Annual Report 2011

SAMCoT
Sustainable Arctic Marine and Coastal Technology

sfi Centre for Research-based Innovation

NTNU – Trondheim
Norwegian University of Science and Technology

SAMCoT

Vision

- To be the leading national and international Centre for the development of robust technology needed by industry for sustainable exploration and exploitation of the valuable and vulnerable Arctic region.
- To work together with our partners to obtain and implement the knowledge that industry requires when meeting challenges due to ice, permafrost and a changing climate. By doing so this will provide overall benefits to the energy sector and society.

Objectives

The objectives of SAMCoT are:

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

International industry is showing increased interest in the Arctic that will lead to more industrial activities there as well as growth in transport in this very vulnerable area. SAMCoT is a Centre for Research-based Innovation that was established by the Research Council of Norway to meet the needs related to the increase in activities in waters such as the Eurasian Arctic, East Greenland and the Chukchi Sea.

SAMCoT Partners in 2011:

NTNU – Trondheim Norwegian University of Science and Technology
SINTEF
UNIS
AkerSolutions
BARLINDHAUG
MANAGING RISK DNV
KYSTVERKET
KONGSBERG
MULTICONSULT
TOTAL
Statoil
HSVA
VTT
TU Delft
Aalto University

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SAMCoT, a flying start in 2011

"The journey of a thousand miles begins with a single step". In 2011, SAMCoT had a flying start thanks to the accumulated knowledge and experience from the PetroArctic and PetroRisk projects. International recognition, well-established research networks and access to the unique infrastructure situated well into the Arctic region (The University Centre in Svalbard, UNIS, at 78°N) were all key elements in launching SAMCoT. The major events and steps forward in 2011 are outlined below.

Kick-off and opening

The kick-off meeting of SAMCoT took place on 17 March 2011 at the Norwegian University of Science and Technology (NTNU). The overall purpose of the Centre was presented as well as the various research areas. Recommendations and discussions with both industry and research partners were the basis for quickly starting on the research tasks.

Torbjørn Digernes Rector NTNU and Eirik Normann, Director, Department for Innovation in Industry, NRC.

Another major event was SAMCoT's opening ceremony on 7 October 2011. More than 50 people took part in the different events and the official ceremony was followed by the 1st General Assembly with all SAMCoT partners present.

SAMCoT's Consortium Agreement was signed by all partners on 16 November 2011.

In addition to the work carried out by the different WP members, the Exploitation and Innovation Advisory Committee (EIAC) has been very active in 2011 with three meetings during the second half of the year.

Physical lab-scale testing

Dynamic ice-structure interaction

SAMCoT initiated the Deciphering Ice Induced Vibrations project. Tests were run for a month in the HSVA Ice Tank in Hamburg. The measurement programme included a test matrix with varying mechanical properties of ice, ice velocity, structure waterline diameter, surface roughness, structure compliance and natural frequencies. Comprehensive ice-structure dynamic interaction measurement data were obtained. The data indicate the ice velocity dependent structural response, including frequency lock-in to the natural mode frequencies of the structure, and shifts from one mode to another.

An attempt was also made to identify the added mass and damping of level ice in interaction with a vibrating structure. This part of the test setup consisted of a cylinder connected to an actuator which provided controlled harmonic motion whilst crushing with different frequencies and amplitudes. The added mass and damping parameters have been identified for several cases from the measured force and displacement signals.

The presence of negative damping, as is also found from indentation tests with stationary cylinders, was reconfirmed in this experiment. Additionally it was found that for low indentation velocities the added mass can also become negative. This result provides a new approach to the development of predictive models for dynamic ice-structure interaction.

Iceberg-structure collision

A proper understanding of ice-structure interaction mechanisms is required to numerically model the processes involved in the interaction of ice masses with ships, offshore and coastal structures. This includes the failure processes under high and low confinement. In the late spring of 2011, we conducted small-scale laboratory ice-indentation tests on freshwater granular and freshwater columnar S2 ice at –10 °C and –40 °C.

The autumn of 2011 was spent on planning some model-scale collision tests in the Aalto Ice Basin in Helsinki, and developing a numerical tool that can provide sufficient analysis of collisions that include deformation of the structure.

Simulation of structure-ice interaction

A structure in drifting ice or a ship advancing in level ice will introduce several failure processes to the ice sheet, such as localized crushing and breaking due to bending stresses. The resulting ice fragments will interact with each other, with water and with the hull of the ship. These fragments may rotate, collide, or slide along the ship's hull, and eventually they may be cleared away. The situation is different in a broken ice field where large floes may behave similar to level ice while smaller floes will mostly be pushed aside, rotated or submerged.

Modelling such a complex system is very demanding and is often computationally expensive. In 2011 we investigated different ways of approaching this problem including the use of physics engines for dynamically detecting the contacts between the objects in the calculation domain, and for calculating the contact forces in three-dimensional space. This novel concept for simulating the ice-floater interaction process has been started and will continue with increased efforts in 2011.

Field studies

UNIS is a unique base for field studies in the coastal areas of Spitsbergen and the Barents Sea. SAMCoT has supplemented the stock of important instrumentation for efficient studies of e.g. coastal erosion and sea ice movement.

Sea ice state

Design of offshore structures will require in-depth knowledge about ice conditions including drift and dynamics. Analysis of data from sea ice drift trackers has given insight into sea ice dynamics that affect the design and assessment of floaters in ice. This applies to the evaluation of ships using dynamic positioning and marine operations as well.

Field studies have been performed to increase the knowledge of the spatial and temporal evolution of morphological, physical and mechanical properties of level ice and ice ridges. Full-scale field measurements have been done on the thickness, temperature, density, salinity, and uniaxial compressive strength of both level ice and ice ridges. These data are highly relevant for industry when estimating ice actions on offshore structures.

Coastal structures and erosion

Surveys have been done to improve the basis for the design of coastal structures, harbours and shoreline protections subjected to ice actions, wave erosion and unstable permafrost soils. These studies have focused on existing harbour infrastructures at Spitsbergen as well as selecting sites for coastal erosion and permafrost studies both at Spitsbergen and the Yamal Peninsula.

Meso-scale floater

Several model tests and numerical studies of floating structures with conical sections at the waterline have shown to be a good design for waters where drifting ice is present. However, in most Arctic waters ice features are only present during parts of the year and a large portion of the operational time of these structures will be in open water. The advantages of deploying a meso-scale floater (buoy) in the Spitsbergen waters have been studied and several site locations evaluated.

Sveinung Løset

Professor Sveinung Løset has his feet firmly planted in the Barents Sea.

The birth of a Centre for Research-based Innovation

The main objective for the Centres for Research-based Innovation (SFI) is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups.

The first funding announcement in the SFI scheme came in June 2005. Fourteen SFI centres were selected by the Executive Board of the Research Council and announced by the Minister of Education and Research June 16th 2006.

Seven new centres were announced on 16 December 2010. The Sustainable Arctic Marine and Coastal Technology (SAMCoT) SFI was one of these.

Why SAMCoT?

The global demand for energy is increasing and most of this increased demand must be met by fossil fuels in years to come. According to the Norwegian Petroleum Department and the Norwegian government considers the high Arctic areas to be Norway's most important strategic prioritized area in the coming years. The Government's objective is to strengthen Norway's sovereignty and to ensure sustainable management of the rich (fish and) petroleum resources in these areas. This will be done through protection of the environment, population and industrial development in the northern areas – in cooperation with Russia and other partners in the north.

There will be a need for concerted efforts from the government and companies, to develop policy, technology, systems and knowledge to ensure that the petroleum activity in the Arctic takes place in a safe and sustainable manner. Further development of the knowledge base, research in relevant areas, technical education and close cooperation between countries and companies, are key elements to achieve this.

Norway's prosperity is built on an environmentally friendly, efficient and long-term management of petroleum resources on the Norwegian continental shelf and the new SFI for sustainable Arctic marine and coastal technology will be a great contribution in the crucial northern areas. The Centre will address challenges pointed out as key topics in recent years by the Norwegian government through several petroleum reports, like the Norwegian Government's Strategy New Building Blocks in the North from 2010, Oil and Gas in the 21st century (OG21) and funding through the Research Council of Norway. And of course, the treaty on maritime delimitation between Norway and Russia signed in September 2010.

Norway is already a leader in research in Arctic technology. But there is still a great need for better understanding of the presence of ice and permafrost to ensure sustainable and safe exploration, exploitation and transport from and within the vulnerable Arctic region.

This Arctic SFI therefore comes at a crucial time in regard to the development of the northern areas. The SFI will provide necessary research based knowledge and education required by industry to develop Arctic technology for the energy sector. The SAMCoT SFI will also be the basis for the development of environmentally adapted coastal infrastructure where there is a pressing need in these vulnerable areas.

Decisions regarding new developments in the northern areas will be based on how much oil and gas we can expect to get out of the fields and the assurance of an environmentally safe utilization of the resources. The SAMCoT SFI will be a leading national and international center for the development of robust technology needed by the industry for sustainable exploration and exploitation of the valuable and vulnerable arctic region. SAMCoT will meet the challenges due to ice, permafrost and changing climate for the benefit of the energy sector and society.

The selection of an SFI centre

The SFI scheme employs two main assessment criteria as basis for selection:

- Potential for innovation and value creation
- Scientific merit

The centres were selected primarily on the basis of their potential to generate innovation and ability for value creation. The scientific merit of the research must be of high international calibre. In other words, you have to be exceptionally good to be an SFI.

The main characteristics of the SAMCoT SFI

The research group behind SAMCoT is well known to the Research Council of Norway through many successful projects in programmes like the PETROMAKS programme. SAMCoT has managed to gather the most relevant researchers in Norway in the field, in interaction with both Norwegian and international key companies on the Norwegian continental shelf. The Centre has extensive ambitions, but we are confident that the research tasks will be handled well.

The cooperation between the SAMCoT SFI and the Research Council of Norway is close through a continuous update of the Centre's activities. The Research Council will attend the SFI board meetings and continue this close contact through the whole period. It is an exciting and important topic that is addressed in this SFI. SAMCoT has already made several deliverables and performed lab and field tests and we are confident that this SFI will continue its excellent results.

The Research Council of Norway congratulates the participants with this SFI on an area of enormous importance for the Norwegian society, the private sector in Norway and the industrial development of northern areas, for both Norway and our neighbours in the Arctic.

I look forward to the outcome of the SAMCoT SFI and the continuance of our collaboration in the years to come.

Kimberly C. Mayes
Senior Adviser Petroleum
Research Council of Norway

SAMCoT – Centre Structure

SAMCoT is hosted by NTNU and managed by a Centre Director and a core team from NTNU, SINTEF and UNIS that together constitute the Centre Management Group (CMG). The Industry Partners (IP) are represented on the Board together with representatives from NTNU, SINTEF and UNIS.

SAMCoT's industrial partners (Aker Solutions AS, Barlindhaug Consult AS, Det Norske Veritas AS, Kongsberg Maritime, Multiconsult AS, Shell Technology Norway AS, Statoil Petroleum AS and TOTAL E&P Norge AS) together with NTNU and SINTEF, constituted an **Exploitation and Innovation Advisory Committee (EIAC)** to follow the research progress and continuously monitor the flow of knowledge and its implementation in the required areas of innovation.

Its responsibility is to identify industrial and societal needs to be met by the research, and to propose specific ways of implementing the results to provide added value to the industrial partners.

The Industry Partners have defined six sets of problem fields (Work Packages – WPs) for which long and medium term strategically important research is required to help reduce risks when deploying and using technologies for oil and gas exploration and exploitation, and for engineering activities in the coastal zone. The WPs build on on-going activities at NTNU, SINTEF and UNIS.

The **Scientific Advisory Committee (SAC)** consisting of professors from leading international academic institutions (Aalto University, School of Engineering; Delft University of Technology, Moscow State University; UNIS; and NTNU) shall provide the necessary research quality assurance, and support the Board in scientific matters. The SAC is to follow up the educational aspects of SAMCoT.

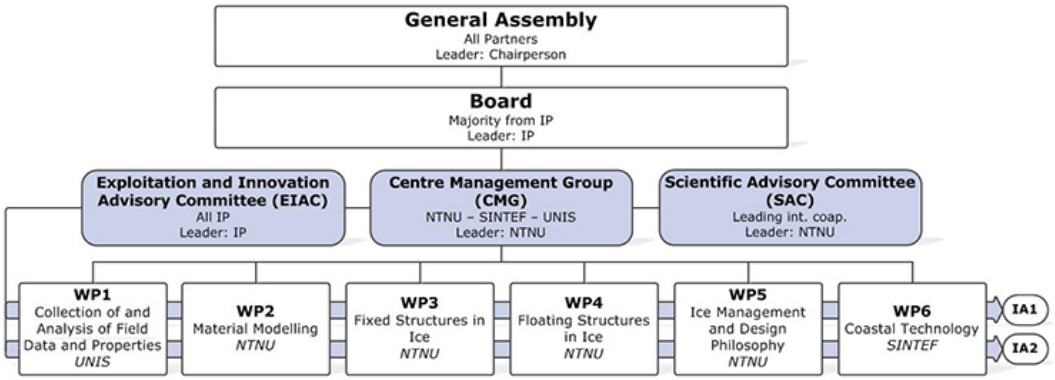
The scientific focus of SAMCoT is supported by SAMCoT's research partners: Aalto University, School of Engineering; Delft University of Technology (TU Delft); Hamburg Ship Model Basin (HSVA); Moscow State University (MSU), Stiftelsen SINTEF, Technical Research Centre of Finland (VTT) and the University Centre in Svalbard.

NTNU – Trondheim
Norwegian University of
Science and Technology

SINTEF

UNIS

SAMCoT Organizational Chart



Also The Norwegian Coastal Administration has a role in supporting SAMCoT and continuing in such a way its long tradition as a supporter of the Port and Coastal Engineering group in NTNU's Department of Civil and Transport Engineering.

In terms of expertise related to the Centre's Human Resources, SAMCoT is manned by professionals in the fields of Arctic Marine Technology and Port and Coastal Technology. The Centre's personnel will be a resource for industry and society, and candidates at NTNU's Department of Marine Technology, those working in Arctic Technology at UNIS and at other international research partners at SAMCoT will become the next generation of engineers and scientists who will ensure the implementation of sustainability in all major development projects in the Arctic.

Personnel	Man years 2011/12
Doctoral candidates	10
Post docs	3
Key scientists	10
Visiting/Partners scientists	2/year
Staff engineers	2
Administrative staff	2
Turnover	**NOK**
Per annum	25 Million
Accumulated over 8 years	200 Million

SAMCoT Governance Structure	
SAMCoT Bodies	**Members**
The General Assembly (GA)	Aalto University, School of Engineering (Jukka Tuhkuri); Aker Solutions AS (Henrik Hannus); Barlindhaug Consult AS (Arnor Jensen); Det Norske Veritas AS (Elisabeth Harstad); Hamburg Ship Model Basin (HSVA) (Peter Jochmann); Kongsberg Maritime (Nils Albert Jenssen); Moscow State University (Eugene A. Voznasensky); Multiconsult AS (Ivar Eng); Norges Teknisk-Naturvitenskapelige Universitet (NTNU) (Asbjørn Rolstadås, Chairperson); Norwegian Coastal Administration (Fridtjof Wangsvik); Shell Technology Norway AS (Gina Ytteborg); Statoil Petroleum AS (Arne Gürtner); Stiftelsen SINTEF (Berit Laanke); Delft University of Technology (TUDelft) (Andrei V. Metrikine); VTT Technical Research Centre of Finland (Matti Kokkala); TOTAL E&P Norge AS (Rune Teigland); Universitetssenteret på Svalbard (UNIS) (Gunnar Sand); Research Council of Norway (Kimberly Mayes, observer); Board–Chairperson (Morten Karlsen, Statoil, observer); SAMCoT CM (Sveinung Løset, GA secretary)
The Board	Arnor Jensen (Barlindhaug Consult); Berit Laanke (SINTEF); Gina Ytteborg (Shell); Gunnar Sand (UNIS); Ingvald Strømmen (NTNU); Morten Karlsen (Statoil)–Chairperson; Per Olav Moslet (DNV); Rune Teigland (TOTAL); Kimberly Mayes Research Council of Norway (observer); Sveinung Løset (SAMCoT Centre Manager, Board secretary)
Centre Management Group (CMG)	Aleksey Marchenko (UNIS); Knut Høyland (NTNU); Kristina Heilemann (SINTEF); Maria Azucena Gutierrez Glez. (NTNU); Nataliya Marchenko (UNIS); Raed Khalil Lubbad (NTNU); Svein Willy Danielsen (SINTEF); Sveinung Løset (NTNU)
Explotation and Innovation Advisory Committee (EIAC)	Annie Audibert-Hayet (TOTAL); Arne Gürtner (Statoil); Arnor Jensen (Barlindhaug Consult); Guido Kuiper (Shell)–Chairperson; Ivar Eng (Multiconsult); Nils Albert Jenssen (Kongsberg Maritime); Per Kristian Bruun (Aker Solutions); Per Olav Moslet (DNV); Svein Willy Danielsen (SINTEF); Sveinung Løset (NTNU)
Scientific Advisory Committee (SAC)	Prof. Aleksey Marchenko (UNIS); Prof. Anatoly Brouchkov (Moscow State University); Prof. Andrei Metrikine (Delft University of Technology); Adjunct Associate Prof. Hans Bihs (SINTEF/NTNU); Prof. Knut Høyland (NTNU)–Chairperson; Prof. em. Mauri Määttänen (NTNU); Prof. Jukka Tuhkuri (Aalto University, School of Engineering)

SAMCoT HSE:

SAMCoT's overall Health, Safety and Environment (HSE) policy statement:

"SAMCoT will work to prevent injuries or accidents associated with our activities. We will minimize any possible negative impacts on the environment and ensure a working environment that is safe, stimulating and rewarding."

- SAMCoT will conduct all of its activities so that safety for the participants is the first priority.
- SAMCoT will follow all Procedures and Documentation from UNIS.
- UNIS will make provision for SAMCoT's logistics, training and procedures.

UNIS HSE Documents that will be followed by SAMCoT are on the UNIS home page: **http://www.unis.no/**

Research Areas

At SAMCoT research is divided in 6 different Work Packages:

WP1	Collection & analysis of field data and properties
WP2	Material Modelling
WP3	Fixed Structures in Ice
WP4	Floating Structures in Ice
WP5	Ice Management and Design Philosophy
WP6	Coastal Technology

Inter-collaboration among the 6 work packages is key to a successful research process.

All Work Packages join efforts to identify, understand and model the full-scale physical processes of the underlying engineering challenges.

To the finest detail possible, we do this aiming for innovative and robust solutions needed for a sustainable development of the Arctic areas.

SAMCoT Team

WP1

Collection and Analysis of Field Data and Properties

THE TEAM

Aleksey Marchenko, Dr., Professor, UNIS; Renat Yulmetov, PhD candidate, NTNU (WP5); Anatoly Sinitsyn, Post. Doc., UNIS; Lars Olav Grande, Dr., Professor, NTNU (WP6); Aleksey Shestov, PhD candidate, UNIS; David Wrangborg, PhD candidate, UNIS; Sergiy Sukhorukov, PhD candidate, NTNU (WP4); Sergey Kulyakhtin, PhD candidate, NTNU (WP2); Jan Otto Larsen, Dr., Associate professor, UNIS; Nataliya Marchenko, Dr., Reseacher, UNIS.

Stanislav Ogorodov, Dr., Senior Researcher Lomonosov Moscow, State University (Moscow).

Marina Karulina, Dr., Senior Researcher, Krylov Shipbuilding Institute. Evgeny Karulin, Dr., Senior Researcher, Krylov Shipbuilding Institute.

Sveinung Løset, Professor, NTNU

Knut Høyland, Professor, NTNU

Jomar Finseth, Senior Engineer, SINTEF

Magne Wold, Engineer, SINTEF

Evgeny Morozov, Professor, Shirshov Oceanology Institute (MSU)

Goals:

To collect and analyse field data on sea ice, icebergs and coastal permafrost. The primary goal is to provide field data as required by the other Work Packages. The main objectives are 1) Occurrence, thickness and geometry of sea ice and icebergs in the Barents Sea, Kara Sea and Fram Strait; 2) Properties of first-year sea ice; Monitoring of tides, currents, ice and seabed/coastal erosion in the Van Mijen and Ice Fjord; 3) Ice loads on Svalbard quays; 4) Physical-mechanical properties of seabed and coastal soils, extent of coastal permafrost and coastal erosion in Svalbard and Northwest Russia; 5) Accurate and reliable instrumentation for field investigations and sampling for laboratory investigations of ice and frozen soil.

Knowledge gaps:

There is no proper understanding of 1) Spatial/temporal variations of morphology and mechanical properties of first-year and multi-year ice, ice ridges and icebergs in the Barents Sea (BS), Kara Sea (KS) and Fram Strait (FS); 2) Occurrence and drift characteristics of first-year and multi-year ice and icebergs in the BS, KS and FS; 3) Ice loads on coastal and floating structures. The WP1 intends to fill the gaps in the following areas: 1) Effects of heat exchange (air, water temperatures, solar radiation), sea currents, ice and waves actions on seabed and shoreline erosion; 2) Coastal permafrost distribution and variability; 3) Proper and reliable field instrumentation and laboratory testing equipment.

Achievements in 2011:

Barents Sea Coast

Barents Sea is an area of great geopolitical and economic importance, as well as an indicator of sustainable development of Russian Federation in Arctic region. The article presents mapping made for the Barents Sea coastal zone. For each area a brief description of distinct geomorphological features and coastal dynamics is outlined. The environmental forcing factors and conditions, which determine the development and present coastal dynamics at Barents Sea are examined.

Russian Northwest Coastal Zone

Baydara Bay is area of gas production and pipelines cross the bay. The field investigation with geological bores had been performed there by a team from the Laboratory of Geoecology of the North of Lomonosov Moscow State University. The results of investigation is engineering-geological profile across Baydara Bay and data base on soils properties across the bay, including the data on mechanical properties of soils. These data will be analysed in the coming years.

Water-ice actions on floating plastic jetty on Svalbard

Field measurements of the floating plastic jetty movements in port of Longyearbyen has demonstrated the existence of angular displacements (pitch, roll and jaw) and vertical displacements (heave) correlated with tidal phase. Angular displacements reached several degrees in the ice season 2011, and in the ice-free season in 2010 they were much smaller. Tide induced heave was stronger in the ice-free season. In the ice season there is correlation between the pitch, roll and heave of the jetty and the air temperature. In the October vertical oscillations of the jetty with period about 1.7 s and amplitude of vertical velocity up to 20 cm/s were registered. 2D model of floating jetty was elaborated taking into account parabolic approximation of the mooring lines shape. Numerical simulations demonstrated the resonant excitation of vertical and angular displacements of the jetty caused by periodic changes of water level with period 0.52 s and 1.07-1.08 s. Periods of natural oscillations of the jetty with respect to the vertical and angular displacements are around 1.18 s and 1 s. Period of natural oscillations in horizontal direction is around 200 s. Resonant excitation of natural oscil-

Fig. 1: A small fjord at Murmansk coast and Coastal erosion on Varandei Island, June of 2000 (photo by S.A. Ogorodov).

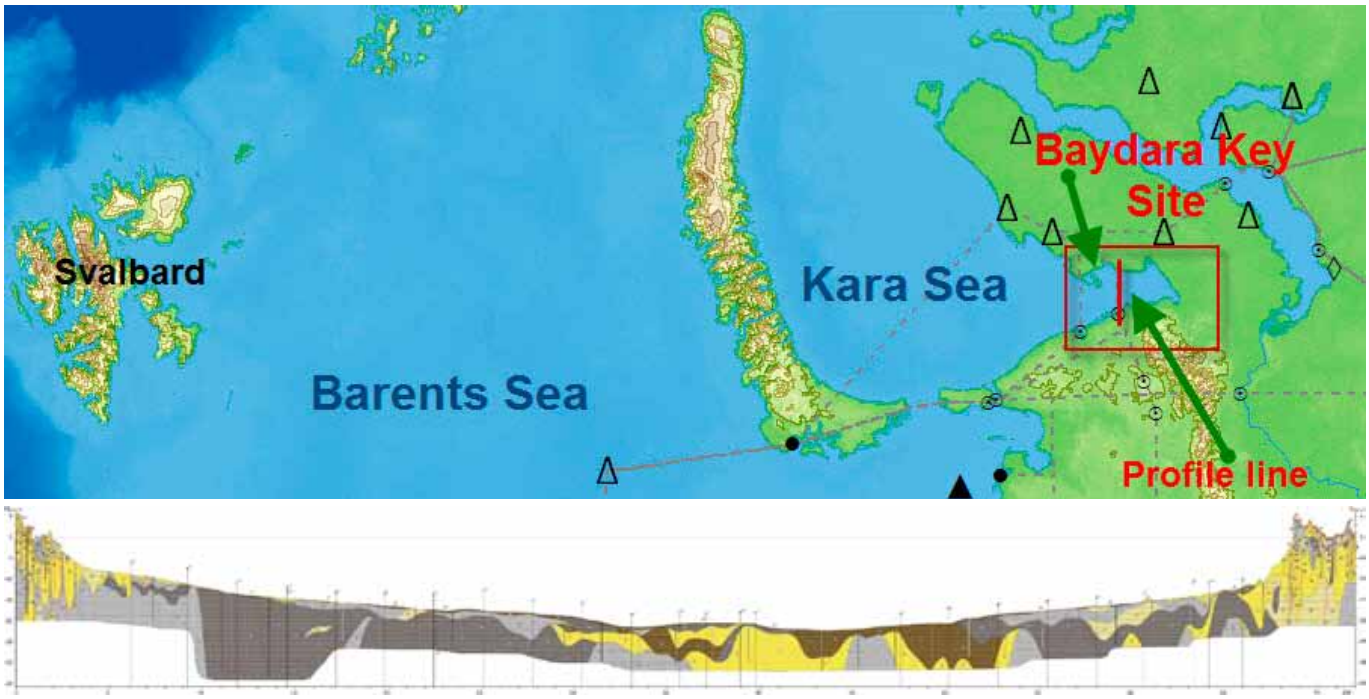
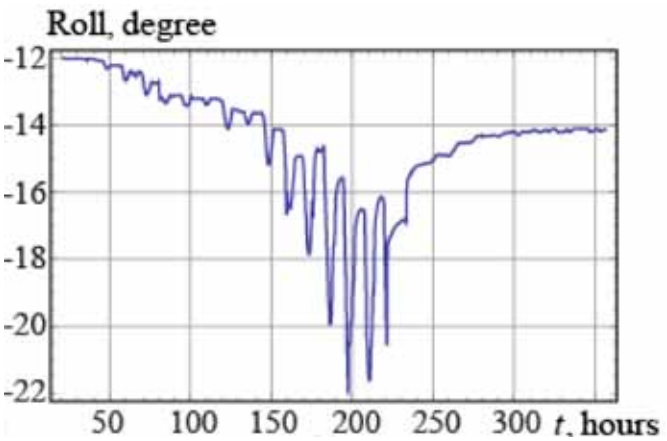


Fig. 2: Location of Baydara Key Site and engineer-geological profile across Baydara Bay.

lations of floating jetty by incoming waves can create problems of their exploitation in ice-free season. Floating jetty moves together with the ice in the ice season. It helps to avoid the formation of ice bustles on the jetty walls.

Field studies of sea water and ice properties in Svalbard fjords

Tide measurements have shown proportional changes of water level amplitudes in Ny-Ålesund, Longyearbyen and Svea during the ice season. In ice-free season water level amplitudes in these locations have higher dispersion around their mean values. Phase shifts between tides in Ny-Ålesund and Longyearbyen are varied within 1 hour with high dispersion around mean value 0.55 h in ice season and 0.59 h in ice free season, so that highest and lowest water levels in Longyearbyen are occurred earlier than in Ny-Ålesund over the semidiurnal cycle. Phase shifts between tides in Ny-Ålesund and Svea are varied within 1 hour with high dispersion around mean value 0.55 h in the ice season and 0.45 h in the ice-free season, so that high-



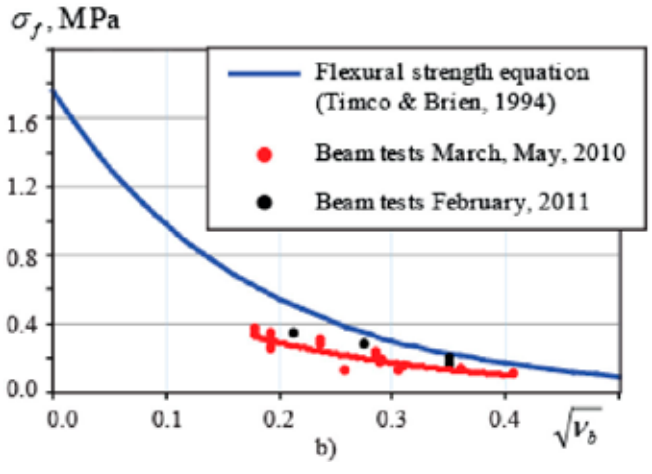
a) b)

Fig. 3: a) Floating jetty in Longyearbyen, b) registered roll movements of the jetty induced by thermal ice loads.

est and lowest water levels in Svea are occurred later than in Ny-Ålesund over the semidiurnal cycle. Akseløya influences phase shift about 0.5 h between the tides on different sides of the island.

Sea water near glaciers has lower salinity and water temperature is close to freezing point. Water temperature near Paulabreen is higher than the water temperature in Sveabukta and adjacent regions of Van Mijenfjord. Water temperature in Tempelfjord depends on the influx of sea water from the ocean. In 2010 the water temperature on 10 km distance from the glacier varied from -1.8 °C to -1.1 °C and was much higher than the water temperature -1.9 °C measured near Tunabreen. In 2011 the water temperature on 10 km distance from the glacier varied from -1.86 °C to -1.82 °C and was almost the same as near Tunabreen. Ice thickness near glaciers is well interpolated by Zubov's formula based on the calculation of degree days of the frost. Heat fluxes from the water can significantly reduce the ice thickness at a 10 km distance from Tunabreen.

Flexural strength measured in Svalbard fjords on ice beam of different thickness corresponds well to the formula of Timco and Brien (1997) showing the dependence of flexural strength from the brine volume. Values of flexural strength of the ice in Svalbard fjords are varied from 0.1 MPa to 0.38 MPa. Effect of ice destruction along shore line in Ice Fjord is explained by the action of swell on the ice on shallow depth. Flexural strength was used in the criterion of ice destruction by swell.



a) b)

Fig. 4: Flexural strength test in Sveabukta of the Van Mijenfjord. Measured flexural strength of sea ice versus square root of brine volume in comparison with other similar tests. (Photo by A. Marchenko).

WP2

Material modelling

THE TEAM

Knut Høyland, Professor, NTNU

Thomas Benz, Professor, NTNU

Aleksey Marchenko, Professor, UNIS

Per Østensen, Technician, NTNU

Jukka Tuhkuri, Professor, Aalto

Kari Kolari, Researcher, VTT

Jaakko Heinonen, Researcher VTT

Arttu Polojärvi, PhD candidate, Aalto

Sergey Kulyakhtin, PhD candidate, NTNU

Yared Worku Bekele, PhD candidate, NTNU (started 2012)

Goals:

To provide constitutive models for ice rubble and permafrost that can be used in advanced analyses of boundary value problems in other WPs and to obtain numerical models that can be used to predict the drift of sea ice and icebergs in the BS and KS.

Knowledge gaps:

The following gaps need to be addressed in order to reach the above goals: 1) Experimental observations of time and confinement effects in ice rubble as a function of the properties of freeze-bonds and ice blocks; 2) A macro-scale (continuum) model for ice rubble that accounts for time effects (rate of loading and creep); 3) An effective stress based permafrost model based on thermo-hydro-mechanical (THM) principles that includes time effects (creep); 4) Ice drift models that include both sea ice and individual features such as icebergs or platforms / vessels.

Achievements in 2011:

General

A workshop with the international research partners was held on 25 May at NTNU and the research plan was further developed. Furthermore, 4 PhD positions were announced and 3 candidates accepted an offer. The fourth position will be re-announced in 2012. One candidate Sergey Kulyakhtin started in November 2011. He works with ice rubble and completed two PhD courses at NTNU in 2011. The two other candidates (Renat Yulmetov – ice drift and Yared Bekele – frozen soils) will start in January 2012.

Ice rubble

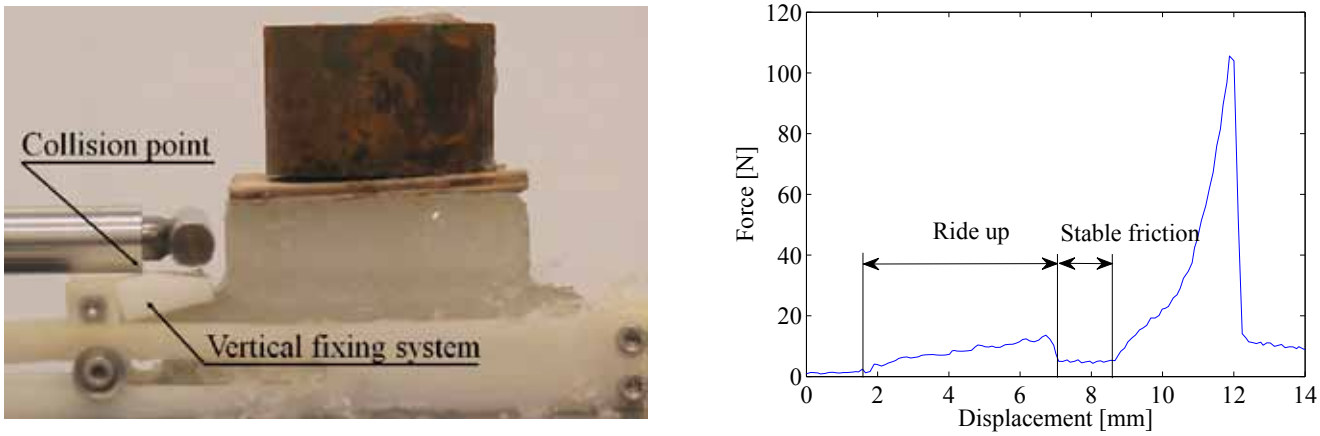
Two PhD candidates (Nicolas Serré and Ada Repetto) defended their theses about ice rubble in 2011. They were a part of the PetroArctic project at NTNU that was sponsored by the Research Council of Norway (http://www.ntnu.no/bat/petroarctic). SAM-

CoT-WP2 builds on their work and three master's students (2 at NTNU and 1 at UNIS) started their theses in freeze-bonds and small-scale characterization of ice rubble. In 2011 they tested individual freeze-bonds for different vertical confinements and ice crystal structure, and measured the mechanical response (Fig. 6) and characterized the freeze-bond crystal structure (Fig. 7). This kind of work creates a necessary background for the development of ice ridge-structure interaction models required by industry. The three theses will be completed in the spring of 2012 and will result in at least 2 conference papers for the POAC'13 conference in Helsinki.

Frozen soil

A preliminary review of existing models for frozen soil was undertaken. Furthermore, existing creep concepts that are commonly used in soil mechanics today were reviewed with a focus on their possible transfer to frozen soil mechanics. The literature review undertaken so far is to be detailed by the PhD candidate working on the topic of frozen soil modelling (started January 2012).

Commercial and research oriented finite element codes were identified that allow for various levels of THM coupling. It is intended to discuss possible implementation options with industry in the first workshop to be held in 2012.



a) b)

Fig. 5: Freeze-bond testing a) Close up picture of a test in progress b) Force-displacement record from a test (Oda Skog Astrup and Henning Helgøy, 2011).

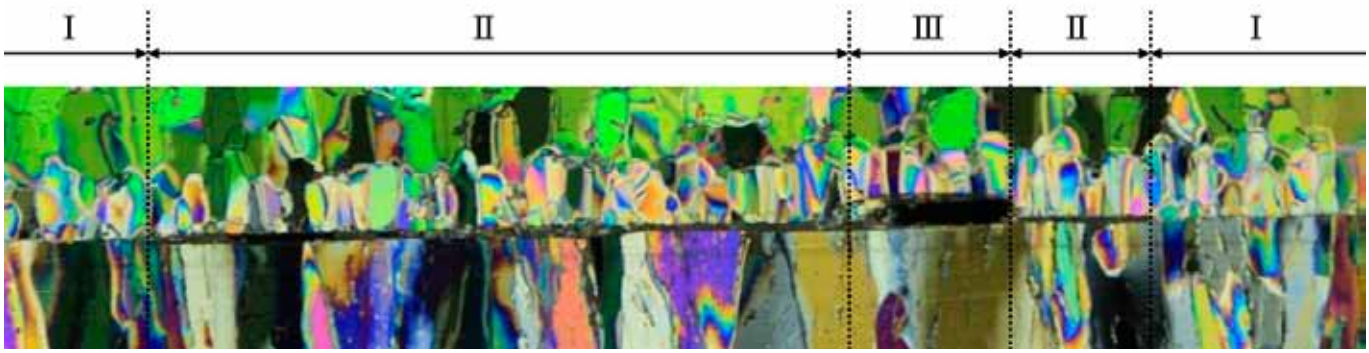
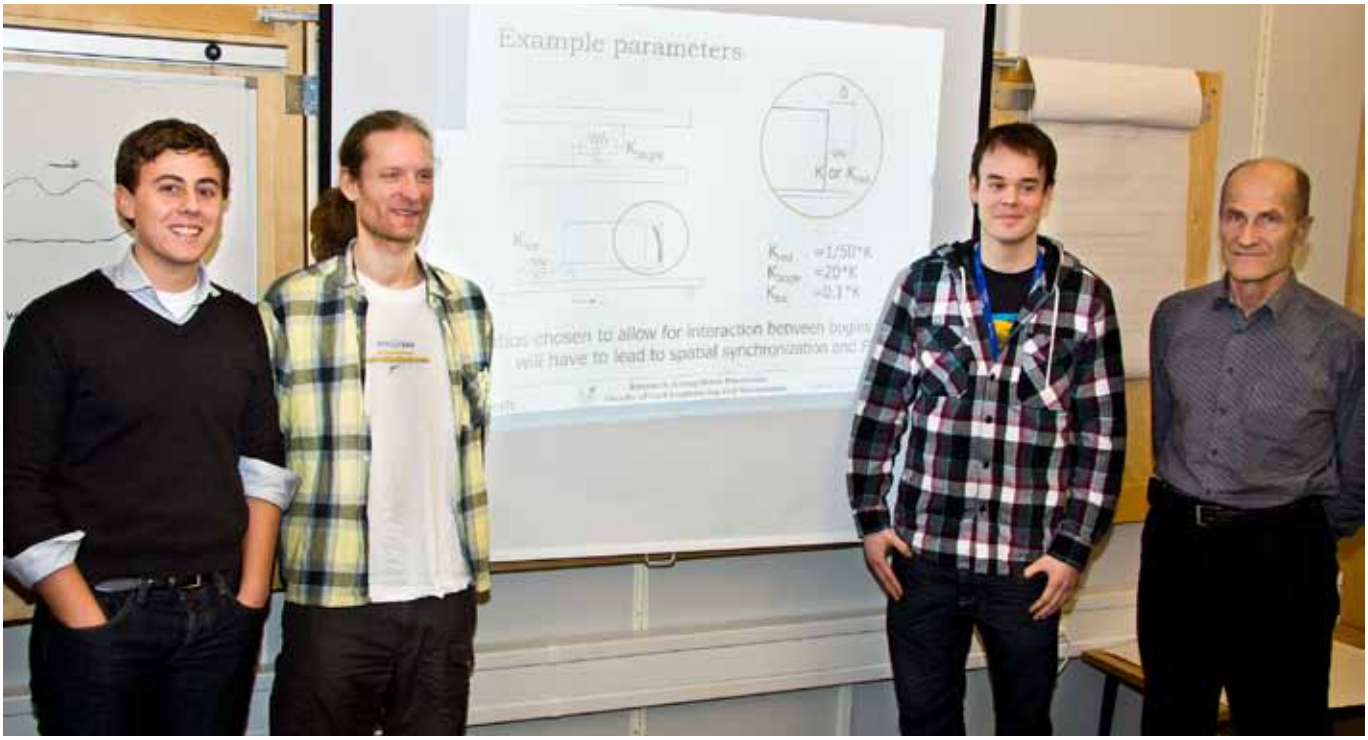


Fig. 6: Crystal structure of a freeze-bond with three different freeze-bond types identified (Henning Helgøy, 2011).

WP3

Fixed Structures in Ice

THE TEAM



Hayo Hendrikse, PhD candidate, TUDelft; Knut Høyland, Professor, NTNU; Torodd Nord, PhD candidate, NTNU; Mauri Määttänen, Professor emeritus, NTNU.

Andrei Metrikine, Professor, TU Delft

Aleksey Marchenko, Professor, UNIS

Jukka Tuhkuri, Professor, Aalto

Jaakko Heinonen, Researcher VTT

Kari Kolari, Researcher, VTT

Goals:

To develop analytical and numerical models needed by industry to predict the action from ice (first- and multi-year, level ice and ice ridges) on fixed single and multi-leg structures. Further to develop innovative vibration mitigation measures.

Knowledge gaps:

WP3 addresses a) Dynamic level ice actions (level ice-structure interaction where the structural response affects the ice actions), and b) Ice ridge action and rubble accumulation on wide structures. The ISO (ISO 99906 Arctic Offshore Structures)

is difficult to use when designing to counter dynamic ice actions and there are no generally accepted engineering models. Further there is a lack of understanding of the physical mechanisms during ice actions on a vibrating structure, in particularly the spatial synchronization has not been properly explained. For ridge actions and rubble accumulation on wide structures there are no satisfactory calculation methods that do not assume a predefined failure mode. Scale-model tests are often done, but there are no accepted models for interpreting these results. Neither the production and scaling of the scale-model ridges nor the up-scaling to full-scale forces and displacements are clear.

Achievements in 2011:

In August 2011 a series of experiments on dynamic Ice actions were conducted at the Hamburg Ship Model Basin (Hamburgische Schiffbau-Versuchsanstalt, HSVA) in Germany. The project was called Deciphering Ice Induced Vibrations (DIIV) and the objective was a) to quantify the physical parameters that control ice-induced vibrations during level ice crushing and b) to identify the added mass and added damping of level ice in interaction with a vibrating structure. Fig. 8 shows the structure, it was constructed so that its natural modes could be adjusted by varying mass and stiffness. A tactile sensor was mounted on the structure surface to record the pressure variations in time and space. It may be difficult to derive a precise direct measurement of the magnitude of the ice force in time from this sensor. So the structural response was carefully measured and a dynamic calibration was carried out to determine the response to force frequency response function. The structure was run through level ice with increasing velocity while the structural response was measured to capture the *Ice-Induced Vibrations occurrence*.

The analysis of the test is being performed by PhD candidates Torodd Nord and Hayo Hendrikse and their supervisors Professors Andrei Metrikine and Mauri Määttänen and three papers will be presented at the International Ice Symposium (IAHR) in Dalian in June 2012.

In late 2011 we did careful preparations of a second experimental programme at HSVA through the EU large-scale facilities program. It is called *Rubble ice transport on Arctic offshore structures* and is headed by Barlindhaug Consult AS (BC). The work will be carried out by a combined team of researchers from BC and NTNU in April 2012.

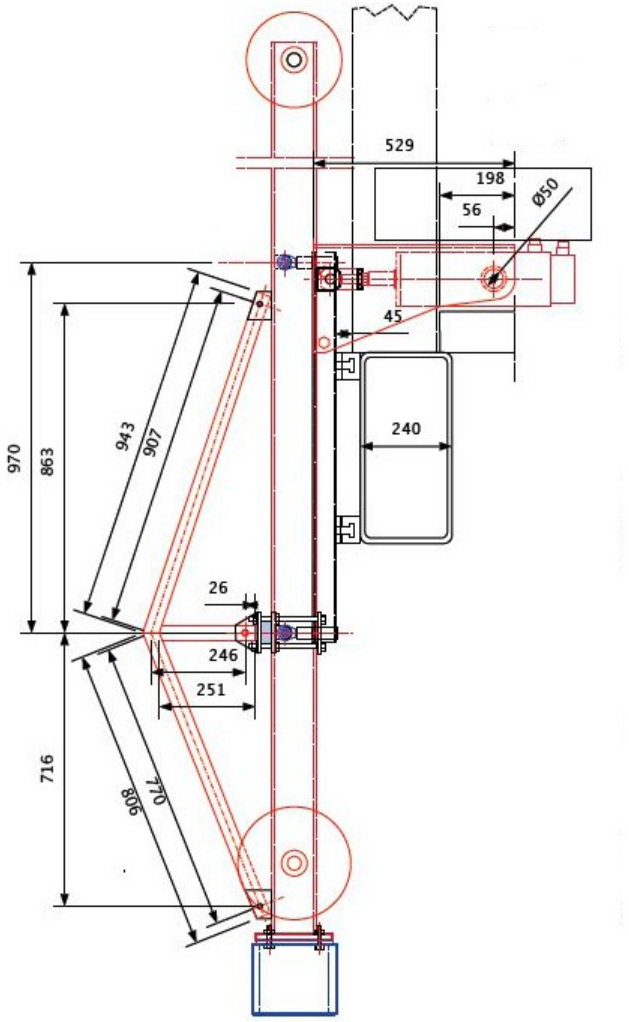
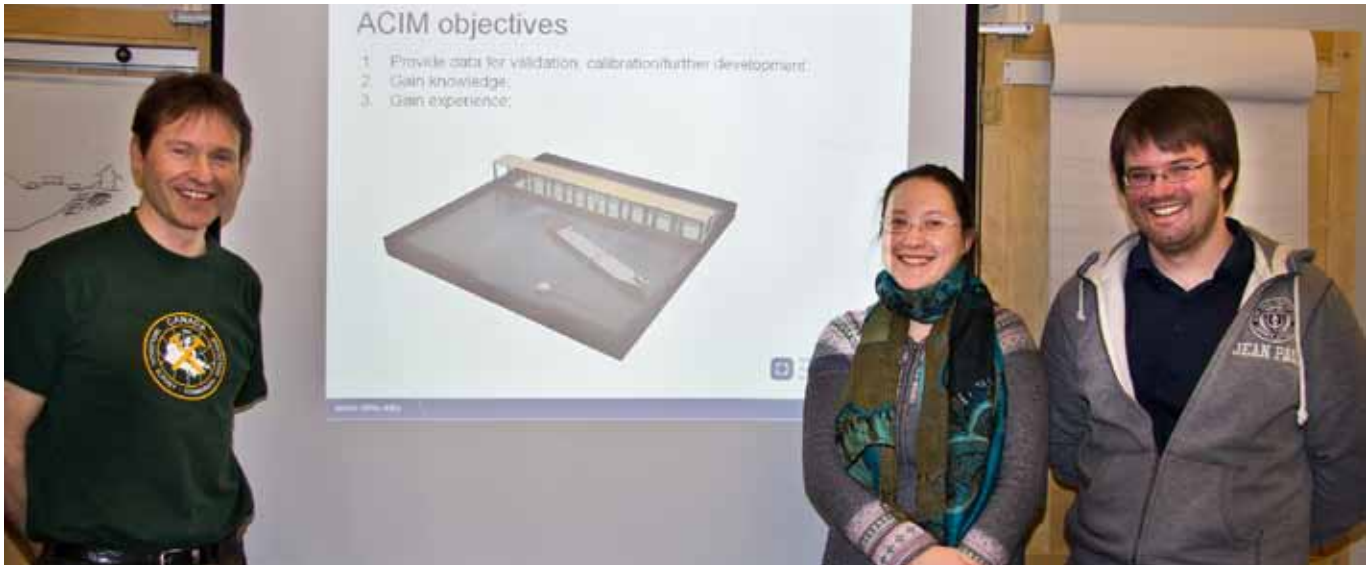


Fig. 7: The model structure: a) Forced movement technical drawing and b) the structure harmonic motion through level ice.

WP4

Floating Structures in Ice

THE TEAM



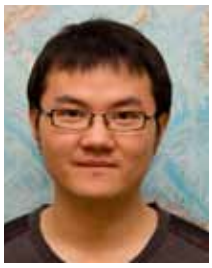
Sveinung Løset, Professor, NTNU; Ekaterina Kim, PhD candidate, NTNU; Martin Storheim, PhD candidate, NTNU.

Jørgen Amdahl, Professor, NTNU

Raed Lubbad, Associate Professor, NTNU

Aleksey Marchenko, Professor, UNIS

Andrei Metrikine, Prof. Dr., TU Delft



Wenjun Lu, PetroRisk PhD candidate,NTNU

Sergiy Sukhorukov, PhD candidate, NTNU

Goals:

To develop new knowledge, analytical and numerical models needed by industry to improve the prediction of loads exerted by first-year and multi-year level ice and ridges as well as icebergs on floating structures. This also implies prediction of the behaviour and performance of the structures.

Knowledge gaps:

There is no proper understanding of the difference between moored structures and fixed structures in ice with respect to ice failure mechanisms or the loads and parameters that affect the dynamics of the coupled system. Firstly there is a need for numerical models that properly predict the behaviour of moored structures in ice and thus address the effect of being moored in ice. Secondly we need to improve methods for assessment of the resistance to the penetration of the inner hull of ships and floating platforms subjected to iceberg impacts, accounting for local ice pressure redistribution during major structural damage.

Achievements in 2011:

Iceberg-structure collision

A proper understanding of the ice-structure interaction mechanisms is required to numerically model the processes involved in the interaction of ice masses with ships, offshore and coastal structures. This includes the failure processes under high and low confinement. In the late spring of 2011 we conducted small-scale laboratory ice-indentation tests on freshwater granular and freshwater columnar S2 ice at –10 °C and –40 °C at Thayer School of Engineering, Dartmouth College, USA. The specific focus of the tests was on the micromechanical processes underlying the indentation pressure as a function of indentation speed, penetration depth and the size of the indenter and the relevance of these processes on larger scales. The experiments indicate that the presence of lateral confinement during indentation is an important factor, as confinement suppresses ice failure by splitting. The results were presented in a paper at the POAC'11 Conference and a paper accepted by the journal *Cold Regions Science and Technology*.

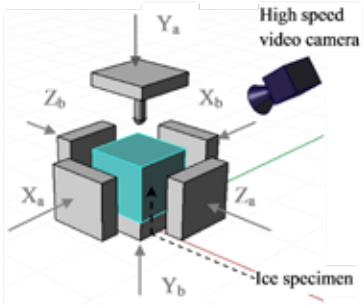


Fig. 8: Schematic sketch of the experimental setup.

The autumn of 2011 was spent on developing a numerical tool for the analysis of iceberg-structure collisions considering deformations of the structure and the iceberg. Further, model-scale experiments were planned for Accidental Collision of Ice Mass with a floating structure (ACIM). The tests are being carried out in the Aalto Ice Basin in Helsinki in Q1 of 2012. These studies are done by two PhD candidates, Ekaterina Kim and Martin Storheim, and are highly applicable to industry when designing structures for use in waters prone to icebergs.

Simulating ice-sloping structure interactions

In past decades, the ice-structure problem has been studied analytically and numerically. One similarity in all the methods applied is the adoption of a continuum approach and focus on the pre-failure process. Nowadays, advances in modern computation capacity have empowered us with the possibility to utilize more comprehensive material models to simulate the failure of ice in a progressive failure manner so we can capture the material degradation of the ice.

The major processes during level ice interaction with sloping structures (especially wide structures) are the fracturing of ice and upcoming ice fragments accumulating around the structure. The cohesive zone method which can simulate both the fracture initiation and propagation represents a potential numerical method that can simulate this process. In one of the numerical methods based on the cohesive zone theory, we have studied the cohesive element-based approach to simulate both the fracturing and upcoming fragmentation of level ice. This work is applicable to the design of offshore structures and has

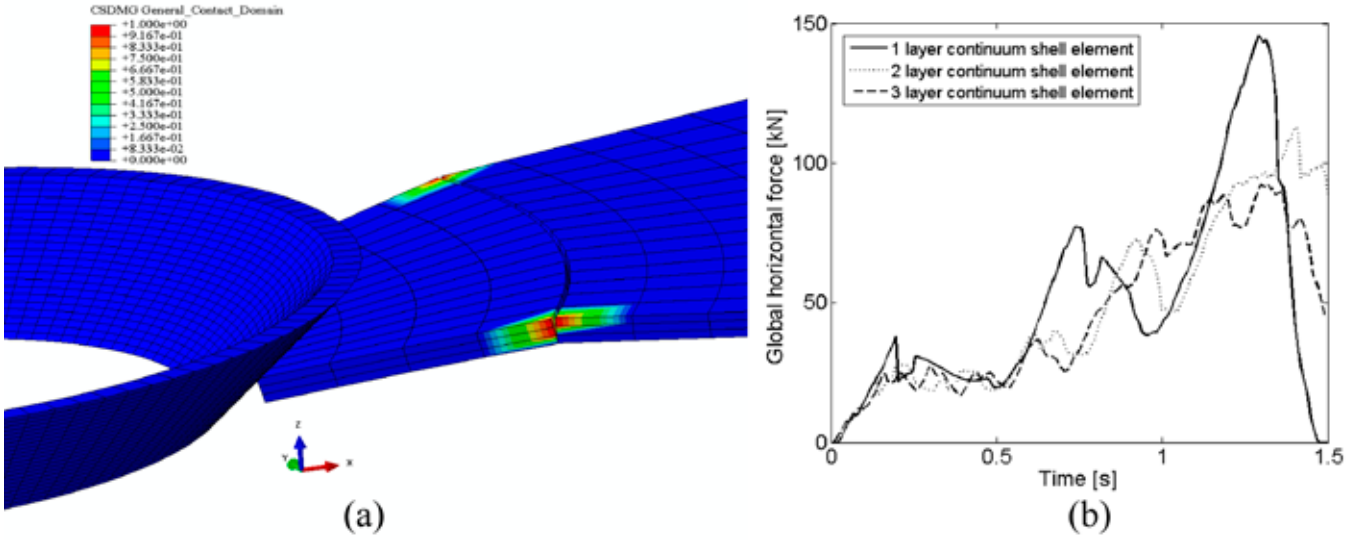


Fig.9: Illustration of the simulation results of DEM with cohesive ties.

mainly been undertaken by Wenjun Lu, PhD candidate and was presented at the POAC'11 Conference.

Location study of a moored meso-scale structure
A meso-scale buoy with a downward facing cone may be moored in the drift ice in one of the proposed sites at Spitsbergen. We expect this shall contribute to bridge the gap between lab-scale data and the non-existing full-scale data. In 2011 we provided statistical data from several sites e.g. with information on ice conditions.

Field experiments on ice-ice friction
Field experiments of the friction of ice on ice were performed in Adventfjorden and the Barents Sea. The ice blocks from level ice and from ridges were pulled on level, snow-free ice. The tests were done both on dry and wet level ice (submerged level ice). The friction force was measured and the kinetic coefficient of friction was derived for a number of settings. Such tests are important when estimating the friction force of ice sliding on ice in the ice-structure interaction process. The tests were headed by Sergiy Sukhorukov, PhD candidate and presented at the POAC'11 Conference.

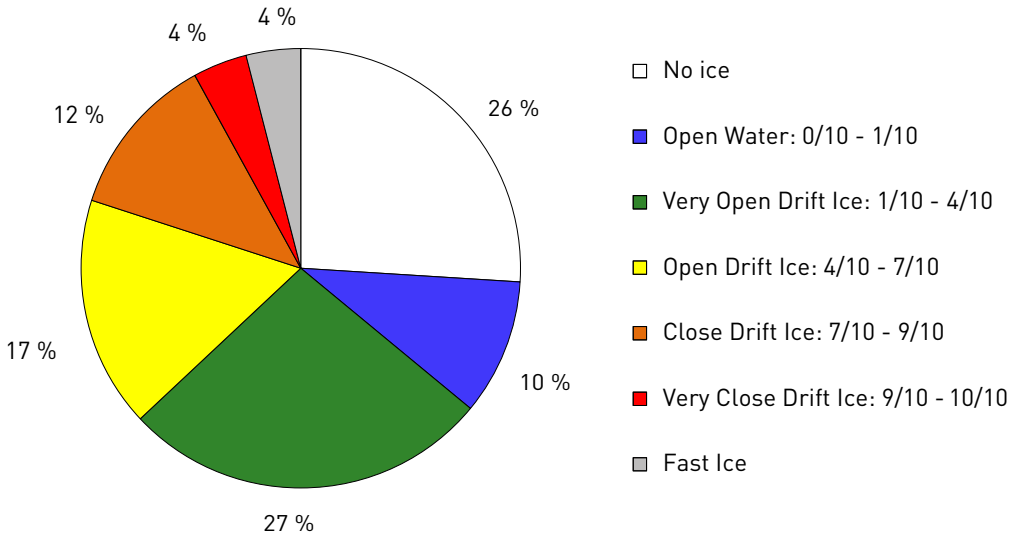


Fig. 10: Location study: example data on ice conditions.

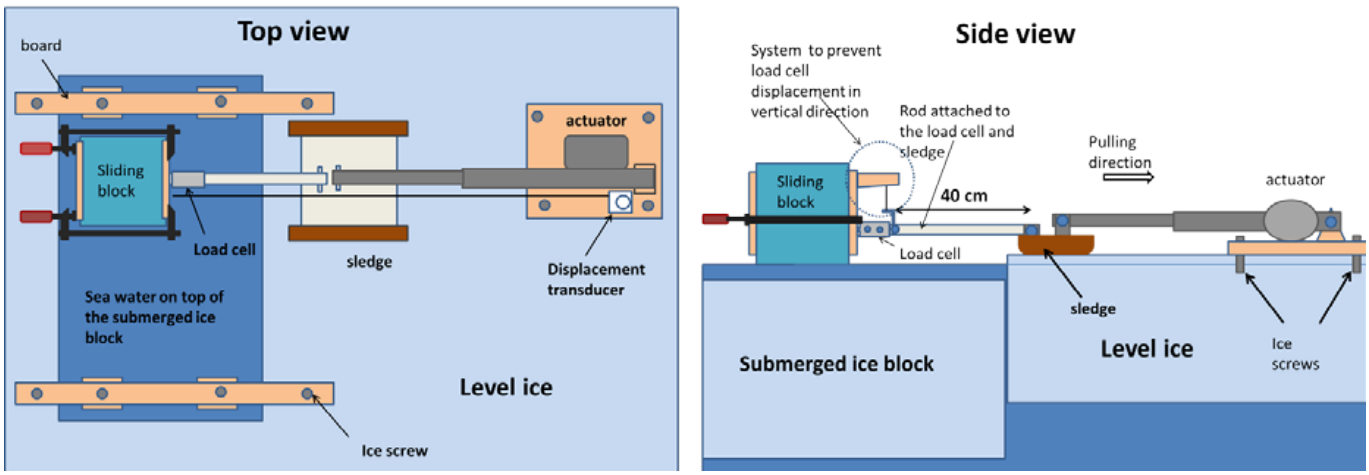


Fig. 11: Experimental setup of friction tests.

WP5

Ice management and Design Philosophy

THE TEAM

Raed Lubbad, Associate Professor, NTNU working together with Wenjun Lu, PetroRisk PhD candidate, NTNU.

Raed Lubbad, Associate Professor, NTNU

Roger Skjetne, Professor, NTNU

Aleksey Marchenko, Professor, UNIS

Renat Yulmetov, PhD candidate, UNIS

Marat Kashafutdinov, PetroRisk PhD candidate, NTNU

Goals:

The primary goal of WP5 is to establish a design philosophy that ensures the fulfilment of the standard design requirements for Arctic offshore structures without being overly conservative. The established philosophy will consider the use of ice management means such as icebreakers, iceberg towing vessels, ice surveillance (detection, tracking and forecasting) and disconnection/reconnection capabilities of moored floating structures.

Knowledge gaps:

Ice Management is defined as the sum of all activities in which the objective is to reduce or avoid actions from any kind of ice features. In order to incorporate such activities in the design, there is a need for a framework that allows proper design documentation relating to safety of the Arctic offshore structures supported by ice management operations.

The main knowledge gaps in this work package are: Decision-making methodology; Human factor effects; Overall safety and reliability estimation; Iceberg detection especially when embedded in sea ice; Iceberg towing especially for icebergs embedded in pack ice; Prediction models for iceberg impact loads; Prediction models for sea-ice loads (managed/unmanaged ice); Sea-ice and iceberg drift models; Icebreaker performance; and Floater behaviour in ice.

Achievements in 2011:

Iceberg towing

Two scenarios of towing an iceberg with a boat using floating and submerged tow lines were analysed and equations governing the towing process and the tension in the mooring lines were formulated. The stability of steady solutions describing the towing process at a constant speed was studied. Numerical simulations were performed to compare the modelling results with the experimental results of towing a model iceberg in HSVA ice tank and to investigate towing a full-scale iceberg. The results of this study are presented in a paper at the *Journal of Cold Regions Science and Technology* and in another paper at the *Miscellaneous Problems in Maritime Navigation conference*.

Characteristics of sea-ice drift

Analysis of drift data from Ice Trackers (IT) deployed on sea-ice in the Western Barents Sea gives e.g. data on the radius of curvature versus ice drift velocities which is very important information for the assessment of drilling and production solutions in ice. The development of efficient ice management operations and simulation needs to include these issues and one way has been to analyse data from ITs. Data of ice tracking buoys *"Oceanetic Model 703"* deployed on drifting ice in the marginal ice zone and on interior drift ice of the West Barents Sea were analysed by Prof. A. Marchenko at UNIS. Mean drift velocities were compared with mean wind velocities and prevailing sea currents in the region. Functions of distributions of absolute ice drift velocities, drift directions, volumetric and shear strain were constructed and analysed for different intervals of the ice trackers trajectories. The trajectories of ice trackers were compared with ice-drift trajectories reconstructed by satellite data provided by IFREMER. The results of this study were presented in a paper at POAC'11 Conference.

Fig. 12: Real-time simulation of Ice Management (NTNU/SMSC).

WP6

Coastal Technology

THE TEAM

Emilie Guegan, PhD, NTNU (start in 2012); Prof. Lars Grande, Professor, NTNU.

Dr. Kristina Heilemann, Senior Researcher, SINTEF

Jomar Finseth, Senior Project Manager, SINTEF

Dr. Svein Willy Danielsen, Project Director, SINTEF

Maj Gøril Glåmen Bæverfjord, Research Scientist, SINTEF

Stein Olav Christensen, Senior Researcher, SINTEF

Dr. Elena Kuznetsova, Research Scientist, SINTEF (start in 2012)

Magne Wold, Engineer, SINTEF

Arne Lothe, Senior Scientist, SINTEF

Hans Bihs; Research Scientist, SINTEF; Adjunct Associate Professor, NTNU

Dr. Arne Instanes, INSTANES POLAR AS; Professor at Bergen University College

Elise Balmand, Master of Science , SINTEF

Goals:

The goal of WP6 is to develop technology and guidelines needed by industry for the development and design of environmentally friendly and sustainable coastal structures in the challenging Arctic areas.

Knowledge gaps:

- Understanding of physical mechanisms (combination of ice, waves and melting permafrost) behind Arctic coastal erosion.
- Efficient ways of utilizing local materials in protective measures for coastal structures and coastlines.
- Technical solution or guidelines for landfall of pipelines and coastal solutions.

Achievements in 2011:

The main challenge for sustainable coastal structures in Arctic areas is the changing condition of the coast due to erosional process by waves, currents and ice. The stabilization of the underground beneath harbour constructions and pipelines in landfall areas and river crossings requires specific technical solutions. Today, the oil related industry has a lot of experience with erosion processes in temperate zones, but only limited knowledge about the driving forces of the process of erosion in the Arctic and the internal parameters of warming permafrost, which occurs on Spitsbergen and on the Russian coast of the Barents Sea.

Essential for achievement of the goals in WP6 is the detailed knowledge about erosional processes on warming permafrost in coastal areas. This provides the fundament for the development of sufficient erosion protection measures, if possible with the use of local materials. The main focus in 2011/2012 is the selection of adequate and representative test sites work that will continue in 2012.

A number of surveys on different coastal cliffs and escarpments in central Spitsbergen were performed during the summer months of 2011. The intention was to document various coastal erosion processes and the erosion rate in the Arctic fjords of Svalbard. The new results indicate the previously suggested high erosion rate to be stable or increasing. Erosion causes difficulties regarding all types of coastal infrastructure and cultural heritage all over the archipelago.

Fig. 13: Survey on a beach bluff edge in central Spitsbergen. It displays the uneven edge and a small detachment of vegetated soil. An old coal depot can be seen in the background.

The results of that study were used to build up cooperation with the Moscow State University and were the starting point for the selection of corresponding sites on Varandei Island and the Baydara Bay in the Barents Sea.

Also in 2011 a project resulted in cooperation with the Svalbard Foundation for Environmental Protection and with Store Norske. This provides a broad overview about the condition of quay structures at Spitsbergen. The scope has been to study the current condition of the quays as a basis for an evaluation of building traditions and materials used when it comes to the suitability for future construction.

The quay structures on Svalbard represent a great variety of building traditions, materials and current condition. They have been made by sheet piling, steel piles, wooden piles and cob work.

The quay structures have been divided into two main groups:

Quays made with steel or concrete

Fig. 14: Quay structure at Barentsburg, summer 2011.

Wooden quays

Fig. 15: Quay structure at Gammelkaia, summer 2011.

The quay sites which have been investigated are exposed to different degrees of wave action. It is well known that the largest threats for the quay structures are probably the ice and the weight of the structures themselves. However, wave action is also an important aspect to consider as it triggers erosion and sediment transport. The quays are only slightly exposed to waves which would directly harm the construction. Nevertheless, powerful wave rushes can influence how usable and accessible are the quays for the berthing of ships.

In addition to indicating the degree of exposure to the waves and the subsequent erosion/sediment transport wave investigations can also give some information about the way that the local conditions were accounted for when choosing a place to establish a quay.

The following figure shows a numerical model of significant wave heights at Kongsfjord estuary.

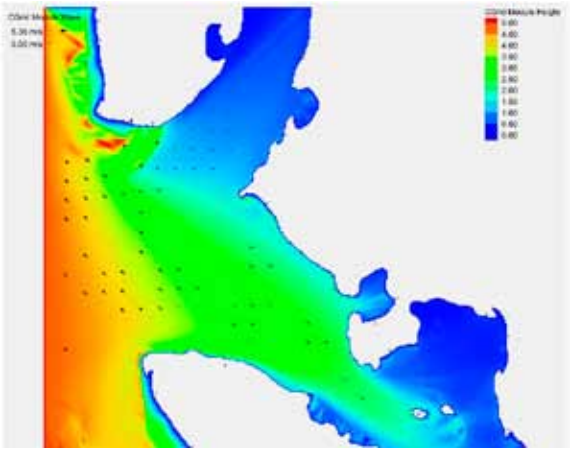


Fig. 16: Example for dispersion of significant wave heights at Kongsfjord estuary.

In most of the cases, the localization of the quay is decided based on the best possible logistical solutions, as for example close to coal exploitations or close to the final destinations of the goods. However, it is also probable that the environmental conditions, primarily waves, wind and depth have been accounted for as well. We assume that the ice laying has had less importance, as the ice would prevent ship traffic whatever locations are selected, and also because it is not possible to change the position of the quay by several hundred metres or kilometres.

A third field investigation on erosion protection measures on Kapp Amsterdam state of the art reports on erosion protection and thermal measurement techniques was produced in 2011.

Fig. 17: Erosion protection in Svea.

SAMCoT, the participants' perspective:

PhD Candidates Hayo Hendrikse (TU Delft) and Torodd Nord (NTNU)

Bad vibrations
Take our word for it: if you're on a platform in the Barents Sea, you really, really want to avoid bad vibrations. The kinds to watch out for are called frequency lock-in. They can literally result in breakdown.

Frequency lock-in may occur when level ice meets fixed structures. The two start to interact, there is an energy exchange and the structure could undergo severe vibrations which in turn can cause material fatigue. This phenomenon is one of the least understood in the Arctic. To put it simply, there is great interest in understanding the phenomenon better so that fixed structures can operate safely in the most vulnerable areas. Luckily, help is underway. PhD candidates Hayo Hendrikse and Torodd Nord are in the help team.

Ice meets steel
Hayo came to SAMCoT from Delft University of Technology in the Netherlands, where he studied dynamics ice-structure interaction. He wanted to visit the Arctic region and took the opportunity to enter SAMCoT's PhD programme when it had a position vacant. NTNU collaborates with the university in Delft, so he still spends most of his time there.

Torodd discovered during his master's programme that working in a theoretical, scientific manner could be both interesting and challenging. This happened at SIMLab, another CRI centre at NTNU, where he studied the fragmentation of metallic materials during impact.

Torodd's switch to ice comes in handy as the two candidates can approach their task in two different manners with an overlapping interface. The aim is the same: to find parameters that can explain frequency lock-in better.

Workshop
How to go about it? Well, there's always the ice basin in Hamburg, where they will perform tests. (See HSVA article.) They've also attended the first International SAMCoT Workshop sharing their experience with many industrial and research partners in SAMCoT. Naturally, industry wants to make sure that they can make designs which will resist the vibrations so they can operate safely. Both the interests of the people on the platform and the serviceability have to be taken care of. Platforms are built today and a lot is known about design but the industry is constantly on the lookout for improvements, understanding more, optimizing solutions. However the central question remains unanswered: have we already seen the most severe case?

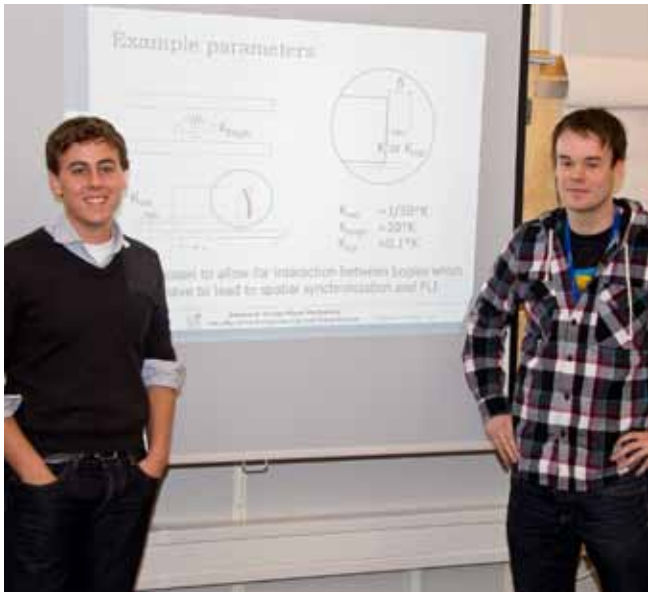
How salt, how porous?
How much do Hayo and Torodd know about frequency lock-in already? They certainly know that the properties of the ice matter and that ice is a complex material. There are many parameters to consider. This all adds up to make the behaviour of ice difficult to predict.

Then there is the movement of the ice, a possible key factor that Torodd and Hayo will study closely, looking at a whole range of velocities. They will perform phenomenological studies and hope to be able to predict outcomes.

Good vibrations
As one would guess, Hayo's and Torodd's lives aren't all about bad vibrations. There are some good ones as well. Travel is what makes Hayo click. He's been to places that really contrast to Arctic ice, namely Lake Toba in Sumatra, possibly the result of the most massive volcanic eruption in the world's history. He has also crossed Canada, part of it hiking. The trip included a slightly thrilling encounter with black bears. Of course, polar bears are next on the list.

Torodd claims that he does not to have much time for leisure but admits to working out. He also enjoys cross-country skiing, glacier walks and hiking.

Outdoor people, well suited for work in the Arctic, it seems. Naturally, potential employers have already an eye on them.



Hayo Hendrikse and Torodd Nord at NTNU Trondheim.

SAMCoT Board and EIAC member, Per Olav Moslet (DNV)

One step up for century-old partnership
DNV can trace its roots back to 1864. It was started to inspect and evaluate Norwegian ships. The collaboration with NTNU is a century old. Therefore, one might say that the newly-established partnership through SAMCoT was unavoidable.

Still, the new agreement is far from business as usual. The establishment of SAMCoT as a Centre for Research-based Innovation (CRI) with DNV as one of eight industrial partners represents a significant change in pace.

Many benefits
"To DNV SAMCoT is the culmination of a broader collaboration on Arctic technology initiated in 2008. Since then both parties have put more effort into this field than ever. SAMCoT takes university collaboration to a new level," says Arctic Technology Programme Director at DNV, Per Olav Moslet.

There are numerous benefits. For instance, the CRI status increases DNV's possibilities for recruiting key personnel. NTNU and its forunner the Norwegian Institute of Technology (NTH) have been the key provider of engineers for Norwegian industry. Now the production of PhD candidates with the relevant expertise will increase. In addition, DNV will have direct access to the results from the Centre itself. This research is well in tune with DNV's own work.

"A third important path is internal development. We will certainly follow the research as part of expanding the competence of our own employees. All in all, SAMCoT is very valuable to us. It is important to support NTNU when they start such an ambitious Centre " Moslet adds.

Taking the lead
Traditionally, Canada, Russia and Finland have had strong clusters driving much of the industrial development in the Arctic region. Norway is now gaining ground, thanks not the least to present SAMCoT head Sveinung Løset and his team of researchers. Per Olav Moslet gained his PhD under the supervision of Professor Løset and is proud to be part of this Norwegian progress.

"Today I think the Norwegian cluster is in the process of becoming one of the strongest if not the strongest university cluster in the world as far as Arctic technology is concerned," says Moslet: "There is a continuous focus on PhD work, consistently resulting in presentations at international conferences," he adds.

Per Olav Moslet (left), attending SAMCoT's 1st International Work Packages Workshop.

A place for spinoffs
As it is, SAMCoT has taken the position as locomotive for Arctic technology research in Norway and internationally. This is demanding, but Per Olav Moslet is confident that Løset and his crew are up to it.

As an industrial partner, Moslet sees clear advantages coming out of the new position as CRI:

"A CRI signifies more extensive industrial participation, enabling greater upgrading of technological competence than would have been possible otherwise.

Furthermore, a CRI has a concrete and predictable path, well suited for industrial partners who want to invest in research on university level.

Collaboration goes both ways. The continuous interaction encourages the spread of results. One of the success criteria will be how deeply industry gets involved. Growing further and recruiting new partners after the start, starting spinoffs from results obtained; this is a model for achieving ever more. We've seen this in other CRIs, it's certainly an aim we have for our participation in SAMCoT, we are very satisfied with the start and we hope that new projects will take form," says Moslet.

Reduce likelihood
DNV started off as a classification society, inspecting and evaluating the condition of Norwegian merchant vessels, including South Pole conqueror Roald Amundsen's famous vessel Gjøa more than a century ago. Today DNV continue with such work, but have expanded their scope significantly. Their focus is on

securing lives, property and environment, including classification of operations and equipment for use in the Arctic region.

"We clearly see an increased interest for activities in the high north and it is important that these activities are conducted safely and reasonably. This is where we bring in our risk-based mind-set. Barriers and incident prevention should be on a par with possible consequences. Likelihood and consequence play against each other. This is an axis, which was basis for the Barents 2020 partnership with the Russians, where the overall aim was to contribute to achieving the same risk level in the Barents Sea as in the North Sea. Since the conditions are more severe further north, we have to reduce the likelihood of incidents correspondingly in addition to being well prepared in case accidents occur. This is our focus and where we hope to apply the outcome of SAMCoT research in an industrial context. One way of doing this could be new standards and regulations to be applied for activities in the Arctic region," Moslet says.

Daily contact

In the time to come, DNV look forward to very close collaboration with SAMCoT. Contact between DNV's own researchers and SAMCoT's PhD candidates takes place nearly on a daily basis. "I have the firm impression that NTNU appreciates this kind of close contact. Personally, I think it serves as a driving force in the development of the projects," Moslet concludes.

PhD Candidates Ekaterina Kim and Martin Storheim

Creative = brilliant

Just do not get fooled. Just because someone is playful it does not mean they cannot be highly competent. Taking pleasure in producing colourful ice-cubes is not an indication of lacking intellectual capacity. An good example of this follows.

She is Ekaterina Kim from St. Petersburg. Ekaterina is definitely not your average young Russian. Her university in St. Petersburg only admits students amongst the top one per cent candidates from all over the former Soviet Union. Ekaterina did very well. When she arrived at the decision point for her master's degree, her professor recommended that she went to Norway. He said nothing about Svalbard, but that is where she ended up, doing her thesis on the characteristics of the freeze bonds between ice block.

After finishing her degree, she returned to Russia. Professor Sveinung Løset at SAMCoT went after her. She was headhunted.

Understanding culture

Sveinung Løset did this because he expects her to deliver a formidable PhD. There are cultural reasons as well. Norwegians and Russians are destined to work together in the exploration and exploitation of the Arctic. Cultural understanding across the border is crucial. That makes Ekaterina doubly valuable.

Back to the ice cubes. Ekaterina puts food colouring in water, adds a little milk for the colour to disperse and puts her ice cube holder in the freeze. Not for consumption, mind you. She simply enjoys watching them.

It could just be that playfulness and creativity is a characteristic of all SAMCoT PhD candidates. When Ekaterina's close colleague Martin Storheim is asked what made him opt for the same path, he answers: "it's fun!"

Perfect match

While Ekaterina's background is ice, Martin's is ships. Coming from Oslo, he has spent a lot of his leisure time in sailboats and enjoys it immensely. Professionally he came to SAMCoT via the Department of Marine Technology at NTNU where he did his master's on ship collisions, followed by some years of structural design work in Moss Maritime AS.

Ekaterina and Martin are the perfect match. At the time of writing they are on their way to the Aalto Ice Basin in Helsinki to

Ekaterina Kim and Martin Storheim at NTNU Trondheim.

perform a test that has never been done before: a collision between a ship and an ice berg where the effects on both are studied in detail. High speed cameras and tactile pressure sensors will register in detail what happens from one split second to the next. Afterwards the result will be studied in close detail. This is lab scale, of course, but it happens in water and Ekaterina and Martin will be able to check a lot of assumptions and hopefully obtain new knowledge. Ahead of the journey they are "calm but excited", extremely curious to know what will be the unexpected something that always occurs during a test...

How to avoid The Titanic

Ekaterina wants to further develop what she terms "an integrated finite element analysis of ice structure interaction". The idea behind is to collect experimental data so she can analyse ice and structure interaction.

"Everyone is interested in this. For instance, if we want to prevent accidents similar to The Titanic, we need to know more about the ice," she says.

Martin approaches the same theme from the other side. He looks for designs of safe floating structures. They will be costly. If you want to limit the consequences of a crash with ice, you need to use reinforcement. What he is looking for, is how.

"Over the last 20 years, there have been many collisions in Arctic waters. We know for sure that traffic will increase, hence the likelihood of collisions will increase and there is work to be done," he says.

Cool work waiting

What they are both sure of, is the desire to prevent accidents. Nobody wants an oil spill in the Arctic. The ice is porous and will absorb the oil, making the clean-up close to impossible.

Since the wish to avoid accidents is universal, the expertise of Ekaterina and Martin is very attractive. Already in the first year of their programmes the candidates at SAMCoT experience interest from potential employers. Centre director Sveinung Løset accepts and appreciates this, although he wants his students to be able to perform their work as undisturbed as possible.

"I have a secret dream," says Ekaterina when asked about future hopes. We accept to leave it at that.

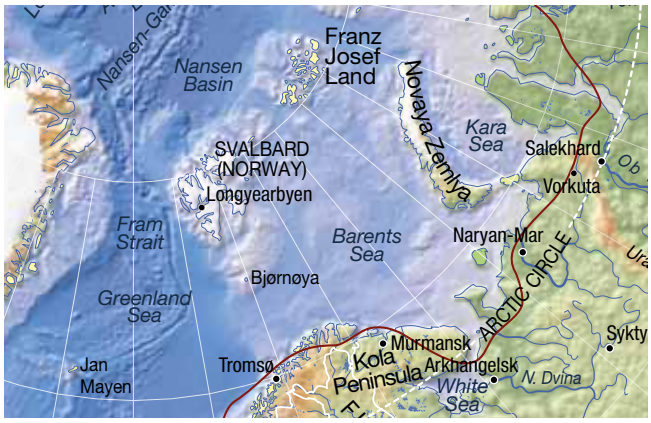
Martin already has work experience and will not be surprised if he returns to one of the industrial companies that are getting more and more involved in the Arctic.

What is equally true for both of them, is the appreciation of SAMCoT as a place to expand their expertise. "This is a good environment. We get to work with people with different kinds of knowledge. It's great fun to be here. It makes us realize that there's a lot of cool work waiting for us after finishing a PhD."

Centre Director and Work Package Leader Professor Sveinung Løset

Preparing for the Arctic

40 years have passed since oil production started in the North Sea. This means that a lot of expertise has been accumulated. Still, the ice-cold atmosphere of the Barents Sea is a completely different story; the Kara Sea yet another. The managing director of SAMCoT Sveinung Løset is well aware of this; his team is up to the challenge.



If you are not familiar with the Kara Sea, it is simple. Pick up your globe and put the finger right east of Novaya Zemlya and you are right onto it. Once you are there, you will be pleased to know that the waters are shallower than in the Barents Sea. In oil-speak: platforms and terminals could be placed on the sea bed. More good news: Earth's largest gas reserves are on the Yamal Peninsula – enough to supply Europe for several decades. But not such good news: the ice is massive and ice ridges may gouge the sea bed. What is the solution? Professor Sveinung Løset has the floor:

Shore-bound

"The special thing about the Kara Sea is that we might have to deal with an ice sheet that stretches all the way to the shore, a bit like a lake. We don't know nearly enough how such an ice sheet will move, what forces we are talking about or how it will behave towards a platform or a ship.

These challenges of the east Eurasian Arctic differ from the open Barents Sea, where drift ice may be broken up by gravitation waves and hit floating installations, and also from East Greenland, where collisions between icebergs and installations are a real risk. In all these cases we are dealing with physical environmental loads that have to be taken into consideration. Some of them will be unavoidable. We have a lot of learning to do."

Who knows when

Timetables are still sketchy when it comes to production in the Arctic. Løset expects the Norwegian fields of Havis and Skrugard to be ready for production during SAMCoT's eight-year long project period. As far as the huge Russian Shtokman field is concerned, one guess is as good as another. Postponements have been plentiful. The reasons for this are partly political but also due to a lack of knowledge.

It is no accident that SAMCoT's partner list includes the large international oil players like Shell, Statoil and Total. They recognize the need for a centre focusing on the robust technology necessary for sustainable exploration and exploitation of the region.

Young but competent

Officially SAMCoT has only existed since October 2011 (Consortium Agreement sign in November), but it would be misleading to call it a baby. The development of Arctic technology dates twenty years back.

The establishment of UNIS, the University Centre in Svalbard in 1993, was an important presupposition and the collaboration with UNIS has been a key in a number of ways: a good basis for logistics, education at master's and PhD levels as well as professional staff both in-house and Russians on loan. In 2005, the PetroArctic Programme was established with many of the same aims as SAMCoT. This collaboration is alive and kicking in the field as well as lab studies and development of theory and numerical models.

Numerical ice simulations

Collaboration with international partners like the ice tanks in Hamburg and Helsinki has also been going on for years. Now SAMCoT aims at developing numerical simulation tools, not to compete with the ice tanks, but to try and establish models for calibration and sensitivity studies that might make research more efficient.

"Figure a ship that you know how it will behave. Expand it 15 metres or change the hull geometry and it will behave differently. Hopefully, our numerical simulation tools will help us finding optimum solutions faster and cheaper," Løset says.

The numerical simulations will also serve to determine the behaviour of floaters in ice; how to keep their position if they are hit by ice, or, if need be, how to keep the ice away.

The calculation of time windows before evacuation is another matter of significant interest.

Important step

The new status as a Centre for Research-based Innovation (CRI, or SFI in Norwegian) is an important step for the SAMCoT team. Not only is it attractive, of 17 applicants from Trondheim in the last round at the Research Council of Norway, only SAMCoT passed.

The status is recognition of the scientific standard of the crew and the programme. This is a signal that the plans are deemed significant and the knowledge needed. Further exploration and exploitation of the Arctic region is dependent on more knowledge about the forces operating there. Sveinung Løset has two relevant examples ready off hand:

"A partner like DNV needs to know the answer when they are asked by a client for the assessment of risk in a certain region. Likewise, a partner like Kongsberg Maritime might get a question about the possibilities for dynamic positioning in a certain location. Before they can answer, they need to know. Guesswork won't do."

World-leading

The education part is also vital; a lot more master's and PhD degrees will come out of the programme. Both the scientists and their commercial partners will benefit from the eight year scope that follows with CRI status.

And although SAMCoT has only just begun, managing director Løset is confident about their position: "We are world-leading. This is illustrated by our planned production of PhDs in SAMCoT. There will be at least 20 doctorates in this field that rank us among the leaders both in expertise and relevance. One important reason for this is our integration with industry."

International Focus

A number of Arctic world-leading universities and research institutes have been invited to take part in SAMCoT by becoming partners in the Centre within their specific knowledge areas. Other international research institutes and universities will contribute through individual collaboration agreements. By including international universities and institutes with Norwegian institutions SAMCoT will ensure its scientific excellence.

SAMCoT will encourage and facilitate international PhD projects involving the partners. On-going MSc and PhD programmes between UNIS/MSU and NTNU/TU Delft will be part of this. This type of collaboration started already in 2011 with SAMCoT's financial support for one PhD position at TU Delft. Other similar actions have been already planned for 2012, i.e. financing of a Post. Doc. position at Aalto University, School of Engineering; Visits from guest researchers from the Technical Research Centre of Finland; jointly financing of a PhD position at the University College of London (UCL) and financing of PhD positions at MSU.

In 2011 model basin test programmes at HSVA were implemented, with participants from relevant SAMCoT Partners (HSVA, TU Delft and NTNU).

In addition fieldwork cooperation took place between SINTEF/MSU/UNIS on specific site studies in NW Russia.

Through the planned 8 year duration of the Centre, international workshops will be organized between the partners and guest institutions to discuss the scientific results as well as the innovative output and possible interactions with other initiatives and projects.

The first SAMCoT International Workshop took place between 30 January and 1 February 2012 in Trondheim.

SAMCoT members participated actively in 2011 at POAC'11.

Port and Ocean Engineering under Arctic Conditions (POAC) conferences address the unique issues related to coastal and offshore engineering in ice-covered waters. The objective of each conference is to improve knowledge of ice-related problems by having scientists, technologists, and design and development engineers discuss and exchange ideas on relevant topics.

SAMCoT's participation in POAC'11 was of great importance and contributed to the *dissemination*.

Future POAC conferences and other International conferences planned for 2012 and future years include: 21st IAHR International Symposium on Ice; OMAE 2012 31st International Conference on Ocean, Offshore and Arctic Engineering; and the 22nd International Offshore (Ocean) and Polar Engineering Conference. These international venues will be used by SAMCoT to increase its international scope.

SAMCoT International research partner and GA member Peter Jochmann (HSVA)

Some are self-evident
When you plan an expedition, some members of the team are self-evident. We have an inkling that HSVA in Hamburg were not entirely taken by surprise when they were invited to join SAMCoT.

Peter Jochmann, head of Ice & Offshore at HSVA, doesn't say it in so many words, but the impression of a long lasting relationship with strong professional ties comes through loud and clear:

Back to the 80s
"When we made a full scale trip with the icebreaker Polarstern in the 80s, Sveinung Løset was invited to join the researcher's team. He also took part in full-scale trials in the Spitsbergen region. Then we had loose contact for some years until the European Commission initiated the Hydralab network in the mid-90s, giving young researchers the possibility to work in our ice model basin. The project has been extended several times and is still in place. Since Hydralab started we have had very close cooperation."

Plenty of proof
The following facts speak for themselves: In Hydralab I 64% of the students came from NTNU, in the follow-up the percentage was 27%. Today Hydralab has reached stage IV with half the students coming from NTNU.

Peter Jochmann illustrates further:
"Last year we had students here as part of Hydralab IV, working with the project "Deciphering of ice induced vibrations" under Professor Mauri Määttänen. As far as I heard, they made very good progress. This is a project that I hope will shed a little more light on some serious challenges concerning offshore wind turbines. So far none have been erected in Arctic waters, but we need to know the answers before this is done."

There have been other links, too, like a full-scale ice test around lighthouse in the Baltic.

Not to mention the many students who have since joined industry and come back as clients. DNV's Per Olav Moslet is a typical example. (See DNV article)

True veterans

HSVA, the Hamburg Ship Model Basin, is a true veteran in the business. Almost a century old, it is an independent and private company. 85% of the research is done for industry and shipowners.

HSVA covers all maritime disciplines. Its facilities include a large open water basin, a hydro-acoustic tank, an ice basin and an environmental basin. This makes the Hamburg complex unique in the world. Add to this a lot of expertise and experience in model and ice testing, including tests with floating offshore structures, and you have a quite obvious partner for SAMCoT.

Win-win

"Our long-term experience with model testing in ice and our scientists' background from other hydrodynamic fields are some of the assets we can bring into this cooperation.

From the earlier collaboration we have learnt that working with NTNU gives us the possibility to develop ourselves both in test setups, procedures, analysis and postprocessing.

What I particularly like about this partnership is the new ideas and new blood that NTNU's master's and PhD candidates bring with them when it comes to test procedures and analytic methods.

This is a typical win-win situation and we are looking forward very much to help in the work for safe and environmentally friendly activities in the Arctic," Peter Jochmann says.

AAA

The CRI construction we have in Norway is not common everywhere. This kind of constellation between university, private and industrial researchers for the common good and with a substantial input from government funds does not exist in Germany. Peter Jochmann likes the concept:

"SAMCoT is a huge, important and multidisciplinary research programme with respect to Arctic development and international involvement and it is very challenging.

SAMCoT has a very broad scope and the advantage of industrial partners in the centre. They will undoubtedly provide very important knowledge and advice. The integration of international partners is another significant plus. This collaboration will have very high importance for us."

If Jochmann is pleased with the model, he is not less pleased with the professional standard of his partners: "If I were to rate Sveinung Løset and his team on the classic scale of the business world, I would give them a triple A," he concludes.

SAMCoT 1st International Work Packages Workshop, 30th January – 1st February 2012.

Statement of Accounts 2011

In December 2011 the Annual Work Plan for both 2011 and 2012 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 2012 were presented to SAMCoT's Board and approved. The CTR's provide a detailed description of each Work Package by defining: Objectives; Knowledge Gaps; Activities planned for the current year; dependencies, critical factors, assumptions, milestones and resource requirements.

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

Annual Work plan 2011 – Cost (All figures in 1000 NOK)

	Host NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV	TOTAL	Multiconsult	Kongsberg Maritime	Barlindhaug Consult	Aker Solutions	Norwegian Coastal Admin	HSVA	TUDelft	Aalto University	MSU	VTT	Total
WP1		230,62	2 111,50															2 342,12
WP2	639,10																	639,10
WP3	1 120,83													283,33				1 404,16
WP4	490,21																	490,21
WP5	218,80																	218,80
WP6	59,11	3 179,46														300,00		3 538,57
EIAC				97,50		170,31		97,06	106,50	330,00								801,37
SAC																		-
Equipment	10,71		2 436,00															2 446,71
Adm.	1 384,14	493,78	100,00															1 977,92
Total budget	**3 922,88**	**3 903,86**	**4 647,50**	**97,50**	**-**	**170,31**	**-**	**97,06**	**106,50**	**330,00**	**-**	**-**	**-**	**283,33**	**-**	**300,00**	**-**	**13 858,94**

Annual Work plan 2011 – Funding (All figures in 1000 NOK)

	Type of Research*	RCN Grant	Host NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV	TOTAL	Multiconsult	Kongsberg Maritime	Barlindhaug Consult	Aker Solutions	Norwegian Coastal Admin	HSVA	TUDelft	Aalto University	MSU	VTT	Total
WP1	F	743,43			1 070,00	125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25						2 548,43
WP2	F	743,43	6,94			125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25						1 485,37
WP3	F	743,43				125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25						1 478,43
WP4	F	743,44	226,00			125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25						1 704,44
WP5	F	743,44	203,82			125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25						1 682,26
WP6	F	743,44		251,26		125,00	125,00	150,00	125,00	31,25	37,50	37,50	62,50	41,25				300,00		2 029,70
EIAC	I					97,50		170,30		97,07	106,50	330,00								801,37
SAC	F																			-
Adm.		743,44	791,71	493,78	100,00															2 128,93
Total budget		**5 204,05**	**1 228,48**	**745,04**	**1 170,00**	**847,50**	**750,00**	**1 070,30**	**750,00**	**284,57**	**331,50**	**555,00**	**375,00**	**247,50**	**-**	**-**	**-**	**300,00**	**-**	**13 858,94**

Fig. 18: ESA reporting SAMCoT 2011.

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

Dissemination

JOURNAL/PAPERS

Ogorodov, S.A. Barents Sea Coasts. Journal of Geography Environment and Sustainability. No. 03[v.04] 2011, pp. 34 – 51

Lubbad, R. and S. Løset. A Numerical Model for Real-Time Simulation of Ship-Ice Interaction. Cold Regions Science and Technology, Vol. 65, pp. 111-127.

Marchenko, A. K. Eik. Iceberg towing in open water: Mathematical modeling and analysis of model tests Cold Region Science and Technology - doi:10.1016/j.coldregions.2011.11.008

PUBLISHED CONFERENCE PAPERS

Marchenko, A., A. Shestov, A. Sigitov and S. Løset Water-ice actions on the coal quay at Kapp Amsterdam in Svalbard. Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-145, 10 p.

Marchenko, A., K. Bråten. Water-ice actions on the floating plastic jetty in Svalbard. Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-146, 14 p.

Marchenko, A., A. Shestov, E. Karulin, E. Morozov, M. Karulina, P. Bogorodsky, S. Muzylev, D. Onishchenko and A. Makshtas, Field Studies of sea water and ice properties in Svalbard fjords. Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-148, 13 p.

Kim, E., J. Amdahl and S. Løset Development of ice failure/yield criteria for accidental limit state design Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-023, 10 p.

Løset, S. Arctic Offshore Field Developments in Deeper Eurasian Waters Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-Keynote Lecture, 10 p.

Masterson, D. and S. Løset ISO 19906: Bearing capacity of ice and ice road Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-142, 10 p.

Sukhorukov, S. and S. Løset. Field experiments on ice-ice friction. Proceedings of the 21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011, POAC11-008, 11 p.

OTHER MEDIA COVERAGE

Løset, S. (2011): Sustainable Arctic Marine and Coastal Technology. Norwegian Academy of Technological Sciences (NTVA), 17th March, 2011, Lerchendal Gård, Trondheim.

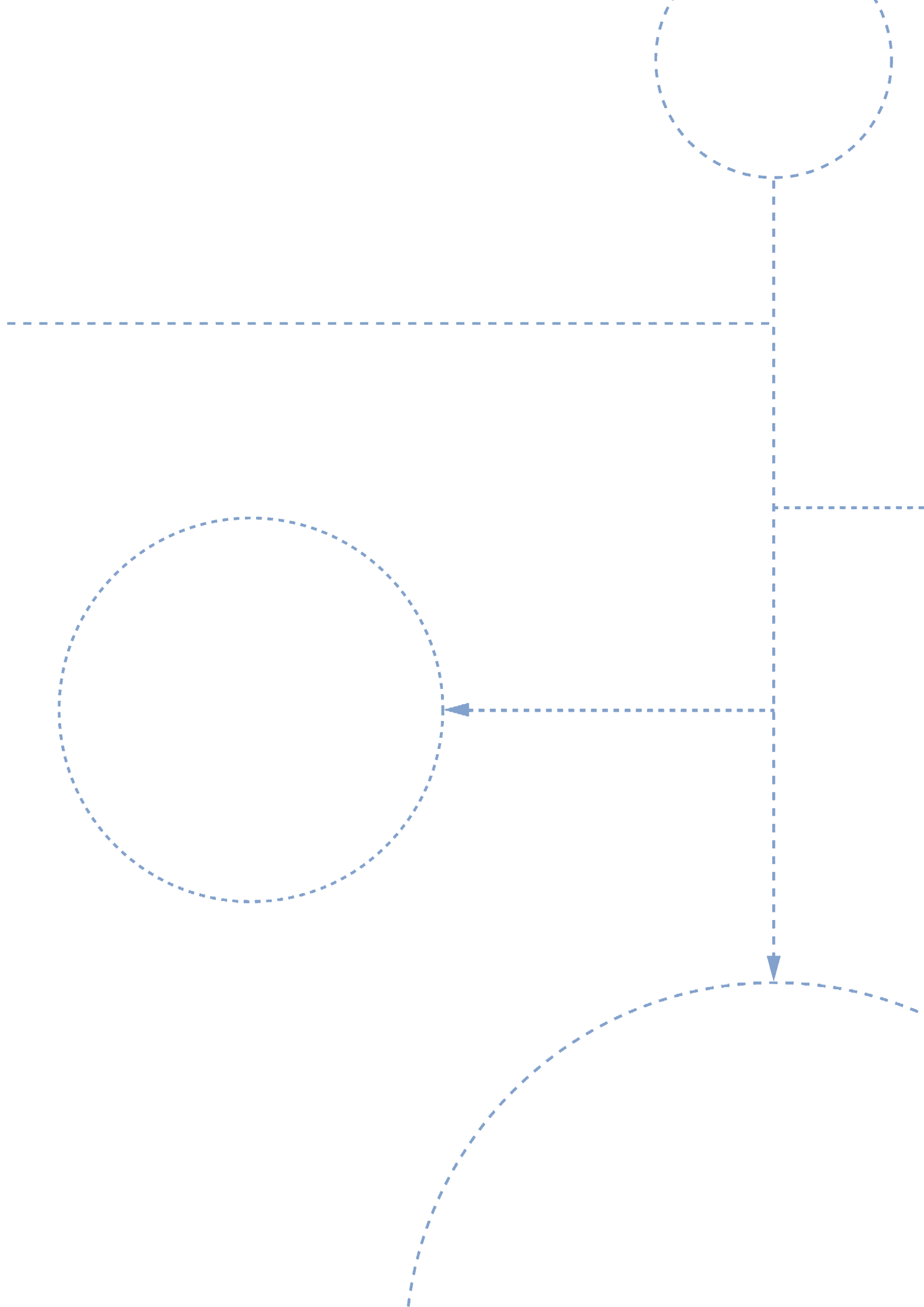
Løset, S. (2011): Arctic Technology. The Norwegian Academy of Science and Letters (DNVA), 21st September, 2011, Oslo.

Johansen A.B. (2011): Forventer mye av iskaldt samarbeid. NRC Website, 10th October, 2011, Trondheim

SAMCoT Website: **www.ntnu.edu/SAMCoT**

ORGANISATION OF INTERNATIONAL CONFERENCES IN 2011

Conference	Person	Responsibility
21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011	K. Høyland	International Committe
21th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Montreal, Canada, July 10-14, 2011	A. Marchenko	International Committee
EURODYN 2011, 8th International Conference on Structural Dynamics, Leuven, Belgium, 4-6 July 2011	A. Metrikine	International Committee
EURODYN 2011, 8th International Conference on Structural Dynamics, Leuven, Belgium, 4-6 July 2011	S. Løset	Mini Symposium Organiser



Annual Report 2011

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

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