ANNUAL REPORT 2017

SUSTAINABLE ARCTIC MARINE AND COASTAL TECHNOLOGY

SAMCoT

sfi

NTNU

SAMCoT KEY FIGURES	2017	2016	2015*	2014	2013	2012	2011	Accum.Fig
Turnover (in 1000NOK)	32 086	39 336	75 299	33 666	59 887	45 770	13 859	299 903
PhD Defences	5	4	5	3	3	1	0	21
Published Journal Papers	10	26	29	16	5	7	7	100
Published Conference Papers	38	43	52	40	40	18	15	246
MSc Thesis	5	6	11	6	7	8	2	45
Mass Media & Other Popular Media	84	36	12	24	11	8	3	178
Industry Partners	13	13	13	13	11	11	9	13
Research Partners	8	8	8	8	7	7	7	8
Public Partners	2	2	2	1	1	1	1	2
PhD Candidates	19 (4 female)	26 (6 Female)	26 (7 Female)	21 (6 Female)	22 (4 Female)	19 (4 Female)	10 (1 Female)	23
Post Docs	9 (0 female)	9 (2 Female)	9 (2 Female)	4 (1 Female)	3	1	0	9

*Turnover including OATRC2015

SAMCoT PARTNERS

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

CONTENTS

CONTACT

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

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

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

Visiting address:
NTNU Høgskoleringen 7a, Trondheim

www.ntnu.edu/SAMCoT

Print, design and layout - NTNU Grafisk Senter

2017

IN REVIEW

ADMINISTRATIVE REPORTING

In 2017 the Sustainable Arctic Marine and Coastal Technology SFI (SAMCoT) continued to pursue its vision. Following its initial strategy to become a leading international centre for the development of robust technology needed by the industry operating in the Arctic region, SAMCoT has achieved this, and both the centre and its research are now well known worldwide in the Arctic research community.

One of SAMCoT's societal responsibilities is to develop key knowledge and innovative tools to promote safe, environmentally sound operations in the Arctic. This fragile, beautiful and unique environment deserves no less, and **Health, Safety and the Environment (HSE)** is at the core of all SAMCoT's activities. Hence, its board, composed of representatives from Aker BP, DNV GL, ENGIE, ExxonMobil URC, Kværner, Lundin, NTNU, Shell, SINTEF, Statoil, TOTAL and UNIS (University Centre in Svalbard), with the RCN as observer, is leading this effort by closely following all of SAMCoT's activities.

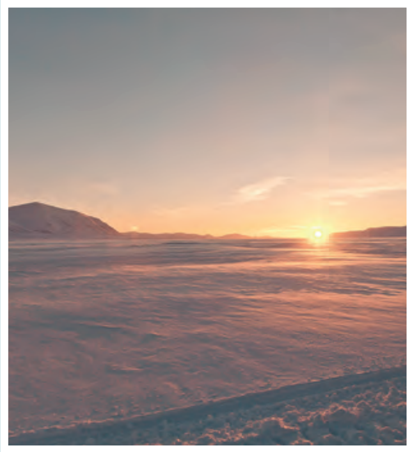
As of the end of 2017 SAMCoT is supported by 23 partners, 12 industry partners, 2 public partners and 9 research partners (with NTNU as host institution).

International research institutions and public institutions contribute with their experience and knowledge to the implementation and development of novel and sound research. In parallel, SAMCoT industry partners closely follow the researchers' work and promote further activities aimed at finding innovative uses of the scientific knowledge gained.

SAMCoT's research strategy is based on four research pillars: theoretical studies; field activities; laboratory work and numerical modelling. SAMCoT gives high priority to collecting and analyzing full-scale data where possible. Having the necessary full-scale data is crucial from a quantitative and qualitative perspective. The data and their analysis enable realistic scaling and a good representation of nature and interaction processes, both numerically and at the laboratory scale.

Therefore, SAMCoT annually promotes **different field initiatives**, carried out in collaboration with some of its key research partners. In particular, UNIS contributes greatly to the fieldwork undertaken in the archipelago of Svalbard. These field activities are very fruitful and influence further research in most of the work packages. In 2017, Statoil's Station-Keeping Trials in Ice (SKT2017) deserves a special mention as it hosted four of SAMCoT's PhD candidates. SKT was a two-week series of full-scale station keeping trials in ice in the Gulf of Bothnia utilizing two ice-classed offshore vessels, Magne Viking (a high ice-classed AHTS vessel) which was moored in ice, while the vessel Tor Viking (Combined AHTS & ice-breaker with DNV Ice-10 notation) was performing ice management. The trials were successful and our PhD students not only advanced their research but also gained important field experience.

In addition SAMCoT continued its important international collaboration with Moscow State University (MSU), carrying out vital fieldwork on the Russian coast. The Russian Arctic coast is key to the scientific advances of Arctic coastal technology in general. Hence, SAMCoT continued the work related to the field studies carried out at Baydaratskaya Bay.



SAMCoT'S IMPACT IN THE ARCTIC RESEARCH COMMUNITY

SAMCoT's high publication record, growing expertise and large network has not gone unnoticed. The centre's **dissemination efforts**, both through scientific publications and the attendance and contribution at key conferences, have provided SAMCoT's researchers with great recognition in the Arctic research community.

A key conference on Arctic research is the International Conference on Port and Ocean Engineering under Arctic Conditions (POAC). Issues unique to **POAC** relate to coastal and offshore engineering in ice-covered waters. Over the years, this conference has become the mainstay of the Arctic engineering community. In 2017, POAC was held in Busan, South Korea where SAMCoT contributed 18 papers. In addition, the president of the POAC International Committee celebrated professor Løset's work with the POAC Founders Lifetime Achievement Award. The award recognizes Løset's efforts to promote the quality of the international POAC conference over the years, as well as his advances in understanding and providing novel knowledge on Arctic technology research.

Moreover, in September 2017 Sveinung Løset was invited to participate in a five-day transdisciplinary white paper workshop hosted by **EU-PolarNet**. EU-PolarNet is the world's largest consortium of expertise and infrastructure for polar research. Seventeen countries are represented by 22 of Europe's internationally-respected multi-disciplinary research institutions. Løset was nominated by the EU-PolarNet consortium and its external expert advisory board as a co-lead of the EU-PolarNet New Technology group. This five-day transdisciplinary white paper workshop was aimed at developing and delivering a strategic framework and mechanisms to prioritize science, optimize the use of polar infrastructure and broker new partnerships leading to the co-design of polar research projects that deliver tangible benefits to society.

As in previous years, SAMCoT has continued its work through different **associated projects** and **national** and **international** research **collaborations**:

- Ice-induced vibrations of Offshore Structures (IVOS) lead by Hamburg Ship Model Basin (HSVA),
- The Centre for Autonomous Marine Operations and Systems (SFF AMOS) hosted by NTNU,
- The Center for Integrated Remote Sensing and Forecasting for Arctic Operations (SFI CIRFA) hosted by the Arctic University of Norway, Tromsø,
- The MOSIDEO project Microscale interaction of oil with sea ice for detection and environmental risk management in sustainable operations led by Norut Narvik,
- The Japan-Norway Collaboration for Sustainable Development of the Arctic, NTNU - Kogakuin University (Tokyo UrbanTech).

NTNU, SAMCoT's host institution, is responsible for **higher education** in technology in Norway. SAMCoT researchers are ambassadors for this task and through education SAMCoT has a bottom up influence in the Arctic research community.

In Norway, SAMCoT has provided postgraduate courses to the Petroleum Safety Authority Norway and the Norwegian Maritime Authority (NMA). Petroleum Safety Authority Norway is an independent government regulator with responsibility for safety, emergency preparedness and the working environment within the Norwegian petroleum industry. The NMA is the administrative and supervisory authority on matters related to safety of life, health, material values and the environment on vessels flying the Norwegian flag and foreign ships in Norwegian waters.

Some of SAMCoT staff have even extended NTNU's educational duties beyond the Norwegian borders. Examples are postdoc Torodd Nord who contributed to an MSc-level course in ice mechanics at Aalto University, Finland and associate professor Ekaterina Kim who lectured at the Far East Federal University in Vladivostok, Russia.

In 2017, SAMCoT has strengthened its links with **NTNU Oceans**, one of four strategic research areas at NTNU that aims to achieve "knowledge for a sustainable ocean". Professor Knut Høyland, SAMCoT WP3 leader, is responsible for the new NTNU Oceans pilot project on Arctic marine environment addressing risk, reliability and ice data in the Arctic marine environment. The Ocean School of Innovation (OSI), with WPAdm. leader Maria Azucena Gutierrez Gonzalez as SAMCoT representative and OSI Board member, continues to create an improved culture for innovation and strengthens awareness and competence in innovation among SAMCoT PhD candidates. OSI aims to contribute to an increase in the commercialization of research results.

Last but not least, SAMCoT's contribution to the development of **ISO 19906**, Petroleum and natural gas industries - Arctic offshore structures can be considered one of SAMCoT's most important contributions to Arctic research. The series of international standards ISO 19900 to ISO 19906 addresses design requirements and assessments for all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, regardless of the type of structure or the nature or combination of the materials used.

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

Sveinung Løset
SAMCoT Centre Director

Sveinung Løset, SAMCoT Centre Director

SAMCoT INNOVATION &

GENERAL BACKGROUND

Industry plays a fundamental role in shaping the research strategies of the Centres for Research-based Innovation (SFIs). SAMCoT is not an exception. The Research Council of Norway (RCN) expects to see clear results obtained from linking fundamental research with innovation targets. Innovation and value creation are among the criteria for success provided by the RCN.

In 2015 SAMCoT underwent a mid-term evaluation by the RCN. Despite a good overall result, it was clear that the centre had to rethink its strategy and efforts concerning innovation. Patents, contribution to the development of international standards, exploitation and innovation templates and spin-off companies are some of the innovation results expected from an SFI, and SAMCoT was scoring low on these aspects. The SAMCoT Exploitation and Innovation Advisory Committee (EIAC), constituted to stimulate the centre's innovative thinking and to achieve SAMCoT's objective of being a facilitator for innovation, was aware of this. The EIAC strengthened its role in monitoring project results with respect to the potential for commercial exploitation, and took the lead in developing and implementing a closer collaboration with the WP leaders to comply with the expectations of the RCN and of SAMCoT's partners.

A RELIABLE NUMERICAL SIMULATOR TO CALCULATE ICE LOADS ON FLOATING STRUCTURES - SAMS

From the very beginning of SAMCoT in 2011, the researchers involved in WP4 (Floating Structures in Ice) understood their role in the development of a reliable numerical simulator to calculate ice loads on floating structures. This simulator should be used by industry as the standard tool for calculating ice loads and it should empower designers to efficiently carry out trials on different structural configurations. It should also make the design and verification process much more theoretically sound and cost effective. Professor Sveinung Løset is the leader of the work package dedicated to the study of floating structures and their interaction with ice. He understands the focus of the industry partners on this particular research topic and works closely with the EIAC and his team of experts to achieve such a tool.
Hence in 2015 SAMCoT's WP4 re-defined its strategy and started searching for soft funding in order to achieve one of RCN's innovations goals: the establishment of a spin-off company. The group identified a viable funding source, NTNU Discovery - one of NTNU's strategic funding schemes, and found a suitable entity, NTNU's Technology Transfer Office (TTO), to define a clear business concept and to deal with important administrative requirements. Within one week, WP4 had 1.4 million NOK in soft funding to establish the project VeriArc.

The project ran from August 2015 to August 2016 and allowed WP4 researchers to prove their technology and to demonstrate its capabilities. ArcISo AS (Arctic Integrated Solutions AS), established in 2016, was the natural follow-up to the VeriArc project. With the encouragement of some of SAMCoT's partners, WP4 researchers (now constituted as the spin-off company ArcISo led by Associate Professor Raed Lubbad) applied for further funding from RCN's programme on commercialising R&D results (FORNY2020). ArcISo received 3.9 million NOK for a period of two years.

The Simulator of Arctic Marine Structures (SAMS) is ArcISo's main product. ArcISo employees plan to develop different versions of SAMS tailoring it to different purposes including SAMS design, operation and on-board tools.

SAMS design aims to be the state-of-the-art tool for the accurate calculation of loads and load effects from ice on a structure which is essential for the verification and classification of Arctic structures. Using SAMS design, operation and on-board tools, ship designers, oil and gas companies, consultancy companies and other Arctic business developers can improve important aspects of their overall safety and reliability.

Technical highlights of SAMS:

- Utilization of a non-smooth discrete element method (NDEM) with an implicit integration scheme, which has been shown to be superior to the traditional smooth DEM due to its high accuracy even with large time steps.
- Improved contact model enabling general visco-elastic contacts.
- Novel closed-form solutions to simulate the fracture of sea ice covering such modes as bending failure, crushing, splitting and radial cracking. These solutions have been developed as a result of long-term research involving both full- and model-scale experiments.
- A sophisticated hydrodynamic model that, in addition to wind and current, also takes into account and simulates the effects of ship propellers on the ice and water flow.
- The ability to model the construction of arbitrary offshore structures.

Thus, the capabilities of SAMS allow engineers to analyse ice-floe impacts and ice loads on arbitrary marine structures in various environmental conditions. Simulations may involve both fixed and floating structures, non-rigid multi floe interactions, ice breaking in various modes and wind, current and propeller-flow effects on both the structure and the ice.

A Minimum Viable Product (MVP) of SAMS

Research at SAMCoT has generated a considerable amount of "academic code" - functional software encompassing advanced theories but which may have been implemented in a simple manner in comparison to industry standards. ArcISo allocates resources to translate these published results into code (SAMS) which is stable, robust, trust-worthy and user-friendly. With the help of an industry reference group, including several SAMCoT partners, that guides the selection of product development and the funding from FORNY2020, ArcISo is working on producing a Minimum Viable Product (MVP) of SAMS. MVP encompasses a multi-body dynamic and contact model, tailor-made for ice-ice and ice-structure contact, including hydrodynamic effects with the ice fracture module implemented on top of that.

Validations and Potential

SAMS is now at the validation stage to ensure/demonstrate its high fidelity. Simulations of icebreaker Oden's transit in the Marginal Ice Zone (MIZ) with SAMS compared against field data from the Oden Arctic Technology Research Cruise 2015 (OATRC 2015) show a remarkably small difference of about 1% between the simulations and the field measurements loads. In 2018 more validations will be carried out to strengthen and improve the accuracy of SAMS in different application scenarios. Other applications of SAMS could be studies of harbour areas, bridges, wind turbines, and fish farms that are under the influence of ice loads.

MONITORING ICE

Ice management is another of SAMCoT´s key research areas where the industry is eager for innovative results. WP5, with Professor Roger Skjetne as its leader, is investing its resources in achieving the link between fundamental research and the innovative advances expected by the RCN and SAMCoT partners.

A forecasting observation tool that would allow simulations to be performed on ever-changing ice conditions within a region is still one of the areas where SAMCoT is focusing its research. Such a tool would allow industry partners to predict the ice conditions they will encounter in a certain area so that they can design their structures to withstand loads in the best possible way.

360 CamSys

This is a 3-camera system with a total of 11 lenses and hardware/software for automated image capture every 2, 5, or 10 seconds, with image data time synchronized to other shipboard sensor measurements. This aids in the observation of ice actions and the understanding of ice-vessel action effects during ice manoeuvring.

The system has been incrementally developed and used on different research expeditions such as the Statoil station keeping trials in spring 2017. The 360 CamSys has currently achieved technology readiness level (TRL) 6 and it is now a central component in our observation and documentation platform for ice-going expeditions.

Shipboard radar-based ice drift detection system
This system, demonstrated during OATRC 2015, captures image frames from the ship radar, processes the images and tracks distinct landmarks in the image that correspond to features of the ice cover in the image. The relative motion between the ice cover and the ship is sensed by this method, and is subsequently merged with ship motion measurements so that the absolute motion of the ice cover can be estimated. This work was executed by Dr Øivind Kjerstad, but it is currently carried out within SAMCoT's framework by PhD candidate Runa Skarbø.

Global ice load estimation system

A system of four or more Inertial Measurement Units (IMUs) installed on an icebreaking vessel makes it possible to accurately measure the full six Degrees of Freedom (DOF) acceleration vector of the ship when moving through ice. In addition, the local ice-induced accelerations in the ship's hull that are typically suppressed by the flexibility of the hull can be sensed. This makes it possible to sense the ice actions and their local intensity distribution in the hull, as well as the global ice loads causing the motion of the vessel.

The global ice load estimation system has the ability to estimate the loads acting on the vessel from vessel-ice interactions. Possible uses include decision support, warning systems, increased autonomy of the station keeping systems or an ice-aware autopilot system.

Shipboard IMU-based ice load detection system

Using the time-synchronized IMU-based system for the detection of ice loads, we have found that the probability distribution of ice-induced accelerations is heavily tailed and follows a t-distribution quite closely. Mathematical results further indicate that the extreme value distribution follows a Frechét distribution. Specific distribution parameters for different ice conditions can then be identified and used in a signal-based statistical detection scheme to automatically identify the prevailing ice conditions for the vessel. A cascaded hypothesis-based detection scheme and an entropy-based detection scheme have been developed, tested and compared with real data from the Arctic Ocean 2016 expedition.

WP5 plans to finalise the method of predicting extreme ice loads based on knowledge of the Frechét distribution, and to show how this can be incorporated into decision support in an ice-aware shipboard system. Finally the plan is to combine the global load estimates and the local acceleration measurements to better estimate (model-based or statistically) the angle of attack of the ice loads on the vessel, and to incorporate a change detection algorithm to monitor and rapidly warn of changes in the relative ice drift direction as experienced by the ship's hull. This will then work as a redundant ice load monitoring system that works on principles other than camera or radar-based systems.

Synthesis of real ice field characterization from images

Former PhD student Qin Zhang has, together with Roger Skjetne, written the book: "Sea Ice Image Processing with Matlab®", CRC Press, Taylor & Francis 2018. The book is accompanied by a Matlab-based software toolbox where the different algorithms presented in the book are provided. These can be downloaded here: www.ntnu.edu/samcot.

Characterization of real ice images for use in numerical models is presently being implemented in the SAMS software. A paper on this by Qin Zhang has been drafted, but further progress has been postponed due to a lack of resources.

AUV for underwater ice observation

A tool has been developed enabling autonomous iceberg mapping using AUVs equipped with a multibeam echosounder (MBE). The tool (AUV, MBE, algorithms and software) is based on a bathymetric Simultaneous Localization and Mapping (SLAM) algorithm, where the AUV's position in an iceberg-fixed coordinate system is estimated. The relative states are then used to guide the vehicle to achieve complete coverage, and to estimate a consistent iceberg-referenced topography. The algorithm also provides an estimate of the drift velocity of the iceberg – an important parameter for the AUV trajectory planning as well as any related ice management operations.

The tool has currently a TRL status 3 – experimental proof of concept. A method verified by a real bathymetric seabed dataset and on a synthesized dataset based on the Program of Energy Research and Development (PERD) iceberg database together with an Arctic AUV simulator, was also developed during this study. WP5 plans to conclude this study within the PhD thesis of Petter Norgren.

COASTAL INNOVATIONS

The coast plays an important role in the research done by SAMCoT. Our researchers, led by Associate Professor Raed Lubbad, are looking into the deep permafrost issues related to the presence of shallow gas or gas hydrates that constitute a risk during drilling. Coastal erosion is affected by climate warming, hence it is important to urgently get a better understanding of these features to ensure safety of operations and installations.

THM model implemented in PLAXIS

As a postdoc in SAMCoT, Seyed Ali Ghoreishian Amiri developed Thermo-Hydro-Mechanical (THM) constitutive models for simulating the behaviour of frozen soils. He developed an elastoplastic and an elasto-viscoplastic model to describe the mechanical behaviour as well as the behaviour due to variation of temperature. The proposed models are able to represent many of the fundamental features of the behaviour of frozen soils such as ice segregation phenomenon, strength weakening due to pressure melting and long term creep deformation. Amiri's models were implemented in PLAXIS in 2016 and since then the "UDSM – Frozen and Unfrozen Soil Model" has become commercially available as a beta version (https://www.plaxis.com/support/models/frozen-and-unfrozen-soil-model/). Finalizing this model and upgrading it to a regular version required extensive efforts in examining simulation results and carrying out debugging and improvements. The activities of Seyed Ali Ghoreishian Amiri during 2017 were mainly focused on improving and debugging the SAMCoT THM model for frozen and unfrozen soil.

WP6 Report II Guidelines

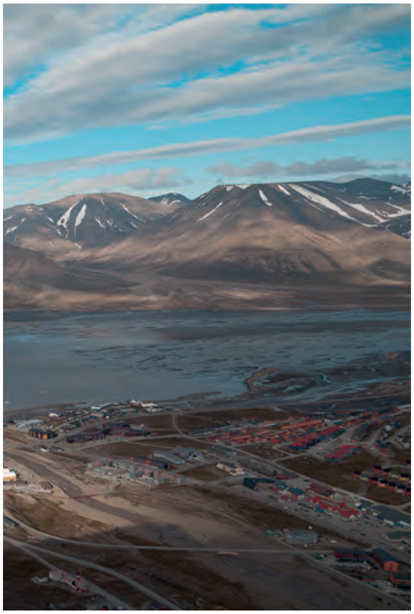
Since 2016 a work group from SINTEF led by Dr Anatoly Sinitsyn has been working on meeting the overall objective of WP6 of the SFI SAMCoT i.e. to develop guidelines needed by the industry for the design of environmentally friendly and sustainable coastal structures and technology. Work progress was presented in WP6 workshops in the spring and the autumn of 2017. The Oil and gas company Total is actively engaged in the development of these guidelines. The final document will be published before the end of 2018. An executive summary will be published in the first quarter of 2019.

SAMCOT CONTRIBUTIONS TO THE REVISED VERSION OF THE INTERNATIONAL STANDARD FOR ARCTIC OFFSHORE STRUCTURES (ISO19906)

The first international standard for Arctic Offshore Structures, ISO19906, was released in 2010. In 2012 work on the first revision was started and SAMCoT staff has been involved in several technical panels and working groups.

SAMCoT personnel participated in the technical panels TP1 (Physical Environmental Conditions) and TP2b (Ice Actions) and headed Working Group 6 on Ice Properties. The knowledge developed in SAMCoT was vital in the rewriting of the section on Ice Properties.

Furthermore, the most commonly used formula in ISO19906 for ice crushing against vertical structures was modified partly based on SAMCoT and NTNU research.



WP1 LEADER

ALEKSEY MARCHENKO

ALEKSEY MARCHENKO

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

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

DATA COLLECTION AND PROCESS MODELLING

Under Aleksey Marchenko's leadership, 2017 has been a very productive year for WP1 with numerous field activities, starting with a field campaign on landfast ice in the Van Mijen Fjord from March 20 to April 1, 2017. Here researchers focused on the study of the physical and mechanical properties of ice and coastal soils.

Nataly Marchenko, a dedicated WP1 researcher for SAMCoT Geographic Information System (GIS), works in collaboration with other WP1 researchers on the observation, measurement and modeling of sea ice properties in the extended region from Spitsbergen to Bjornoya. The work encompasses study of the characteristics of ice drift, heat fluxes from the ocean to drift ice and surface waves penetrating into drift ice.

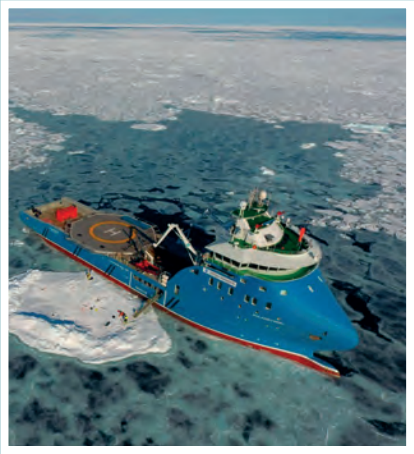
Postdoc Aleksey Shestov contributed to important field activities related to the mechanical properties of sea ice and sea state in the North West Barents Sea. These involved the study of ice rubble thermodynamic consolidation and the physical and mechanical properties of ice rubble consolidated layers.
Shestov, following WP1's mandate of collaboration and providing field data to other SAMCoT research activities, contributed to several field expeditions linked to WP4 on the topic of ice fracture and microstructure analysis of fracture zone in ice. Overall, Shestov has been responsible for preparing and leading the implementation of different field and lab activities from January to the middle of May, in addition to his own research within WP1 and WP4 and contribution to publications.

WP1 researchers took part in the Polarsyssel research cruise in April to investigate the sea state and ice conditions as well as to monitor sea ice and iceberg drift in the Spitsbergenbanken* region in the Barents Sea. (*the basin area extending from Bjørnøya northeast to Hopen Island and north to the southern tip of Spitsbergen)
WP1 researchers also performed three laboratory campaigns in 2017 in the cold laboratory at the University Centre in Svalbard (UNIS).

WP1 researchers undertake mathematical modeling and numerical simulations using the data they acquire, in addition to publishing and presenting their research in a variety of different forums and conferences.

In 2017 WP1 researchers participated in: The Arctic Science Summit Week in Prague, Czech Republic; the Port and Ocean Engineering Under Arctic Conditions (POAC17) meeting in Busan, Korea; the 12th International Symposium on Marine Navigation and Safety of Sea Transportation, TransNav in Gdynia, Poland; the international conference and exhibition on the development of oil and gas reserves of the Russian Arctic continental shelf of the RAO / CIS Offshore in St.Petersburg, Russia and the Programme of the Isaac Newton Institute of Mathematics (INI) on sea ice phenomena in Cambridge, UK.

A. Marchenko and his team also organised a workshop on Ice-Structure Interactions within the INI programme and attended different SAMCoT workshops at NTNU and University College London, UK.



SEA STATE AND ICE CONDITIONS IN THE NORTH-WEST BARENTS SEA

Sea ice characteristics and SAMCoT GIS

Knowledge of sea ice behavior and displacement in the Arctic is important for both practical and purely scientific reasons. Accurate forecast of sea ice behaviour, retreating and advancing of the ice edge, probability of icebergs approaching offshore constructions, etc. is important for the sustainable development of the Barents Region.

N. Marchenko uses Data for Ice Motion, from the French Research Institute for Exploitation of the Sea, to build ice-drifting trajectories for various parts of the Barents Sea over the last 15 years. This work enables an understanding of the origin of ice formations found near Bjørnøya and provides answers to questions such as where is the ice coming from and how fast is it moving? To do this work WP1 researchers compare remote sensing data with data from ice trackers deployed on drift ice since 2008 and data from numerical ocean dynamics simulations using the Russian Institute of Numerical Mathematics Ocean Model (INMOM).

The SAMCoT GIS online solution makes all the data collected by WP1 available to their partners.
Dr. Kenneth Eik and Dr. Sigurd Teigen from Statoil tested the SAMCoT GIS online portal in November 2017 with good results and provided feedback to WP1 to enable further improvements. Statoil has already used information from the portal in a project aimed at detecting icebergs from satellite images.

Consolidation of ice ridges

WP1 researchers have observed sea ice drift around Bjørnøya occurring as a result of polar cyclones over a period of a few weeks. The ice can stay in the region until it melts. The phenomenon was confirmed using the analysis of satellite images and modeling with Cosmo-Ru technology of meso-scale hydrodynamic weather forecast on European part of Russia, developed on the bases of non-hydrostatic model Cosmo. (Marchenko et al, 2016). The origin of thick ice and drift ice ridges is associated with land fast ice formed near outflow glaciers on the east coast of Spitsbergen. Researchers at WP1 have registered and analyzed the regular formation of a big ice rubble field near glacier Stonebreen on the North-East coast of Edgøya, using high-resolution satellite images. The rubble was discovered during the Lance research cruise in 2016.

WP1 has developed a mathematical model of the thermodynamic consolidation of drift ice rubble which takes into account the impact of meltwater from the bottom of the keel of the ice ridge. Numerical simulations confirm that the melting of ice ridge keels from below due to oceanic heat flux occurs simultaneously with consolidation of the upper part. In the case of oceanic heat flux values above 100 W/m^2, full consolidation can occur within 1-2 months.

WP1 researchers performed laboratory experiments to investigate the influence of the initial temperature of the water, which is slightly above the freezing point, on the consolidation due to surface cooling. These experiments were performed in the UNIS cold laboratory and focused on the consolidation of ice rubble submerged in seawater at different temperatures.

The experiment used a vessel filled with ice rubble and seawater insulated from the sides and below. It was placed in the cold room at an air temperature of -5ºC. During the experiment the rubble and water temperatures were monitored with a fiber optic thermistor-string over the entire thickness of the vessel. The weight and thickness of the ice and the water and ice salinities were measured before and after the experiment. The weight and thickness of the consolidated layer was measured after the experiment. It was discovered that the consolidated layer that formed in the rubble submerged in the water with an initial temperature slightly above the freezing point is greater than the consolidated layer formed in the rubble submerged in the water at freezing point.

Drift and towing of icebergs

By analyzing water velocity profiles measured below the drift ice, WP1 researchers have observed that the sea surface tilt induced by the semidiurnal tide in the north-west Barents Sea gives the same input to the driving forces influencing iceberg drift as wind drag.
The tide-induced sea surface tilt estimated from co-tidal maps is about 10 cm over 100 km. Similar estimates were obtained from the momentum balance equations of the ocean layer when measured water velocities are substituted. Numerical simulations of iceberg drift demonstrated a better correlation with the data from ice trackers deployed on icebergs when the projection of the gravity forces on the sea surface was included in the momentum balance.

WP1 researchers ran numerical simulations of iceberg towing to investigate the influence of iceberg shape on the tension of towlines. The iceberg was modeled as an elliptical cylinder with a vertical axis. The motion of the model iceberg is described by the Kirchoff equations complemented by drag forces and the towline tension force. The towline is placed around the iceberg and both of the towline ends are fixed at the ship's stern. In the numerical simulations this point is assumed fixed, and the iceberg moves due to the drag force caused by the prescribed water flow. It has been discovered that the elliptical shape of the iceberg influences its motion in both the transverse and parallel directions relative to the water flow. This iceberg motion influences the force, changing the direction applied to the ship's stern. Further modeling will be performed which will take into account the thrust and inertia of the ship.

MONITORING OF SEA ICE AND ICEBERG DRIFT

During the field cruise of Polarsyssel in April 2017 CTD (Current Temperature Depth) profiling and visual observations of the sea ice tongue extending from Spitsbergenbanken to Bjørnøya were performed. Ice trackers with wind and wave measurements were deployed on the drift ice, and measurements of under-ice water velocity profiles and turbulence were performed from the drift floe. It was found that the ocean heat flux to the ice bottom has a significant tidal variability over a day, and maximum values of the heat flux are estimated to be above 200 W/m^2. The drift ice consisted of pancake floes with a diameter up to 10 m and a thickness below 30 cm together with fragments of thick ice and ice ridges. For comparison, the field observations were obtained from drift floe of 4 m thickness and 30 m diameter.
The presence of thick floes between pancake floes has a significant influence on the performance of ships with low ice classes: usually the captain drops the speed to 2 knots in such ice.

Two ice trackers equipped with an anemometer and accelerometer were deployed on the same drift floe and provided information over 2 weeks. The data consist of the GPS position, wind velocity and vertical acceleration. The sampling interval for wind velocity and GPS position is 10 minutes. Vertical acceleration was measured with frequency of 5 Hz for 5 minutes every two hours. The trackers stopped communications during storms when the measured wind speed reached 30 m/s.

In one day the ice tracker measurements were supplemented by a) Acoustic Doppler Current Profiler (ADCP), b) Acoustic Doppler Velocimeter (ADV) and c) water temperatures from 'Seabird'. During this day the floe was disconnected from the ship and drifted surrounded by ice. Initially the floe shape was analyzed using laser scanning and drilling studies. Ice temperature, salinity and density were measured in several floe locations at different depths. These data are used for the parametrization of met-ocean forces on the drift ice.

PHYSICAL AND MECHANICAL PROPERTIES OF ICE AND COASTAL SOILS

Ice strength

The team of researchers in WP1 performed full- and small-scale tests on ice strength under compression, tension and bending both in the cold laboratory and in-situ on land fast ice in Van-Mijen Fjord, drift ice in the Barents Sea and fresh water lake ice in Longyearbyen. During the full scale tests the load was applied to natural floating ice over its entire thickness. The ice samples in the small scale tests are smaller than those in the full scale tests, and the temperature and salinity gradients inside the ice samples in the small scale tests are much lower than in the full scale tests. Therefore direct comparison of small scale strengths and full scale strengths is not possible. When the samples have the same mean temperature and salinity it was shown that full scale compression and tensile strengths are lower than small scale strengths by 3-4 and 1.5-2 times respectively. Failure scenarios observed in the full scale tests on ice compression and tension are reproduced with numerical modeling using the Ls-Dyna software/computer program for numerical simulations of physical and mechanical problems.

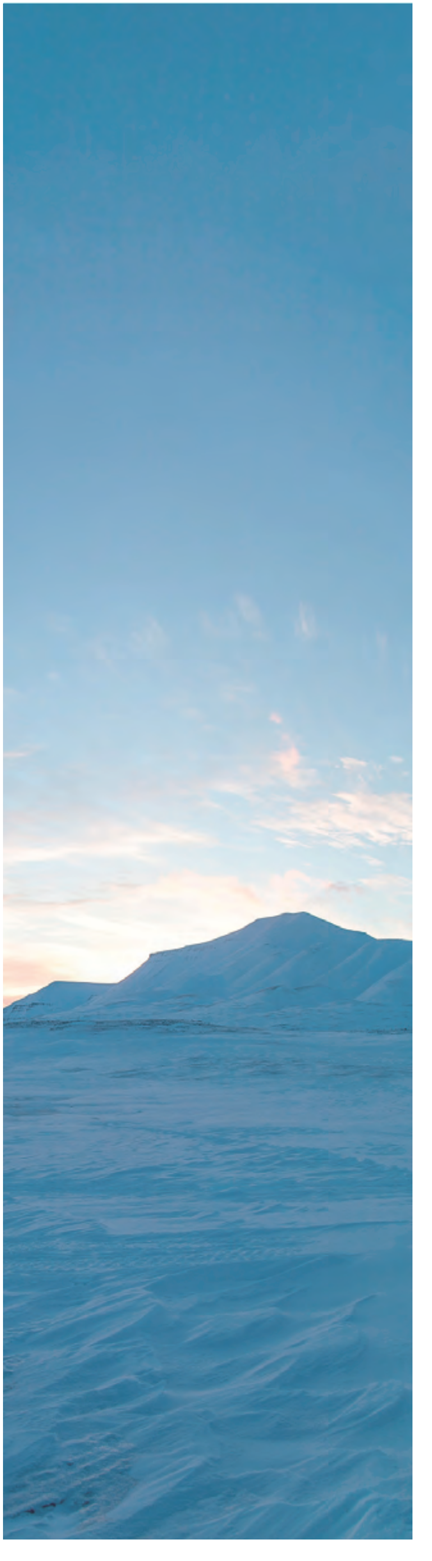
The team discovered that the flexural strength obtained from the small scale tests using 3-point bending of ice beams, and tests using central loading of ice disks, is higher than the flexural strength obtained from tests with floating cantilever beams. Tests with floating cantilever beams are characterized by linear dependence between the applied load and the displacement of the beam end. The dependence of the sea ice flexural strength on the liquid brine content of the ice, obtained from more than 60 tests performed on land fast sea ice in the Svalbard region and on drift ice in the Barents Sea, is well described by the empirical curve calculated from the test data. Empirical rules for the recalculation of full-scale flexural strength from small scale tests will be further analyzed and formulated.

Changes of structure and permeability of deformed ice

Researchers from MSU – Moscow State University, VNNIG – The B. E. Vedeneev All-Russia Research institute of hydraulic engineering and SPbSPTU – St'Petersburg State Polytechnic University, visiting WP1 staff carried out several full-scale indentation tests as well as bore-hole jack tests. Analysis of thin sections prepared from the ice immediately after the tests demonstrated the formation of a zone with smaller grains in front of the contact surface and a "shear" zone with a thickness of about 1 cm near to the indentation surface. In-situ experiments demonstrated a significant reduction of the sea ice permeability in the ice compressed by the indenter. The salinity gradients in the ice forced by the indentation will be further measured and analyzed.

Frozen soils behavior under cyclic changes of temperature

Measurements of the thermal deformations of frozen soil samples were performed in the cold laboratory at a temperature range from 0°C to -12°C. Fiber Bragg Gratings strain and temperature sensors were used to measure the deformation and temperature inside the samples. A number of tests were performed on samples prepared from Kaolin and Cambrian clay saturated with fresh water and samples prepared from fine and silt sand saturated with fresh or saline water. Thermal deformations of the samples were analyzed to study the cyclic changes of their temperature.



SEA ICE AND WATER ACTIONS IN THE COASTAL ZONE

Thermally induced ice loads on fixed quay

A mathematical model describing the changes of temperature and stresses in ice confined below the coal quay in Kapp Amsterdam has been formulated. Field observations performed in 2013-2015 showed that variations of ice temperature have a semidiurnal periodicity and are therefore associated with the vertical migration of sea water brine through the ice caused by the tide-induced water pressure. Vertical migration of the brine is also observed in the semidiurnal flooding of the ice surface below the quay during spring tides. Based on these observations an additional term describing the advective heat transfer was included in the heat transfer equation. Numerical simulations performed with Comsol Multiphysics software demonstrated a good correlation with the field data obtained on the ice temperature. The flooding of brine onto the ice surface is modeled using Darcy's equation validated with the observed periods of the ice flooding. Finally the ice stresses on the sheet piling of the quay are simulated using the equation describing the formation of thermo-elastic stresses with creep relaxation in the ice. Simulation results show stress amplitudes similar to the measured values (up to 0.5 MPa in spring tide conditions). Phase shifts between the times of maximum water level and maximum ice stress are adjusted to the measured values by variation of the amount of liquid brine trapped in closed pockets and permeable channels.

Field modeling of strudel effect

A field experiment was performed on land fast ice in Svea to model the scour strudel effect. The strudel scours are formed on the seabed when melt water floods the ice surface and runs down below the ice through holes or cracks. Vortices of melt water have been observed on the surface of land fast ice on the shelf of Alaska during melt seasons. It is assumed that this process influences seabed erosion in shallow water regions with depths below 10 m (Reimnitz, 1997). During the experiment a pool was built on top of the ice surface and filled with fresh water so that the water level in the pool was 30 cm above the ice surface. Then a hole of 5 cm diameter was drilled through the ice inside the pool and the fresh water drained through the hole below the ice. Water velocities above the ice were registered with an ADV, and below the ice with an ADCP. During the experiment fresh water drained through the ice with a clearly visible vortex above the ice surface. The water velocity below the ice was very small because it was spread between the ice and the sea water, and the ADCP did not register any significant velocities below the ice. The strudel scour effect was not confirmed.

Ice stresses in the hinge zone of coastal ice

Measurement of ice stresses were performed in the hinge zone of sea ice in the Vallunden Lagoon, which is connected to the Van Mijen Fjord by a narrow strait. The stresses have a semidiurnal periodicity and are associated with tide-induced changes of the water level in the lake. Stresses were measured with 4 cells Geokon (Four pressure cells) frozen into the ice in the hinge zone. The tidal amplitude was measured with a pressure recorder (SBE 39Plus) deployed at the bottom of the Lagoon. Tidal movements of ice were accompanied by brine migration on the ice surface causing temperature changes in the ice. The temperature profile in the ice was registered with a temperature-string (Geoprecision). The ice shape and locations of the cracks in the hinge zone were registered with a laser scanner. A similar effect of the ice stress formation in the hinge zone was investigated earlier in the Van Mijen Fjord, where the origins of the ice stresses were not clear because of a complicated system of cracks in the hinge zone. The structure of the hinge zone in the Lagoon is simpler and provides a better possibility to interpret the physical mechanisms of ice stresses on the shoreline in tidal seas.

APPLIED OCEANOGRAPHY

Wave damping in marginal ice zone

A model of wave damping by floating broken ice was developed and validated. It is assumed that wave damping is caused by energy dissipation in the wave-induced boundary layer below the ice. The water viscosity in the boundary is equal to the eddy viscosity which was found from the field measurements of the water velocity below the drift ice using an ADV SonTek Hydra 5 MHz. Based on these measurements performed on the drift ice in the Barents Sea since 2006, the eddy viscosity is estimated to be below 200 cm^2/s. Observations show that under-ice turbulence is associated more with ice drift than with wave propagation. The wave induced boundary layer is characterized by the ratio of floe velocity amplitude to the amplitude of the velocity of surface water particles caused by waves. According to the model the floe motion is similar to the water motion when the wave length is much greater than the floe diameter and floe-floe interactions are absent. In this case the wave damping by ice is zero. In the case when floe-floe interactions cause floe motion relative to the water, the wave damping is calculated with the formula following the theory of wave-induced oscillating boundary layers. Comparison of the simulated wave damping with wave damping found from the analysis of high resolution satellite images in the Barents Sea, and by the field measurements in the marginal ice zone to the north of Spitsbergen, shows good correlation between the model results and observations.

Investigation of tidal currents in navigational straits of Spitsbergen

A model of tidal current in the navigational strait Akselsundet was developed to predict the slack water periods available for navigation in the strait. According to the request of the Port Captain in Svea, the water speed should be less than 0.7 knots in the slack water period. The model was validated using field measurements of the water velocity profile performed in the strait in November 2015 to March 2016. Field measurements were performed with an ADCP (AWAC 400 kHz Nortek) deployed in the strait at the sea floor in an up-looking position. Measurements demonstrated that the tidal variability of the water speed in the strait depended on the moon phase. The shortest slack water period is estimated to be around 40 minutes in the spring tide when the tidal amplitude reaches its maximum value and the maximum speed of the tidal current reaches 3 m/s. The results of numerical simulations show very good correlation with the results of measurements. Numerical simulations were also applied to model tidal currents in the Heleysundet Strait between Edgeøya and Spitsbergen. Results of the modeling are well correlated with information provided by the Norwegian pilot and from data from ice trackers deployed on the ice passing through the strait in 2013 and 2016. The maximum speed of the tidal current reaches 5 m/s in the strait and the slack water period is shorter than 6 minutes.


1TON
WORKHAND

WP3 LEADER | KNUT HØYLAND

KNUT HØYLAND

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

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

He is a member of the International POAC committee and has been a member of the International IAHR Ice committee. He recently joined the editorial board of the Journal of Cold Regions Science and Technology.

FIXED STRUCTURES IN ICE

In recent years the increased economic interest in the Arctic and its natural resources is reflected in the construction of many new offshore structures such as offshore rigs and wind farms within the Arctic and sub-Arctic oceans, including the Baltic Sea.

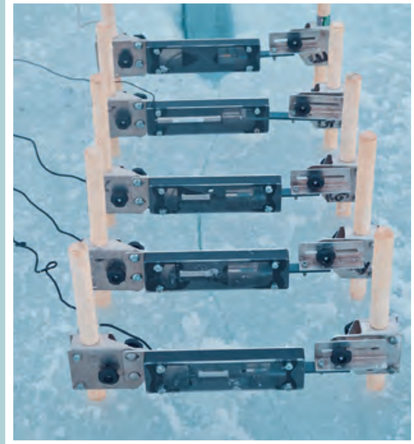
Sea ice, driven by winds or ocean currents, can pose a formidable hazard to offshore structures. This poses financial risk to commercial interests in the vicinity, as well as potential environmental risks to marine ecosystems and local communities.

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

Full-scale data are essential in the ice engineering community and WP3 makes novel use of the measurements on the Swedish lighthouse Norströmsgrund carried out in the two EU projects LOLEIF (Validation of Low Level Ice Forces on Coastal Structures) and STRICE (1997-2003) (Measurements on structures in ice). The novel methods developed for data analysis and numerical simulations by SAMCoT facilitate the novel analysis of the LOLEIF and STRICE measurements. The recently published Copernicus database is also useful in our work on understanding and making use of full-scale measurements.

Under the topic of Ice Induced Vibrations, Torodd Nord (NTNU) and Hayo Hendrikse (TU-Delft) are currently engaged as SAMCoT postdocs. They started their work in 2011, initially as PhD students and defended their theses successfully under financing from the Centre. A new NTNU postdoc, Deniz Gedikli, joined the team in 2017. Together they address the problem through advanced data analysis and numerical simulations.

Within Ice Ridge Action there are five active PhD candidates addressing:
(a) numerical modelling and full-scale analysis of measurements of ice ridge action; (b) scale model testing and
(c) structural reliability.



ICE-INDUCED VIBRATIONS

Postdocs Hayo Hendrikse and Torodd Nord address ice-induced vibrations, Hendrikse works with numerical simulations and Nord with data analysis

Numerical simulations

Hendrikse defended his PhD 'Ice-induced vibrations of vertically sided offshore structures' in Delft at the beginning of 2017. This work includes the SAMCoT results on modelling of ice-induced vibrations obtained in the 2012-2017 period. The thesis was well received by the committee and rewarded with the distinction of cum laude. After the defence he continued his work at SAMCoT on ice-induced vibrations with a twofold aim. The first aim is to validate the numerical model based on experimental results obtained from the SAMCoT associated project IVOS (Ice-induced vibrations of offshore structures). During the summer Hendrikse worked extensively with Gesa Ziemer (HSVA, Hamburg Ship Model Basin) and Cody Owen (TUDelft) resulting in a journal paper in which they have taken the first validation steps. The work is currently under review for the journal of Cold Regions Science and Technology. The researchers found that it is possible to determine a unique set of model input parameters characterizing the ice, which is an important step on the road towards the application of the model to full-scale engineering challenges. The second aim is to show the applicability of the numerical model to a full-scale scenario. In order to achieve this, Hendrikse worked closely with Nord looking at the Norströmsgrund lighthouse data and comparing model predictions with real observations. This work is expected to deliver results by the end of 2018.

Besides this work, a step has been made towards the development of a simplified approach for the design of structures for ice-induced vibrations which can be used in the pre-design stages. This work has been undertaken in collaboration with Marc Seidel at Siemens Gamesa Renewable Energy. It has resulted in a journal paper which has been accepted for publication in the journal of Marine Structures.

Hendrikse attended the POAC'17 (Port and Ocean Engineering under Arctic Conditions) conference in Korea in June where he presented a paper on the determination of the susceptibility of structures to ice-induced vibrations. This paper was written in collaboration with Marc Seidel, Andrei Metrikine, and Sveinung Løset. The results are the first test of the theory developed for full-scale measurement data, and demonstrated the potential risks designers take in relying on the old theories when designing new structures. At the IQPC (International Quality& Productivity Center) conference on Offshore foundations in Bremen in July, Hendrikse gave an invited lecture on the modelling and design of ice-structure interactions aimed at the offshore wind energy community. This event allowed him to strengthen his connections with this industry which is currently building structures in cold environments.

At the Dutch annual Symposium of Engineering Mechanics in October this year Hendrikse won the Biezeno Award for the best PhD thesis in solid mechanics and presented SAMCoT work. He also presented our recent developments in an invited presentation at the Isaac Newton Institute for Mathematical Sciences as part of the workshop on ice-structure interaction in early November.

Data analysis

In 2017 Torodd S. Nord worked extensively with data measured on the Norströmsgrund lighthouse. The first objective was to test how well we can identify the modal properties of a structure when it is surrounded by different ice conditions. The initial assumption was that during interaction with heavy ice this would be difficult, because the system changes, whereas for light ice conditions, identifying the modal parameters would be possible. The results showed that under all ice conditions the identification of structural parameters was difficult. This implies that if the same method was applied for structural health monitoring of an Arctic offshore structure the approach may be useless during the winter months.

The second objective was to perform a review of the frequency lock-in events that have been measured on the Norströmsgrund lighthouse. This work was performed alongside Åse Ervik's review of the ice-structure interaction events that resulted in the highest global forces on the lighthouse. Both studies enhanced the available data with the EU Copernicus online met-ocean database. The use of this database gave more information on the conditions for the occurrence of frequency lock-in. The study also involved a review of work in the 1980s on frequency lock-in vibrations on the Norströmsgrund lighthouse, where it became clear that for several winter seasons in the 1980s no vibrations occurred at all.

Nord supervised Niek Heijkoop who defended his MSc thesis on "Sea Ice Subjected to Cyclic Compression" during the summer of 2017. In collaboration with David Cole, Niek showed that it was possible to recreate the frequency-dependent properties of ice by using strain-controlled testing instead of the more common stress-controlled tests. This significant frequency-dependence in the storage and loss compliances corresponded well to David Cole's model predictions. This may be of importance when modelling wave-ice interaction as well as ice-structure interactions. Nord also supervised MSc student Maren Salte Kallelid together with Wenjun Lu (SAMCoT) and Arne Aalberg at UNIS. Her work aims to assess the ice conditions and enhance the measurement programme that the Norwegian Polar Institute runs on the Troll Airfield in Antarctica. The new measurement programme should provide information for better risk assessment for aircraft pilots.

In the autumn of 2017 Nord and Deniz Gedikli worked on identifying pressure modes under different regimes of ice-induced vibrations. The result of this will provide the necessary conditions for the correct modelling of the pressure distribution during ice-induced vibrations. Because of the strong link between identification and modelling, this work is performed together with Hayo Hendrikse.

SCALE-MODEL RIDGES

PhD candidate Evgenii Salganik focused on Ice ridges formed from deformed ice, and their consolidated layer formed under atmospheric cooling. In recent years deformed sea ice is increasing. Ice ridges are usually responsible for the largest loads on structures. At the same time, fieldwork studies with ice ridges are time-consuming and usually cannot provide data about ridge formation processes, initial conditions before consolidation or about potential full-scale loads on offshore structures and vessels. Thus almost all the parameters governing consolidation process are unknown or quite uncertain: initial macro-porosity η (the volume of water in the total ridge volume); initial size, orientation, salinity and temperature of broken ice blocks forming the ridge and snow thickness.

Scale basin tests can be used for the design of new structures. However, scale models of ice ridges have disadvantages: complications arise with scaling down of ice microstructure, mechanical properties and in performing natural ridge formation. Significant scaling of ice mechanical properties is possible only by using dopants, which make the solidification process more complicated. The research goal is to study ice ridge solidification at different scales in order to be able to predict the growth rate in basin and laboratory tests, and to provide a better understanding of ridge thermodynamics in general.

In previously performed basin tests with ridges it was reported that the consolidated (fully refrozen) part was significantly thicker than the surrounding ice formed from pure liquid by cooling. This is not usually observed in natural ridges where the thickness of the consolidated layer h_c is usually assumed to be 1.6–2.2 times thicker than the surrounding level ice h_i. This means that common approaches to the ice ridge consolidated layer growth might need to be updated for smaller scales in order to perform accurate basin experiments.

Salganik's main goal for 2017 was to obtain both analytical solutions and experiments on the consolidation of fresh and saline ridges at different scales, and to find out which initial and external conditions are the most important for consolidated layer growth. Both analytical solutions and experimental data were obtained for small-scale fresh ice ridges. For saline ridges, only experiments at small and medium-scales were performed in laboratory and field conditions. Experimental results for saline ice ridge small-scale consolidation agree quite well with the fresh analytical model simulations. For consolidation of saline ice ridges, it was found that block orientation is one of the most important parameters for the compressive strength.

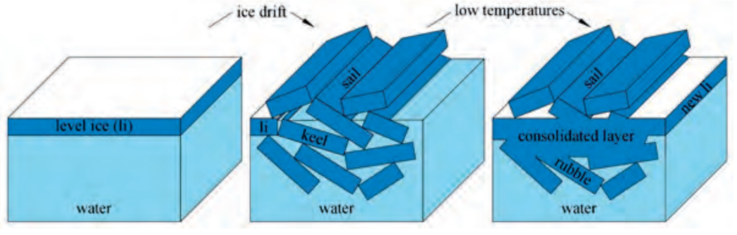
Field and laboratory activities

Salganik participated in a series of laboratory experiments on small-scale ridge consolidation performed at UNIS during August 2017 and at NTNU during November and December 2017. These experiments provided data about the consolidation of saline ice, small-scale ridge consolidation with randomly oriented blocks and the consolidation of fresh ice small-scale ridge with specified block orientations. Results of the experiments with saline ice were presented at the POAC'17 conference in South Korea. The results of the fresh ice experiments and the corresponding analytical solutions will be presented at the IAHR'18 International Symposium on Ice in Russia and at the AIC 2018 Transportation Infrastructure Engineering in Cold Regions conference in Greenland.

A medium-scale consolidation experiment was performed during February-May 2017 in Sveagruva, Svalbard in cooperation with UNIS postdoc Aleksey Shestov. This experiment provided data on ridge solidification in the natural environment and on the development of its mechanical parameters in comparison with surrounding level ice. Parameters of medium-scale saline ridges were also obtained from splitting experiments in cooperation with SAMCoT postdoc Wenjun Lu. Salganik presented his work in two conference papers that were presented at the POAC'17 in Busan, South Korea. In addition Salganik presented his analytical and experimental results on fresh saline ridge consolidation at different scales at the SAMCoT WP3 workshop in University College London (UCL), Great Britain.

FULL-SCALE DATA AND NUMERICAL SIMULATIONS

During 2017 PhD candidate Åse Ervik worked on classifying the types of ice-ridge interaction modes from signatures in force and response time series measured at the lighthouse Norströmsgrund. The signatures in force and response time series from ice-ridge interactions on vertically sided structures are not described in standards, and are among the least understood types of ice-structure interactions. By the end of 2017 Ervik and co-authors completed a journal paper on ice-ridge interactions with the lighthouse Norströmsgrund which will be submitted in January 2018. In the paper Ervik and co-authors show that the largest measured forces came from deformed/ridged ice. They also compare the signatures of force and response during ice-ridge interactions to those known for level ice. The paper was prepared together with supervisors Prof. Knut Vilhelm



Ice ridge formation scheme: level ice is breaking forming ice blocks of the same thickness, and then freezing again forming a consolidated layer inside the ridge and newly formed ice around it

Høyland and Dr Torodd Nord as well as PhD candidates Ilija Samardzija and Hongtao Li. In May 2017 Ervik gave a pitch presentation at the Ocean Week Conference in Trondheim about the thickness of ice in the Marginal Ice Zone.

In June 2017 Ervik presented a paper for the POAC conference in South Korea where she describes a continuum model for large deformation crushing of the ice ridge consolidated layer. Ervik tested different numerical formulations and constitutive models used for simulating the process of ice crushing against a vertically sided fixed structure. The paper was prepared together with supervisors Prof. Knut Vilhelm Høyland, Prof. Gustav Grimstad and Dr Torodd Nord.
By the end of 2017 Ervik had started working on her third journal paper where she compares numerical simulations to measurements of ice-ridge interactions with the lighthouse Norströmsgrund. Ervik aims to submit her third paper and PhD thesis by the summer of 2018

PROBABILISTIC ANALYSIS

PhD candidate Ilija Samardzija completed his mandatory courses in 2017. Samardzija participated in Station Keeping Trials (SKT) in the Baltic Sea financed by Statoil. The main goal of the SKT was to collect full-scale measurements during ice management operations where one vessel is anchored while another icebreaking vessel is breaking the ice to reduce the loads on the anchored vessel. During the SKT project Samardzija spent three weeks on the icebreaker Tor Viking where he assisted with data collection and gained valuable first-hand experience of sea ice. During the time spent offshore, he developed an algorithm for tracking ice drift from radar images.

The probabilistic assessment of ice loads requires careful analysis of all aspects of ice-structure interactions, both from the point of view of the basic assumptions and from the statistical interpretation. For the purpose of this analysis the available long-term experimental and observational data and the analytical findings are inadequate. The results obtainable at present should therefore be considered suggestive rather than conclusive. It is the insight into the nature of the uncertainties and the essence of the resulting statistical distribution of ice actions that is of immediate practical interest.

During 2017 Samardzija worked on the development of a probabilistic model, based on the Monte Carlo method, for estimating the statistical distribution of ice loads on an offshore structure. In the scope of this work, a conference paper (for the IAHR2018 conference in Vladivostok, Russia) is being prepared with a title "Probabilistic assessment of ice environment and ridge loads for the Norströmsgrund lighthouse". In this paper, a case study is analysed where ice ridge loads on an offshore lighthouse were simulated using the Monte Carlo method. The same topic, in a concise form, will be presented as an extended abstract and oral presentation at the AIC2018 conference in Sisimiut, Greenland.

Samardzija also developed an algorithm for tracking ice drift using pairs of subsequent images. The algorithm can use marine radar images, camera images or satellite imagery. The essence of the algorithm is not novel but two applications of it are. The first novel application of the algorithm is to obtain a real-time estimate of global ice drift velocity in the vicinity of an ice managing vessel using radar images. This use represents a robust way to reliably estimate ice drift velocity which is crucial information in ice management operations.
The second application of the algorithm is to estimate ice drift velocities using camera images from a fixed offshore structure (the Norströmsgrund lighthouse). In this way a continuous measurement of ice drift velocity can be made. This information is crucial for understanding ice-structure interaction phenomena. Work on this project will be presentedat the IAHR 2018 Symposium on Ice. The title of the conference paper is "Two applications of a cross-correlation based ice drift tracking algorithm; Ship-based marine radar images and camera images from a fixed structure".

SMALL-SCALE INVESTIGATIONS

PhD Candidate Mark Shortt's research over the past year has consisted of two different experimental investigations on the physical properties and strength of freeze-bonds. Summaries of these investigations are outlined below.

In May 2017 Shortt spent four weeks at the Hamburgische Schiffbau-Versuchsanstalt (HSVA) Ice Tank performing ice-rubble friction experiments as part of a HYDRLAB+ project led by Sally Scourfield (UCL). During this time, it was also possible for him to undertake consolidation experiments as the main experiment occupied only a relatively small proportion of the total tank area. This was therefore a good opportunity to perform experiments on the consolidation of ice blocks on a scale larger than would be possible in the UCL cold rooms. Tests were performed on scales typically encountered in the field but under more controlled conditions, enabling simpler analysis of the results.

The aim was to investigate the effect of two factors on the consolidation of two 1m^2 blocks of saline ice: (1) free-floating vs. submersion beneath the water surface and (2) a 3 mm liquid layer vs. direct contact between the ice blocks. The different combinations of these scenarios gave a total of four experiments covering a range of conditions encountered in rafted and ridged sea ice. A labelled photograph of the experimental arrangement used during the two direct contact experiments is shown in Fig. 1. Each experiment was left to consolidate for five days during which the temperature and salinity evolutions were measured. Cored samples from each experiment were taken from which salinity, density and porosity profiles were determined. The compressive strengths of samples from the direct contact experiments were measured and compared to level ice. Attempts were also made to measure the shear strengths but only the level ice was successfully measured. An abstract covering the work undertaken in these experiments has been submitted to the upcoming IAHR 2018 Symposium on Ice. A full description of the results obtained from these experiments will be given in the corresponding conference paper.

Throughout the past year Shortt has also focused on the experimental set-up at the Deben Microtest Deformation rig, and has performed practice tests on fresh ice samples. The first half of 2017 Shortt focused on completing and refining the experimental set-up. In the latter months a number of practice tests were performed on fresh ice samples. Pre- and post-failure SEM images from a practice compression test are shown in the figure below.. For this test the ice was deformed at a nominal strain rate of 1.28×10^{-4} s^{-1} and exhibited a compressive strength of 1.07 MPa Over the next year further tests will be performed on practice samples under compression, tension and bending, and over a range of strain rates. Following this, equivalent tests will be conducted on higher quality level ice samples, and eventually freeze-bonded samples.

In addition to the research described above, Shortt gave several talks at various SAMCoT events during 2017. In May he gave presentations for the SAMCoT Scientific Seminar and the WP3 Ice Rubble Workshop. In October 2017 he co-organised the subsequent Ice Rubble Workshop which took place in London. During these seminars and workshops he gained informative feedback and suggestions which have helped to improve the experimental procedures and analysis throughout the past year.

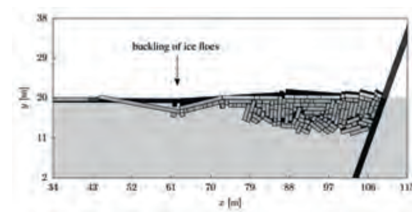
RIDGE ACTIONS

Statistics of ice rubble pile-up

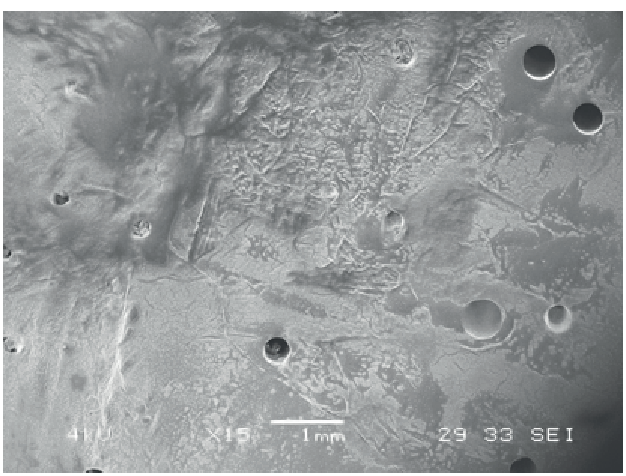
Determination of ice loads is one of the fundamental problems in ice mechanics. It is also a problem that is central to SAMCoT's WP3 "Fixed Structures in Ice" where Janne Ranta is involved as a PhD candidate. Ice-structure interaction processes are complex and ice loads related to them depend on several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

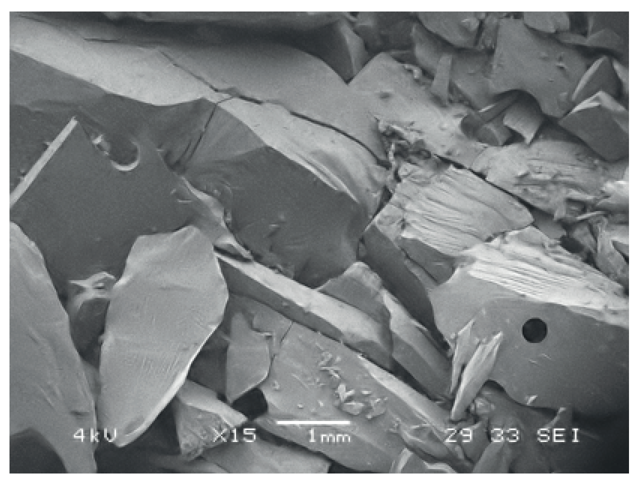
As observed in full-scale measurements of ice loads on structures, the FEM-DEM simulations show that the peak ice load values have considerable scatter (Ranta et al. 2017, 2018a, b). Thus statistics have an important role in describing loads in ice-structure interaction processes, and FEM-DEM simulations are a cost effective way to study these processes. A series of FEM-DEM simulations using slightly varying initial conditions together with homogeneous ice yield highly scattered peak ice load data. Interestingly the corresponding simulations with non-homogeneous ice sheets show virtually the same amount of scatter (Ranta et al. 2017). This result, first presented by Ranta at the POAC'17 conference in Korea, indicates that the ice-structure interaction process itself is a significant source of scatter in load values.

Ranta et al. (2018c) analysed a large number of simulations and recognized that the buckling of individual ice floes in front of the structure is an important limit load mechanism in ice-inclined structure interactions. In the study, a simple buckling load model was developed and used to quantify the force-chain buckling related peak ice load values. The study on the load limiting mechanisms in Ranta et al. (2018c) finishes the doctoral study of Ranta who will have his doctoral defence during 2018.



Buckling of ice floes in front of an inclined structure. The buckling model introduced in Ranta et al. (2018c) quantifies the ice load and the length of the buckling ice floes.





SEM image of a pre-deformed fresh ice sample, and SEM image of the equivalent sample at the end of the deformation process

WP4 LEADER | SVEINUNG LØSET

SVEINUNG LØSET

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

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


SVALBARD
ADVENTURE
GROUP
SVALBARD
ADVENTURE
GROUP
LYNX

FLOATING STRUCTURES IN ICE

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

ICE ACTIONS

To estimate sea-ice actions, most design standards and recommended practices suggest starting by defining the design scenario. This implies that the designer should select the one ice feature and the one limiting mechanism that yields the highest ice action. Apart from icebergs (and bergy bits), the limiting stress is usually thought of as the one mechanism that gives the highest ice action. The ice failure is typically chosen based on the structure geometry, e.g. crushing and bending failure modes against vertical and sloping structures respectively. Eventually, the design standards provide a set of empirical and semi-analytical formulae to estimate the ice actions that correspond to the design scenario, e.g. level-ice actions on sloping structures and ice ridge actions on a vertical structure.

The above scenario is obviously inadequate when dealing with floe-ice. This is because the interaction processes between floe ice and structures are highly nonlinear and the outcome depends strongly on the initial conditions (e.g. the ice concentration and floe size distribution), boundary conditions (e.g. confinement), driving forces (e.g. wind and current), structure response, etc. The different limiting mechanisms will coexist, and it is very challenging to identify the limiting mechanism that will cause the highest action on the structure. The term floe ice here is quite generic and can be used to describe level ice or any fragmented ice field whether it is naturally broken, e.g. by gravity waves or artificially broken, e.g. by ice management (IM) operations.

Because of the nonlinearities, time-domain modelling becomes inevitable in order to calculate floe-ice actions and action effects on Arctic marine structures. Until recently, time-domain models of sufficient quality to perform numerical simulations of floe-ice and marine structures interactions have not existed. Today this has changed, partly through the efforts of SAMCoT laying the foundation for a versatile and highly accurate high-fidelity numerical simulator for offshore structures in various ice conditions such as level ice, broken ice and ice ridges.

EXPERIMENTAL AND THEORETICAL FRACTURE OF SEA ICE

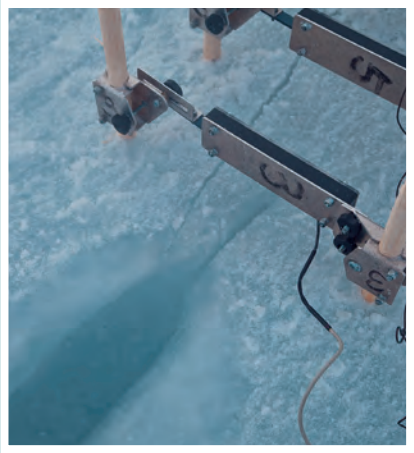
2017 is the third year of Wenjun Lu's postdoctoral study, and is a harvesting year based on the previous years' research work. The research work has focused on the following three aspects: 1) field experiments for the fracture properties of sea ice; 2) an XFEM (The extended finite element method) based numerical scheme to simulate the fracture of floe ice and 3) a comprehensive study on the fracture mechanism of long cracks forming between parallel channels.

Field Experiments

2017 is the third year SAMCoT has made good progress in the field studying the loading rate effects on the fracture properties of sea ice. In 2016 size effects were studied by splitting 17 ice floes of different size. In 2017, we split 17 ice floes with three different speeds.

In this test campaign, aside from large-scale measurements, a comprehensive microscopic approach was taken to study the fracture of sea ice. This includes the x-ray scanned image taken by Dr Sönke Maus and the thick section study by Dr Aleksey Shestov.

The preliminary results were presented by Professor Sveinung Løset and Dr Wenjun Lu in Cambridge, UK at a prestigious workshop titled 'Ice fracture and cracks'. The presentation and research work were highly appreciated by the workshop participants.



XFEM-based numerical scheme for fracture simulations

To simulate the fracture of an ice floe of arbitrary shape, an XFEM-based numerical scheme was developed. Aside from practical floe ice fracture simulations, this scheme allows us to further develop analytical solutions for the crack initiation with ice floes of certain specific geometries.

One of the practical simulations is illustrated below with data collected during OATRC2015 (the Oden Arctic Technology Research Cruise 2015). This includes a 180° camera identifying the geometry of the incoming ice floe and an IMU (Inertial measurement unit) system back-calculating the impact force.

One conference paper and one journal paper were published in relation to this numerical scheme.

The same numerical scheme was further utilised to study the formation of long cracks between parallel channels during ice management operations.

Fracture mechanism of long cracks developed between parallel channels

Long cracks developing between the parallel channels during ice management operations have been observed for a long time.

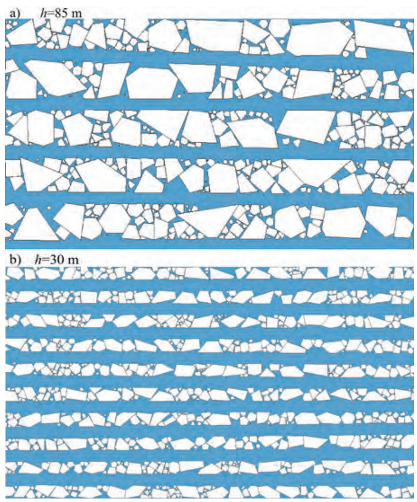
Since 2015, a substantial effort has been made to study such cracks with the hope of providing quantitative guidance for effective ice management operations ('greener' ice management). With abundant field data at hand, both theoretical work and field data based validation were conducted in this work package.

The problem outlined above was reformulated into a problem with crack kinking in an off-centre loaded ice load, and was extensively studied by the same XFEM-based numerical scheme mentioned before. A simplified off-centre loaded mechanical model was simulated and the crack propagation was extensively studied to derive relevant analytical solutions of practical importance.

The predictions derived from the analytical solutions were validated against image data collected during OATRC2015. The theoretical model developed can be used to predict an upper size bound for broken ice floe produced between parallel channels of varying distance.

A side product of this work allows the floe size distribution between channels to be derived. Based on this, we will be able to numerically generate a managed ice field given different ice management strategies (e.g. different parallel channel spacing).

An example of a numerically generated managed ice field with two different channel spacings of 85 and 30 m

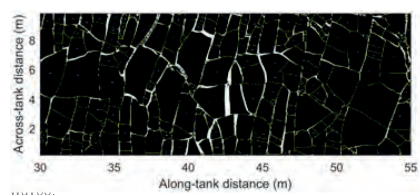


HYDRODYNAMICS

At the end of 2016, an experimental campaign to study ice-wave and ice-wave-structure interactions was conducted at HSVA (Hamburg Ship Model Basin) under the Hydralab+ project. This campaign, which involved participants from NTNU, the University of Gdansk, Clarkson University, Kvaerner AS and HSVA, was led by SAMCoT's postdoc Andrei Tsarau supervised by Professor Sveinung Løset. The working title of the campaign was "Loads on Structure and Waves in Ice" (LS-WICE) which reflects the three main research topics investigated in this project: ice fracture under wave actions; wave attenuation/dispersion in broken ice covers and ice-structure interactions under wave conditions.

During 2017, the LS-WICE data have been analysed and a number of scientific publications have been prepared based on this analysis. The scope of the project and its preliminary results were presented at the POAC 2017 conference. There were three related publications at this conference, each addressing a particular objective of the LS-WICE project. As an example, one of the publications presented an analysis of the combined wave and ice loads on the model structure. From this analysis it was concluded that the energy transmitted due to floe-floe interactions in the broken ice field under wave conditions was influencing both the occurrence of ice-floe impacts on the structure and the associated ice loads on this structure. This was also dependent on the wave height and period and the interaction area between the structure and the adjacent ice floe.

Another important aspect of the wave-ice interaction studied within LS-WICE and presented at POAC 2017 was ice fracture under wave actions. The corresponding measurements consisted of two groups of tests with a constant wave period in each group. The wave amplitude was increased stepwise, starting from a value too low to break the ice until a major fragmentation of the ice occurred. After each group of tests, the locations of cracks were determined and the floe-size distribution was estimated using an image-processing algorithm



The third part of the LS-WICE data analysis was related to wave attenuation and dispersion in ice covered waters. Ice covers attenuate waves most markedly in the marginal ice zone (MIZ), which commonly consists of discrete floes interspersed in frazil, brash ice or open water. Floe size distribution has been identified as an important factor for wave scattering but its effect on wave dispersion is much less understood. Therefore one of the objectives of LS-WICE was to investigate the effect of floe size and the Young's modulus on wave celerity and attenuation.

DISCRETE NUMERICAL MODELLING

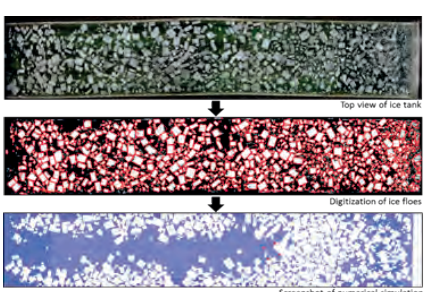
PhD Candidate Marnix van den Berg worked on further validation of his ice-structure interaction model. Validation cases included splitting of a level ice sheet represented by a random lattice model and comparison with ice tank tests in order to validate the floe ice interaction algorithm which consists of a novel time stepping scheme and contact model.

Splitting of the level ice sheet was validated by comparison with an analytical solution for a rectangular plate body.

The simulation registered the force needed to propagate the crack. This result was then compared to an analytical solution for different lattice mesh sizes.

The numerical results show some scatter which can be attributed to the randomness of the lattice model. This scatter is most apparent for the finer mesh size. Overall, the lattice solution matches the analytical solution.

The time stepping scheme and contact model were validated by comparison to ice tank test results. The ice tank tests used for this comparison were performed in 2014 as part of the Hydralab IV project. The tests were performed as part of a collaboration between Delft University of Technology and HSVA. During the project, a four-legged structure with circular legs and a vertical waterline was tested in several different ice conditions. One of the tested floe ice fields was used for model validation.



Floe digitization process and screenshot of numerical simulation

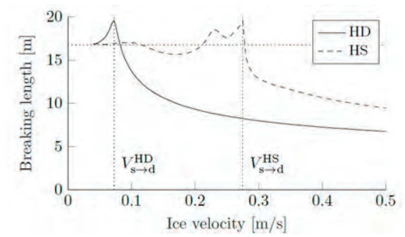
In order to validate the numerical model, top view photos of the ice field were initially digitized to get an accurate numerical representation of the floe ice field. Results showed that the numerical model is able to capture some key interaction phenomena that occurred during the ice tank tests. Two important phenomena captured by the numerical model are the jamming of ice floes between the structure legs and the accumulation of ice floes in front of the structure. This results in a significantly higher ice concentration and structure load near the end of the test.

HYDROSTATIC/HYDRODYNAMIC EFFECTS ON BENDING FAILURE

During 2017 PhD Candidate Chris Keijdener completed a study on the effects of hydrodynamics on the bending failure of level ice due to the interaction with a downward sloping structure. This study was achieved by comparing the predictions of a model that includes both hydrostatic and hydrodynamic effects with the results of a model that includes only hydrostatics.

For both models, the ice is modeled as a semi-infinite Kirchhoff-Love plate that is assumed to float on an infinitely wide fluid layer of finite depth. The fluid pressure exerted on the ice is governed by the nonlinear Bernoulli equation. The ice moves towards the structure, impacts with its downward sloping structure, slides down the structure and ultimately fails by downward bending. The time-domain solution of this problem was obtained using semi-analytical techniques. This type of solution method has not been used before to solve this type of ice-structure interaction problem. Validation of this model shows good agreement with experimental data.

The study showed that the nonlinear term in the Bernoulli equation has a negligible effect on the interaction, and can be ignored. The effect of hydrodynamics can thus be attributed to the linear part of the hydrodynamic pressure. The effect of the rotational inertia of the ice and axial compression is also negligible. At low velocities, ice fails in a quasi-static manner, while at higher velocities the failure takes place shortly after the contact initiation as can be seen in the figure. The transition between these two regimes is marked by a transition velocity, that is significantly lower for the hydrodynamic model than for the hydrostatic one. Because of this we conclude that it is not desirable to use the hydrostatic model for velocities above the transition velocity of the hydrodynamic model.



The breaking length as a function of ice velocity for the hydrodynamic (HD) and hydrostatic (HS) model. The dotted line is the static breaking length. The dotted vertical lines indicate the transition velocity of each model.

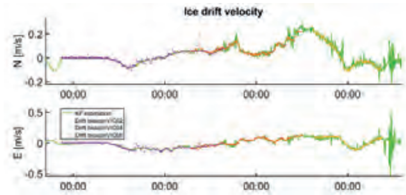
REMOTE SENDING AND DRIFT SIMULATION OF ICE

In March 2017, four SAMCoT PhD candidates were involved in Statoil's Station Keeping Trials in Ice (SKT2017). The two-week SKT trials were conducted as full-scale station-keeping trials in ice in the Gulf of Bothnia, with two ice-classed offshore vessels. The vessel Magne Viking was moored in ice, while the vessel Tor Viking was performing ice management.

PhD Candidate Runa A. Skarbø was onboard the moored vessel. Her PhD topic is ice drift prediction, and she is working on combining the estimation of ice drift with drift prediction. For real-time ice drift estimation she is using previous SAMCoT post doc Øivind Kjerstad's algorithm for ice drift estimation using the marine radar
.

Skarbø installing the hardware for capturing radar images on the Tor Viking bridge during SKT2017

During SKT2017 Skarbø collected data for estimating and predicting ice drift in the form of radar images from both vessels. Preliminary analyses of the ice drift estimation, shows good correlation between the ice drift measured with physical drift beacons and that estimation by the algorithm.



Ice drift velocity from 06 to 10 March, northwards drift (top) and eastwards drift (bottom). Drift velocity measured by drift beacons (dots) and preliminary estimates by the Kjerstad algorithm (green line) shows good correlation.

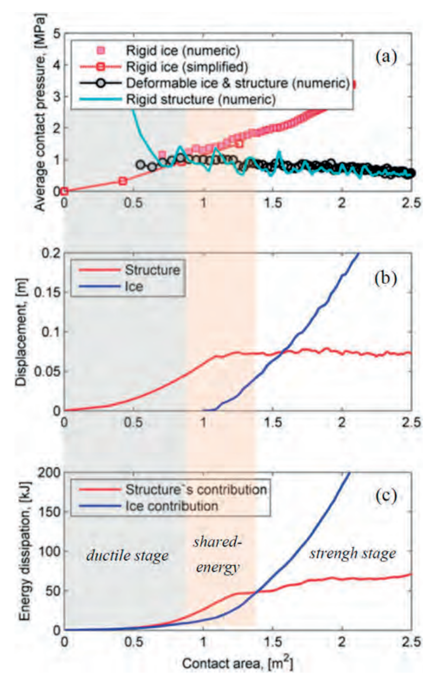
Skarbø is currently working on an ice drift simulation model which will use the output from the ice drift estimation algorithm as real-time input to the prediction of ice drift in the near future. This will provide valuable input for ice management, and the model will be used to estimate forces on the hull which is valuable for DP (Dynamic Positioning) applications as well.
Several journal papers on her model and the SKT2017 data will be written in 2018.

LOCAL ICE ACTIONS

Researcher Ekaterina Kim is continuing to study ice-structure interaction scenarios in which both the ice and the structure deform (so-called shared energy interactions). Our nonlinear finite element analysis indicates that a decreasing pressure-area trend may not be valid for situations in which the structure can undergo substantial deformations. The pressure is limited either by the ice strength or by the structural resistance. Attention must always be paid to selecting the appropriate ice pressure-area relationship for local design. In situations where the structure resistance limits the pressure, the shape of the ice matters. Sometimes the pressure limitation may alternate between the structure and the ice strength, and the process becomes more complex.

In general, the collision process is categorized into three main stages according to the distribution of damage and the energy absorbed. The stages are denoted as the ductile, shared-energy and strength stages.

The first ductile stage is dominated by deformation of the FPSO (Floating production storage and offloading vessel) side; the ice is stronger than the side in this stage. The pressure-area curve is limited by the structural capacity (virtually rigid ice) and resembles the curve obtained for the case of the rigid ice penetrating the side. In the second stage, both the ice and the structure undergo deformations. However, the FPSO side is stronger than the ice, and the deformation of the ice increases faster than that of the struck side. The pressure values are limited by the ice resistance and decrease with increasing area. In the last stage, there is continuous crushing of the ice due to the increasing resistance of the structure to further deformation. The relationship between the pressure and area is governed by the ice behaviour (a virtually rigid structure). If the structure should undergo "sudden" collapse of a main frame, the deformation could switch to a new ductile stage and so on.



Simulation results.


TOR VIKING

WP 5 LEADER | ROGER SKJETNE

ROGER SKJETNE

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

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

ICE MANAGEMENT AND DESIGN PHILOSOPHY

The goals of WP5 (Ice Management and Design Philosophy) are to study the design philosophies and methods ensuring safe operation of floating structures in the presence of sea-ice and icebergs, by including ice management (IM) functions as part of the operational philosophy. The work package has been broadly focused on the areas of design philosophy, IM risk and barrier management, iceberg management, ice surveillance, and physical IM.

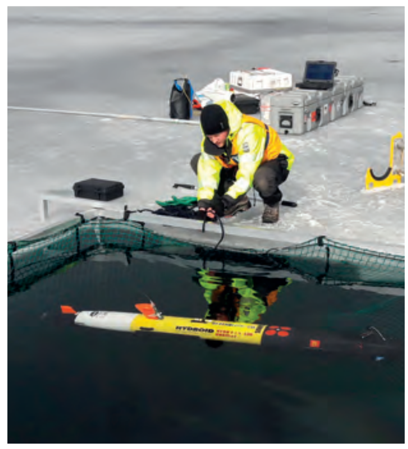
The PhD resources of WP5 have been used to support three SAMCoT-financed PhD projects, while three additional PhD projects have been shared with the NTNU Centre of Excellence on Autonomous Marine Operations and Systems (NTNU AMOS) on common and relevant topics. As the activities within design philosophy and iceberg management were ended in 2016-2017, the main ongoing activities are now on IM barrier management, ice monitoring, and icebreaker operations.

A particular problem for IM-based Arctic offshore operations is the lack of experience and statistical data from which to derive models. Farzad Faridafshin studied this problem in relation to the design of Arctic offshore structures, and defended his doctoral thesis in June 2017 on reliability assessment when data is scarce. Researcher Stian Ruud is considering this problem from a different angle for IM operations, with a focus on qualitative and quantitative barrier descriptions and the method of safe learning principle.

Renat Yulmetov and Martin Hassel also defended their theses in 2017: first Yulmetov on modelling and simulation of icebergs in broken ice and then Hassel on risk analysis and modelling of allisions between vessels and offshore structures.

Within the area of ice surveillance, Hans-Martin Heyn is working on statistical modelling and change detection based on onboard measurements of ice-induced accelerations experienced when moving a vessel through different forms of sea ice. Petter Norgren is studying the use of an AUV (Autonomous underwater vehicle) and multibeam echosounder for mapping the underwater topography of sea ice and icebergs, and the detection of ridge keels based on Simultaneous Localization And Mapping (SLAM) methods. In addition, Runa Skarbø has been working on combined satellite and radar-based ice monitoring, while Øivind K. Kjerstad has developed a method for online ice drift monitoring based on ship's radar. Finally, Jon Bjørnø is working on IM operation in which he is building a numerical model of an icebreaker operating in a realistically simulated sea ice environment. The goal is to establish a high-fidelity simulation model of icebreaker actions and action effects which Bjørnø can subsequently use as a platform for assessing icebreaker efficiency under different ice conditions, and for formulating guidance and control strategies for deployment and operation of the icebreaking fleet.

These activities define the work package and its ongoing research.



A NEW RISK MODEL BASED ON A BAYESIAN NETWORK

With the emergence of various sensing technologies, "big data" collection and analytics have received a lot of attention in the recent past. However, there are still many realistic situations in which "little data" creates the major challenge for scientific inference or prediction. Here, "little data" does not only refer to the amount of data but also to the quality of the available data. As a perfect example, in Arctic offshore field developments limited recorded metocean data exist in most geographical regions of interest because operators do not invest in expensive data collection and site-specific studies before a relatively large discovery has been made. It is therefore very important to be equipped with analytical tools that are capable of covering a wide range of scenarios concerning the amount and nature of available data and information, and particularly in the cases of "little data".

PhD Candidate Farzid Faridafshin's research introduced and studied methodologies for covering a wide range of realistic problems involving little or limited to big or inclusive data, but his work specifically considered the methodologies for quantifying the safety of offshore structures in Arctic conditions where the available data are sparse or limited. He published two papers in Structural Safety in 2017 laying down the theoretical foundation for the introduced methodologies which form the basis of his thesis.
His thesis presents a detailed introduction and discussion of the alternative methodologies for reliability assessments, and provides insights regarding the design philosophy of Arctic offshore structures - particularly those protected by IM operations. A case study is also presented in the thesis which applies the alternative reliability assessment methodologies to the design of an Arctic offshore floating structure protected by IM.

Faridafshin defended his PhD in June 2017. His trial lecture was entitled: «Load Characterization in Offshore Design Codes – Development of Practical Codes in Arctic Environments» and was followed by the defence of his thesis, generating lots of interesting discussions with the assessment committee from Germany and the UK.

ICE MANAGEMENT OPERATION

Researcher Stian Ruud continued his work with Ice management. IM defines all activities carried out with the objective of mitigating hazardous situations by reducing or avoiding actions from any kind of ice feature to a protected unit (e.g. drilling vessel) and includes several types of barriers. IM barriers range from ice observation, ice prediction, ice alerting, ice fighting with icebreakers, and disconnection procedures of the protected unit. Qualitative descriptions of independent and dependent barriers may precede the quantitative barrier descriptions. National barrier regulations e.g. PSA, (The Norwegian Petroleum Safety Authority) contain requirements to quantitatively model IM performance and uncertainties. Quantification of the performance is a major challenge due to the lack of data and existing uncertainties. The safe learning principle may give the IM designer options for including extra high barrier contingencies. The examples included demonstration of the application of the safe learning principle and decision making under uncertainty, both in the design phase and in the operational phase.

DNV GL rules for 'Drilling facilities' DNVGL-OS-E101 developed in 2017 are relevant to Ice management and disconnection of drilling systems. For this reason DNV GL and SAMCoT has co-operated in formulating similar methods for modelling disconnection of drilling vessels. Stian participated in hearing process in DNV GL for the development of class rules for Drilling facilities. The new version of class rules for Drilling facilities is based on the barrier concept. The IM barriers for disconnection of the drilling system are now covered by the E101. This is planned to be further elaborated by DNV GL and IM-SAMCoT in 2018.

STENA world's first dynamically positioned, dual mast ice-class drillship. Operated by Stena Drilling, STENA ICEMAX is the worlds most advanced, and ice capable drilling vessel that has been involved in the IM case study "Drilling in Ice Conditions'.

THE RISK OF ALLISION BETWEEN SHIPS AND INSTALLATIONS

The oil and gas industry operating on the Norwegian Continental Shelf (NCS) is required to assess the risk of allision between ships and installations. The primary goal of Martin Hassel's PhD thesis is to improve our understanding and advance our knowledge of the currently available risk analysis tools and models, and to develop an updated and improved risk model to better reflect current procedures, operations and practices. His research has mostly focused on passing vessels, but some underlying aspects and factors may be applicable to field-related vessel scenarios as well.

SEA ICE AND ICEBERGS

Sea ice and icebergs are the major challenges facing offshore activities in the Arctic. Design loads for Arctic offshore structures can be significantly reduced if the drift of sea ice and icebergs can be forecast accurately to warn of physical ice management requirements. To date, this has been achieved successfully only for sea ice or for icebergs drifting in open water. There is a lack of knowledge about icebergs drifting together with broken ice and there is a lack of operational experience of deflecting icebergs in broken ice as well.

An iceberg moving relative to sea ice should experience an additional resistance force, which in general grows as the ice thickness, relative velocity or ice concentration increases. This force complicates the drift forecasting and potentially threatens iceberg towing operations in sea ice. The force is hard to estimate. However, the work of PhD Candidate Yulmetov has contributed to an increased understanding of these processes and force levels. His thesis covers observations, tracking and forecasting of icebergs and sea ice in the Greenland Sea and in the Barents Sea, and numerical modelling of iceberg towing in broken ice. His work related to the Barents Sea increases the impact of SAMCoT research on the Johan Castberg field development south of Bjørnøya.

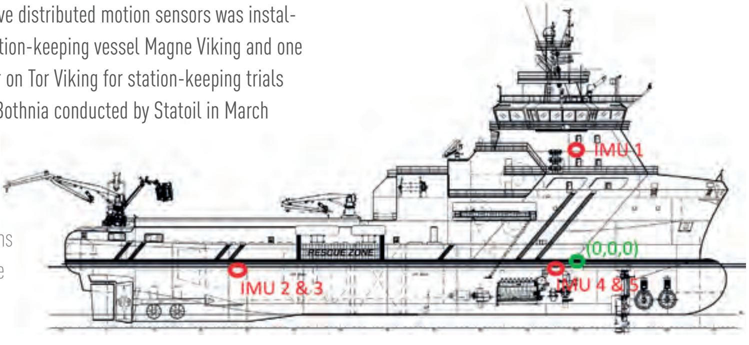
CONTROL AND PARAMETER ESTIMATION FOR THRUSTER ASSISTED POSITION MOORING IN ARCTIC OFFSHORE CONDITIONS

PhD candidate Hans-Martin Heyn concentrates in his research on sensor technologies that allow for safer transit, and station-keeping operations, especially in Arctic waters. The PhD project "Control and Parameter Estimation for Thruster Assisted Position Mooring in Arctic Offshore Conditions" deals with the following Research questions in 2017:

- What characteristics do ice loads have during a typical station-keeping operation?
- How can we measure the ice-induced load and what information about the ice load is required for station-keeping operations?
- How can we extract information about environmental loads from the measurements supporting operations in ice-infested waters?
- How can we use the information obtained to ensure a safer and more efficient (mooring) operation in ice?

Ice drift detection using distributed motion sensors

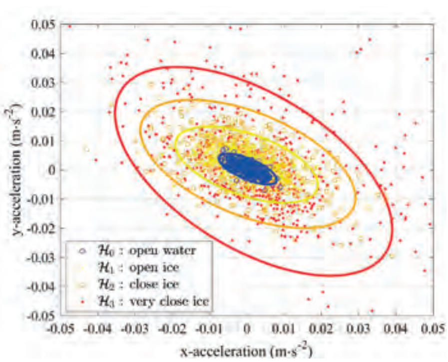
A system of five distributed motion sensors was installed on the station-keeping vessel Magne Viking and one motion sensor on Tor Viking for station-keeping trials in the Bay of Bothnia conducted by Statoil in March 2017. Up to now, only data from vessels transiting in sea-ice were available. Thanks to the data collected during the station-keeping trials, a methodology for ice drift change detection using motion sensors can be developed. The measurement setup will be presented during the OMAE 2018 (Conference on Ocean Offshore & Arctic Engineering) conference, and a journal paper on ice drift change detection using distributed motion sensors is in preparation.



Sensor positions onboard Magne Viking

Detection of changes in ice conditions during Arctic operations

The data from the Arctic Ocean 2016 expedition have been processed and used to develop a methodology to detect changes in the ice conditions around a vessel using data from motion sensors in the hull of the vessel. By stochastic modelling of the induced accelerations, and by using statistical change detection, an early warning can be issued upon changes in the ice conditions around a vessel operating in sea-ice. The work has been conducted in collaboration with DTU Elektro during an exchange stay from August 2017 to December 2017. A journal paper in the IEEE Oceanic Engineering journal is under revision and will be published in the first half of 2018.



Scatter plot showing how the variance of the recorded signal changes under different ice conditions.

Information on Field/Lab activities

Statoil offered NTNU the opportunity to join station-keeping trials in the Bay of Bothnia in March 2017. NTNU's motion sensors were installed on both vessels and the motion data of both vessels during transit were collected as well as additional station-keeping data from Magne Viking. The data will be essential for further research on sensor systems for station-keeping in ice, and they are the only data available for a vessel under position mooring in sea-ice.

MODELLING OF THE ICEBREAKER ODEN HULL

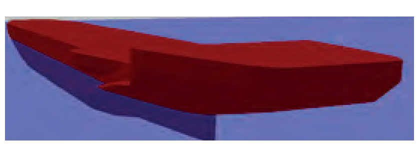
PhD Candidate Jon Bjørno worked on modelling of the hull of Oden to improve the hull shape and to include both the critical parts of the ice knife and the reamers. The two hull shapes were tested in the numerical ice tank simulator to check the difference and compare against full scale data from OATRC2015.

Making a numerical simulator that contains vessels that exist in full-scale, like Oden, would be beneficial for planning the most efficient IM operations. It could also be used to perform benchmark tests against other vessels, to compare their IM capabilities in different scenarios. The work with the numerical ice tank simulator and the Oden model will result in a journal paper in 2018.

Jon Bjørnø participated in Statoil's Station-keeping Trial 2017 (SKT 2017) in the Gulf of Bothnia. Statoil financed and led the sea trials, with the main mission of collecting full-scale data for validation of numerical models of moored floaters interacting with sea ice. In addition to the main mission, several other smaller missions were executed, e.g. gathering vessel data while performing IM manoeuvres. The intention with the IM data is to use it to validate/adjust IM simulation models.

The paper "Modeling, Parameter Identification and Thruster-Assisted Position Mooring of C/S Inocean Cat I Drillship" was presented at the OMAE 2017 conference. This research was about developing both a simulation model and a physical vessel model of the Statoil's CAT I drillship design by Inocean, to be used in the Marine Cybernetics Laboratory at NTNU. As a result of this work NTNU now have a new research platform to be used by students and researchers in the Marine Cybernetics Laboratory.

Old hull shape



New hull shape

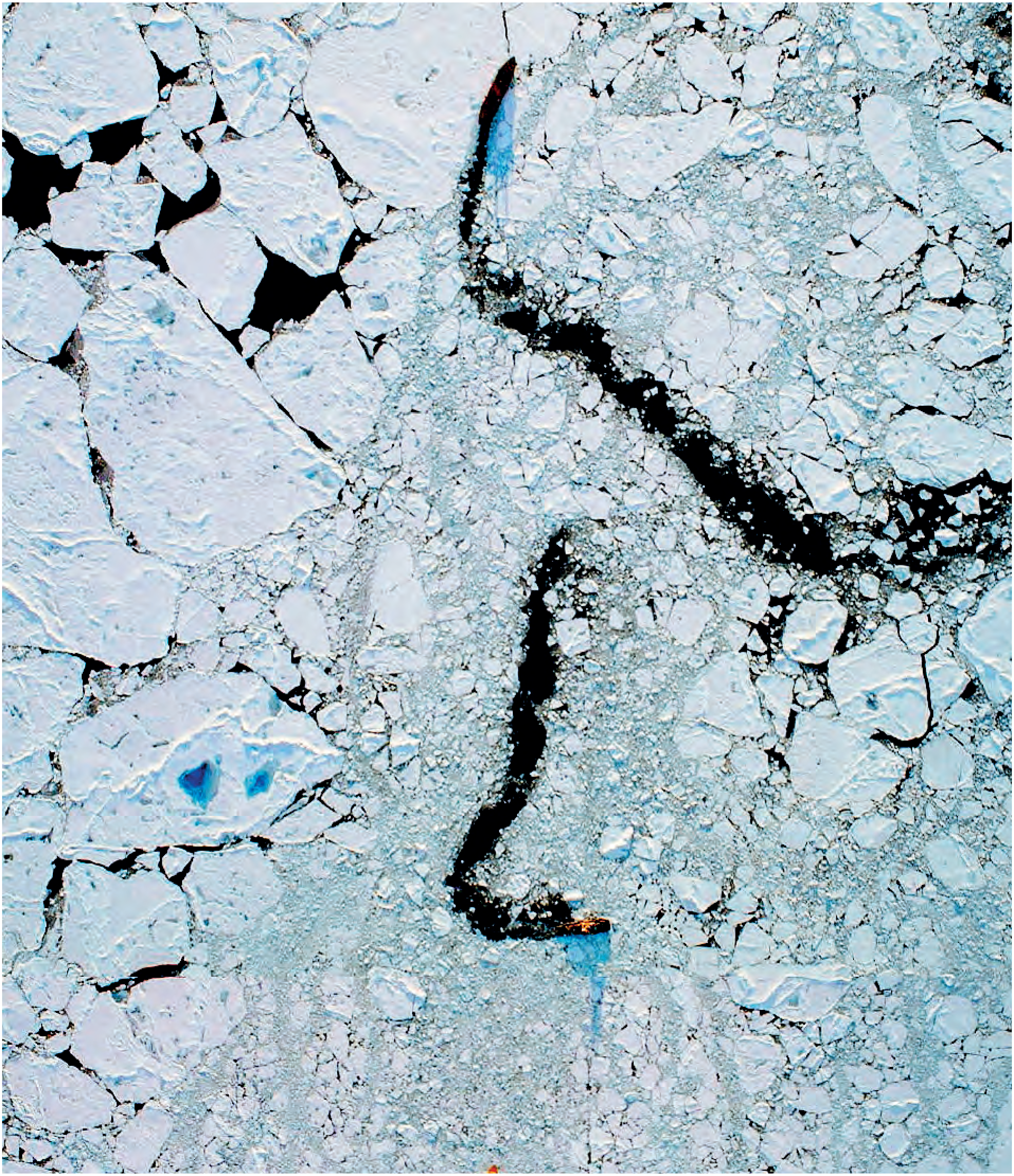
UNDERWATER ROBOTICS

PhD candidate Petter Norgren participated in a research campaign in Ny-Ålesund, Svalbard. The campaign involved performing sampling of water column data with two autonomous underwater vehicles (AUVs) as part of the Underwater Robotics and Polar Night biology course, and conducting a test of co-operative operations between unmanned surface vehicles (ASV) and AUVs.

At the end of April Norgren left for Svalbard to perform under ice operations with the NTNU REMUS 100 AUV. The project was aimed at gaining operational experience with Arctic AUV operations, as well as assessing the capabilities of AUV platforms in activities related to ice management. Several missions were performed under the ice, and both oceanographic data and multibeam echosounder (MBE) measurements of the underside of the ice were captured. The project was in collaboration with the Future Arctic Algae Bloom (FAABulous)-project and was coordinated with the main FAABulous field activity. The data collected by the AUV may also be of use for this project, and several transects were conducted with remotely operated vehicles (ROVs) to assist the FAABulous campaign.

During the summer Norgren was a part of a multi-agency exercise aimed at preparing for oil spill responses. The EU-project Underwater Robotics Ready for Oil Spill (e-URReady4OS) exercise was conducted in June in Cartagena, Spain. The LAUV (Light AUV) Harald was equipped with a rhodamine flourometer and coordinated activities with 5 other AUVs as well as a USV and two unmanned aerial vehicles (UAVs) to detect the simulated oil spill.

Norgren has continued his research into iceberg mapping using simultaneous localization and mapping (SLAM) with AUVs equipped with multibeam sonar. Part of the work was presented at the OMAE conference in Trondheim in the summer, and in the autumn the work was extended and a journal paper will be submitted in the beginning of 2018.



WP6 LEADER | RAED LUBBAD

RAED LUBBAD

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

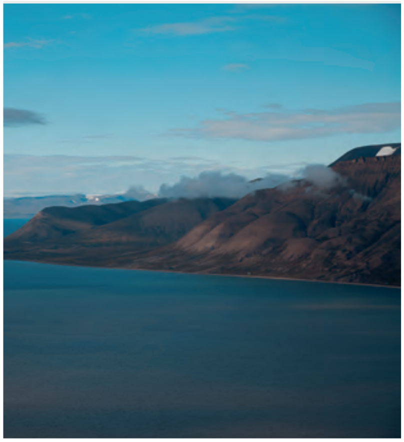
In Trondheim he met Professor Sveinung Løset who played important role in shaping his future career. Under Sveinung`s guidance, Raed completed his PhD in Arctic Marine Civil Engineering. Since 2011, he holds a position as Associate Professor in the Department for Civil & Environmental Engineering, NTNU.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

COASTAL TECHNOLOGY

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

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

In order to address these general challenges in response to our industry partners' needs for innovation, several research projects have been carried out.



NUMERICAL MODELLING OF FROZEN SOIL BEHAVIOUR

The activities of postdoc Seyed Ali Ghoreishian Amiri during 2017 were mainly focused on improving and debugging SAMCoT's Thermo-Hydraulic-Mechanical (THM) model for frozen and unfrozen soil. Amiri's model was implemented in PLAXIS software in 2016 and since then it has become commercially available as a beta version (https://www.plaxis.com/support/models/frozen-and-unfrozen-soil-model/). Finalizing this model and upgrading it to a regular version required extensive efforts to examine simulation results and to carry out debugging and improvements. The main bulk of this work was done during 2017 by postdoc Amiri, Prof. Gustav Grimstad and masters students Hooman Rostami and Kaja Sørvig Østbye.

During his masters thesis work, Rostami aimed to back-calculate results from large-scale frost heave tests. His work helped Amiri to discover some important shortcomings in the elastic-plastic version of the THM model. Consequently, Amiri applied significant improvements to the formulation of the model, and made it more robust and precise in simulating freezing process. However, some additional efforts are still required to reach a robust formulation of thawing processes.

During her masters project work, Østbye used the elastic-viscoplastic version of the THM model and aimed to back-calculate results from creep tests on frozen clay samples. She showed that some modifications are required for the model formulation in this version as well. The required modifications are being implemented.

The geotechnical group will continue working on this topic under the umbrella of PoreLab and NUNATARYUK (EU Horizon2020 funded research project) projects to fulfil the other necessary modifications and improvements. The results and findings will be shared with SAMCoT

SAMCoT GUIDELINES FOR DATA COLLECTION SUITABLE FOR GENERIC MODELLING OF ARCTIC COASTAL EROSION

Dr Anatoly Sinitsyn continued to work on SAMCoT guidelines for coastal infrastructure in cold climates. Progress on the work was presented in the WP6 technical workshops held in spring and autumn 2017. In December 2017, Dr Sinitsyn submitted a revised article "Fifty four years of coastal erosion and hydro meteorological parameters in the Varandey region, Barents Sea" to the journal of Coastal Engineering. Dr Sinitsyn continued to maintain the Vestpynten test site in 2017, and to collect full-scale data from there, i.e. permafrost temperature and footage from a time-lapse camera.

COLLABORATION WITH MSU

With support from SAMCoT/WP6, Moscow State University (MSU) performed an extensive fieldwork campaign at Baydaratskaya Bay in September 2017. The test site is situated on the west coast of the Baydara gulf of the Kara Sea. The fieldwork was conducted in order to: 1) study the processes and mechanisms behind coastline retreat; 2) investigate the properties of permafrost in the area of interest; 3) examine the interaction between permafrost and existing engineering structures (e.g. cofferdam, pipelines) and 4) prepare for in-situ validation of some elements of thermal abrasion modelling.

This year's survey is the sixth fieldwork campaign in the area. MSU researchers visited the Baydaratskaya Bay site for the first time in 2012 just at the start of the SAMCoT WP6 activities. Over the years valuable full-scale data were gathered and made available to SAMCoT researchers. This includes mapping, measuring coastline retreat rate and observing the underlying physical processes, time-lapse photography of slope degradation processes, continuous temperature measurements of the soil at two typical sites of the coast, etc.

NUMERICAL MODELLING OF ARCTIC COASTAL HYDRO-DYNAMICS AND SEDIMENT TRANSPORT

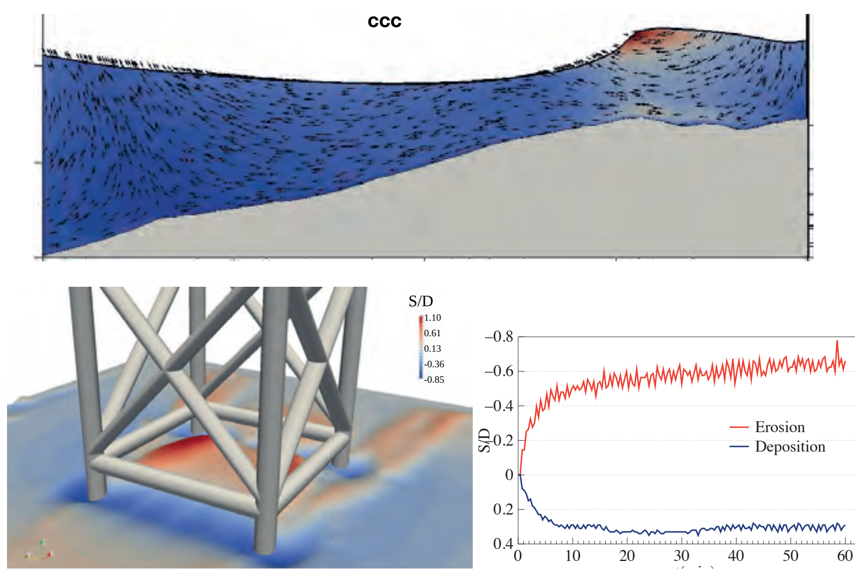
The year 2017 has witnessed a remarkable increase in WP6 research activities related to numerical modelling of Arctic coastal hydrodynamics and sediment transport. This includes:

CFD modelling of local scour and coastal erosion

Currently, there is no model to simulate scouring/erosion under different wave conditions which captures the free surface and bed level changes in detail. The problem becomes even more complicated when the flow on the coastline is obstructed by coastal structures or the stability of the coastline itself is vulnerable to climate change.

PhD candidate Nadeem Ahmad is working on high resolution CFD modelling of erosion in the Marine environment. Nadeem's research focuses on the vulnerability of coasts to climate change, Arctic coastal erosion, pipeline erosion under the combined action of the waves and current, scour around large diameter cylinders, scour around jacket structures and on seawall erosion. The modelling of the erosion process is based on three-dimensional (3D) Navier-Stokes equations coupled to the 3D morphological model by incorporating sediment properties such as median sediment size, sediment density, sediment porosity and the Shields parameter. This feature makes the model more robust and efficient in simulating the erosion processes for different morphologies.

In 2017, Nadeem submitted two journal papers to the Coastal Engineering journal and to the International Journal of Offshore and Polar Engineering. Nadeem attended three important conferences in the fields of Arctic coastal engineering (ISOPE-2017), hydrodynamics and sediment transport problems EUG2017 (European Geosciences Union General Assembly 2017) and the development of advance computational Mechanics (MeKIT 2017). He gained knowledge dealing with numerical modelling of hydrodynamics and the erosion by accounting for the impact of climate change . His ongoing research is focused on erosion caused by large waves.
Taken together, the results submitted to journals and presented at conferences mirror closely the experimental and field observations. Such research is helpful in the field of numerical modelling to solve the problems of erosion on the coastline.



CFD modelling of local scour.

Modelling of ocean waves propagating under sea-ice

Because of global climate changes, many researchers anticipate that sea-ice extent in the Arctic will decrease dramatically in the coming decades. Consequently, there will be larger open water areas for waves to grow suggesting that wave climate in the Arctic will change. On the other hand, greater open water areas provide a greater potential to harvest hydrocarbon resources and enable further commercial shipping activities in the Arctic. Thus, accurate forecasting and hindcasting of wave climate becomes more urgent than ever.

However, waves and ice interact in an extremely complicated manner. Waves herd ice floes, break ice sheets, accelerate ice melting in the summer season and contribute to the formation of pack ice in winter. Concomitantly, ice scatters waves, changes their dispersion relation and attenuates them.

One of the wave-ice interaction mechanisms, which has long been neglected, is the collisions between ice floes forced by waves. Collisions contribute to the formation of pancake ice, which has become predominant in the Arctic seas during this decade. In addition, collision dissipates wave energy due to the viscoelasticity of ice. According to PhD candidate Hongtao Li, there have not been enough studies in the past on the quantification of wave energy losses resulting from inelastic collisions of ice floes. The Structure and Waves in Ice project (LS-WICE) offers a great opportunity to change this and to improve our understanding of the physics involved in the wave-induced collisions between ice floes. In 2017, Hongtao Li was focusing on analyzing the data collected during this project to quantify the significance of collisions in dissipating wave energy. The results of this work will be published as a conference paper presented at ISOPE 2018 (International Society of Offshore and Polar Engineers) in Japan.

Apart from this, Hongtao Li worked on identifying the knowledge gaps in wave-ice interaction studies. This work will be presented at AIC 2018 (ARTEK International Conference) - Transportation Infrastructure Engineering in Cold Regions in Greenland. As an additional result of this work, one more conference paper reviewing wave-ice interactions will be presented at IAHR 2018 (International Association for Hydro-Environment Engineering and Research) in Russia. This paper summarizes important theoretical, field and laboratory studies performed in the last half century.

From this literature survey, Hongtao Li has found that wave climate forecasting is still far behind the stage reached by weather predication. Though many theoretical models are proposed to describe wave-ice interactions, new laboratory and field data are required for model validation. In addition, the calibration of these models is extremely laborious, and presently no universal mathematical model is applicable to wave-ice interactions across all ice types.

The paper submitted by Hongtao Li to IAHR serves as a guide to formulate Li's research questions. In the coming several months Hongtao Li plans to develop a new wave-ice interaction model which has a proper representation of the viscoelasticity property of ice.

As for seminars, Hongtao Li attended the annual DTU (Technical University of Denmark)-NTNU visit last November 6-7. In DTU, Li presented the current status of knowledge on wave-ice interactions. During this meeting Li had the chance to become familiar with the DTU research groups in Arctic Technology and obtained input from other researchers to help him to refine his research directions further. Lastly, Hongtao Li and his collaborating PhD candidate Dennis Monteban from DTU discussed the further steps they can take to converge our research directions.

Measurements and modelling of Arctic coastal environments

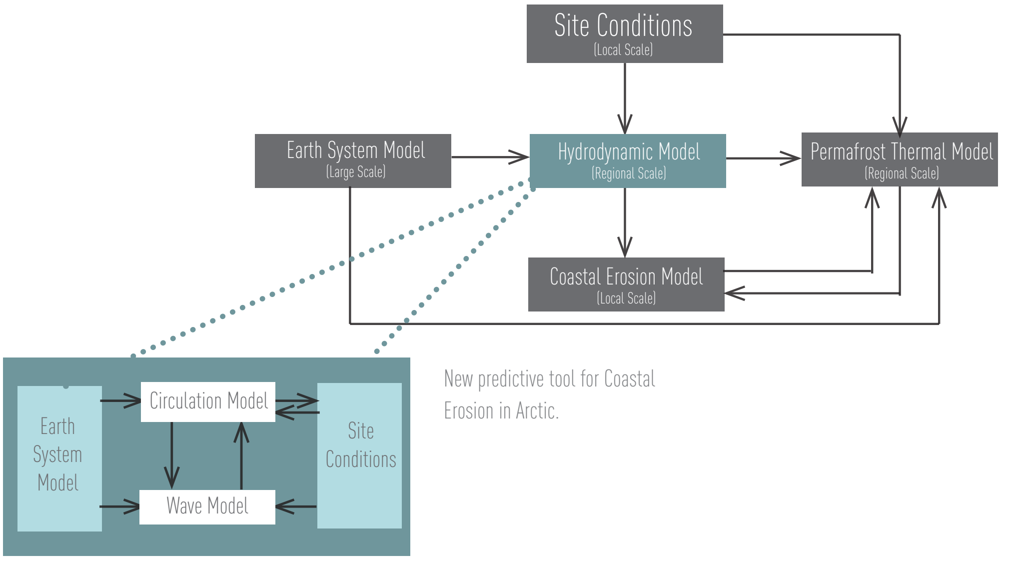
Dennis Monteban is a PhD candidate at the Technical University of Denmark (DTU) and NTNU. He started his PhD in November 2016, the title of which is 'Measurements and Modelling of Arctic Coastal Environments'. In addition to the two partnering universities, the PhD study is carried out in close collaboration with DHI (Danish Hydraulic Institute). The two main supervisors of the research project are Jens Olaf Pepke Pedersen from DTU and Raed Lubbad from NTNU..

The focus of the research carried out in 2017 was the Arctic fjord system Kangerlussuaq, located on the west side of Greenland. The data collected at the study site was analysed and used to setup multiple models of the fjord system. Two different hydrodynamic models were set up, one in 2D and one in 3D and a spectral wave model was constructed. All the models used the MIKE software developed by DHI. The modelling work resulted in well calibrated and validated models, and provided a detailed overview of the hydrodynamic and wave conditions in the fjord. A picture of the study site is provided in the figure below.

The overall objective of the PhD project is to contribute to safe and reliable Arctic coastal facilities in a changing climate. Consequences of a warmer climate and warmer sea temperatures include thawing of permafrost, decreasing sea ice extent and increasing ice sheet melt causing changes in relative sea level. The longer open water seasons and increasing storminess will result in an increased rate of coastal erosion in the Arctic. An understanding of the interaction of waves with ice is of vital importance in order to predict the effects of a changing climate. In the coming two years this research project will be focused towards the interaction of waves with ice and will be done in close collaboration with colleague Hongtao Li, also a PhD candidate at NTNU and DTU. Potentially a fieldwork campaign in Greenland will be undertaken in order to collect more data on waves under the ice. Remote sensing has the potential to provide supplemental data for the study site. The newly collected data will provide new insights into the mechanisms in play when waves interact with ice. Furthermore, these data together with remote sensing data can be used to validate new potential theoretical models of wave action under the ice.

DEVELOPMENT OF AN INTEGRATED SYSTEM MODEL (PREDICTIVE TOOL) FOR ARCTIC COASTAL EROSION

The main research objective for postdoc Mohammad Saud Afzal was to develop a predictive tool for coastal erosion in the Arctic. In the beginning of 2017, he conducted a comprehensive study of all existing models.



New predictive tool for Coastal Erosion in Arctic.

ERODIBILITY CHARACTERISTICS OF FROZEN/THAWING SOILS

The research project of PhD candidate Julie Malenfant-Lepage intends to assess the Critical Shear Stress (CSS) of frozen and thawing soils with the aid of an in-situ method developed for unfrozen cohesive soils: the Cohesive Strength Meter (CSM). The erodibility potential of permafrost and fine-grained active layer soils has not yet been studied and documented. The CSS of frozen/thawing soils is a fundamental property for assessing bank erosion in the Arctic. CSS allows characterisation of the susceptibility of a soil particle to be detached on the lower beach and subsea by wave action. It also helps in quantifying the energy required to remove soils by running water on the bluff face due to precipitation (rain or snow melt) producing characteristic geomorphological features such as gullies.

In summer 2017, Julie Malenfant-Lepage performed fieldwork to test the CSM directly on permafrost at two different sites where important thermo-erosion events had occurred in the past. The CSM was first tested in the eastern Canadian Arctic, in the village of Salluit, Nunavik, Canada and thereafter in the Yukon Territory, in the western Canadian North. The results obtained with the CSM at both locations show very low values of CSS corresponding to a very high erodibility potential. Benoit Loranger, PhD candidate within the NTNU research program Frost Protection of Roads and Railways (FROST) was financed by the Nordic Road Association (NVF) to participate in the fieldwork to find a potential linkage between the erosion sensitivity of frozen soils and their segregation potential.

In the autumn of 2017, Julie Malenfant-Lepage conducted laboratory work at NTNU to develop a methodology for the use of the CSM that can be easily reproduced on any fine-grained frozen soils. The methodology developed was thereafter tested in the laboratories of Université Laval, Quebec City, Canada in December on the soil samples that were brought back from the two field sites. The results obtained in the laboratory correlate with the CSS values measured in the field.

The CSS has great potential for applications in permafrost science and engineering. The research project of Julie Malenfant-Lepage is in collaboration with the Department of Civil and Water Engineering of the Université Laval, so the values of CSS obtained with the CSM will also allow calculation of the critical slope and the maximum flow that can be concentrated in one channel (e.g. ditch and culvert) to limit soil erosion around infrastructures built on permafrost.

The next steps for Julie are to undertake intensive laboratory tests to determine values of CSS according to different soil types, soil temperatures, water temperatures and ice contents. The laboratory method developed will help identify factors that most affect CSS values. The final output of this research will be a chart of CSS values that Arctic engineers will be able to use in their infrastructure design to limit soil erosion.

Measurements of the critical shear stress in a small gully at the Inuit village of Salluit located north of the province of Quebec in Canada

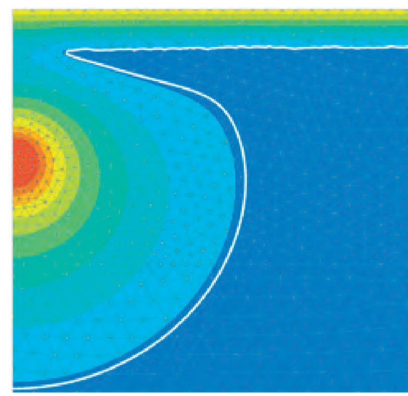
DESIGN CONSIDERATIONS FOR PIPELINES IN THE ARCTIC

Dr Ivan Depina is a researcher at SINTEF Building and Infrastructure involved in WP6 of SAMCoT. The research activities of Ivan in the past year were focused on pipelines in the Arctic environment and on modelling Arctic coastal erosion processes.

Pipelines have been used in several developments in the Arctic as a cost effective, safe and reliable mode of hydrocarbon transport. Research on reliable pipeline solutions in the Arctic contributes to one of the main objectives of the industrial partners in WP6. The research activities include preparation of a report summarizing the design considerations and the corresponding technical solutions specific for pipelines in such environments. The report was structured to examine specific design elements and technical solutions for onshore, shoreline transition and offshore sections of a pipeline system. The report was presented at the SAMCoT WP6 technical workshop in May 2017. Complementary to the report, a series of numerical studies were performed as part of a case study to provide insight into the effects of salinity on the estimates of thaw settlements around warm pipelines. The case study examined the predictions of thaw settlements on the shoreline transition on the Yamal side of the Baydaratskaya pipeline crossing based on preliminary site investigations. The case study demonstrated that relatively high salinity levels can significantly affect the development of temperatures in the soil surrounding the pipeline and the predictions of thaw settlements.

The research on modelling of coastal erosion processes on Arctic coasts was conducted in cooperation with Prof. Raed Lubbad and Dr Mohammad Saud Afzal from NTNU who supervised Agnes Schneider for her masters thesis at NTNU. The objective of the thesis was to establish a thermo-hydro-mechanical model to evaluate the stability of thawing coastal slopes, estimate the coastal retreat rates and the volume of unstable soil masses to quantify the erosion process. The objectives of the thesis were achieved with the implemented model providing estimates of coastal retreat rates comparable to values measured in the Arctic. The effects of climate change were implemented by modelling the projected temperature increase over the coming decades. The resulting model predictions indicate negative effects on the coastal retreat rates due to projected climate change. Development of such models can significantly contribute to the quantification of climate effects on coastal retreat rates. This can support improved planning and decision making for infrastructure operators along Arctic coasts. The main results of the research on modelling coastal erosion processes on Arctic coasts will be published as a conference paper.

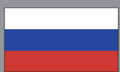
The knowledge built from these research activities will be integrated in the development of guidelines to support the development of pipeline infrastructure and coastal erosion protection structures in the Arctic. Additional activities of Dr Ivan Depina included participation on the 6th Biot Conference on Poromechanics in Paris to present research activities on wave induced liquefaction around buried pipelines, and collaboration with Dr Thi Minh Hue Le, Dr Anatoly Sinitsyn, and Dr Emilie Guegan on a journal paper on modelling thermal processes on Arctic coasts.



Development of temperatures surrounding a pipeline.

SENIOR STAFF

ULF HEDMAN
SPRS
Ice Management and Design Philosophy



ALEKSEY MARCHENKO
UNIS - SAMCoT Leader WP1
Data collection and process modelling

ANATOLY BROUSHKOV
MSU
Cold regions geology

ANATOLY SINITSYN
SINTEF
Physical-mechanical properties and extent of coastal permafrost

ANDREI METRIKINE
TU Delft
Dynamic ice action

NATALY MARCHENKO
UNIS
Geographic Information System GIS

TATIANA GULLIKSEN
NTNU
Business Finances

EKATERINA KIM
NTNU
Integrated Finite Element method in Ice – Structure

VLADISLAV ISAEV
MSU
Geocryology

ALEKSEY SHESTOV
UNIS
Ice ridge properties

STIAN RUUD
NTNU
Verification and Examination Management Arctic Offshore Operations

INGRID UTNE
NTNU
Ice Management/Safety

SVEINUNG LØSET
NTNU - SAMCoT Leader WP4
Ice actions on floaters

ARNE INSTANES
INSTANES POLAR AS
Geotechnical engineering

ARVID NÆSS
NTNU
Mathematical Statistics

JØRGEN AMDAHL
NTNU
Iceberg Impact on floaters

KNUT V. HØYLAND
NTNU - SAMCoT Leader WP3
Ice rubble and ice ridge action

ROGER SKJETNE
NTNU - SAMCoT Leader WP5
Ice Management

STEINAR NORDAL
NTNU
Coastal Technology

JUKKA TUHKURI
Aalto
Discrete Element Modelling of ice rubble and ice ridges

MAURI MÄÄTTÄNEN
NTNU
Dynamic ice action

VLADISLAV ISAEV
MSU
Geocryology

ELIZ-MARI LOURENS
TU Delft
Dynamic ice action

M. AZUCENA GUTIÉRREZ
NTNU-SAMCoT Leader WPAdm.
International Management

PETER SAMMONDS
UCL
Ice friction

RAED K. LUBBAD
NTNU - SAMCoT Leader WP6
Ice Management and Coastal Technology

VISITING RESEARCHERS

EVGENY KARULIN
KSRC
Physical-Mechanical properties of ice

MARINA KARULINA
KSRC
Ice-structure interaction

NIKOLAY VASILIEV
B.E. Vedeneev VNIIG, JSC
Ice and ice-soil composites

ALEXANDER SAKHAROV
MSU
Physical-Mechanical properties of ice

PETER CHISTYAKOV
MSU
Phys-mech properties of ice, instrumentation

CARL RENSHAW
Dartmouth College
Sediment Transport

DAVID COLE
CRREL
Ice mechanics, ice modeling, ice structure

DEVINDER SINGH SODHI
CRREL
Ice mechanics, ice modeling, ice structure

JUNJI SAWAMURA
Osaka University
Fluid Engineering

IAN TURNBULL
Memorial University of Newfoundland
Arctic field program in Barents Sea

PETER WADHAMS
University of Cambridge, UK
Ocean Physics. Sea Ice

ÅKE ROHLEN
Arctic Marine Solutions
Ice Management and Design Philosophy

ANDREI SLIUSARENKO
Soft Engineering
Physical-Mechanical properties of ice

SPRS - Swedish Polar Research Secretariat Sweden

MSU - Moscow State University, Russia

NTNU - Norwegian University of Science and Technology, Norway

TU Delft - Delft University of Technology, The Netherlands

UCL - University College London, UK

UNIS - University Centre in Svalbard, Norway

Soft Engineering, Ukraine

KSRC - Krylov State Research Centre, Russia

Memorial University of Newfoundland, Canada

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

Aalto - Aalto University, Finland

Dartmouth College, USA

Osaka University, Japan

B.E. Vedeneev VNIIG, JSC Research institute of hydraulic engineering, Russia

University of Cambridge, UK

Arctic Marine Solutions, Sweden

PHD CANDIDATES

MARTIN HASSEL*
Risk and Safety of Marine Operations under Arctic Conditions

ÅSE ERVIK
Ice ridge action, numerical modelling Sep

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

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

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

PETTER NORGREN
Autonomous Underwater Vehicles for operations under ice

EVGENII SALGANIK
Thermodynamic scaling of first-year ice ridges

ANNA PUSTOGVAR
Const. models for ice rubble, experimental

SERGEY KULYAKHTIN*
Constitutive modelling of ice rubble, FEM

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

CHRIS KEIJDENER
Stationary dynamic regimes of ice-floater interaction

HAYO HENDRIKSE*
Ice-induced vibrations – numerical modelling

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

FARZAD FARIDAFSHIN*
Alternative methods for quantifying safety

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

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

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

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

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

JULIE MALENFANT-LEPAGE
The critical shear stress of frozen soils

HONGTAO LI
Wave energy dissipation due to ice floes collisions

*PhDs promoted in 2017

POSTDOCTORAL RESEARCHERS

TORODD NORD
Ice-induced vibrations – analysis of measurements

ØIVIND K. KJERSTAD
Arctic Marine Cybernetics

MOHAMMAD SAUD AFZA
Numerical Modelling of Coastal Waves in the Arctic

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

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

WENJUN LU
Numerical modelling of ice-structure interaction

HAYO HENDRIKSE
Ice-induced vibrations – numerical modelling

SERGEY KULYAKHTIN
Constitutive modelling of ice rubble, FEM

ERSEGUN DENIZ GEDIKL
Ice-induced vibrations of offshore structures

MSC STUDENTS

SILJE AARVIK JOHANNESSEN
Autonomous heading control in position mooring with thruster assist

GUTTORM UDJUS
Force field identification and positioning control of an autonomous vessel using inertial measurement units

HOOMAN ROSTAMI
Finite Element Analysis of Coupled Thermo-Hydro-Mechanical Processes in Fully Saturated, Partially Frozen Soils

AGNES KATHARINA SCHNEIDER
Assessing Stability of Coastal Bluffs Due to Combined Actions of Waves and Changing Ambient Temperatures in the Arctic

ARTEM NESTEROV
Temperature deformations of frozen soils in the foundations of hydrotechnical structures.

DISSEMINATION

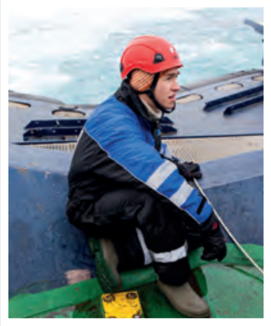
SAMCoT International Research Partners: Aalto University, School of Engineering; Delft University of Technology (TUDelft); Hamburg Ship Model Basin (HSVA); Moscow State University (MSU); Norwegian University of Science and Technology (NTNU); Technical Research Centre of Finland (VTT); Technical University of Denmark (DTU); University College London (UCL) and the University Centre in Svalbard (UNIS) greatly contribute to the Centre scientific dissemination goals.

SAMCoT`s Scientific Advisory Committee (SAC), comprising leading international academics under the leadership of Professor Erland M. Schulson, expressed their satisfaction with the dissemination work of the centre in their report for 2017: 'SAMCoT has shown an extraordinary level of productivity—both of young people and of contributions to the literature. SAMCoT continues to generate new and important results of significance to the sustainable development of the Arctic.'Info about the PHD:

Sergey Kulyakhtin

Sergey Kulyakhtin finished writing his doctoral thesis "Unconsolidated Ice Rubble Modelling with Continuum Approach" in 2017. The highlight for him was the successful public defence at NTNU on June 21. His thesis developed a model that includes volumetric behavior of ice rubble, and forms the basis for the modelling of ice ridge action on structures.

Renat Yulmetov



Renat Yulmetov submitted his thesis "Observations and Numerical Simulations of Icebergs in Broken Ice" and defended it successfully on January 12, 2017 at The University Centre in Svalbard. It was a lack of knowledge about icebergs drifting together with broken ice, as well as a lack of operational experience on deflecting an iceberg in broken ice, which motivated him to write about this topic.

Martin Hassel

On 28 November 2017 Martin Hassel successfully defended his PhD thesis "Risk Analysis and Modelling of Allisions between Passing Vessels and Offshore Installations" at NTNU. The thesis identifies risk influencing factors, and models the risk of allision between passing vessels and offshore installations on the Norwegian Continental Shelf. This work is also relevant for offshore operations in Arctic waters.

Hayo Hendrikse

Hendrikse submitted his thesis "Ice-induced Vibrations of Vertically Sided Offshore Structures" and defended it successfully on January 20, 2017 at Delft University of Technology. The thesis was rewarded with the distinction of cum laude. Hendrikse will continue working on ice-induced vibrations as a Postdoc within SAMCoT for the period 2018-19.

Farzad Faridafshin

On 8 June 2017 Farzad Faridafshin successfully defended his PhD thesis "Probabilistic, Non-probabilistic, and Distributionally Robust Approaches to Reliability Assessment: with a Focus on the Design of Arctic Offshore Structures" at NTNU. The thesis explored the theoretical basis of how to deal with uncertain data, and becomes a building block for further reliability research in SAMCoT.

PhD Theses (5)

Farid Afshin, F. Probabilistic, Non-probabilistic, and Distributionally Robust Approaches to Reliability Assessment: With a focus on the design of Arctic Offshore Structures. NTNU Doctoral Thesis 2017:161

Hassel, M. - Risk Analysis and Modelling of Allisions between Passing Vessels and Offshore Installations. NTNU Doctoral Thesis 2017:305

Hendrikse, H - . Ice-Induced Vibrations of Vertically Sided Offshore Structures. Delft University of Technology, Doctoral Thesis ISBN 978-94-6186-746-9

Kulyakhtin, S. - Unconsolidated Ice Rubble Modelling with Continuum Approach. NTNU Doctoral Thesis 2017:173

Yulmetov, R. - Observations and numerical simulation of icebergs in broken ice. NTNU Doctoral Thesis 2017:240

Published International Refereed Journal Papers (10)

Farid Afshin, F., Grechuk B., and Næss, A. - Calculating Exceedance Probabilities Using a Distributionally Robust Method. Journal Structural Safety.

Farid Afshin, F. and Næss, A. - Multivariate log-concave probability density class for structural reliability applications. Journal Structural Safety.

Fomin, Y.V., Zhmur, V.V. and Marchenko, A. - Transient seawater inflow into seacoast aquifers. The Journal of Water Resources (Vodnye Resursy)

Marchenko, A., Morozov, E. and Marchenko, N. - Supercooling of seawater near the glacier front in a fjord. Earth Science Research, International Journal published by the Canadian Center of Science and Education

Marchenko, A. and Lishman, B. The influence of closed brine pockets and permeable brine channels on the thermo-elastic properties of saline ice.
The Journal of Philosophical Transactions of the Royal Society A

Marchenko, A., Vasiliev, N., Nesterov, A., Kondrashev, Yu. and Belyaev, N. - Laboratory investigations of the thermal strain of frozen soils using fiber-optic strain gauges based on Bragg gratings. The Journal of Sciences in Cold and Arid Regions

Nord, T., Bjerkås, M., Petersen, Ø.W., Kvåle, K. A. and Lourens, E-M. - Operational modal analysis of a lighthouse structure subjected to ice actions. The Journal of Procedia Engineering

Nuijten, A.D.W. and Høyland, K.V. Modelling the thermal conductivity of a melting snow layer. Journal of Cold Regions Science and Technology.

Ranta, J., Polojärvi, A. and Tuhkuri, J. - Ice loads on inclined marine structures - Virtual experiments on ice failure process evolution. Journal Marine Structures.

Yulmetov, R. and Løset, S. - Validation of a numerical model for iceberg towing in broken ice. Journal of Cold Regions Science and Technology.

Published International Conference Papers (38)

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

Ahmad, N., Bihs, H. and Arntsen, Ø. - 3D Numerical modelling of pile scour with free surface profile under waves and current using the level set method in model REEF3D. International Society of Offshore and Polar Engineers (ISOPE)

Ahmad, N., Bihs, H. and Arntsen, Ø. - A numerical investigation of erosion around offshore pipelines. National Conference on Computational Mechanics (MekIT)

Amiri, A.G. and Grimstad, G. Coupled THM constitutive model for porous materials under frost action: Application to frost heave simulation. on Porous Media (INTERPORE)

Amiri, A.G. and Grimstad, G. Constitutive Model for Long-Term Behavior of Saturated Frozen Soil. Poromechanics VI

Berg, vd M., Lubbad, R. and Løset, S.- Accuracy of a Non-Smooth Time Stepping Scheme with Non-Rigid Contacts for Ice-Structure Interaction. Port and Ocean Engineering under Arctic Conditions (POAC)

Bihs, H., Ahmad, N., Kamath, A. and Arntsen, Ø. A. CFD Modeling of Local Scour under Complex Free Suface Flow. European Geosciences Union General Assembly (EGU)

Bjørnø, J., Heyn, H-M., Skjetne, R., Dahl, A.R. and Frederich, P. Modeling, parameter identification and thruster-assisted position mooring of C/S Inocean Cat I Drillship. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Chen, X., Høyland, K.V. and Ji,S. The Determination of Heat Transfer Coefficient on Water-ice Surface in a Free Convection. Port and Ocean Engineering under Arctic Conditions (POAC)

Cheng, S., Tsarau, A., Li, H., Herman A., Evers, K-U. and Shen, H. - Loads on Structure and Waves in Ice (LS-WICE) project, Part 1: Wave attenuation and dispersion in broken ice fields. Port and Ocean Engineering under Arctic Conditions (POAC)

Depina, I. Wave induced response of seabed around a buried pipeline in silty soil. Poromechanics VI.

Ervik, Å., Høyland, K.V., Grimstad, G. and Nord, T. - A continuum model of continuous ductile ice crushing. Port and Ocean Engineering under Arctic Conditions (POAC)

Herman, A., Tsarau, A., Evers, K.-U., Li, H. and Shen, H. - Loads on Structure and Waves in Ice (LS-WICE) project, Part 2: Sea ice breaking by waves. Port and Ocean Engineering under Arctic Conditions (POAC)

Heyn, H-M., Zhang, Q., Knoche, M. and Skjetne R. - A system for automated vision-based sea-ice concentration detection and floe-size distribution indication from an icebreaker. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Heyn, H-M., Udjus, G. and Skjetne, R. - Distributed motion sensing on ships. OCEANS MTS/IEEE

Isaev, V., Koshurnikov, A.V., Sergeev D.O., Amangurov R.M., Grishakina E.A. and Buldovich S.N. Dynamics of thermal erosion process for the coastal line of Baydara Bay on Kara Sea at the site of Bovanenkovo-Uhta pipeline cofferdam junction (public joint stock company Gazprom). Innovations in geology, geophysics and geography

Karulina, M., Sakharov, A., Marchenko, A., Karulin, E. and Chistyakov, P. - A study of ice oblique drift action onto the structure partially sheltered by another object. Port and Ocean Engineering under Arctic Conditions (POAC)

Kim, E., Amdahl, J. and Song, M. On a shifting pressure-area relationship for the accidental limit state analysis of abnormal ice actions. International Conference on Marine Structures (MARSTRUCT 2017)

Keijdener, C. and Metrikine, A. Is Linear Hydrodynamics Sufficient to Predict Breaking Lengths Correctly? Port and Ocean Engineering under Arctic Conditions (POAC)

Koshurnikov, A.V. and Zheltenkova N.V. - Evaluation of the influence cofferdams on permafrost on the example of Bovanenkovo - Ukhta pipeline in the Baydaratskaya Bay. Innovations in geology, geophysics and geography.

Koshurnikov, A.V. and Skosar, V.V. - Electrical prospecting arctic shelf and submarine permafrost. Innovations in geology, geophysics and geography.

Kulyakhtin, S. and Polojärvi, A. Variation of Stress in Virtual Biaxial Compression Test of Ice Rubble. Port and Ocean Engineering under Arctic Conditions (POAC)

Lu, W., Heyn, H-M., Lubbad, R. and Løset, S. - Large Scale Simulations of Floe-Ice Fractures and Validation against Full-scale Data. Port and Ocean Engineering under Arctic Conditions (POAC)

Løset, S. - Sustainable Arctic Marine and Coastal Technology. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, N. and Marchenko, A., - Investigation of large ice rubble field in the Barents Sea. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, N. and Sakharov, A. Laser Scanning in Mechanical Ice Tests. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, A. and Cole, D. - Three Physical Mechanisms of wave energy damping in solid ice. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, A., Karulina, M., Karulin, E., Chistyakov P. and Sakharov, A. - Flexural Strength of Ice Reconstructed from Field Tests with Cantilever Beams and Laboratory Tests with Beams and Disks. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, A. and Kowalik, Z. Investigation of Ocean Currents in Navigational Straits of Spitsbergen. Marine Navigation and Safety of Sea Transportation, TransNav 2017

Nazarov, A.S. - Calculation of slopes stability (by the example of a seaside part in the place of gas-pipe "Yamal" transition on the west coast of Baydara Bay). Innovations in geology, geophysics and geography.

Norgren, P. and Skjetne, R. - A particle filter SLAM approach to online iceberg drift estimation from an AUV. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Ranta, J. - Sources of Stochasticity in Ice-Structure Interaction. Port and Ocean Engineering under Arctic Conditions (POAC)

Salganik, E., Høyland, K.V. and Shestov, A. - Thermodynamics and Consolidation of Ice Ridges for Laboratory Scale. Port and Ocean Engineering under Arctic Conditions (POAC)

Shestov, A. and Salganik, E. Thermodynamic Consolidation of Ice Rubble in the Small Scale in-situ Experiment. Van Mijen Fiord, Spitsbergen, March 2016. Port and Ocean Engineering under Arctic Conditions (POAC)

Skarbø, R. and Løset, S. - Ice Intelligence Retrieval by Remote Sensing – Possibilities and Challenges in an Operational Setting. Port and Ocean Engineering under Arctic Conditions (POAC)

Skjetne, R., Sørensen, M.E.N, Breivik. M., Værnø, S.A.T., Brodtkorb, A.H., Sørensen, A.J., Kjerstad, Ø. K., Calabrò V. and Vinje, B.O. - AMOS DP Research Cruise 2016: Academic full-scale testing of experimental dynamic positioning control algorithms onboard R/V Gunnerus. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Tsarau, A., Sukhorukov, S., Herman, A., Evers, K.-U. and Løset, S. - Loads on Structure and Waves in Ice (LS-WICE) project, Part 3: Ice-structure interaction under wave conditions. Port and Ocean Engineering under Arctic Conditions (POAC)

Ruud, S. - Ice Management and Design Philosophy. International Marine Design Conference

MSc Theses (5)

Johannessen, S.A. - Autonomous heading control in position mooring with thruster assist. MSc Theses, NTNU

Nesterov, A. - Temperature deformations of frozen soils in the foundations of hydrotechnical structures. MSc Theses, Peter the Great St. Petersburg Polytechnic University, Russia

Rostami, H. - Finite Element Analysis of Coupled Thermo-Hydro-Mechanical Processes in Fully Saturated, Partially Frozen Soils. MSc Theses, NTNU

Schneider, A.K. – Assessing stability of coastal bluffs due to combined actions of waves and changing ambient temperatures in the Arctic. MSc Theses, NTNU

Udjus, G. - Force field identification and positioning control of an autonomous vessel using inertial measurement units. MSc Theses, NTNU

Key Notes and Oral Presentations (131)

Ahmad, N. - Numerical modelling of erosion in the Arctic environment. SAMCoT Scientific Seminar

Ahmad, N. - High Resolution CFD modelling of scour in cold climate. Workshops Other

Aker A.H. - DNVGL-OS-E101 Drilling facilities (2017) Barrier requirements and relations to modelling of ice management barrier performance. Workshops Other

Albert, A. - Iceberg tracking by drones. SAMCoT Scientific Seminar

Amdahl, J. - Brittle Fracture of Steel under Arctic Conditions. Workshops Other

Amiri, A.G. and Grimstad, G. - Thermo-Hydro-Mechanical model for frozen/freezing ground. SAMCoT Scientific Seminar

Amiri, A.G. - Numerical Modelling of Saturated Frozen Soil. Workshops Other

Berg, vd M. - Lattice fracture modelling. Workshops Other

Bjørnø, J. - Experiences from the Statoil SKT expedition, status so far, and plans for further studies. SAMCoT Scientific Seminar

Bjørnø, J. - Modeling, parameter identification and thruster-assisted position mooring of C/S Inocean Cat I Drillship. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Dahlin, R. Ch. - Preliminary results on the use of the OceanEye for ice surveillance. SAMCoT Scientific Seminar

Depina, I. - Pipelines an Arctic Environment. Workshops Other
Eik, K. J. - Expected performance of ice management: Why so important? Workshops Other

Ervik, Å. - Modelling of large deformations continuous crushing of consolidated ice. SAMCoT Scientific Seminar

Ervik, Å. - Ice ridge load measurements. SAMCoT Scientific Seminar
Farid Afshin, F. - Probabilistic, non-probabilistic, and Distributionally Robust Approaches to Reliability Assessment. With a focus on the design of Arctic Offshore Structures. Presentation of the doctoral thesis.

Farid Afshin, F. - Load Characterization in Offshore Design Codes: Development of Practical Codes for Arctic Environments. Trial lecture for the degree of Philosophia Doctor.
Grimstad, G. and Amiri, A.G. - Coupled THM constitutive model for porous materials under frost action: Application to frost heave simulation. Workshops Other

Gong H. - DEM Modelling on Ship-Ridge Keel Interaction. Ice Rubble Workshops (IRWS, UCL)
Gutierrez Glez, M.A. – EIAC MoM2-2016_Presentation Board 2017. SAMCoT Board Meetings

Gutierrez Glez, M.A. – SAMCoT Communication. NRC SFI Forum Oslo.

Gutierrez Glez, M.A. – SAMCoT Communication Int. SAMCoT Board Meetings

Gutierrez Glez, M.A. – SAMCoT WP Adm Activities/Update2017. SAMCoT Board Meetings

Gutierrez Glez, MA – SAMCoT WP Adm Activities/CTR2018. SAMCoT GA Meeting

Gutierrez Glez, MA – SAMCoT WP Adm_Status Board 2_2017. SAMCoT Board Meetings

Hassel, M. - Risk Analysis and Modelling of Allisions between Passing Vessels and Offshore Installations. Presentation of the doctoral thesis.

Hassel, M. - Collision risk for autonomous ships – critical accident scenarios and feasibility of existing collision risk models. Trial lecture for the degree of Philosophia Doctor.

Heinonen, J. - Ice ridge simulations. Ice Rubble Workshops (IRWS, UCL, London)

Hendrikse, H. - Numerical analysis of ice-induced vibrations. SAMCoT Scientific Seminar

Heyn, H-M. - Extreme value statistics of ice-induced accelerations, and some on ice concentration and floe-size distribution detection. SAMCoT Scientific Seminar

Heyn, H-M. - Automated vision-based sea-ice concentration detection and floe-size distribution indication. International Conference on Ocean, Offshore and Arctic Engineering (OMAE)

Heyn, H-M. - Distributed motion sensing on ships. OCEANS MTS/IEEE Hinse, P. - IVOS Project. SAMCoT Scientific Seminar

Høyland, K.V - WP3 Update. SAMCoT Board Meetings

Høyland, K.V. - Overview WP3. SAMCoT Scientific Seminar

Høyland, K.V. - WP3 Presentation. SAMCoT Technical Workshop

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

Isaev, V. - MSU-SAMCoT 2017. Workshops Other

Keijdener, C. - The importance of nonlinear hydrodynamics for the correct prediction of breaking lengths. SAMCoT Scientific Seminar

Kim, E. - Towards simplified methods for damage assessment of structures subjected to abnormal ice actions. SAMCoT Scientific Seminar
Kim, E. - Local Ice Actions Status. Workshops Other

Kim E. and Amdahl J. - On a shifting pressure-area relationship for the accidental limit state analysis of abnormal ice actions. Dalian University of Technology, Dalian, China
Kolari, K. - Modelling of Splitting and Spalling in Columnar Ice. Ice Rubble Workshops (IRWS, UCL)

Kondrashev - Laboratory investigations of frozen soils thermal expansion. SAMCoT Scientific Seminar

Kulyakhtin, S. - The role of viscoelasticity in ice failure and actions on offshore structures. Trial lecture for the degree of Philosophia Doctor.

Kulyakhtin, S. - Unconsolidated Ice Rubble Modelling with Continuum Approach. Presentation of the doctoral thesis.

Lange, F. - EIAC reporting. SAMCoT Board Meetings

Li, H. - Wave energy dissipation due to ice floes collisions. . SAMCoT Scientific Seminar

Li, H. - Wave – ice interactions review. Workshops Other

Lu, W. - CAE in Arctic Marine Technology. Workshops Other

Lu, W. - Fracture of sea ice: applied simulations and fundamental experiments. SAMCoT Scientific Seminar

Lu, W. - Semi-Analytical and Semi-Numerical (XFEM) fracture simulations for ice-structure interactions. Workshops Other

Lu, W. - Strategies of floe ice's fracture simulation in the framework of Non-smooth DEM. SAMCoT Scientific Seminar
Lubbad, R. - WP6 Coastal Technology. SAMCoT Scientific Seminar

Lubbad, R. - WP6 – Coastal Technology. SAMCoT Technical Workshop

Lubbad, R. - WP6_Programme_Lubbad. Workshops Other

Lubbad, R. - WP6 Review 2017, SAMCoT Board Meetings

Løset, S. - Action MoM/1/2017. SAMCoT EIAC Meetings

Løset, S. - Agenda WP4 Workshop 8th May. Workshops Other

Løset, S. – ArcISo SAMCoT spin-off. NRC SFI Forum Oslo.

Løset, S. - ArcISo SAMCoT spin-off. Workshops Other

Løset, S. – Briefing on Activities_Board 2 2017 . SAMCoT Board Meetings

Løset, S. - Commercialization of Research (Presentation from the RCN). SAMCoT EIAC Meetings

Løset, S. - CTRWP4 Presentation. SAMCoT EIAC Meetings

Løset, S. – HSE Reporting. SAMCoT Board Meetings

Løset, S. - HSE Status 2017. SAMCoT Board Meetings

Løset, S. - Overview WP4. SAMCoT Scientific Seminar

Løset, S. – SAMCoT GA Briefing on Activities. SAMCoT GA Meeting

Løset, S. – SAMCoT Update_GA. SAMCoT GA Meeting

Løset, S. - Simulation Technology for Estimation of Ice Load Time Series on Floating Offshore Structures in the Arctic. International conference on Arctic Vision 2017 (ICAV)

Løset, S. - SPRS_Field Course_ Handbook. SAMCoT Board Meetings

Løset, S. – Wrap-up Science Seminar. SAMCoT EIAC Meetings

Løset, S. - WP4 - Floating Structures in Ice. SAMCoT Technical Workshop

Løset, S. - WP4 - Floating Structures in Ice. SAMCoT Workshop Other

Løset, S. - WP4_Innovation Initiatives. SAMCoT EIAC Meetings

Løset, S. - WP4 Review2017. SAMCoT Board Meetings

Løset, S. - Arctic Course, Petroleum Safety Authority Norway

Løset S. and Lu, W. - Global ice iracture experiments at Spitsbergen and its impact on numerical simulation of ice actions. Ice Fracture and Cracks, SIPW04, Isaac Newton Institute of Mathematical Sciences, Cambridge.

Malenfant-Lepage, J. - Project : Critical shear stress of frozen/thawing soils. Workshops Other

Malenfant-Lepage, J. - The critical shear stress of frozen soils. SAMCoT Scientific Seminar

Marchenko, A. - Attenuation of surface waves in the marginal ice zone of the Barents Sea: Field observations and modelling. Cambridge, UK

Marchenko, N. – GISREPORT. SAMCoT Board Meetings

Marchenko, N. – GIS. SAMCoT Scientific Seminar

Marchenko, A. - Overview_WP1. SAMCoT Scientific Seminar

Marchenko, A. - Thermo-mechanical loads of sea ice on structures. Cambridge, UK

Marchenko, A. - WP1 Review 2017. SAMCoT Board Meetings 24 Marchenko, A. Karulina, M. and

Karulin, E. - Flexural strength of ice reconstructed from field tests with cantilever beams and laboratoty tests with beams and disks. Port and Ocean Engineering under Arctic Conditions (POAC)

Marchenko, A.and Kowalik, Z. - Investigation of ocean currents in navigational straits of Spitsbergen. TransNav, Gdynia, Poland

Monteban, D. - Measurements and modelling of Arctic coastal environments. SAMCoT Scientific Seminar

Nord, T - Frequency lock-in vibrations, the signature and occurrence. SAMCoT Board Meetings

Nord, T. - Ice-structure interaction: structural monitoring, system identification and machine learning. SAMCoT Scientific Seminar

Nord,T., Bjerkås, M., Petersen, Ø.W., Kvåle K.A. and Lourens E-M.- Operational modal analysis of a lighthouse structure subjected to ice actions. International Conference on Structural Dynamics (Eurodyn)

Norgren, P. - Simultaneous localization and mapping under icebergs, and preliminary results from REMUS 100 deployment under ice in Van Mijenfjorden. SAMCoT Scientific Seminar

Ranta, J. - Statistics of sea ice loads on structures from virtual experiments. SAMCoT Scientific Seminar
Ruud, S. - Methods for modelling Ice

Management performance. SAMCoT Scientific Seminar

Ruud, S. - SAMCoT Technical WP5. SAMCoT Technical Workshop

Ruud, S. - Workshop agenda and Ice Management performance models and comments. Workshops Other

Ruud, S. - WP5.2 SpecificWorkshop_1. Workshops Other

Ruud, S. - WP5.2 SpecificWorkshop_3. Workshops Other

Ruud, S. - WP5.2 SpecificWorkshop_4. Workshops Other

Ruud, S. and Løset, S. - SAMCoT Workshops WP5.2 and WP 4: WP5.2 Modelling Ice Management Performance. Workshops Other

Salganik, E. - Thermodynamics and consolidation of ice ridges for different scales. SAMCoT Scientific Seminar

Samardzija, I. - Risk, reliability and ice data in the Arctic, how to keep a sufficient safety level with little available data. SAMCoT Scientific Seminar

Saud Afzal, M. - Arctic Coastal Erosion Modelling tools overview. Workshops Other

Saud Afzal, M. - Development of Predictive Tool for Coastal Erosion in Arctic; A Review. Workshops Other

Saud Afzal, M. - Numerical modelling of coastal waves in the Arctic. SAMCoT Scientific Seminar

Schneider, A. – Assessing stability of coastal bluffs due to combined actions of waves and changing ambient temperatures in the Arctic. Workshops Other

Schulson, E.M. - Fatigue of Ice: A surprise. SAMCoT Scientific Seminar

Shestov, A. - Thermodynamics of Ice Ridges during Spring Season in the Arctic Ocean. Results from R/V Lance N-ICE 2015 campaign. SAMCoT Scientific Seminar

Shestov, A. and Salganik, E. - Thermodynamic consolidation of ice rubble in small scale in-situ experiments. Port and Ocean Engineering under Arctic Conditions (POAC)

Shortt, M. - Freeze-bond experiments - large scale and micro-scale. Workshops Other

Shortt, M. - Modelling freeze bond failure in saline ice as a function of the degree of consolidation. Ice Rubble Workshops (IRWS, UCL)

Shortt, M. - Strength of consolidated ice - experimental approach. Workshops Other

Sinitsyn, A. - Guidelines for the design of environmentally friendly and sustainable coastal structures and technology – Update. Workshops Other

Skarbø, R. - Ice Intelligence Retrieval by Remote Sensing – Possibilities and Challenges in an Operational Setting. SAMCoT Scientific Seminar

Skarbø, R. and Løset, S. - Ice drift estimation for Arctic marine operations. CIRFA Workshop

Skarbø, R., Kjerstad, Ø.K. Løset, S. and Skjetne, R. - Real time ice drift estimation using data from the marine radar. CIRFA Workshop

Skarbø, R. - WP5.2 Specific Workshop 2. Workshops Other

Skjetne, R. - Data Management WP5. SAMCoT Board Meetings

Skjetne, R. - Overview WP5 activities. Workshops Other

Skjetne, R. - WP5 Review 2017. SAMCoT Board Meetings

Skjetne, R. - WP5_Innovation Initiatives. SAMCoT EIAC Meetings

Sodhi, D. - An Overview of Field and Laboratory Tests at UNIS. SAMCoT Scientific Seminar

Sulisz, W. - Vulnerability of the Arctic Coasts to Climate Changes. The ARCCOAST project. SAMCoT Scientific Seminar

Tsarau, A. - Ice in Waves. Workshops Other

Tsarau, A. - Learning from the experimental campaign at HSVA in Oct/Nov. 2016. SAMCoT Board Meetings

Tsarau, A. - Learning from the experimental campaign at HSVA in Oct/Nov. 2016 (LS-WICE project). SAMCoT Scientific Seminar

Tsarau, A. - Loads on Structure and Waves in Ice (LS-WICE) project, Part 3: Ice-structure interaction under wave conditions. Port and Ocean Engineering under Arctic Conditions (POAC)

Tsarau, A., Shestov, A. and Løset, S. - Wave Attenuation in the Barents Sea Marginal Ice Zone in the Spring of 2016. Port and Ocean Engineering under Arctic Conditions (POAC)

Yulmetov, R. - Observations and numerical simulation of icebergs in broken ice. Presentation of the doctoral thesis.

Yulmetov, R. - Oil and Gas in the Arctic: Past, present and future technological challenges with respect to fixed versus floating structures. Trial lecture for the degree of Philosophia Doctor.

Mass Media & Other Popular Media (84)

Bazilchuk, N.R. - Making the Arctic safer for travel, operations (Video). GEMINI

Brandslet, S. and Midling, A.S. - Crushing ice to save platforms. GEMINI

Brandslet, S. and Midling, A.S. - Knuser is for å berge plattformer. GEMINI

Brandslet, S. and Midling, A.S. - Crushing ice to make ships Safer (Video). GEMINI

Foss, M.H., - Making Arctic travel safer. GEMINI

Gutierrez Glez, M.A. - SAMCoT Annual Report 2017. NTNU Graphic Center

Gutierrez Glez, M.A. - SAMCoT Newsletters 2017 (2). NTNU Graphic Center

Gutierrez Glez, M.A. – SAMCoT Videos of research activities (73). SAMCoT e-room

Kim, E., Amdahl, J. and Song, M. - On a shifting pressure-area relationship for the accidental limit state analysis of abnormal ice actions. CRC Press

Wolden, G. - Creating systems that understand the Arctic. GEMINI

Wolden, G. - Lager systemer som forstår Arktis. GEMINI

FIGURES 2017

In October 2017, SAMCoT's Centre Management Group (CMG) presented the Cost, Time and Resources (CTR) plans for 2018. SAMCoT's Board approved them. In December, the Research Council of Norway (RCN) approved SAMCoT's CTRs for 2017 and 2018. The tables below show, following the European Free Trade Association (EFTA) Surveillance Authority (ESA) reporting format, the funding and incurred costs for 2017 as reported by the Centre on January 20 2018 to the RCN.

SFI Annual accounting report 2017 - Project Characteristics and Costs (All figures in 1000 NOK)

Item	Host NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	Exxonmobile URC	ENGIE	AkerBP	Norwegian Coastal Adm.	Swedish Polar Research Secretariat	Lundin	Kværner	UCL	HSVA	TUDelft	DTU	Aalto University	MSU	VTT	Total cost
WP1			4 535	20	23	9	22								7	55							31	4 702
WP3 & IVOS	6 513			20	23	9	54								7	55	217	406	866	250	294		31	8 745
WP4	4 636			20	23	9	54		77						7	55							31	4 912
WP5	3 029			20	23	25	54		57					40	7	55							30	3 340
WP6	4 143	2 157		20	23	9	174	16							7	55				250		188	30	7 071
EIAC				138	69	24	32	88	28	8						46								432
SAC	30																							30
SFI Equipment	148																					107		255
SFI Administration	1 955	70	281	47						8	210			10										2 598
Total budget	20 453	2 227	4 816	284	183	86	408	104	163	16	210	0	0	50	33	321	217	406	866	500	294	295	153	32 086

SFI Annual Work Plan 2017 - Funding (All figures in 1000 NOK)

ITEM	Host NTNU	Stiftelsen SINTEF	UNIS	Statoil	Shell	DNV GL	TOTAL	Multiconsult	Kongsberg Maritime	Exxonmobile URC	Engie	AkerBP	Lundin	Kværner	Norwegian Coastal Admin	Swedish Polar Research Secretariat	UCL	HSVA	TUDelft	Aalto University	MSU	DTU	VTT	RCN Grant	Other Public funding	Total cost
WP1			1 542	167	170	156	169	74	44	147	147	147	154	129									31	1 746		4 822
WP3 & IVOS	4 226			167	170	156	201	74	44	147	147	147	154	129			59	68	166	92		250	31	1 746		8 173
WP4	1 660			167	170	156	201	74	122	147	147	147	154	129									31	1 745		5 048
WP5	485			167	170	172	201	74	102	147	147	147	157	129		40							30	1 745		3 909
WP6	1 537	612		167	170	156	321	90	44	147	147	147	157	130	330						108	250	30	1 745		6 284
EIAC				138	69	24	32	88	28	8				46												432
SAC																										0
SFI Equipment																					107					107
SFI Administration	1 272			47			18			8	210					10								1 745		3 311
Total budget	9 181	612	1 542	1 019	918	821	1 143	471	385	751	945	735	768	689	330	50	59	68	166	92	215	500	153	10 473		32 086