Project information

Keywords
Ice; waves; marine operations; Technology
Project title
Ice floe interaction with ships and waves - IFiSaW
Year
2016
Project leader
Karl Gunnar Aarsaether
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
69.6492° N, 18.9553° E
Participants

SINTEF Nord

Universtitetet i Tromsø

Troms Offshore

Opelion AS

Flagship
Arctic Ocean
Funding Source

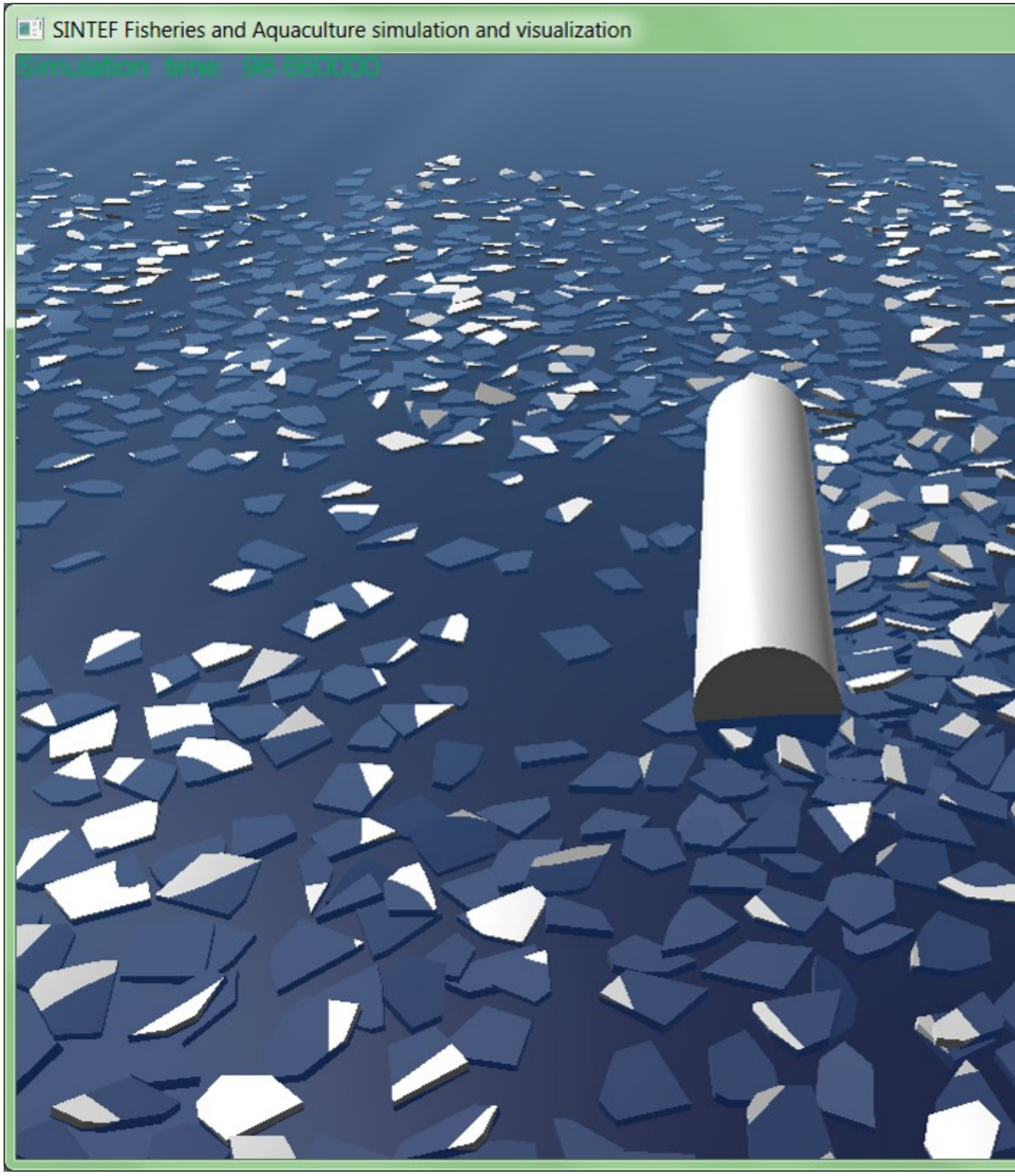
Arctic Ocean Flagship at the fram Center

Summary of Results

The project has continued the work from 2015 with the goal of extending the work of wave driven ice floe impacts to:

- Multiple ice floes
- Irregular seas
- Arbitrary impact geometry

The model has been extended to include the above mentioned efatures, although work is ongoing for quality assurance and production of results which can be published in a scientific paper. A visualization of the present state of the model is shown in the figure below.



The cooperation between the University of Tromsø has continued and project thesis topics have benn defined and it is expected that student(s) will be working with project related theses in the autumn of 2016. The student(s) will receive guidance and support as a part of the project.

The project description for possible master thesis project(s) is oven below

Master thesis project

Reliability of subsea operations in waters with dispersed ice floes. The project thesis will study the reliability of subsea operations in artic waters with regard to the prevailing meteorological conditions for sea and air while considering the possible effects of dispersed ice floes. The thesis will:

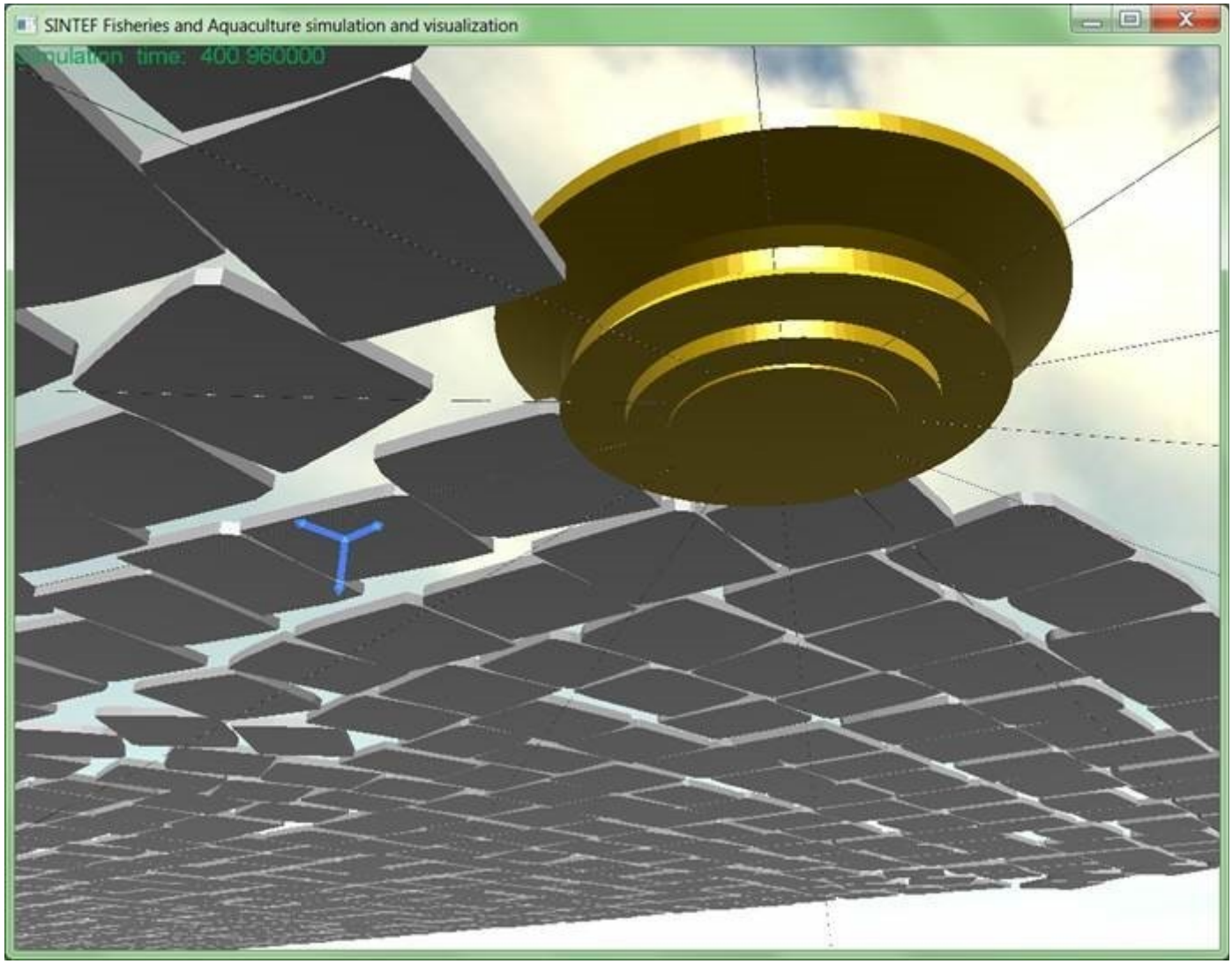
- Describe a typical subsea scenario for exploration of subsea resources and maintenance of subsea installations. Example: the vessels and platforms involved in subsea drilling.
- Identify key marine operations which are needed in order to support the scenario. Example subsea drilling or subsea installation and maintenance
- Develop a statistical model for ice impact forces from disperse ice depending on ice floe size and sea state. Example: derive the relationship between ice impact forces and the sea state on the drill-string during a subsea drilling operation
- Conduct a simplified risk analysis of the operation with a scenario where dispersed ice floes enter the operation area.

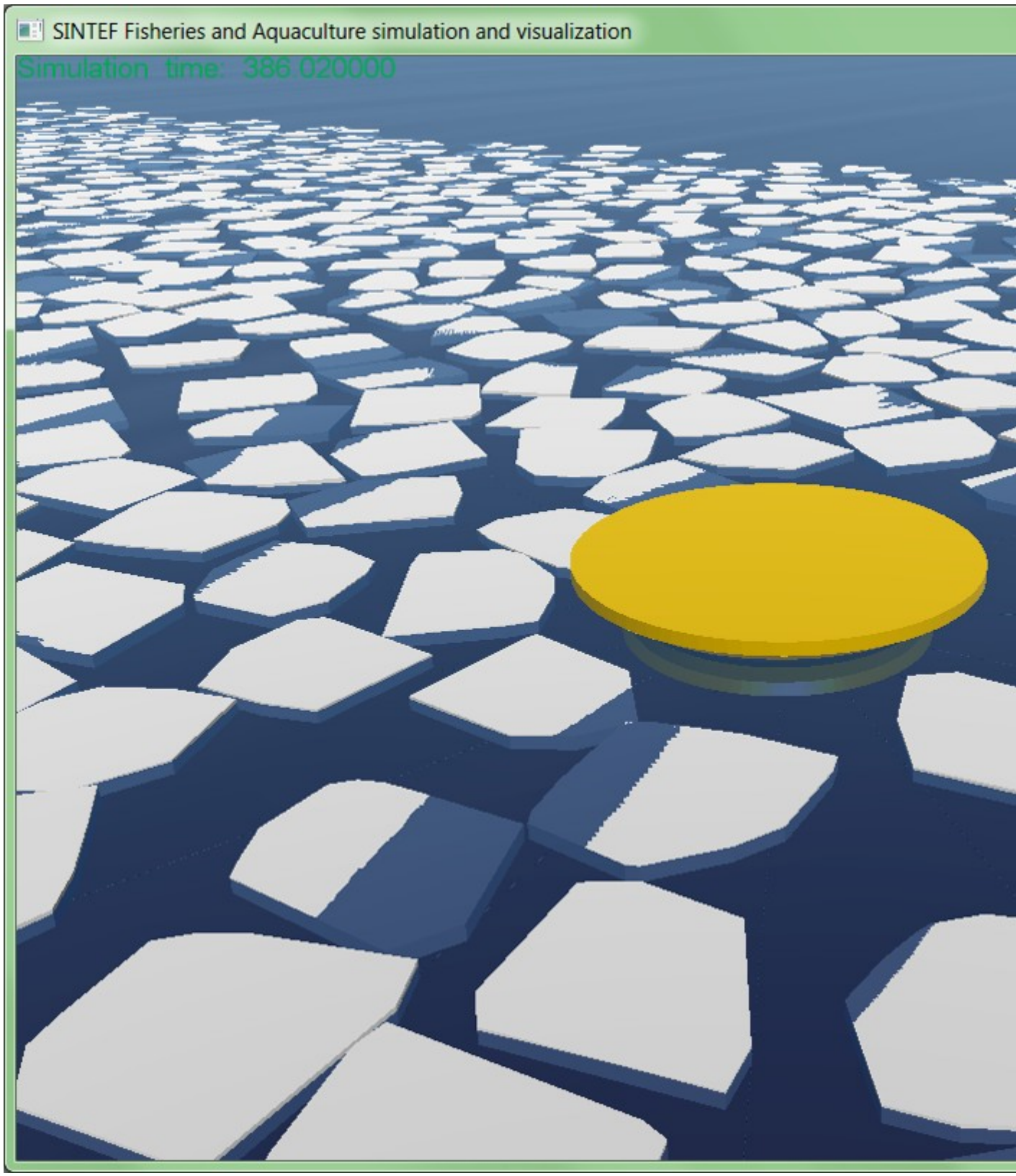
The student is expected to complete the project with the use of common reliability and risk analysis techniques. Software for prediction of ice floe impact forces will be made available from SINTEF North for use within the project. The software is able to predict the impact forces of wave driven ice floes on structures. The project thesis must include the theory behind engineering predictions of impact forces as defined by ISO

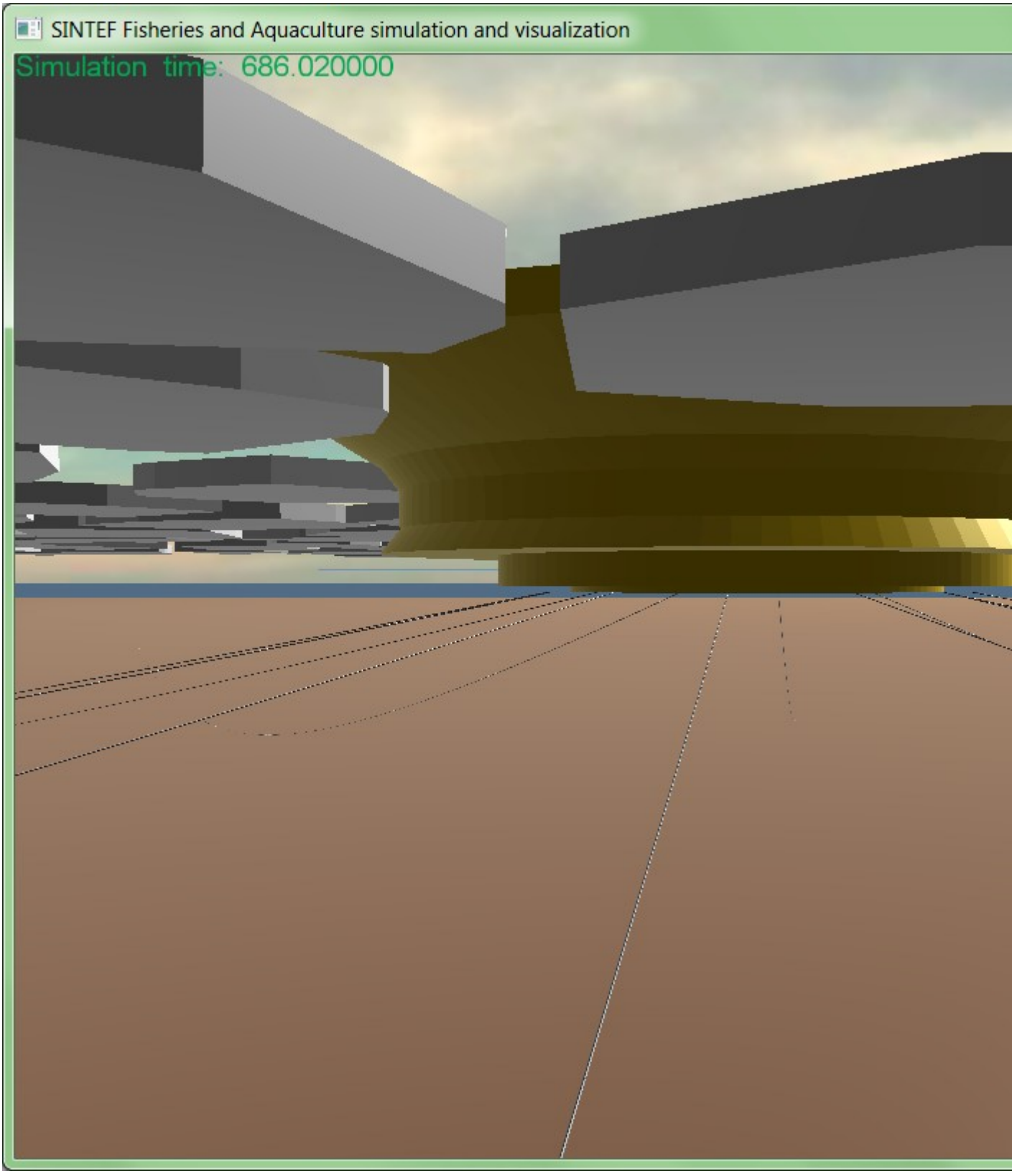
The ice floe field model described earlier has been used to model the case of a moored cylyndrical drilling platform in ice. The new developed numerical model can simulate a moored structure in a broken ice filed of thousands of ice floes, where the loads from waves and current can also be considered. There appears to be, to the best of the authors' knowledge, no previous work have included the coupled simulations with mooring lines and considering the wave effects in ice-structure interaction. The implemented ice floe model has been included in a coupled simulation with mooring cables in order to model the complete scenario of a floating structure moored in ice subjected to both waves and ice floe impacts.

A conical drilling unit, named the "Kulluk", was used for drilling operations in the intermediate to deeper waters of the Beaufort Sea (20-80m) from the middle 1970s to the early 1990s. The Kulluk’s experience base provides the best source of data for most considerations related to moored vessel stationkeeping operations in various pack ice conditions (Wright, 2000). Therefore, the Kulluk structure is selected as the prototype for a case study and the results will be present in OMAE'17, with the comparison between numerical simulations and field measurements.

The Kulluk structure has been chosen since there exist full sacle data which can be used for verification of the interaction model between the structure and the ice floes.

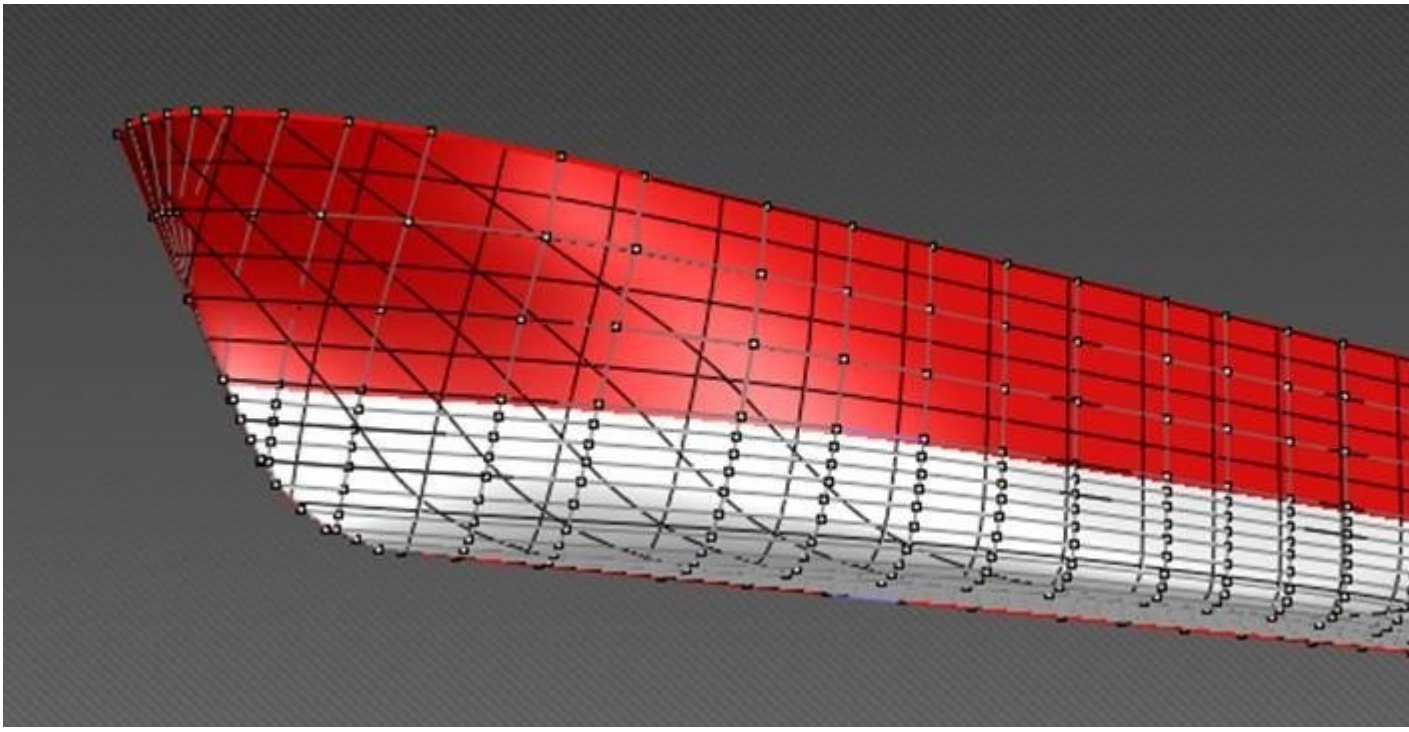

SINTEF Fisheries and Aquaculture simulation and visualization
ulation time: 400.960000

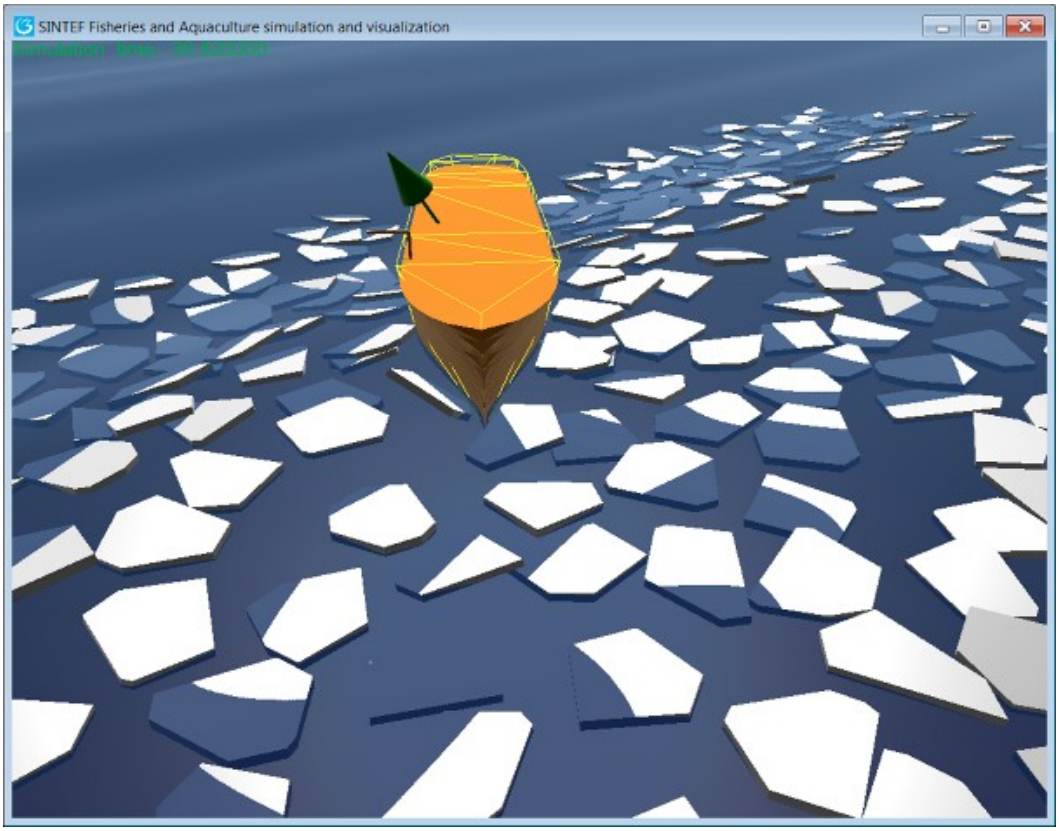

SINTEF Fisheries and Aquaculture simulation and visualization
Simulation time: 386.020000



Update 21.11.2017

A ship geometry with the same main dimensions as one of the norwegian Snow Crab vessels has been generated and a dynamic model has been developed for use with the developed ice-floe model. The geometry has been used to model the contact geometry of the ship in the ice-floe field and there is feedback of the impac forces from the ice floes into the ship dynamic.





References:

Wright, B., 2000. Full Scale Experience with Kulluk Stationkeeping Operations in Pack Ice (With Reference to Grand Banks Developments). PERD/CHC Report 25-44, 2000-07.

Master and PhD-students involved in the project

Espen Bergland, MSc student at ISS-UiT will write his master thesis as a part of this project. The final title and topic selection for the master thesis will be completed during the latter half of december 2016.

Espen Berglands problem formulation is as follows:

"In this paper, a scenario with a drilling barge in arctic waters will be described. Impact forces from floating ice will then be simulated with different amounts of sea ice and in different sea states using FhSim. The added forces from floating ice will potentially cause a change in the drilling barges horizontal position and this can cause a potential hazard to the tension in the riser. The potential scope of this hazard is evaluated as well as the potential need for risk mitigating measures in the form of ice management. Furthermore the paper will discuss the possibility to predict the need for ice management by evaluating the sea state and weather condition."

Software which contain the current state of the ice-wave-structure interaction has been transferred and the IFiSAW project leader has been formally appointed as co-supervisor for the work.

Update - 07.09.2017:

Espen bergland has submitted his master thesis and received a MSc degree

Published Results/Planned Publications

1. The paper submitted to OMAE 2015 has been presented and is now indexed and published in the conference proceedings.
    1. Biao Su, Karl Gunnar Aarsæther, David Kristiansen, *Numerical Study of Wave-Driven Impact of a Sea Ice Floe on a Circular Cylinder*, Paper No. OMAE2016-54296, pp. V008T07A008; 9 pages, doi:10.1115/OMAE2016-54296. ASME 2016 35th International Conference on Ocean, Offshore and Arctic Engineering, Volume 8: Polar and Arctic Sciences and Technology; Petroleum Technology. Busan, South Korea, June 19–24, 2016, ISBN: 978-0-7918-4999-6
1. The results of the work in 2016 on multiple ice floes in iregular waves will be published either in the proceedings of the OMAE 2017 conference (Trondheim) with a possible extension to the level 2 scientific journal associated with the conference which allows expansion of works published in the conference proceedings (ASME Journal of OMAE). The first draft version of the paper for OMAE 2017 is due 14. january 2017. The following abstract has been submitted and accepted:

Numerical study of a moored structure in moving broken ice driven by current and wave

The use of moored structures in ice represents a promising solution for marine operations in Arctic and Sub-Arctic areas, in particular for the drilling, storage, production and offloading of hydrocarbons. Data from full-scale experiences and model basin experiments have been used for studying moored structures in drifting ice. Due to the complexity of modelling interactions between a moored structure and the drifting ice, numerical studies have been focusing on the ice load model, while the mooring load and the dynamic response of the structure are often simplified.

This paper presents a numerical model intended to simulate the mooring load and the dynamic response of a moored structure in drifting ice. The mooring lines are explicitly modelled by using a generic cable model with a set of constraint equations providing desired structural properties such as axial, bending and torsional stiffness. The 6 degrees-of-freedom (DOF) rigid body motions of the structure are simulated by considering its interactions with the mooring lines and the drifting ice. In this simulation, a fragmented ice field of thousands of broken ice pieces can be considered under the effects of current and wave. The ice–ice and ice–structure interaction forces are calculated based on a viscoelastic-plastic rheological model (Løset, 1994). The hydrodynamic forces acting on the floating structure, mooring line and drifting ice are calculated by using Morison's equation. The present study, in general, demonstrates the potential of developing a full numerical model for the coupled simulation of a moored structure in broken ice.

The full-scale experience with the conical drilling unit, named Kulluk, provides the best source of data for most considerations related to moored structure in various pack ice conditions (Wright, 1999&2000). Therefore, the Kulluk structure is selected as a prototype for the present numerical study. The numerical simulation results are then compared with the relevant full-scale data. The mooring load is a result of the structural response and it differs from the ice load acting on the structure. This will be discussed in the paper. Waves are often neglected in the numerical study of ice–structure interactions. A simplified wave force model has been applied by the authors in a previous study for simulating wave-driven impact of an ice floe on the structure. The influence of waves on the ice floe impact forces and the resulting mooring loads will be briefly discussed in this paper. There is no published data on the wave effects in such condition, which remains for further analysis.

The OMAE 2017 paper has been submitted and has receied the paper ID OMAE2017-61252

Update - 07.09.2017:

The paper has been presented at OMAE, but the conference proceedings are not yet online/registered by AMSE (organizer). The paper will be expanded for submission to the Journal of OMAE (seperate from the conference).

A new conference paper for OMAE is planned for 2018.

Update - 21.11.2017:

The expanded version of the OMAE2017 paper is under preparation and will be submitted for the Journal of OMAE at the end of 2017.

An abstract has been prepared for the OMAE 2018 conference:

Numerical study of a fishing vessel operating in partially ice covered waters

The arctic ocean has been the focus of increasing activities in oil and gas, marine traffic and fisheries as the resources in the Arctic area becomes more attractive for exploitation. There have been several studies on the response of ships and structures in ice covered waters, mainly for oil and gas applications. This paper presents a scenario simulation model for fisheries, crab pot retrieval, in partially ice covered waters. This is an ongoing commercial activity where partial ice covers may appear over crab pots which need retrieval. This scenario is unique in the sense that the ship and ice can be expected to experience wave forcing in addition to the ice–structure interaction. The complexity of such scenarios favor simplified models and a coupled simulation model consisting of ship hydrodynamics, ice hydrodynamics, ice–ice and ice–ship interactions.

A numerical simulation model for ice–ice and ice–structure interactions that has been developed and compared with experimental and field measurement data (Su et al., 2016 & 2017) and a model for the fishing gear are used in this paper to study the ice impact forces, resulting motions and ice buildup of a fishing vessel operating in partially ice covered waters. The ice impact forces are calculated based on a viscoelastic-plastic rheological model (Løset, 1994). The 6 degrees-of-freedom (DOF) rigid body motions of the vessel are simulated by considering its interactions with a number of broken ice pieces driven by current and wave. The ice buildup on the hauling side of the fishing vessel is tracked and its effect on the hauling operations is evaluated. This paper, in general, presents a unique scenario simulation and relevant results that can be used for reliability studies of such operations.

Update 14.09.2018

The conference paper, result from the abstract above:

Aarsæther KG, Su B, and Kristiansen D - Numerical Study of a Fishing Vessel Operating in Partially Ice Covered Waters - ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering. American Society of Mechanical Engineers, 2018. OMAE2018-77464.

Has been published and presented at the OMAE 2018 conference (level 1).

An expanded version of the OMAE2017 paper "Numerical Study of a Moored Structure in Moving Broken Ice Driven by Current and Wave" has been submitted both as draft, and an updated version with reviewer revisions to the "Journal Of OMAE" (level 2).

Communicated Results

The ongoing work was presented at OMAE2016 and will be followed by a paper and presentation at OMAE2017 and OMAE2018.

The project was presented at the opening seminar for Fram2 as representative for "Flagship Arctic Ocean" with the title : "**Forbedret sikkerhet i isen - hvordan kan tallene hjelper?**"

The project manager served as one of the session chairs for the "Polar and Arctic Technology" track at OMAE2018

Update - 07.09.2017/14.09.18:

See "published results"

Budget in accordance to results

The project was awarded a funding of 1 000 000 NOK for 2016.

As of **24. June 2016** 500 000NOK of the 1 000 000 NOK budget has ben used for project work. The tasks for 2016 is proceeding accoridng to plan and will be detailed in the progress report at the end of the year

As of **26. August 2016** 720 000 NOK og the 1 000 000NOK budget has been used for project work. The tasks are proceeding according to plan, however some slight modifications have been deemed neccesary.

1. The availability of full scale data for the Kulluk floating structure made it an attractive option to verify ice loads in stead of using a ship hull at this stage. Note that the underlying geometry description of the Kulluk can be used to represent a ship hull with the proper geometric information.
2. Ice floe structural failure has been downprioritized due to the rarness of theese events in a less dense ice field. This was also subject to discussions at OMAE.

Publication of results will be prioritized. Possible internal funding for completion of paper.

As of **15 November 2016** 935 000NOK has been spent on research activities and the remaining 65 000 NOK allocated to preperation of the paper to OMAE2017

As of **31 December** 2016 the full budget has been utilized.

60 000 NOK in base funding from SINTEF has been approved and utilized for preperation of the OMAE2017 paper in January 2017. These funds are additional funding for the publication from SINTEF.

As of **07.09.2017** ~625k remains of SINTEFs allocated funds for the year which will be utilized in the autumn for research and publication. UiT will utilize their funds, but invoice SINTEF in November. There has been limited research in the spring as OMAE prepreations and MSc guidance was prioritized. OMAEs abstract deadline is in the autumn and research usually follows for sceintific produciton.

As of **21.11.2017**: ~310k remain of SINTEFs allocated funds for the year which will be utilized before christmas for model development and publication of project results related to scenario simulation of marine operations in areas with waves and partial ice cover (Snow crab fisheries as case operation).

As of **14.09.2018 ~**80k remain of SINTEFs allocated funds for the year. The funds will be utilized before christmas and allocated for publication of results, and finalizing numerical models within the scope of the project.

Could results from the project be subject for any commercial utilization

No