distinct studies of Arctic coastal permafrost erosion behaviour on northern Russia shorelines: at Varandey on the Barents Sea coast of northern Russia; and within Baydaratskaya Bay (Baydara), a gulf in the adjacent Kara Sea. The researchers selected these locations based on the high erosion rates, relative accessibility to the areas and availability of vital temporal data.

Photo: Nataly Tikhonova

Landing on Pesyakov Island, July 2012.

Photo: Ivan Rodionov

Dr. Anatoly Sinitsyn during the Survey on Medynsky Zavarot Peninsula, July 2012.

According to Moscow State University (MSU) professor Anatoli Brouchkov, "It is important to establish research sites for studies of coastal permafrost, with the intention of long-term monitoring. To build sustainable infrastructure along the northern-most coastlines, where bedrock may not exist and fine-grained soils contribute to significant erosion and instability, one must understand coastal permafrost behaviour, in particular the mechanisms causing high erosion rates."

Photo: Anatoly Sinitsyn

To develop models required to determine historic erosion behaviour patterns and monitor changes into the future, researchers employed a number of resources. The scientists culled initial data for creation of the model from topographical surveys, satellite images and meteorological records, as well as existing studies citing characteristics of temperature regimes and soil behaviour.

"Field monitoring is key to understanding natural processes. We hope to create a model of erosion that can be applied to other areas where solifluction, thawing and wave transport of eroded sediments contribute to the degradation of permafrost," said Prof. Brouchkov.

Dr. Anatoly Sinitsyn, a post doc researcher at SAMCoT who participated in the Varandey expedition, holds similar views. "Field work on Varanday is highly important for SAMCoT as a research project. This research site is unique due to the significant amount of data available and the precise character of our investigations. The researchers set out with their goal to create a robust model that monitors and evaluates erosion processes in this area," he said.

Drilling works on Pesyakov Island, July 2012.

Dr. Sinitsyn's research group pursued three primary goals in their work:

- to continue topographical measurements of erosion rates in this area based on survey profiles established and maintained since 1980;
- to make existing systems of profiles denser and to establish one profile with boreholes for temperature measurements and soil analysis, and to designate an area in proximity of one of the profiles (within 0.5 km) to be topographically surveyed as well;
- to investigate local logistic possibilities and conditions to determine accessibility for further field work.

"Field work during the research project covered the entire 72 kilometer coastline in the Varandey area, which gives researchers the ability to study erosion processes systematically in full-scale within a large nature subject. We included in our survey at Varandey Island, Pesyakov Island and the Medynsky Zavorot Peninsula," said Dr. Sinitsyn.

The Baydaratskaya Bay field site was established by SAMCoT scientific partner Moscow State University (MSU) as joint activity with SINTEF. SAMCoT participated in important discussions that determined the importance of this specific field work and Prof. Brouchkov recognizes that the exchange of experience provided by SAMCoT's researchers was particularly helpful.

The 20-day Varandey Expedition 2012 was organized in cooperation with the State Oceanographic Institute (SOI), UNIS and SINTEF. SOI provided scientific basis for research, communication with official authorities, transportation to the site, equipment, human resources and HSE documentation.

UNIS provided scientific basis, HSE documentation, equipment and human resources. SINTEF provided equipment and consulting support for technical solutions.

The extensive technology and methods used in the Varandey Expedition include:

- Drilling work: drilling and penetration tests
- Soil sampling for physical analysis and radiocarbon analysis (isotope 14C)
- Arrangement of wells for temperature measurements
- Topographical measurements at polygon with drilling works
- Topographical measurements for erosion rates estimation
- Measurements of erosion rates with use of ruler
- Observations of geocryological structures on thermo-abraded slopes
- Survey on distribution of the thickness of active layer across Pesyakov Island

Photos: Sergey Buldovich

The Baydaratskaya Bay field site. SAMCoT PhD candidates during Core sampling in Baydaratskaya Bay, June 2012.

KV Svalbard

KV Svalbard is a Norwegian Coast Guard icebreaker that operates in the Norwegian Arctic. The performance of KV Svalbard in ice was studied by SAMCoT researchers, and a set of full-scale experimental data was collected in the Fram Strait from the 8th to the 18th of March, 2012.

During the survey, participants tested the performance and manoeuvrability of the vessel in different ice conditions and in open water, studied the interaction between the ship and ice at the waterline, analysed ice management scenarios and deployed buoys to monitor and study sea ice drift. "These tests provided us with necessary data to validate and calibrate the numerical models we have created for floaters in ice," said Dr. Lubbad.

Joining Dr. Lubbad on the survey were SAMCoT PhD candidates Wenjun Lu and Qin Zhang, as well as Runar Hassel, Stig Rune Søberg and Kristina Simankova from Trondheim's Ship Modelling & Simulation Centre (SMSC).

Stig R. Søberg and Wenjun Lu measuring temperature of an ice core.

RV Lance

The Department of Arctic Technology at UNIS regularly charters RV Lance for research cruises in the waters around Svalbard. In 2012, SAMCoT participated in an expedition to the western Barents Sea on 16-25 April. The cruise was conducted by 27 researchers and students, headed by Professor Aleksey Marchenko. SAMCoT provided financial and research support. A number of experiments were performed beyond the Spitsbergen shoreline and in the waters around Hopen Island:

- Ice trackers were deployed on sea ice to provide statistics on drift patterns and speeds
- Uniaxial compression tests were performed to give mechanical strength of ice; borehole jack tests were also performed to provide mechanical strength values
- Ice ridges were surveyed at the surface by laser scanning and the internal structure mapped by manual drilling
- Beam tests were performed to estimate the flexural strength of the ice
- The breaking patterns in the ice-ship bow interaction zone was monitored by video cameras
- Sea currents and CTD profiling was also a part of the research programme

An important part of the cruise was to give the students "hands-on" and experience operating in the Arctic.

The research crew on board Lance; a mixture of researchers, MSc & PhD candidates.

SAMCoT Scientific Production
The Scientific Advisory Committee (SAC)

The Scientific Advisory Committee at SAMCoT comprises leading academics to provide the Centre with necessary research quality assurance and to support the Board in scientific matters. The SAC produces an annual report of scientific quality of the work carried out by SAMCoT researchers, in particular the PhD candidates. In addition, the SAC monitors all educational aspects of SAMCoT.

SAMCoT SAC

- Prof. Aleksey Marchenko (UNIS)
- Prof. Anatoly Brouchkov (Moscow State University)
- Prof. Andrei Metrikine (Delft University of Technology)
- Dr. Hans Bihs (NTNU)
- Prof. Knut Høyland (NTNU) - Chairperson
- Prof. em. Mauri Määttänen (NTNU)
- Prof. Jukka Tuhkuri (Aalto University)

In September 2012, SAMCoT celebrated its first International PhDs Workshop, hosting more than 60 participants from research and industry partners. On this occasion the SAC committee also attended to review the research plans of the SAMCoT PhD candidates. Their participation in the Workshop and contributions to the SAMCoT Centre Research Programme is extensive, as many of the SAC members are leading international researchers in key areas of Arctic research and also engaged as supervisors to SAMCoT's PhD candidates.

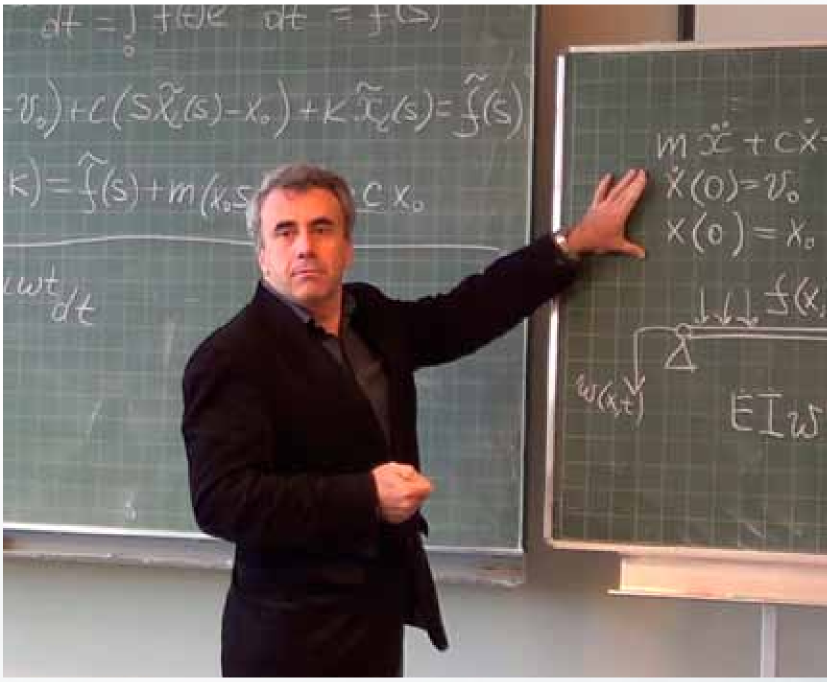
We have interviewed two of the SAC members in order to learn a bit more about them and their research:

Professor Andrei Metrikine of Russia has a background in physics and mathematics. He has worked with dynamics for many years in Russia, Germany and the Netherlands. He and his group at Delft University of Technology primarily work with dynamical behaviour of offshore structures.

Spiral platforms next?

BMW owners may have noticed that the radio antennas on their cars have helical strakes around the mast. This is to keep them from vibrating in the wind. The same phenomenon exists in the Arctic. It's called ice induced vibration and occurs when ice crashes against offshore platforms.

This is Andrei Metrikine territory. From his position as professor at the Delft University of Technology he was asked by British-Dutch oil giant Shell to advice. They,



Prof. Metrikine lecturing at Delft University of Technology.

like the rest of the energy-hungry world, are looking to the north for future supplies. And while the ice may be rapidly melting, it is still around in a myriad of shapes, forms and sizes, causing vibrations. The phenomenon is the same, but the challenge is immense compared to that of the radio antenna. Furthermore, solving one problem always contains the risk of creating another.

Global approach

It is hardly an accident that Andrei Metrikine has been invited to join both SAMCoT's scientific advisory committee (SAC) and the leadership of Work Package 3, "Fixed Structures in Ice". His qualifications were revealed in a presentation in Delft where SAMCoT director Sveinung Løset was present. The two were soon involved in exciting conversation and before long Metrikine was invited to Trondheim. "I think they like my expertise because it differs slightly from the rest of the team since I have worked with vibrations of various structures in wind and water. This gives me a somewhat global theoretical point of view," he says.

Really, really interested

Andrei Metrikine is truly enthusiastic about SAMCoT: "What I like most of all, is the team of really, really interested engineers. When you combine SAMCoT's own team of very strong researchers with the most powerful offshore companies sending their best R&D people, you get this result. This is not given. Quite often you don't see this kind of drive. SAMCoT meetings always have a high nerve. Everybody is interested, we know what we want and we have real cooperation. This is how it should be. We see the value of each other."

Engineering as art

Working in such an atmosphere would be a true asset under any circumstances. The task of ice versus fixed structures makes it all the more valuable. Metrikine illustrates: "Take a cube of silicon used in the manufacture of computer chips. You can describe what happens with the cube under loading: you can introduce simulations and apply multi-scale theories at the atomic, molecular and macro level and then the model can mimic the reality. But silicon is much easier than ice, being a very well-structured material. Ice isn't. We cannot know with certainty its material structure in every particular case. That's where art comes in, trying to find a model that describes and solves. The main challenge is to model ice without knowing the details. We have to be able to identify and focus on only truly significant properties. True physics never goes without lyrics. If we are weak humanitarians we will never succeed. The major thing is to see reality, extract the most important processes and make a model. To run algorithms is also a challenge but it contains much less of an art."

Maths and sports

Andrei Metrikine comes from a family of mathematicians. Both his parents are mathematicians. His parents wanted him to go a school where math was taught at a high level. His grandmother, a teacher of math at that same high level school, protested: "We can teach him maths at home. Let him study something normal."

The young Metrikine was sent to a school where focus was placed on sport. He learned volleyball, rowing, table tennis and other sports. In parallel, under his mom's pressure, he studied music. Later on he became passionate about history in general and the history of science in particular: "I think it is important to be piece of a chain."

"Meet a Nobel Prize Winner"

As a post-doctoral researcher in 1995, Andrei Metrikine met Vitaly Ginzburg who later won the Nobel Prize for Physics for his pioneering contributions to the theory of superconductors and superfluids. Ginzburg invited Metrikine to present his research at his famous seminar. In order to receive this invitation, Metrikine was given three minutes to explain his topic and succeeded. At that time, he was working on the ground vibrations induced by high speed trains and approached the problem by comparing it with radiation of electromagnetic waves. Ginzburg, being an astro-physicist, liked the approach and the lecture and invited Metrikine to write an article to a special issue of the journal on achievements of physics which was dedicated to Ginzburg's 80th anniversary. "It gave me a big boost. I think every scientist should try to meet a Nobel Prize Winner at least once," Andrei Metrikine says today.

Professor Jukka Tuhkuri of Finland has worked with ice mechanics and ice engineering for more than 20 years. He and his group at Aalto have for the last 10 years worked with numerical simulations with the Discrete Element Method (DEM).

Touch ice*

Spin-off is fun. Who would have thought that ice expert Jukka Tuhkuri was attractive to the forestry guys? Well, he is. His knowledge of ice as a discontinuous and heterogeneous material could possibly save the Finnish wood industry millions.

As it happens, wood is also a discontinuous and heterogeneous material. This might seem like a digression, since the main point of this article is to present Jukka Tuhkuri as member of SAMCoT's scientific advisory committee (SAC). But then, what's wrong with fun? And isn't it a good sign that a scientist is open to new impulses and happily engages in a new material when he is invited to? We think so, especially when the ultimate target of the research is to radically decrease the use of energy in wood processing.

15 years' history

Now ice. From a background in naval architecture, Jukka Tuhkuri went on to study ice mechanics and in particular ice loads to ships. He obtained his professorship in solid mechanics at the Aalto University in 2001 and advanced to head the department of applied mechanics. In an environment of engineers and geophysicists he and his team model ice as a discontinuous and heterogeneous material by using the Discrete Element Method.

His links with the people at SAMCoT date way back. More than 15 years have passed since he first met WP2 leader Knut Høyland through the common interest for ice ridges. Since then they have met countless times through everything from two-day seminars with doctoral students to the extensive collaboration between NTNU and his own university in Espoo.

Now Tuhkuri is happy to be a part of the SAMCoT team: "We need collaboration in research. We have different approaches and therefore discussion is fruitful," he says. He points to Nordic Five Tech, the cooperation between the five Nordic technological universities, as an example and where a new initiative on joint doctoral education in Arctic technology is one of several areas covered.

Monitor

Jukka Tuhkuri is member of the WP2 team which deals with material modelling. The goal is to provide constitutive models for ice rubble and permafrost that can be used in advanced analyses of boundary value problems in other work packages, and to create numerical models that could be used to predict the drift of icebergs and sea ice in the Barents Sea and Kara Sea. "This is exciting stuff. We still don't understand how ice ridges fail.

Prof. Tuhkuri during his participation at SAMCoT's 1st International PhD Workshop.

We want to understand loads to structures by studying the physics of the ridges through modelling individual ice blocks," says Tuhkuri.

He describes his role on the SAC as monitoring: "We check if SAMCoT's work holds high international level. Should we find that it doesn't, we must do something. As part of this work, we ask doctoral students to come to our meetings and present their work."

Small community

With good reason Norwegians consider national hero Fridtjof Nansen a polar pioneer. Although this was not his primary field of research, his findings on structures in ice continue to impress today's scientists. Nansen was far from alone, though. The Finns were also eagerly working with ice engineering back in the 1800s. Still, the community of ice researchers has remained relatively small until now. When Jukka Tuhkuri meets up with Knut Høyland and the rest at international conferences, they are seldom more than 200. This fact is rapidly changing. Climate change is opening new areas for exploration and possible production of oil and gas and interest is booming.

Jukka Tuhkuri will surely have his hands full as long as he wants. And when he no longer does, he can resort to sailing. His 34 feet six-tonner is waiting in the harbour.
* The saying goes "touch wood", "bank i bordet" in Norwegian, "toca madera" in Spanish and "paina puuta" in Finnish. But if wood is just as discontinuous and heterogeneous as ice, we hereby suggest that experts on ice mechanics are entitled to say "Touch ice" instead. In Finnish that would be "paina jäätä."

DISSEMINATION

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Photo: Øyvind Hagen, Statoil

Statement of Accounts 2012

In December 2012 the Annual Work Plans for both 2012 and 2013 were presented and approved by the Research Council of Norway (RCN). The RCN has the task to monitor the activities planned ensuring their compliance with the EFTA Surveillance Authority (ESA) requirements.

In addition the Cost, Time and Resource (CTR) plans for each Work Package for 2013 were presented to SAMCoT's Board and approved. The CTR provide a detailed description of each Work Package by defining: objectives; knowledge gaps; activities planned for the current year; dependencies, critical factors, assumptions, milestones and resource requirements.

The funding and cost plans for 2012 are shown below following the ESA reporting format.

SAMCoT FUNDING 2012 (ALL FIGURES IN 1000 NOK)

Activities/ Items	Type of Research	RCN Grant	Host***** NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV	TOTAL	Multiconsult	Kongsberg Maritime	Barlindhaug Consult	Aker Solutions	SMSC	GDF SUEZ	Norwegian Coastal Admin	HSVA	TUDelft	Aalto University	MSU	VTT	Total funding
WP1	F	1478			1456	167	167	167	247	42	50	50	94	88	292	55						**4351**
WP2	F	1478	934			167	194	194	247	353	50	667	94	88	292	55	87		329		253	**5481**
WP3	F	1478	179			167	194	193	247	42	172	50	94	176	292	55	15	80	15			**3449**
WP4	F	1478	2059			167	194	224	247	42	172	50	94	176	292	55	15					**5264**
WP5	F	1478	449			14355	167	193	247	172	50	50	94	172	292	55	15					**17787**
WP6	F	1478	198	676		167	167	192	247	42	50	50	94	93	292	55				408		**4208**
EIAC	I					224	220	44	80	39	57	39	11	16								**728**
SAC	F																		28			**28**
Equipment				377		433																**810**
Management		1478	1228	204	105	224	80	52	139		20	61		16			28		12		18	**3663**
Total budget		**10346**	**5046**	**1257**	**1561**	**16069**	**1383**	**1258**	**1700**	**730**	**622**	**1016**	**576**	**825**	**1750**	**330**	**158**	**80**	**384**	**408**	**271**	**45770**

* F. = Fundamental research. I. = Industrial research

SAMCoT COSTS 2012 (ALL FIGURES IN 1000 NOK)

Activities/ Items	Host***** NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV	TOTAL	Multiconsult	Kongsberg Maritime	Barlindhaug Consult	Aker Solutions	SMSC	GDF SUEZ	Norwegian Coastal Admin	HSVA	TUDelft	Aalto University	MSU	VTT	Total funding
WP1			6068				80				11									**6159**
WP2	2304					27	80	311		617	11				87		329			**3766**
WP3	1719				28	26	80		122		11	89			15	930	15		526	**3561**
WP4	2643				28	57	80		122		11	89			15					**3045**
WP5	8262			2751	28	26	80				11	84			15					**11257**
WP6	1214	3942				25	80	130			11	6						406		**5814**
EIAC				224	220	44	80	39	57	39	11	16								**728**
SAC																	28			**28**
Equipment	4548	958	1633	433														3		**7575**
Management	2164	919	105	224	80	52	139	61	20			16			28		12		18	**3838**
Total budget	**22855**	**5819**	**7806**	**3631**	**383**	**257**	**700**	**541**	**322**	**656**	**76**	**300**	**-**	**-**	**158**	**930**	**384**	**408**	**544**	**45770**

Photo: Øyvind Hagen, Statoil

Annual Report 2012

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