SOME PROJECT/MASTER TASK SUGGESTIONS IN MARINE CIVIL ENGINEERING (Marin byggteknikk/IBM) 2021/2022

Information in English. However, you may write your project report/master thesis in Norwegian if you prefer.

Prerequisites:

Student in the last year of study for a Master degree in a relevant field of Civil Engineering.

The student has acquired a minimum of 90 credits at Master level on the time of starting on the master thesis.

Passed exam in TBA4265 Arctic and Marine Civil Engineering and passed minimum <u>one</u> of the following NTNU courses or similar:

TBA4145 Port and Coastal Facilities

TBA4260 Ice Actions on Arctic Structures

TBA4270 Coastal Engineering

TBA4275 Dynamic Response to Irregular Loadings

Other prerequisites are given at each task description.

If you find some topics of interest or have your own ideas in some of these areas, contact the person at NTNU listed.

- **Port Infrastructure and Coastal Engineering:**
  Raed Lubbad (raed.lubbad@ntnu.no);
  Hans Bihs (hans.bihs@ntnu.no);
  Arun Kamath (arun.kamath@ntnu.no)
  Jomar Tørset (jomar.torset@ntnu.no)

- **Arctic Marine and Cold Climate Engineering:**
  Knut V. Høyland (knut.hoyland@ntnu.no);
  Raed Lubbad (raed.lubbad@ntnu.no);
  Wenjun Lu (wenjun.lu@ntnu.no)

- **Offshore Wind Turbines:**
  Michael Muskulus (michael.muskulus@ntnu.no)
  Jomar Tørset (jomar.torset@ntnu.no)

For practical issues, contact: Knut V. Høyland (knut.hoyland@ntnu.no)

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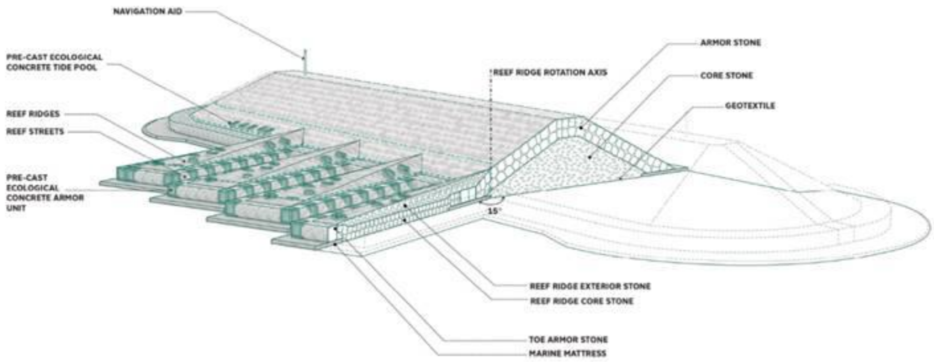
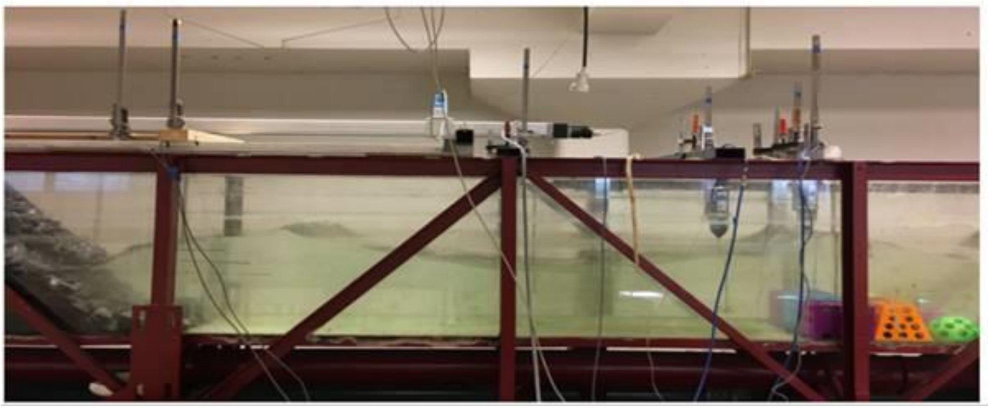
1 Port Infrastructure and Coastal Engineering

1.2 Living Breakwaters



Climate change can pose threat to cities, existing infrastructures and coastlines. The threat is often manifested in terms of sea-level rise, increased intensity and frequency of storms and extreme events which can lead to coastal erosion, flooding, etc. To manage this, proper climate change mitigation and adaptation measures must be implemented. In this context, the emerging concept of "Living Breakwaters" appears as a promising adaptation measure. Here, Artificial Reefs (ARs) are used to improve the efficiency of existing breakwaters, to increase the stability of these structures and in the same time to enhance/restore the ecological conditions in the area. The turbulence created by the ARs contributes to the attenuation of waves and it can create suitable living conditions for different spices. In this study, the hydraulic performance of different configurations of ARs and their effects on the stability of a chosen breakwater and on the and the ecological conditions will be investigated experimentally. During the pre-project, the student will familiarise himself/herself with the research problem by conducting a thorough literature review and running pilot tests in the laboratory. The main experiments will be conducted during the work for the master thesis at the Harbour and Coastal Laboratories at NTNU with a wave flume of the following dimensions: 20m x 0.6m x 0.85m (length x width x height). The detailed geometry of the ARs will be modelled using 3D printing technology.

Recommended subject: TBA4265 Arctic and Marine Civil Engineering; TBA4145 Port and Coastal Facilities
Key words: Breakwaters, Climate change
Type of project: experimental work
Number of students: 1 to 2
Contact person at NTNU: Raed Lubbad
Continuation of project: Can be extended into a Master Thesis



1.3 Generation and propagation of extreme waves due to landslide events

Several regions in Norway such as around Åkneset in Møre and Romsdal, Stampa in Sogn and Fjordane susceptible to landslide events due to unstable mountain slopes along the fjords. Landslide events of large magnitude with impulsive impact of debris into the fjords can lead to the generation of extreme waves. The generation and propagation of these extreme waves has to be studied in detail to better understand the risk to the built-up areas around the fjords and reduce loss of life and property. Numerical modelling using Computational Fluid Dynamics (CFD) can provide a large amount of detail regarding the hydrodynamics involved in the process and several scenarios can be studied through a thorough parametric analysis.

The objective of this Masters thesis is to model the generation of extreme waves due to impact of a falling object into a water body and study the wave propagation characteristics. The effect of the volume and density of the falling body on the wave generation, wave kinematics of the extreme wave and the run-up on the coast will be studied. The study will be carried out using the open-source CFD model REEF3D. The six degrees-of-freedom (6DOF) algorithm in REEF3D will be used to model the falling object. The difference between a sub-aerial landslide and a submerged landslide and the characteristics of the consequent extreme waves generated will be studied.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites:TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

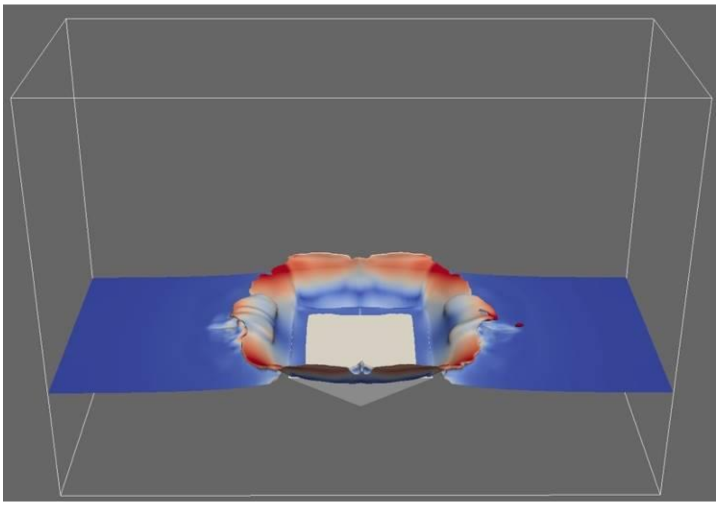


Figure 1.3: Impact of a freely falling wedge on water simulated using the 6DOF algorithm in REEF3D

1.4 Hydrodynamics of a floating bridge pontoon

The E39 project envisioned by the Norwegian Public Roads Administration involves replacing the ferry crossing along the highway with floating bridges and tunnels. The floating bridges and tunnels will be supported by moored floating pontoons. The wave and current interaction with such floating pontoons is to be studied in detail to obtain a better insight into the safety and stability of the floating bridges and tunnels. Conventional wave modelling techniques with potential flow and Boussinesq wave modelling can provide an overview on the wave and current propagation characteristics on a large scale. Whereas the near-field interaction with the floating pontoon has to be studied with a focus on detailed hydrodynamics around the structure. This includes diffraction around the pontoon, the mooring forces and the motion of the pontoon.

The objective of this Masters thesis is to simulate the wave and current interaction with a floating pontoon using the open-source Computational Fluid Dynamics (CFD) model REEF3D which provides detailed information of the flow features around the pontoon. The interaction of the pontoon with waves of different heights and wavelengths and currents will be studied. The mooring forces on the the pontoon and the motion of the pontoon under the action of waves and currents will be calculated. The six degrees-of-freedom (6DOF) equations implemented in REEF3D will be used to model the motion of the pontoon and calculate the forces and moments.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites:TBA4265 Arctic and Marine Civil Engineering..
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

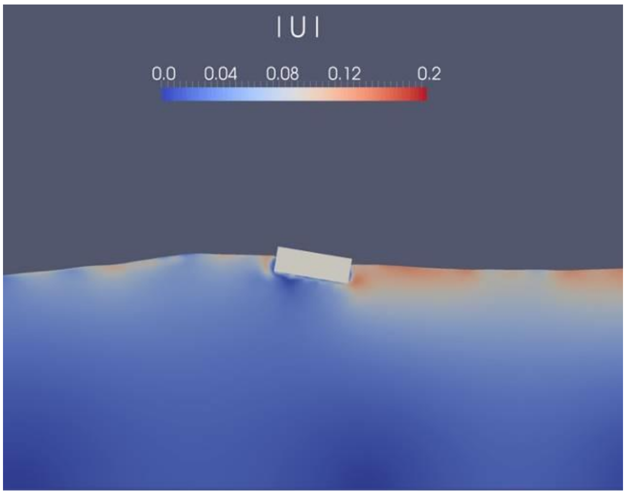


Figure 1.4: Roll motion of a rectangular barge under wave action modelled using 6DOF algorithm in REEF3D

1.5 Modelling of wave interaction with a breakwater using REEF3D

Breakwaters are the most common coastal constructions used to control wave action in a near-coastal region and protect the coastline form erosion or provide harbour tranquillity. The rubble mound breakwater is a type of commonly used breakwaters. Here, the breakwater is made of several layers and the porosity of the layers reduces towards the core of the structure. In order to model such structures, the numerical modelling of porous objects should be studied in detail, including the pore pressure and the velocity of the water through the porous layer. A computational fluid dynamics (CFD) model can calculate the wave hydrodynamics accurately and further research is required to include the hydrodynamics of a porous breakwater.

The objective of this Master's thesis is to model wave interaction with a breakwater including the porosity of the layers using the open-source CFD model REEF3D. Different approaches for the inclusion of the porosity will be explored. The results for the pressure, the free surface and velocities will be compared to experimental data. Simulations in three-dimensions will be carried out to study wave interaction including diffraction around the breakwater, erosion at the toe due to the action of waves and breakwater toe stability.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites:TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

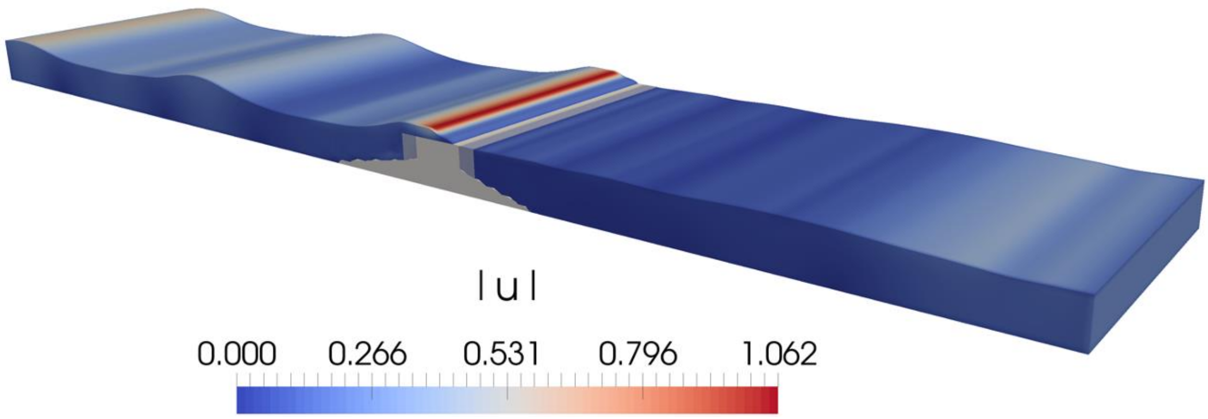


Figure 1.5 Wave interaction with a breakwater modelled with a porous layer around the crest.

1.6 Application of REEF3D to the study of wave overtopping

Wave overtopping is an important physical process on coastal structures such as sea walls and breakwaters. Excess overtopping volumes over coastal structures leads to flooding of the area behind the structure leading to loss of property or maintenance and operational problems. In current practice, overtopping is calculated using empirical formulae and further research can provide deeper insight into the overtopping process and the contribute to the design process.

The objective of this Master's thesis is to model wave overtopping using the open-source CFD model REEF3D. The water free surface undergoes complex deformations including wave breaking as it approaches the overtopping structure and further parts of the water volume propagate over the structure. The numerical model will be used to evaluate the free surface deformations on approach, over the structure and the overtopping water volume. The numerical results will be compared to experimental data. The effect of different slopes and crest heights of the overtopping structure on the free surface, the overtopping distance and the overtopping volume will be investigated in the thesis work.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites:TBA4265 Arctic and Marine Civil Engineering..
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

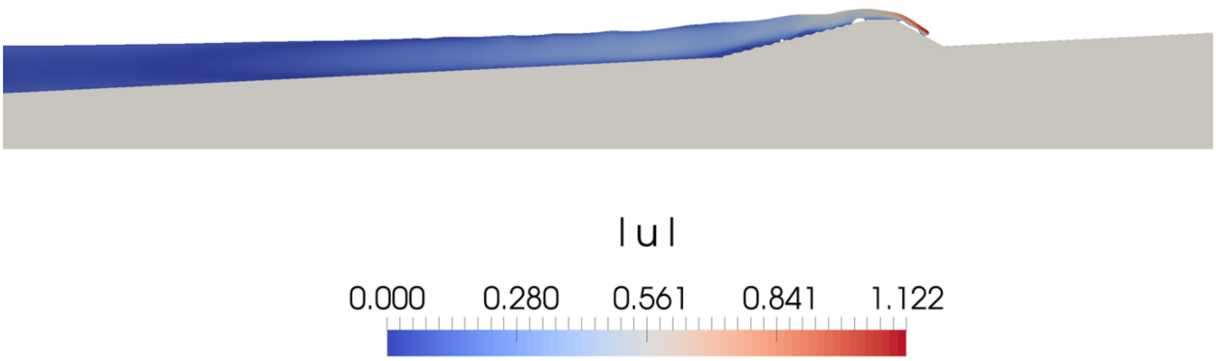
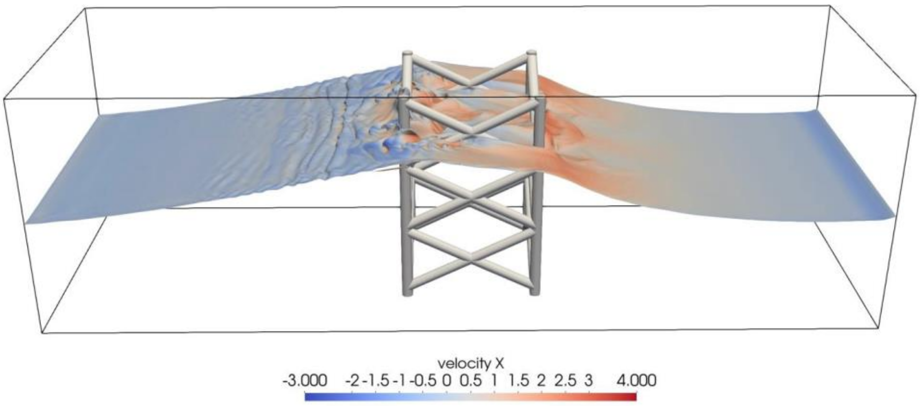


Figure 1.6 Solitary wave overtopping modelled using REEF3D

1.7 Numerical study of the irregular wave forces on a truss structure

Substructures of the offshore wind turbines are exposed to the irregular sea states. Interaction of the waves with the offshore structures is a vital factor in the safety and design of the offshore structures. The substructure can be a monopile or a truss structure. The waves undergo transformations due to non-linear, wave-wave interactions and due to interaction with the structures they are incident on. The wave forces on structures placed in such a wave field are influenced by the stochastic nature of the incident waves.



The objective of this study is to investigate irregular wave interaction with a truss structure. Numerical simulations will be carried out using the open-source CFD model REEF3D (www.reef3d.com), to simulate the irregular waves with the different peak periods and the different significant wave heights and their interaction with a truss structure. The numerical model will be validated by comparing the numerical results with the experimental results. The wave forces and the free surface features during wave-structure interaction for every member of the truss will be analysed in detail.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

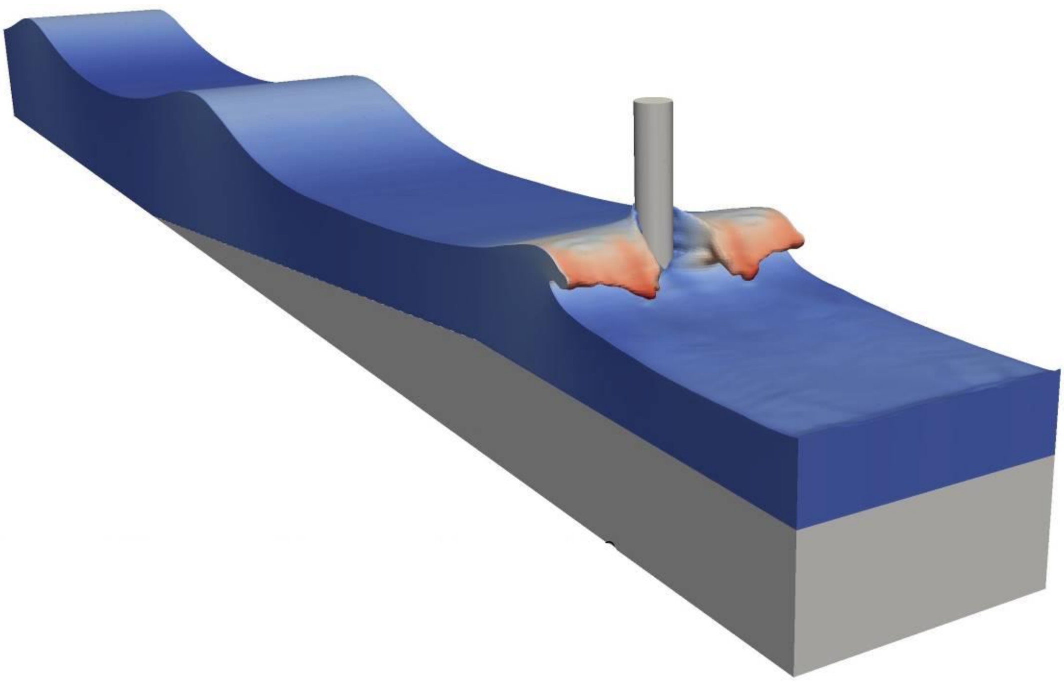
1.8 Breaking Wave Forces on Offshore Wind Substructures

Breaking wave forces a highly non-linear and very difficult to estimate with simplified approaches. For offshore wind substructures, such as monopoles, tripods or truss structures, the breaking wave impact forces are design critical. With computational fluid dynamics (CFD), the wave hydrodynamics can be resolved with a large degree of accuracy and detail. Also, the extremely complex wave breaking process can be simulated in a very realistic manner.

In the current project, the in-house open-source CFD code REEF3D (www.reef3d.com) will be used to calculate breaking wave forces on different types of offshore wind structures. The model calculates the flow for water and air and has advanced methods for capturing the interface between the two phases. The model is fully parallelized and runs on NTNU's supercomputer facilities. In this project, the breaking wave kinematics and the hydrodynamic loads will be analysed for different wave, structure and sea bed properties.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no



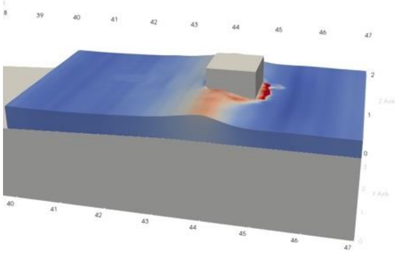
1.9 Investigating deployment of elevated coastal structures for coastal resilience through coupled numerical simulations

Due to climate change, associated sea level rise and increased frequency of extreme events along the coasts, resilience strategies to protect infrastructure and design future infrastructure need to be identified and developed. One of the strategies to address these problems is through accommodation. Here, the expected increased sea levels and waves due to extreme events are considered in the design and improvement of infrastructure.

Increasing the elevation of coastal structures is a possible solution to mitigate the possible damage due to extreme events and increased sea levels. In this context, the accurate representation of the incident extreme waves and the hydrodynamic loading due to the nonlinear extreme waves becomes highly essential. Several analytical expressions exist for the calculation of such forces, they restricted to bridge piles and simpler constructions. Extreme nonlinear events are also not well represented through these approaches. Thorough model testing of every scenario and structure is constrained by time and costs involved.

A suitable alternative is numerical modelling of such events and the evaluation of the extreme hydrodynamic forces. Modelling using the Navier-Stokes equations provides a large amount of information about the flow field and loading but is restricted by the computational time and expense. The fully nonlinear potential flow approach provides rapid evaluation of nonlinear waves but cannot resolve the flow field in the vicinity of the structure with the required resolution. Therefore, a coupled approach, utilising the advantages of both numerical approaches is seen to be a feasible approach with high utility.

In this project, the REEF3D::FNPF (fully nonlinear potential flow model) is used to evaluate the nonlinear waves propagating towards the structure and the REEF3D::CFD (Navier-Stokes) solver is used in the vicinity of the structure to evaluate the detailed fluid mechanics. The results will shed more light on the complex wave-structure interaction in the coastal region and on the capabilities of coupled numerical approaches to deal with such problems.



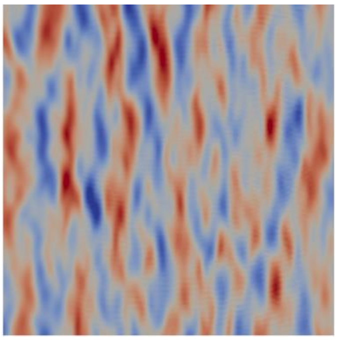
Task type: Literature survey, numerical modelling, calculation.

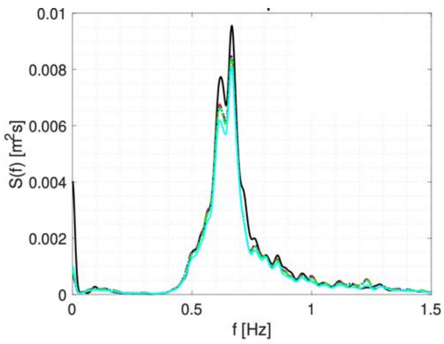
Prerequisites: TBA4265 Arctic and Marine Civil Engineering, TBA 4270 Coastal Engineering
Number of students: 1
Contact person at NTNU: Arun Kamath arun.kamath@ntnu.no

1.10 Large-scale wave modelling for event identification and force estimation for offshore wind farms

Rapid development of offshore wind farms will play a crucial role in addressing the need for increasing the share of reliable, cost-effective renewable energy in the global energy supply. A large amount of experience, data and design guidelines on design and operation in the offshore marine environment exist but are drafted considering the needs and requirements of the traditional offshore industry. In the case of offshore wind farms, the requirements are different due to the changed risks and design requirements. Therefore, it is essential to gain more insight into the wave-structure interaction and hydrodynamic loading on the offshore wind substructures. In this regard, the analyses of the sea state, identification of extreme events and the quick estimation of the incident wave loading are of great importance in engineering design. An effective reduction in the time and cost of design calculations and more focused model testing can be carried out by obtaining an initial engineering estimate through nonlinear numerical modelling.

In this project, the Laplace equations-based fully nonlinear potential flow modelling model REEF3D::FNPF is used to analyse the sea state at a wind farm level, identify extreme wave events and determine the hydrodynamic loading. The Arbitrary Eulerian Lagrangian approach is used along with REEF3D::FNPF. This makes it possible to analyse the forces on a cylindrical structure that the wind turbine substructures are formed of without including the complex geometry of the structure in the numerical model. Such an approach reduces the computational effort and aids in the analysis of several sea states to generate the required sea state statistics and wave loading statistics that are essential for initial design at a reasonably low cost.





Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering, TBA 4270 Coastal Engineering
Number of students: 1
Contact person at NTNU: Arun Kamath arun.kamath@ntnu.no

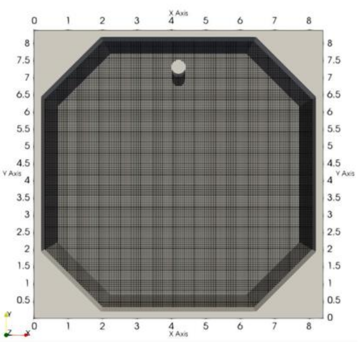
1.11 Investigating the flow environment for fish in closed aquaculture structures using RANS modelling

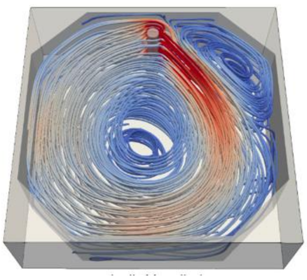
The aquaculture industry is one of the largest contributors to the Norwegian economy after the offshore activities. With the ambitious goals set by the industry for increased production and innovative concepts, the development of new knowledge is essential. A high utility is seen in the design stage for aquaculture structures to better identify the relationship between the hydrodynamic flow conditions and the interaction of the fish in such flows. This helps in monitoring the feeding, feed input, maintaining the required environmental conditions for fish welfare amongst others. The problem is especially interesting in the case of closed structures as this provides more control over the flow situation, while at the same time demanding large control input from the operators to maintain the necessary conditions in the tank.

In this project, the Navier-Stokes solver REEF3D::CFD is utilised to study the detailed interaction between the flow situation, such as currents with the hydrodynamics of a fish-shaped structure. This will help in connecting the two essential components in aquaculture: hydrodynamics and fish welfare. Different inflow velocities for water, outflow, settling and pollution and the effect on the hydrodynamic flow around fish are investigated.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering, TBA 4270 Coastal Engineering
Number of students: 1
Contact person at NTNU: Arun Kamath arun.kamath@ntnu.no





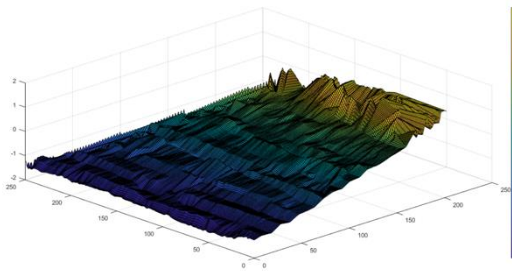
1.12 Coupled numerical modelling approach for large scale wave propagation and surf-zone wave transformation

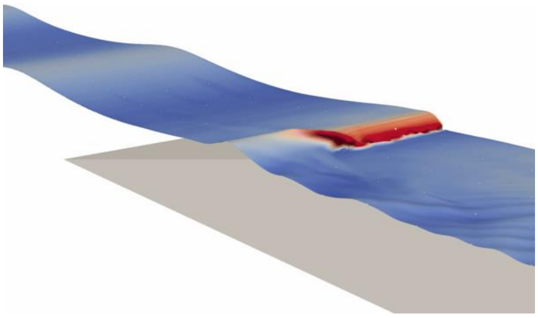
The near-shore wave hydrodynamics involve highly nonlinear waves and their transformation in response to the local topography. While large-scale phase-averaged wave modelling approaches cannot capture the detailed hydrodynamic flow field, the high-resolution phase-resolved modelling approach is seen to be extremely computationally demanding. Nevertheless, the use of phase-resolved models is essential to gain useful information about the wave transformation in the near-shore and surf zone.

To address this problem, a coupled approach using a nonlinear potential flow model, such as REEF3D::FNPF, and a high-resolution model such as REEF3D::CFD can be used. The FNPF model provides rapid solutions for the large-scale wave propagation, providing accurate detail regarding the propagation of waves from the deep-water region to the near-shore region. On the other hand, the detailed wave hydrodynamics in the near-shore region, such as wave breaking are not well-represented. The CFD model is then used in the last stretch of the coastal zone to evaluate wave breaking and wave run up.

This project will use data available from large-scale measurements using Lidar and model the incident waves towards the coast using REEF3D::FNPF. The region where is it critical to transfer the wave hydrodynamics from the FNPF model to the CFD model will be identified and the CFD model will be used to continue the simulation to propagate the waves to the shoreline. The numerical results will be validated through comparison with the field data available from the large-scale Lidar measurements.

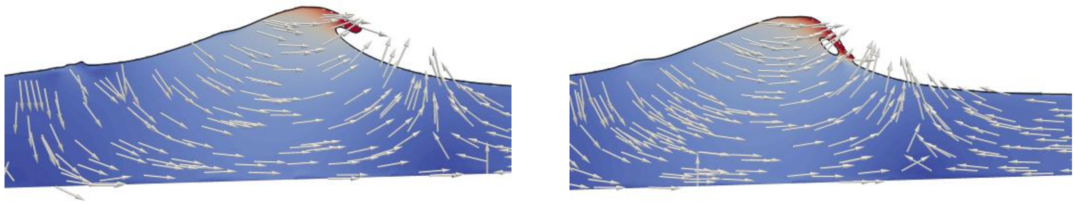
Prerequisites: TBA4265 Arctic and Marine Civil Engineering, TBA4270 Coastal Engineering
Number of students: 1
Contact person at NTNU: Arun Kamath arun.kamath@ntnu.no





1.13 Numerical investigation of shoaling and breaking characteristics of waves on beaches

The breaking process involves many complex parameters and breaking waves may occur at the site depending on the water depth, wave height, seabed slope, wave period and steepness. An exact numerical modeling of wave breaking process is still highly challenging due to the strong non-linear air-sea interaction at the free surface, air entrainment, and strong turbulent production by breaking is highly dissipative. Accurate assessment of wave shoaling and breaking wave characteristics is essential for an accurate prediction of wave forces on coastal structures.



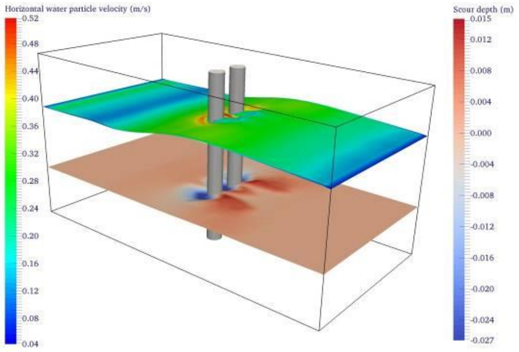
The main objective of the study is to investigate the shoaling and breaking characteristics of waves on plane beaches numerically. In the present study, the numerical experiments will be performed in a three-dimensional wave tank based on a two-phase flow CFD model REEF3D (www.reef3d.com), developed at the Department of Civil and Transport Engineering. The study investigates the features of the shoaling and the breaking process of waves over plane beaches in detail to gain more insight into the physical phenomenon. The outcomes of the project determine the key parameters of many field problems in nearshore coastal processes such as wave forces on coastal structures due to steep waves, non-breaking and breaking waves, surf-zone dynamics, sediment transport, run-up and scour around coastal structures etc.

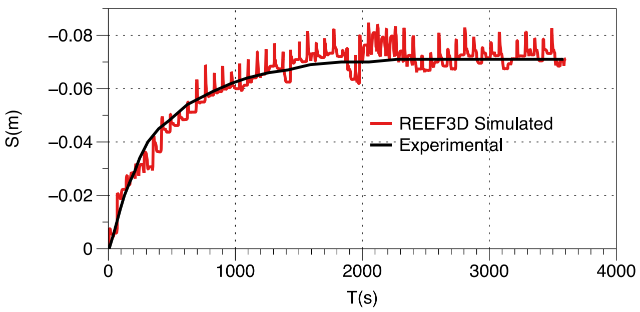
Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

1.14 3D Numerical modelling of local scour processes in coastal environment

Sediment transport plays an important role in many aspects of coastal and marine engineering such as local scour, beach erosion, scour below coastal pipelines and harbor accretion. Sediments are transported by waves or currents or sometimes through a combined action of both. An accurate prediction of sediment transport rates becomes an important element for the safety of hydraulic structures in coastal environments.





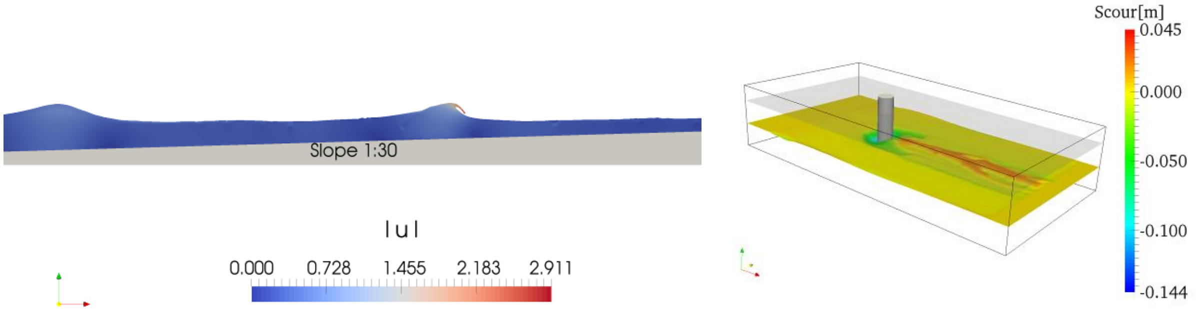
The main objective of the study is to investigate the local scour process in coastal environment using the open-source CFD model REEF3D. The task will focus on detailed analysis of the waves and current flow hydrodynamics, the resulting scour/deposition and the subsequent changes in the bed elevation using different sediment transport formulations available in the code. The numerical results will be compared with experimental data. The results shall be discussed in forms of time evolution of scour processes, the free surface profile and maximum scour/deposition contours.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

1.15 3D Numerical modelling of cohesive sediment transport under wave and current action

Generally, cliffed-shorelines and foundations of coastal structures are composed of cohesive soils which consist of very fine grained silt and clay particles in a well bounded form. Continuous exposure of the cohesive sediment bed to waves or current causes horizontal and vertical erosion that can be a serious concern for the stability of structures on horizontal and sloping beds respectively. Further, suspended load due to higher fine particle concentration can also lead to other problems such high turbidity, live bed scour and beach accretion. The numerical modeling of cohesive sediment transport process is a challenging task, since unlike non-cohesive soils, there is a lack of practical measurements, numerical models and accepted guidelines on scour processes.



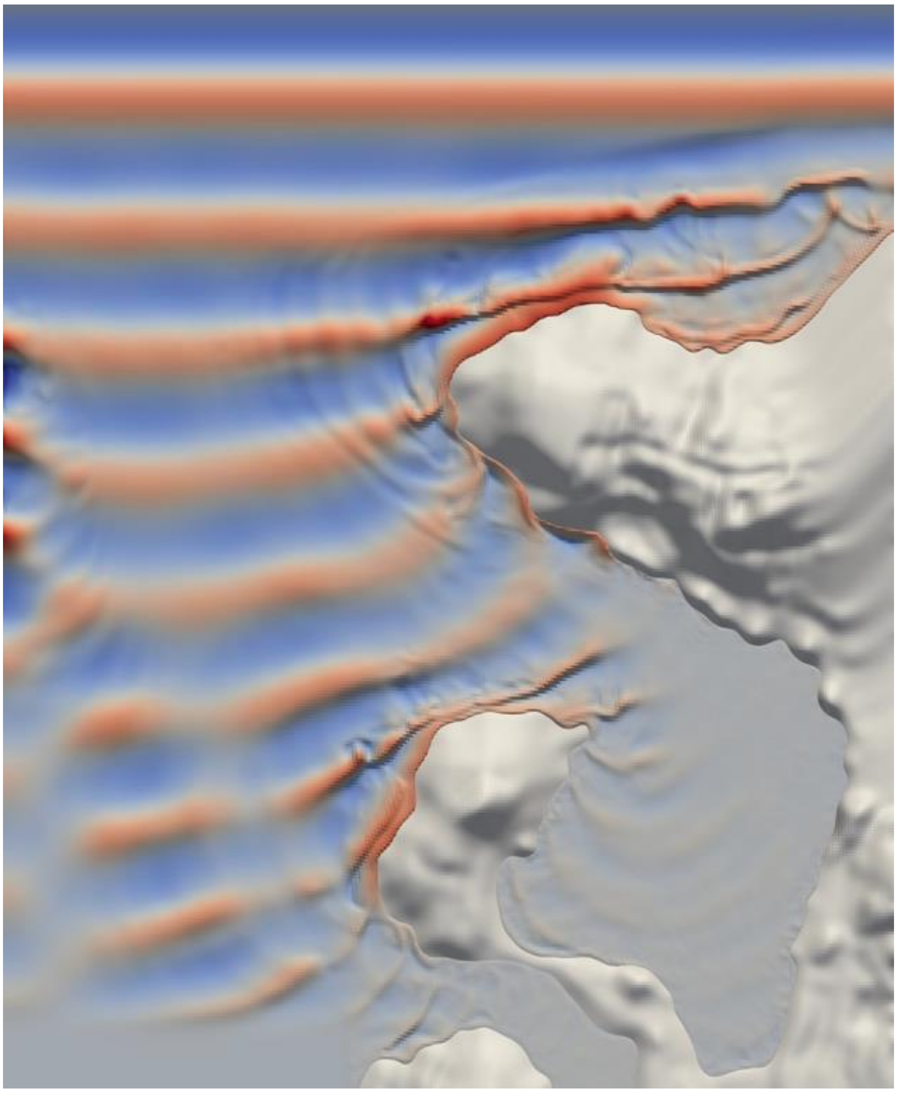
The study shall investigate cohesive sediment transport under waves and currents. The open-source CFD model REEF3D (www.reef3d.com) will be used. Emphasis shall be placed on analysis of hydrodynamics, resulting scour/deposition and subsequent change in bed elevation using different sediment formulations available in the code. The numerical results shall be compared with experimental observations. The expected results are an improved understanding of spatial and temporal distribution of suspended load concentrations, time evolution of scour processes, changes to the free surface profile and maximum scour/deposition contours.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

1.16 Large Wave Modeling of Norwegian Harbors with REEF3D::SFLOW

For harbors, diffraction effects are very important, prohibiting the use of phase-averaged spectral wave models. For large scale wave phase-resolved wave modelling, Boussinesq models are often used. Their drawback is a severe lack of robustness for real-world applications. A new and more robust class of phase-resolved large scale wave models are models that solve the shallow water equations and take dispersion into account through solving for the non-hydrostatic pressure.



The study shall investigate waves and currents in the vicinity of the coast, especially outside and inside harbors. The open-source hydrodynamics model REEF3D (www.reef3d.com) will be used with the wave model module REEF3D::SFLOW. Emphasis shall be placed on analysis of wave propagation and resulting wave conditions for ships berthing in the harbor. The numerical results shall be compared with experimental and field observations.

Task type: Literature survey, numerical modelling, calculation.

Prerequisites: TBA4265 Arctic and Marine Civil Engineering.
Number of students: 1
Contact person at NTNU: Hans Bihs hans.bihs@ntnu.no

1.17 Structural behavior of big «floating solar panels».

The goal of the project is to get familiar with **big floating structures** and how they behave in ocean. What impact have wave, wind and current on the structure dependent of where the structure is placed? All design loads must be defined (as in Trondheimsfjorden) that includes selfweight, stability and dynamic for different alternatives (for example 3 alternatives).

Learning objectives:

- How sea loads on large floating structures are modelled and simulated
- Give structural understanding with respect of response (forces, deflections) and how a structure behaves in water.

Approach:

- Literature study
- Modelling and analysis of "floating solar panels"

Prerequisites:

- Interest in design of ocean/offshore structures
- Knowledge of wind, waves and sea loads including dynamics
- Basic programming skills (e.g. Python, MATLAB, Fortran, R)

The work can also be continued in a master thesis.

Contact person: Jomar Tørset (jomar.torset@ntnu.no)

2 Arctic Technology (ice mechanics and ice actions on marine structures/vessels)

When designing coastal and marine structures (including vessels) the actions from floating ice covers often gives the most important environmental actions. There are mostly three scenarios that can be critical: icebergs, ice ridges and level ice.

2.1 Ice-induced Fatigue damage on Offshore Wind turbines or other bottom-fixed structures

Equinor, Multiconsult, Kværner and other Norwegian companies are active in the development of Offshore wind production in the Baltic and in many cases drifting ice needs to be taken into account so that ice actions become important. A project thesis can work with numerical or experimental aspect of ice actions on structures for the exploitation of wind energy. Collaboration with European partners such as TU-Delft, Aalto, HSVA, TUHH is possible.
Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

2.2 Ice action on typical structures in Norwegian waters

Ice actions on typical Norwegian structures in harbors, fjords, rivers and lakes have some different challenges that typical Arctic Offshore structures where the driving forces are often unlimited. The current regulations are adopted from the international standard for Arctic Offshore structures and not well suited for Norwegian waters. The IMB groups for Marine Civil Engineering (MB and Hydraulic structures (VT) works together with The Norwegian Road administration (SVV) and consulting companies through field work and modelling to improve the regulations.

- Field work in fjord and/or river
- Numerical analysis and development of standards

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

2.3 Ice ridges and ice ridge actions

- Ice ridge action on offshore structures - ice ridges as extreme ice features
- Ice ridge consolidation and properties – analyze data from the MOSAiC campaign (https://mosaic-expedition.org/)
- Probabilistic analysis of ridge properties and ridge action

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

2.4 Ice drift and ice action on structure

The drifting ice causes load and dynamic response of structures and in the design process statistics of ice conditions at site must be estimated. This is usually done as a combination of satellite data, local data and ice drift models, and the correlation between the relevant parameters (wind velocity, ice velocity, ice thickness and ice concentration) must be estimated. Wind and ice drift velocity are coupled through equations and a project thesis could be to carry out simple modelling of how the ice drift velocity relates to wind velocity.

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

2.5 Climate change and sea ice.

The world's climate is changing and only minor changes in air temperature gives large changes in the sea ice cover. NTNU particiaptes in the MOSAiC campaign and the student could work with analysing data, or carrying out field or laboratory work to study this effect.

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

2.6 Development of laboratory or full-scale procedures and instrumentation.

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no.

- Instrumentation of ice growth tank and characterization of ice
- Study the reliability and accuracy of Borehole Jack

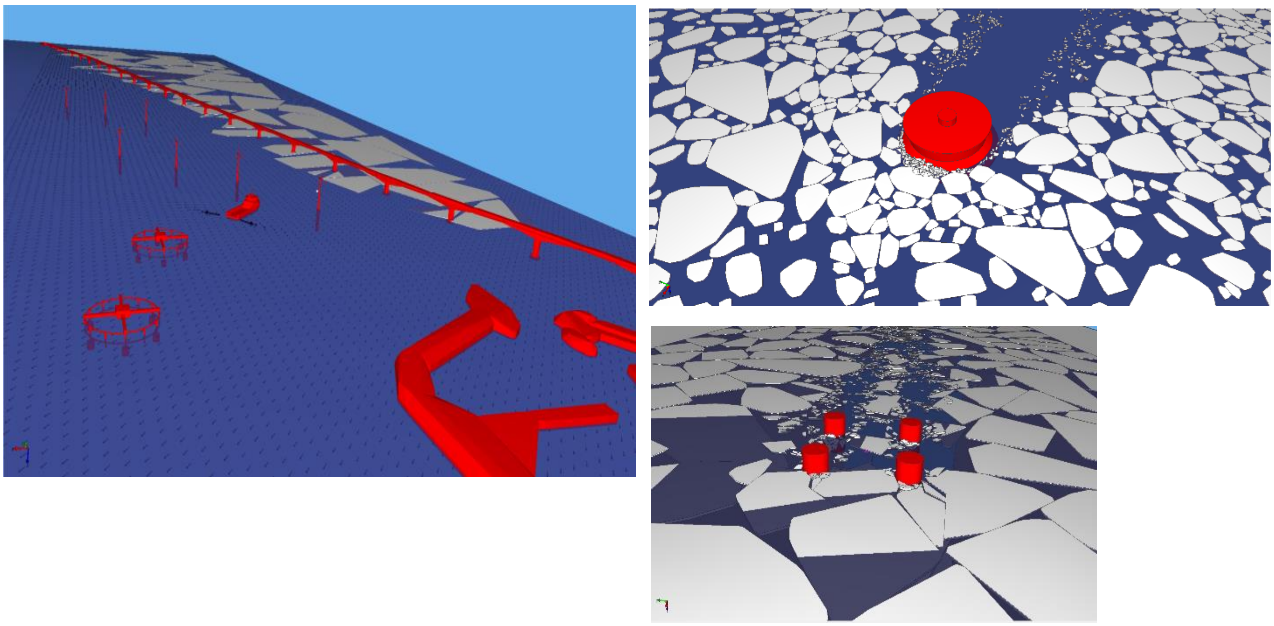
2.7 Ice thickness and level ice properties

Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no

- Level ice thickness in the Van Mijen fjord in Svalbard, analysis of existing data and / or perform new measurements on Svalbard / UNIS
- Level ice thickness for design of structures – practical guidelines

In most of these tasks it is possible to have a part-time stay at UNIS on Svalbard. Please get in touch with Sveinung Løset / Knut V. Høyland if you are interested in this.

2.8 Numerical Simulations of ice actions on fixed and floating structures



Numerical simulations of ice actions on coastal and offshore structures involve modelling a wide range of physical processes such as impacts, friction, buoyancy, hydrodynamics, fracture and fragmentation of ice. The Simulator for Arctic Marine Structures (SAMS) represents the state-of-the-art and it will used in this study. First, the design ice events must be determined. Thereafter, the numerical model should be configured, and numerical results generated. The numerical results should whenever possible be compared with available full-scale and model-scale data.

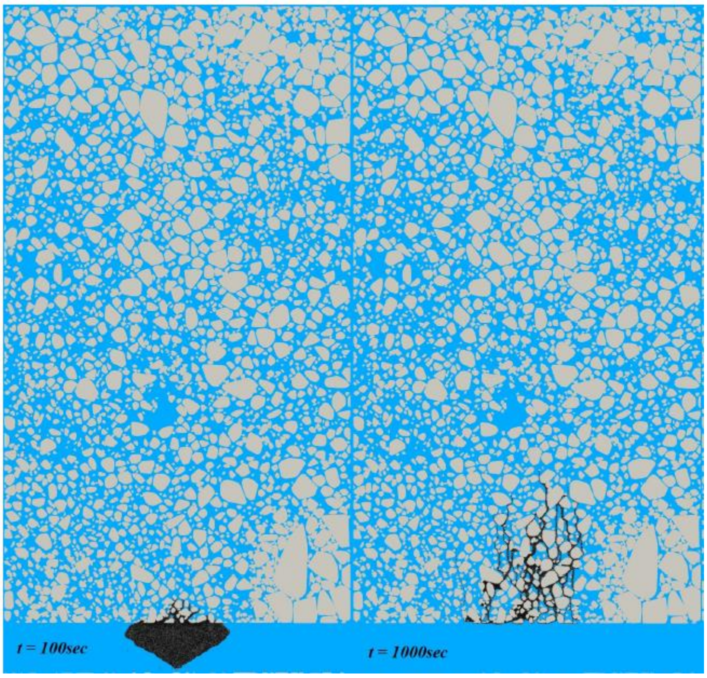
Recommended subject: TBA4265 Arctic and Marine Civil Engineering; TBA4260 - Ice Actions on Arctic Structures, AT327 Arctic Offshore Engineering
Key words: Coastal and offshore structures subjected to ice actions
Type of project: Numerical simulations and data analysis
Contact person at NTNU: Raed Lubbad
Continuation of project: Can be extended into a Master Thesis

2.9 Arctic coastal erosion

Arctic coastal erosion demands more attention as the global climate continues to change. Unlike those along low and mid latitude, sediments along Arctic coastlines are often frozen, even during summer. Thermal and mechanical factors must be considered together when analysing Arctic coastal erosion. Two major erosion mechanisms in the Arctic have been identified: thermodenundation and thermoabrasion. Field observations of Arctic coastal erosion are available at sites in Russia and in Svalbard. The objective of this study is to model the observed coastal erosion. Xbeach will be used in this study. One core advantage to use XBeach is the avalanching mechanism of the dunes at the end of the beaches. Although the avalanche mechanism is designed for the sand, with proper modifications it can be applied to the Arctic coasts to simulate slumping, sliding and bluff collapse.

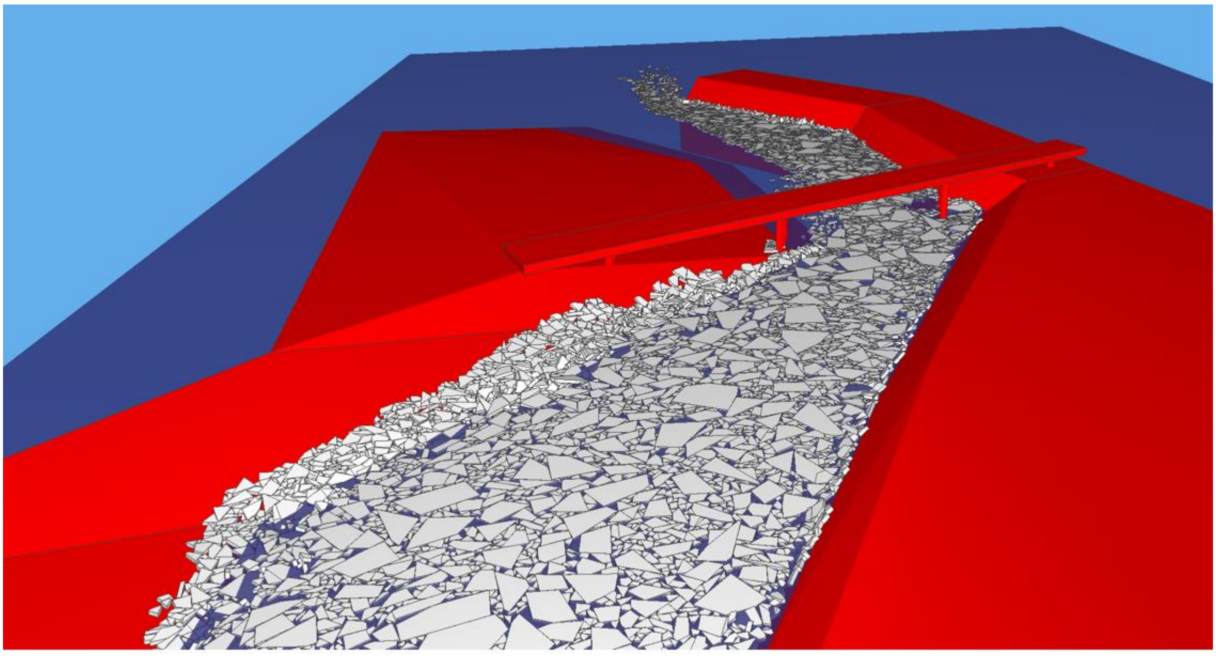
Recommended subject: TBA4265 Arctic and Marine Civil Engineering.
Key words: Arctic coast
Type of project: Numerical calculations
Contact person at NTNU: Raed Lubbad
Continuation of project: Can be extended into a Master Thesis

2.10 Modelling of oil spill in icy waters



Recommended subject: TBA4265 Arctic and Marine Civil Engineering.
Key words: Modelling of oil spill fate and transport in icy waters
Type of project: Numerical calculations
Contact person at NTNU: Raed Lubbad
Continuation of project: Can be extended into a Master Thesis

2.11 Modelling river-ice break-up, run-off, jamming and consequent flooding



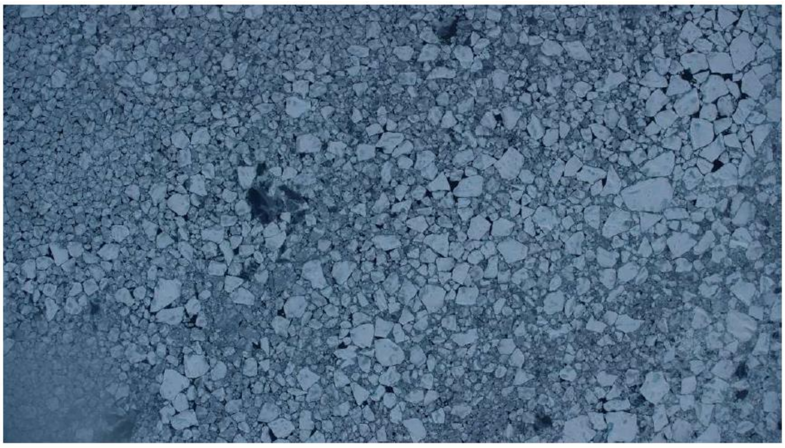
Recommended subject: TBA4265 Arctic and Marine Civil Engineering, TBA4260 - Ice Actions on Arctic Structures
Key words: Ice runs, jamming, flood
Type of project: Numerical calculations
Contact person at NTNU: Raed Lubbad
Continuation of project: Can be extended into a Master Thesis

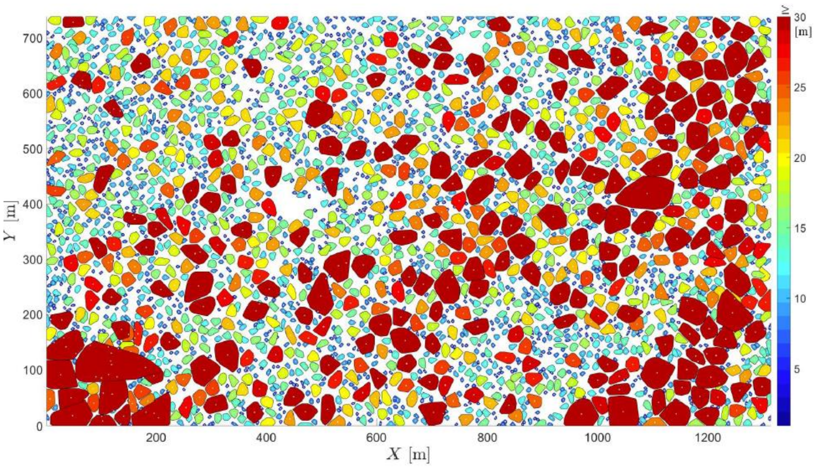
2.12 Characterizing the size and shape of sea ice floes

The size and shape of ice floes influence the overall ice drifting pattern as well as ice action on various structures in ice. Modern technology (e.g., satellite) enables us to survey/observe ice conditions at large scales and with great details. However, effort is still needed to extract and digitalize useful information for further studies.

The Norwegian University of Science and Technology (NTNU) participated the expedition, Oden Arctic Technology Research Cruise 2015 (OATRC'15) in the Arctic region in September, 2015. Among many scientific activities, a helicopter flight mission was accomplished when icebreaker Oden was transiting in the Marginal Ice Zone (MIZ). An optical camera mounted on a helicopter documents ice conditions at the MIZ; and many high-resolution images of sea ice were collected.

In this project, the student will have the opportunity to learn basic image processing technique and apply it to a relevant problem. The student shall digitalize the ice images through image processing. Thereafter, the size and floe shape information can be extracted from the digitalized information. The student shall gain great insight and contribute knowledge with regard to ice properties in the MIZ.





Learning objectives:

- basic applied image processing technique, which has a wide application nowadays
- floe size distribution and ice concentration in the MIZ, which is important for both engineering application and environment consideration (e.g., less concentrated and smaller ice floes)

Approach:

- Literature study
- Programming (mainly using existing toolboxes or functions)

Prerequisites:

- Basic programming skills (e.g. in MATLAB or Python)
- Basic knowledge in statistics

Key words: Digitalization, Ice floes, Image processing

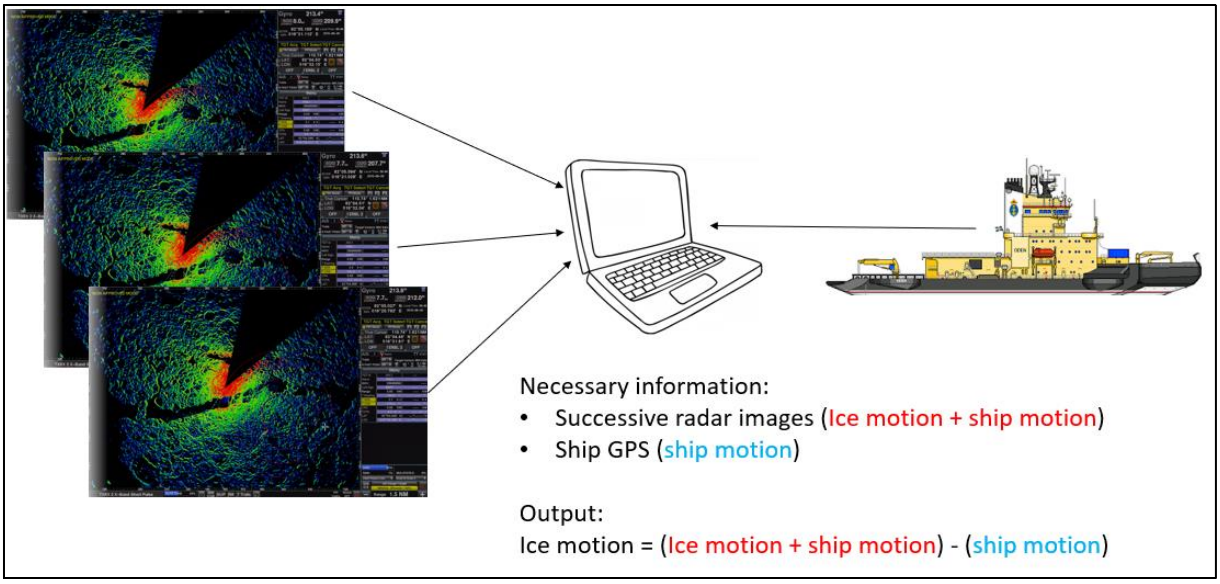
Contact person at NTNU: Wenjun Lu (wenjun.lu@ntnu.no)

Continuation of project: Can be extended into a Master Thesis. If successful, the MSc thesis work can be published in an international conference paper. The research group will pay all costs related to this, such as travel costs and conference fees.

2.13 Tracking regional ice drift using marine radar images

Successive marine radar images not only tell people imminent ice environment but also the kinematics of the drifting sea ice. Instead of having an experienced ice expert watching and making interpretation of ice images, this process can be automated.

In this project, the student shall utilize image processing technique (marine radar images are available) to give the best estimation of ice drift vectors. The logic behind this method is simple as illustrated in the following:



The challenge is that the image information is 'polluted' by the ship motion, which has to be filtered away to get the ice motion. Some data science technique can be adopted, e.g., Kalman filter.

Learning objectives:

- basic applied image processing technique, which has a wide application nowadays
- experience with the powerful method 'Kalman filter' to process noisy information. This method is widely used in everyday engineering, from our mobile phones to satellites.

Approach:

- Literature study
- Programming (mainly using existing toolboxes or functions)

Prerequisites:

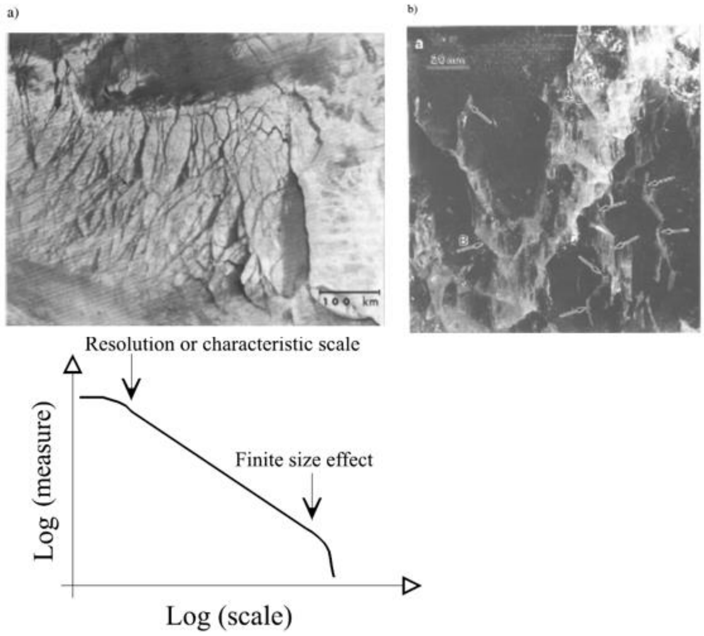
- Interested in solving old problems with emerging technique from other disciplines.
- Basic programming skills (e.g. in MATLAB or Python)

Key words: Digitalization, Image processing, Ice drift, Kalman filter

Contact person at NTNU: Wenjun Lu (wenjun.lu@ntnu.no)

Continuation of project: Can be extended into a Master Thesis. If successful, the MSc thesis work can be published in an international conference paper. The research group will pay all costs related to this, such as travel costs and conference fees.

2.14 Multifractality of sea ice fracture and fragmentation



Look at the fractures in the top left and top right figures. Can you tell which are from large and small scales? There is a theory of multifractality to link these different scales together. Look at the lower Log-Log plot. Any measures (e.g., ice floe sizes, the number of fractures) at different scales can be portraited as a straight line in this Log-Log plot. In this project, you will take the opportunity to experience this theory in the Arctic. You need to find information (e.g., ice floe sizes) from different scales (e.g., satellite images for a large scale and marine radar images for small scales). Image processing technique is needed to extract information from these two scales. Then you need to investigate if the information you extracted fulfils the multifractality theory.

Learning objectives:
- basic applied image processing technique, which has a wide application nowadays
- experience with the multifractality theory.

Approach:
- Literature study
- Programming (mainly using existing toolboxes or functions)

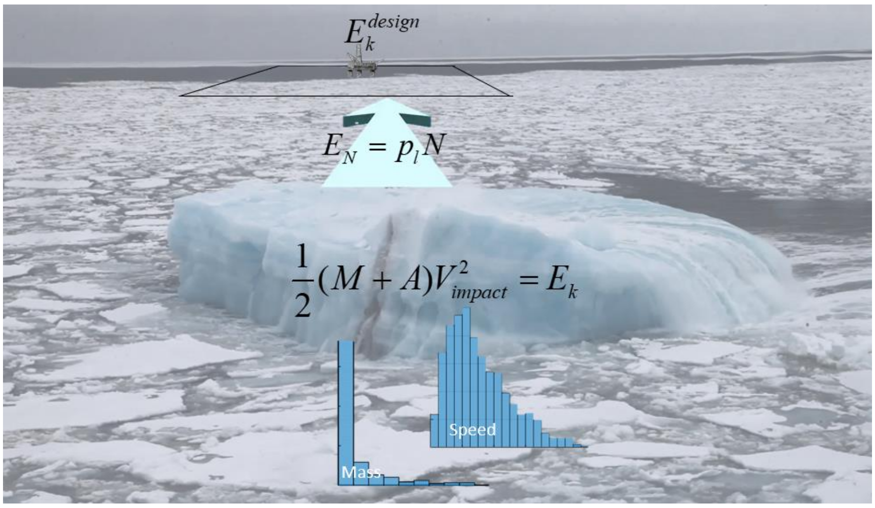
Prerequisites:
- Interested in attacking problems at different scales.
- Basic programming skills (e.g. in MATLAB or Python)

Key words: Digitalization, Image processing

Contact person at NTNU: Wenjun Lu (wenjun.lu@ntnu.no)

Continuation of project: Can be extended into a Master Thesis. If successful, the MSc thesis work can be published in an international conference paper. The research group will pay all costs related to this, such as travel costs and conference fees.

2.15 Design iceberg impact energy



Offshore development in the Barents Sea needs to consider possible iceberg impact. How to determine the design impact energy? Yes, you are familiar with the formula Energy = 0.5*Mass*(Velocity)^2. How are we going to input the mass and velocity values in the above formula from a statistic point of view?

There are several factors to consider:

1. Iceberg is rare
2. Icebergs have different sizes
3. Iceberg motions are different in different wave and current environment
4. The size and location of the structures.

Learning objectives:

- a complete walkthrough/exploration of the design process for iceberg impact energy
- experience with iceberg drift, wave and current forces.

Approach:

- Literature study
- Statistics and standard ISO19906
- Synthetic time series
- Programming

Prerequisites:

- Interested in a practical designing case.
- Basic programming skills (e.g. in MATLAB or Python)

Key words: Designing a structure, iceberg impact, iceberg drift

Contact person at NTNU: Wenjun Lu (wenjun.lu@ntnu.no)

Continuation of project: Can be extended into a Master Thesis. If successful, the MSc thesis work can be published in an international conference paper. The research group will pay all costs related to this, such as travel costs and conference fees.

2.16 Ice quality in skating facilities

Bakgrunn

Det er lite formalkunnskap om hva som skal til for å lage god is i en ishall. Lokal vannkvalitet, isleggerens erfaring og tilgjengelig utstyr for ispreparering varierer, og dette fører til at isens kvalitet både på kort sikt (time/dag) og sesong kan variere i større eller mindre grad. Dårlig iskvalitet gir svak overflate, fare for oppsprekking og dermed redusert prestasjon for utøvere. Ulike krav til kvalitet for ulike is-idretter kompliserer bildet ytterligere. Eksempelvis vil hockey ha en tynn, hard og kald is, mens kunstløp gjerne vil ha en tykkere og mykere flate for å få bedre sviktegenskaper.

Problemstilling

Det er behov for å utvikle kunnskap som viser sammenheng mellom vannkvalitet, ispreparering og funksjonelle egenskaper.

En hypotese er at vannkvalitet og -temperatur kan påvirke fryseprosessen, og dermed iskvalitet. Videre antas det at isens fasthet avhenger av temperaturgradient mellom underliggende kuldebærer og luften over isflaten.

Vannets innhold av luft under fryseprosessen kan gi innfrysing av gassbobler i isflaten, noe som kan påvirke isens fasthet.

En introduksjon til erfaringsbasert kunnskap finnes her: https://fliphtml5.com/bookcase/olnwc

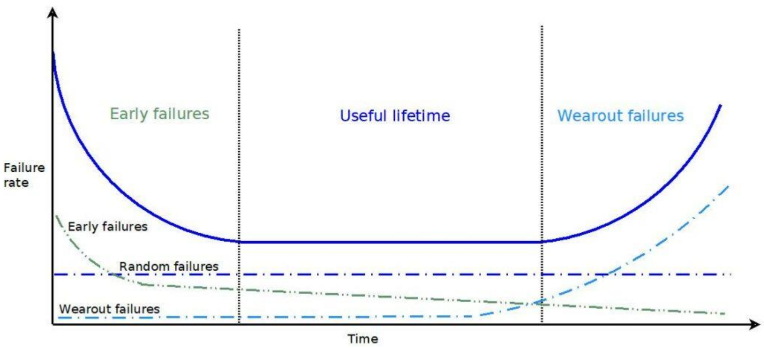
Contact person at NTNU: Knut V. Høyland, knut.hoyland@ntnu.no og

Bjørn Aas, bjorn.aas@ntnu.no Senter for Idrettsanlegg og Teknologi

3 Offshore Wind Turbines

3.1 Estimation of bathtub failure curve

The failure rates of wind turbine components typically follow the so-called bathtub curve: In the first few years of operation the failure rate is somewhat higher, then drops to a more or less constant level after, while rising again at the end of the design lifetime.



The objective of this project is to simulate failures randomly from an assumed bathtub failure curve and then try to estimate this curve as accurately as possible, e.g. using statistics or machine learning.

Learning objectives:
- How the failure of (wind turbine) mechanical components can be described and simulated
- How statistics can be used to estimate important information about wind turbine operation
- First hand experience with statistics and/or machine learning for big data applications

Approach:
- Literature study
- Programming a simple failure simulation
- Finding and applying a suitable statistical method / model to estimate the curve

Prerequisites:
- Interest in reliability and statistical modelling / machine learning
- Basic programming skills (e.g. in MATLAB or Python)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.2 Stress concentration factors for tubular joints of wind turbine support structure under time-varying loading

Offshore wind turbine support structures (e.g. monopile or jacket) are typically fatigue-driven. The fatigue damage is estimated from computer simulations with a multibody / finite-element software. The results of these simulations is data that contains the displacements and stress resultants at a number of different positions in the structure (e.g. in all joints of a jacket) at each point in time. These time series need to be post-processed to check if the design is safe according to current guidelines and standards (e.g. DNVGL and NORSOK).

Thereby, stress concentration factors (SFC) are used, in order to account for geometrical influences which are not covered within the computer simulations. Especially for tubular joints within jacket structures, these SFCs are highly dependent on the prevalent loading situation. Despite the fact, that these loading situations vary over time, it is common practice to utilize constant SCFs for a single load case.

The objective of this project is to investigate the influence of these fixed SCFs on the fatigue design of tubular joints in comparison to SCFs which change over time in equal measure as the present loading situation.

Learning objectives:
- How wind turbine structures are designed and analyzed
- How to perform the code checks that design codes and international standards require
- How important SCFs are for the structural design

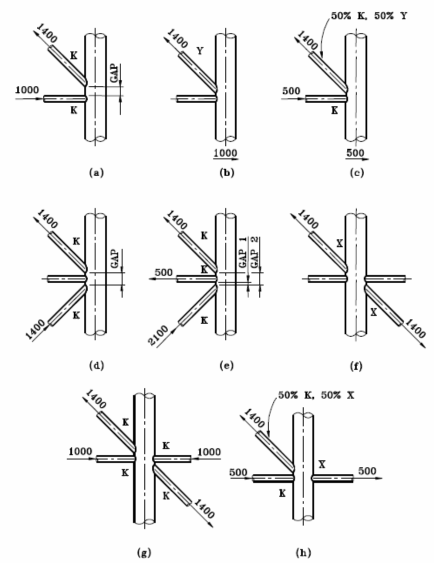


Figure B-1
Classification of simple joints

Approach:
- Literature study
- Wind turbine modelling and simulation with existing tools
- Programming the post-processing and analyzing the results

Prerequisites:
- Knowledge of structural design and analysis
- Basic programming skills (e.g. in MATLAB or Python)

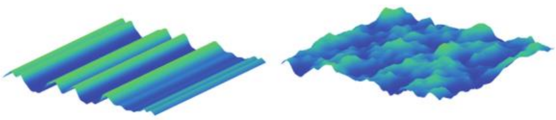
If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

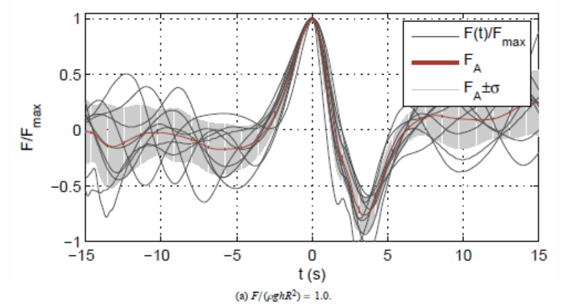
3.3 Constrained short-crested extreme waves

Offshore wind turbines have to withstand extreme loads safely, both from extreme winds and extreme waves. These extreme events are checked with simulations, but only one-dimensional (long-crested) waves are normally used for this.

Extreme linear waves are implemented by arranging the phases of the wave components such that large amplitudes can be obtained at a specific time in the simulations.



The aim of this project is to extend this so-called "NewWave" approach to more realistic two-dimensional (short-crested) waves.



Learning objectives:

- How extreme wave events are modelled in the offshore and wind energy industry
- How two-dimensional waves can be simulated
- How wave simulations can be constrained

Approach:

- Literature study
- Programming of a wave simulation
- Evaluating the wave loads

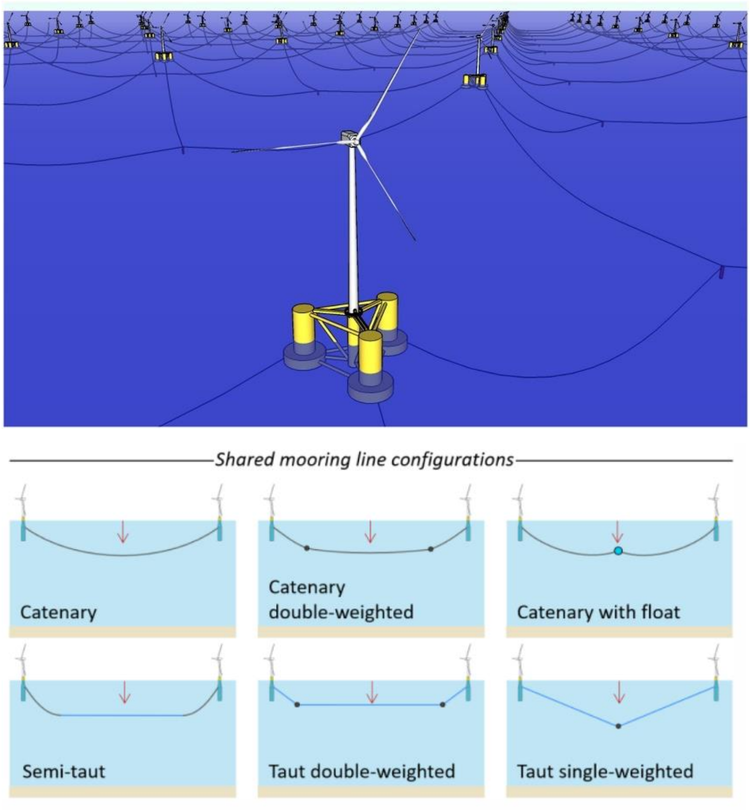
Prerequisites:

- Knowledge of linear wave theory
- Interest in offshore design against extreme events
- Basic programming skills (e.g. in MATLAB or Python)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.4 Shared moorings for floating wind turbines



Floating wind turbines (such as Hywind) are used in deep water (from about 60m water depth). These need to be moored (e.g. using anchors and chains) to keep them from drifting away under wind and wave actions.

Traditionally each wind turbine in a floating wind farm has its own mooring system, but since these are expensive, there is an interest in sharing the moorings between floaters and using less anchors.

The aim of this project is to develop a simple numerical model for the dynamics of such a shared mooring, based on coupled springs and masses, and to perform some simulations to assess the motions and vibrations of the turbines and mooring elements.

Learning objectives:
- How floating wind turbines are designed
- How mooring systems for floating wind turbines can be simulated
- How to assess the performance of a mooring system

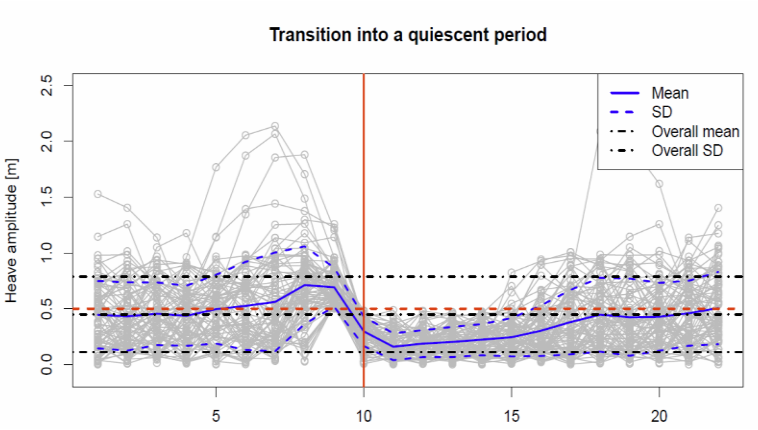
Approach:
- Literature study
- Programming of a simple mooring system simulation
- Case studies

Prerequisites:
- Interest in offshore wind energy
- Basic knowledge of mechanical systems and their vibrations
- Basic programming skills (e.g. in MATLAB or Python)

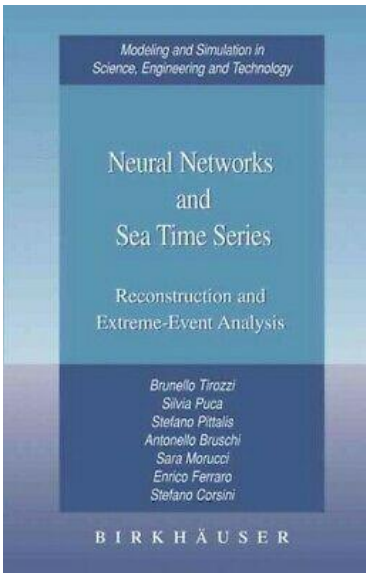
If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.5 Quiescent periods in linear waves



Although sea surface waves are irregular, it often happens that the surface is relatively quiet for a certain period of time (on the order of 5-10 waves).
If one could predict the beginning of such "quiescent periods" using past measurements of the waves, this would be very interesting for applications such as access to wind turbines or helicopter landing on ships.



Two new approaches have been suggested for this: Either the use of a neural network, or estimating the wave components and their phases (the so-called "Prony-type" method). The objective of this project is to test one of these approaches using simulations.

Learning objectives:
- How to describe and model irregular linear waves
- How to estimate the waves in a seastate from measurements
- Experience with neural networks and machine learning techniques

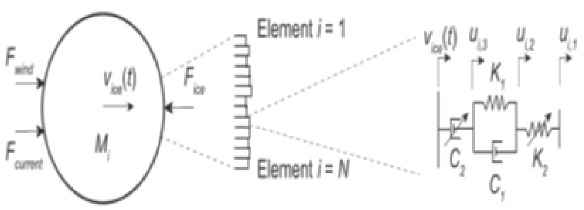
Approach:
- Literature study
- Programming an approach to predict future quiescent periods
- Case studies

Prerequisites:
- Interest in offshore engineering
- Basic knowledge of waves
- Basic programming skills (e.g. in MATLAB or Python)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.6 Detailed analysis of a simplified ice-structure interaction model



Ice loads are important for the design of offshore wind turbines in waters with potential sea ice risk. However, the interaction with the turbine is quite complex. Recently a stochastic ice-structure interaction model was developed that is capable of describing the most important features of this interaction, and which is also mathematically very interesting.

The aim of this project is to implement a simplified version of this model and to benchmark the differences with the original model.through computer simulations.

Learning objectives:
- How to assess ice-structure interaction using state-of-the-art models
- How to simulate / solve such a stochastic model numerically

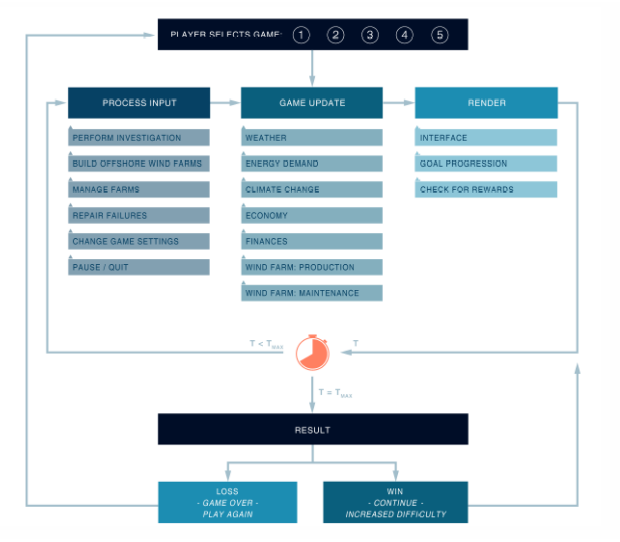
Approach:
- Literature study
- Implementing / simplifying the existing model
- Case studies

Prerequisites:
- Interest in arctic / wind engineering
- Some knowledge of numerical analysis (e.g. numerical solution of ordinary differential equations)
- Basic programming skills (e.g. in MATLAB or Python)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

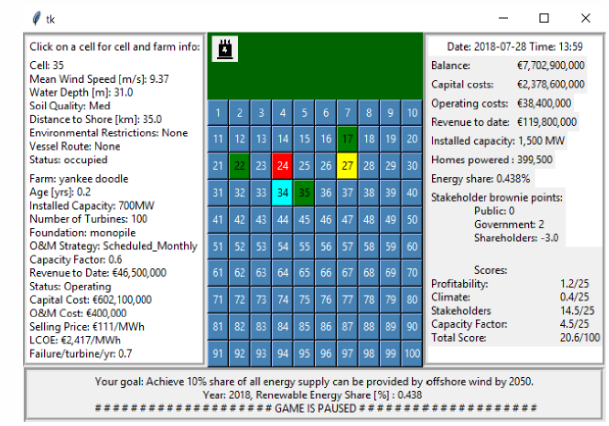
3.7 Improvement of simulations in Vindby, the serious wind farm computer game



During a recent master thesis a computer game was developed that lets the player build and develop wind farms. The game has been programmed in Python and is used as a teaching tool. A first version of the game can be found at: http://folk.ntnu.no/muskulus/vindby/

The aim of this project is to further improve the simulation behind Vindby, e.g., the models used for the environmental loads and project finance, and the gameplay.

Learning objectives:
- How wind farm development works
- How to improve an existing simulation game



Approach:
- Literature study
- Design of new features
- Programming and testing

Prerequisites:
- Interest in offshore wind energy
- Interest in computer simulations
- Programming skills in Python

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.8 Hydrodynamic loads on big floating structures

The goal of the project is to get familiar with the methods for calculation of hydrodynamic loads on big floating structures, based on the theory of diffraction implemented in the open source software Nemoh (https://lheea.ec-nantes.fr/research-impact/software-and-patents/nemoh-presentation), and to perform tests on relevant examples.

Nemoh is a Boundary Element Method (BEM) code developed over 30 years at Ecole Centrale de Nantes, and can calculate wave forces on offshore structures (added mass, radiation damping, and diffraction forces). Nemoh solves in the frequency-domain, so an important part of the assignment is to propose and test procedures for converting the results to time series for a given wave spectrum, in order to use them as load functions in a time-domain simulation of a floating structure.

Learning objectives:

- How sea loads on large floating structures are modelled and simulated
- How to convert between time- and frequency-domain in hydrodynamic modelling

Approach:

- Literature study, Installation and testing of Nemoh, Programming pre- and post-processing

Prerequisites:

- Interest in the dynamics of floating offshore structures
- Knowledge of waves and sea loads
- Basic programming skills (e.g. Python, MATLAB, Fortran, R)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.9 Standing and/or propagating waves in offshore mooring lines

Standing waves have been shown to occur in the mooring lines of floating offshore bodies, especially for small floater movements. And when a floating structure is undergoing large motions, this can cause waves that propagate along the mooring lines. However, research on such standing or propagating waves in mooring lines is scarce. The goal of this project is to find out under which circumstances these phenomena can occur in mooring lines, especially for floating wind turbines, and which impact such waves have on mooring system reliability.

Learning Objectives:

- Deep understanding of mooring line dynamics
- Insights into floating wind turbine design and dynamics
- Understanding of wind turbine fatigue and reliability calculations

Approach:

- Literature study, simulation of standing / propagating waves (using e.g. MoorDyn software), determination of necessary model resolution (timesteps, number of finite elements), uncertainty quantification and load simulations to assess impact of standing / propagating waves on overall mooring reliability

Prerequisites:

- Background in physics or (offshore) engineering
- Interest in computer simulations
- Basic programming skills (e.g. Python, MATLAB, Julia, Fortran, C++)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.10 Vortex induced vibrations (VIV) in mooring lines of floating wind turbines

Vortex induced vibration (VIV) is a dynamic phenomenon where a steady flow around a structure causes vortices which excite the structure through time-varying lift forces. VIV has been investigated for offshore oil and gas applications in a lot of detail. However, VIV in mooring lines of floating wind turbines is mostly unexplored. Under what conditions can VIV occur here, and how does it impact the dynamics and reliability of mooring lines?

Learning Objectives:

- Knowledge of the VIV phenomenon and how to analyze it (its theoretical basis and practical assessment)
- Insights into floating wind turbine design and dynamics
- Experience with floater simulation and load analysis

Approach:

- Literature Review, Numerical modeling and simulation of VIV, Analysis of results

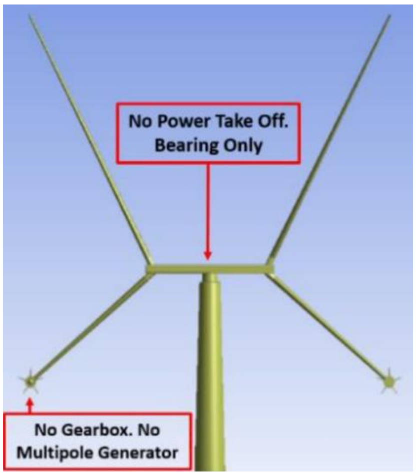
Prerequisites:

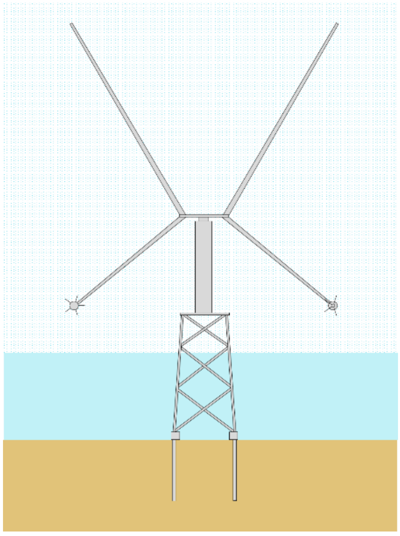
- Knowledge of basic hydrodynamics and/or offshore engineering
- Interest in computer simulations
- Basic programming skills (e.g. Python, MATLAB, Julia, Fortran, C++)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay all costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.11 Designing a novel hybrid wind turbine concept





The Xrotor is a new hybrid vertical-horizontal axis wind turbine that promises cheaper power production. A primary vertical axis rotor turns to rotate small secondary horizontal axis rotors fixed at the lower primary blades.

Our research group is performing the structural design and optimization of this concept, and we are looking for students to help with a number of different tasks.

For example, we have been designing a jacket for this concept, but there is still a lot of room for improvement and more detailed analyses. Also the structural design of the blades, the drivetrain, the aerodynamic loads, the soil model, the controller, or the dynamics of the turbine have to be checked – and can be improved.

Learning objectives:

- Understanding of wind turbine dynamics and design
- Practical experience with wind turbine load simulations
- Insights into what is needed to build an efficient wind turbine

Approach:

- Literature study
- Wind turbine modelling and simulation
- Improvement / analysis of a component

Prerequisites:

- Basic knowledge of structural dynamics
- Interest in learning about aerodynamics and wind turbine design
- Basic programming skills would be useful (e.g. in MATLAB or Python)

If successful, the project work can be published as a conference paper and presented at the DeepWind conference in Trondheim, or at an international conference. The research group will pay costs related to this, such as travel costs and conference fees. The work can also be continued in a master thesis.

Contact person: Michael Muskulus (michael.muskulus@ntnu.no)

3.15 Structural health monitoring of structures

Structures are designed according to established rules like Eurocode and NORSOK. These codes/rules have been developed gradually based on both theoretically and practical experiences. The basis for these rules are experiences with and testing of materials and environmental loads. These material and load data are not exact but based on statistics. To manage the uncertainty of these data, rules and regulations specify how to find and specify materials qualities and load intensity with belonging security factors. These rules are well established and the principals for how these rules work, and design practice connected to these rules has not change much for many decades.

"Structural health monitoring" (SHS) is used for additional control of complex loadbearing structures. There are several technologies that can be used which has different advantages and disadvantages. This these consider evaluating how take advantage of modern technics in evaluation and design of structures. In this case we look at the FEMM (Ferrx electromagnetic magnetic method) technology delivered by the company Ferrx (www.ferrx.no).

Several issues are made which fits to project and master theses to use this technology on marine and onshore structures.

Topics to look at:

1. How to use FEMM in lifetime estimate?
2. Guidelines for the best possible location of FEMM measuring points for construction monitoring of structures in the ocean space.
3. Investigate the significance of natural oscillations for the service life of structures
4. How does it affect that a large proportion of wind and wave forces have a short duration of construction life?

Relevant points for this master's thesis include:

• Literature study: Get acquainted with FEMM to form an idea of how the measurement technique can best be utilized.

• Element method model: Establishment of necessary FEM models

• Model validation: Compare with FEMM measurements

• Numerical survey: Investigate how different load models affect response

Instrumentation on Hell bridge

Contact person: Jomar Tørset (jomar.torset@ntnu.no)