Marin Byggteknikkdagen NTNU/PIANC , 29. april, 2019

Arctic Engineering

A/Prof. Raed Lubbad, NTNU

Sustainable Arctic Marine and Coastal Technology (SAMCoT)

12 Industry Partners
9 Research Partners
2 Public Partners

Research Strategy

SAMCoT

sfi Centre for Research-based Innovation

Mantra: Full-scale Data if possible

SAMCoT

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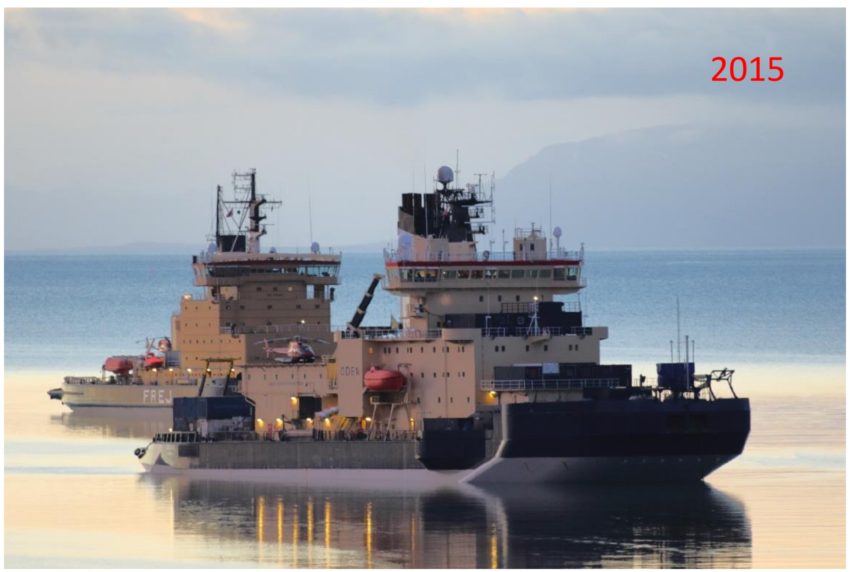
2012

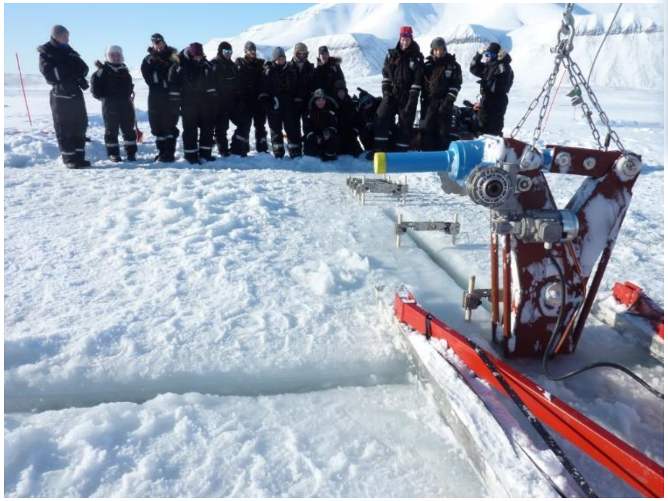
2013


2015


SKT 2017

Oden Arctic Technology Research Cruises: 2012, 2013 and 2015

Arctic Ocean 2016



SAMCoT

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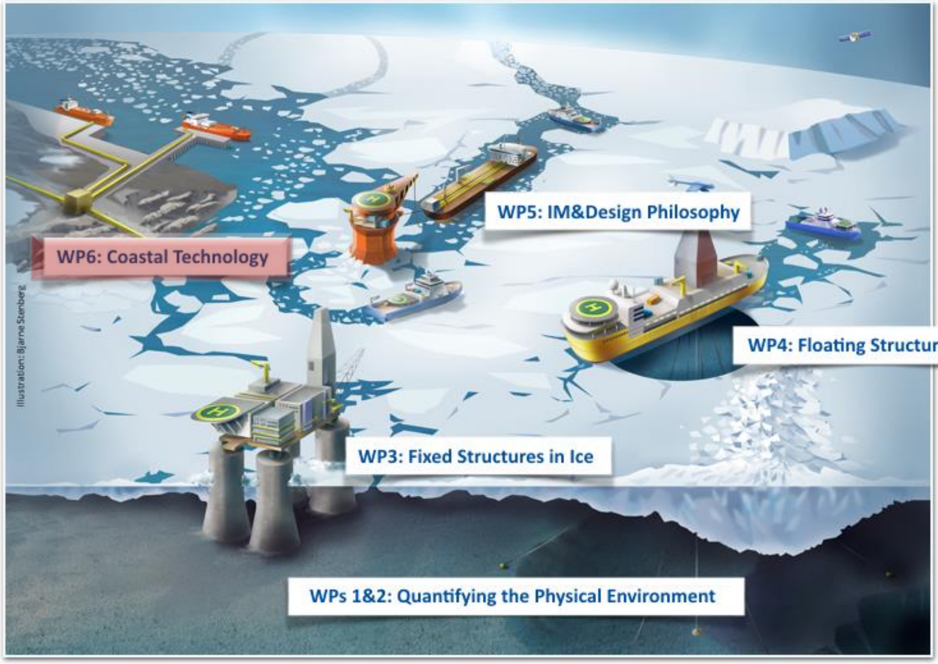
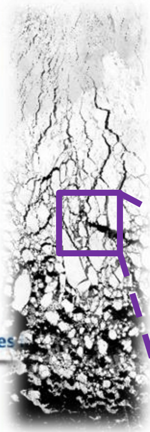
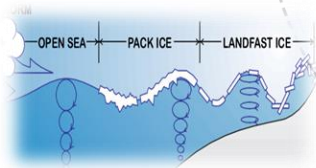
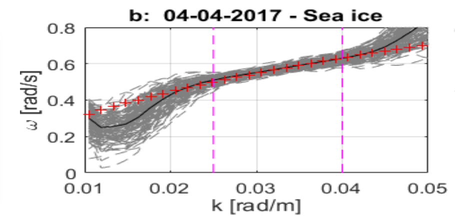
Overview

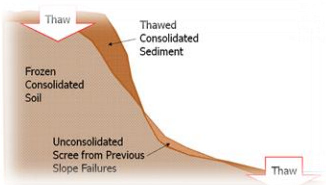
SAMCoT

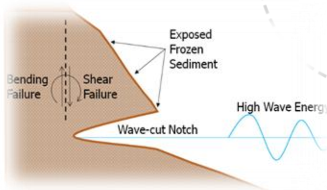


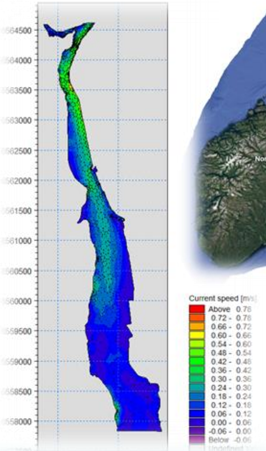


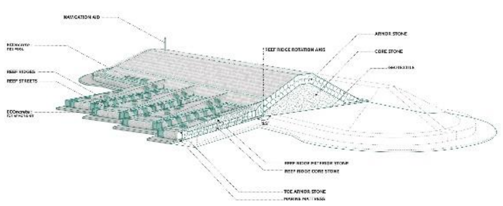


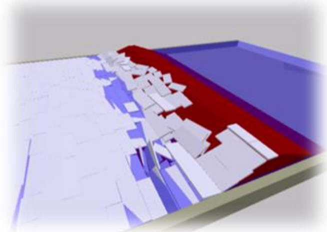


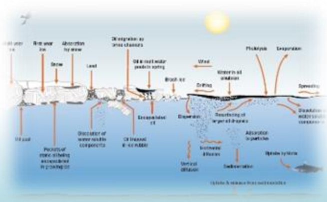












www.ntnu.edu/samcot

Overview

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Simulator for Arctic Marine Structures (SAMS)

Ice Features Driven by Waves

Glacial ice accelerated by waves may e.g. hit a vessel above the strengthened part of the hull.

Bow camera pointing forward (KV Svalbard; Fram Strait, March 2012)

Simulator for Arctic Marine Structures (SAMS)

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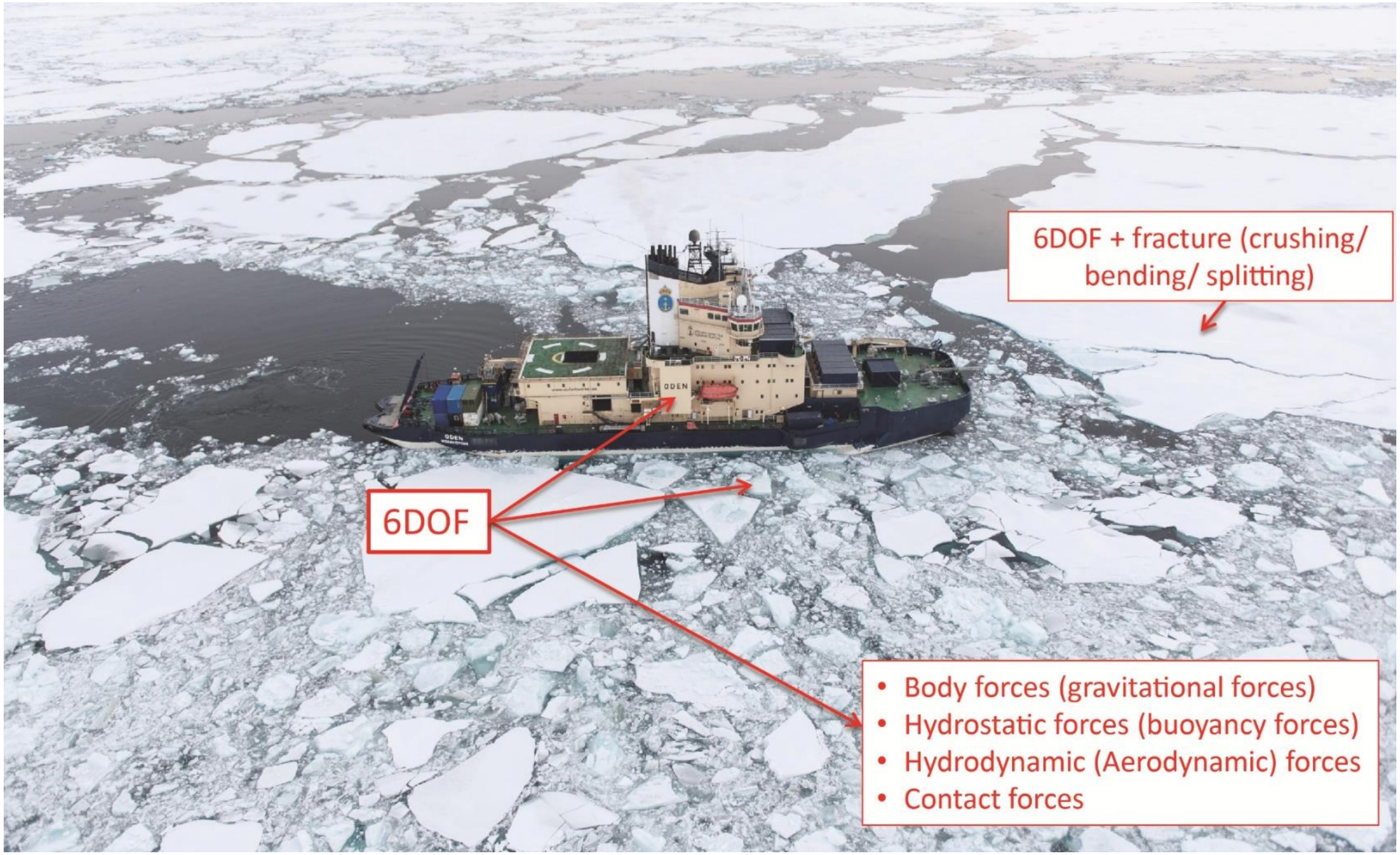
Theoretical Basis

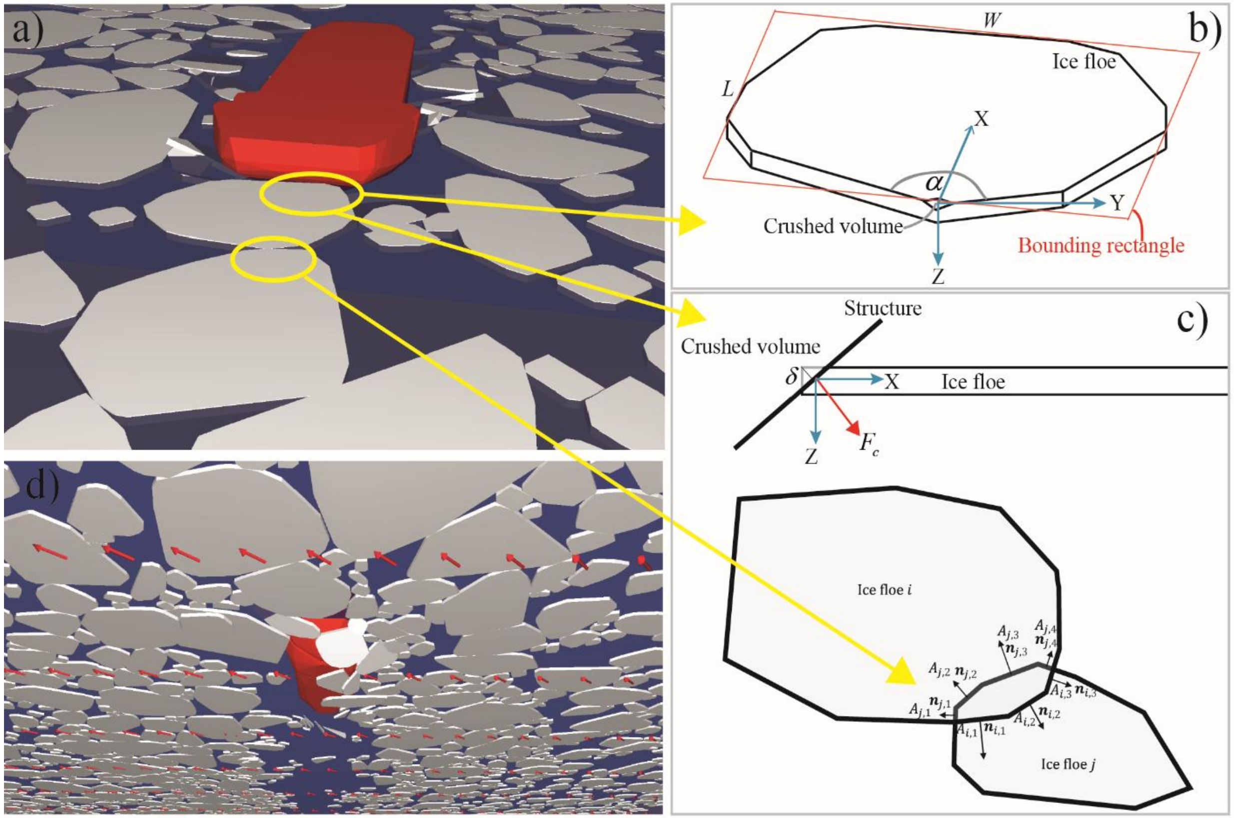


Simulator for Arctic Marine Structures (SAMS)

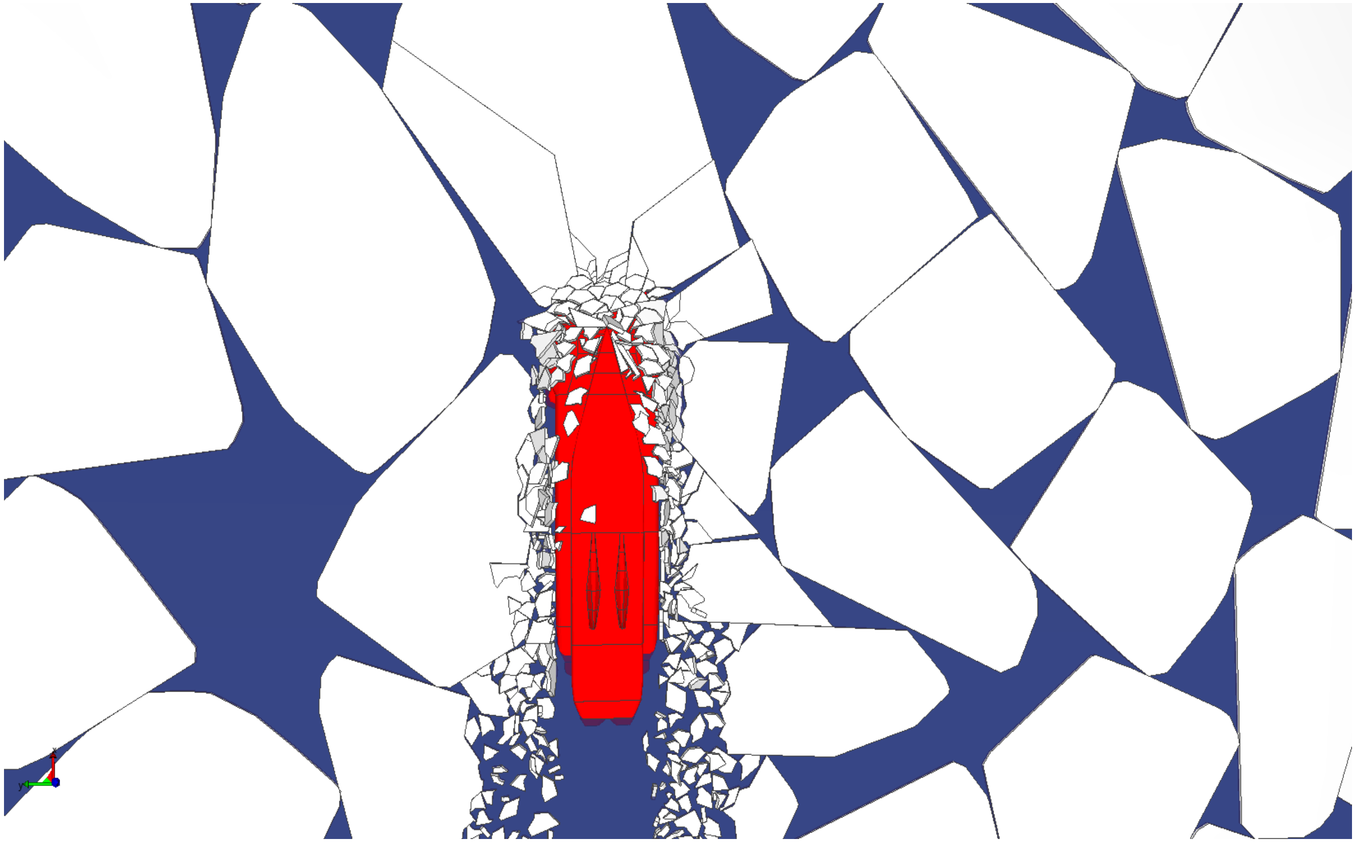
Theoretical Basis

The building blocks of SAMS are illustrated in this figure, namely:

1) the NDEM or multi-body dynamics module,
2) the fracture module, and
3) the hydrodynamic module.



Theoretical Basis – Fracture Module

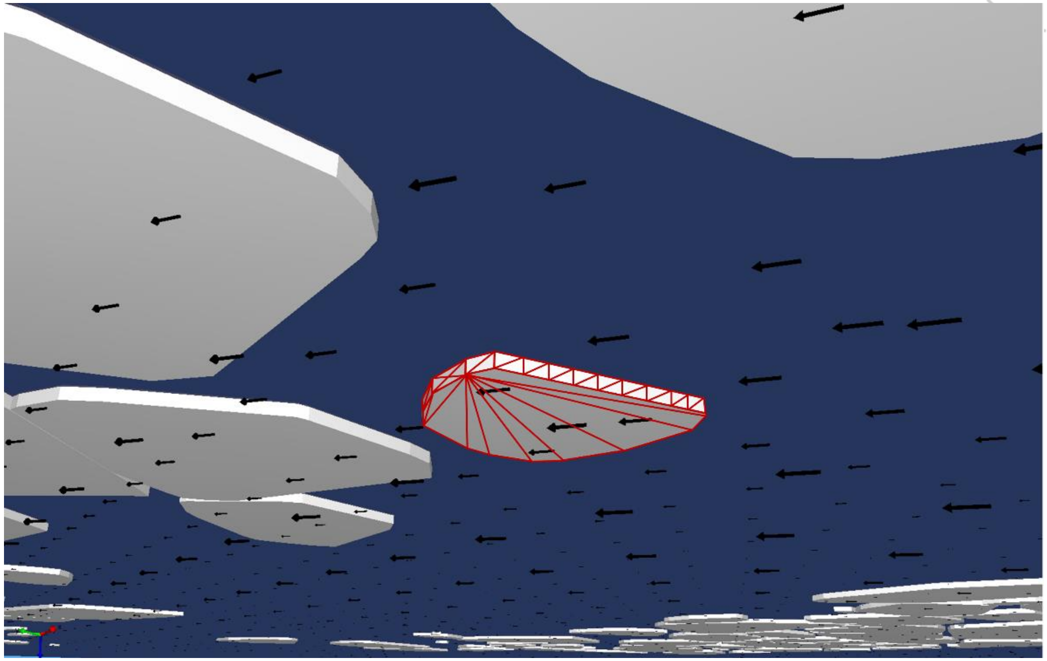


Theoretical Basis – hydrodynamic module

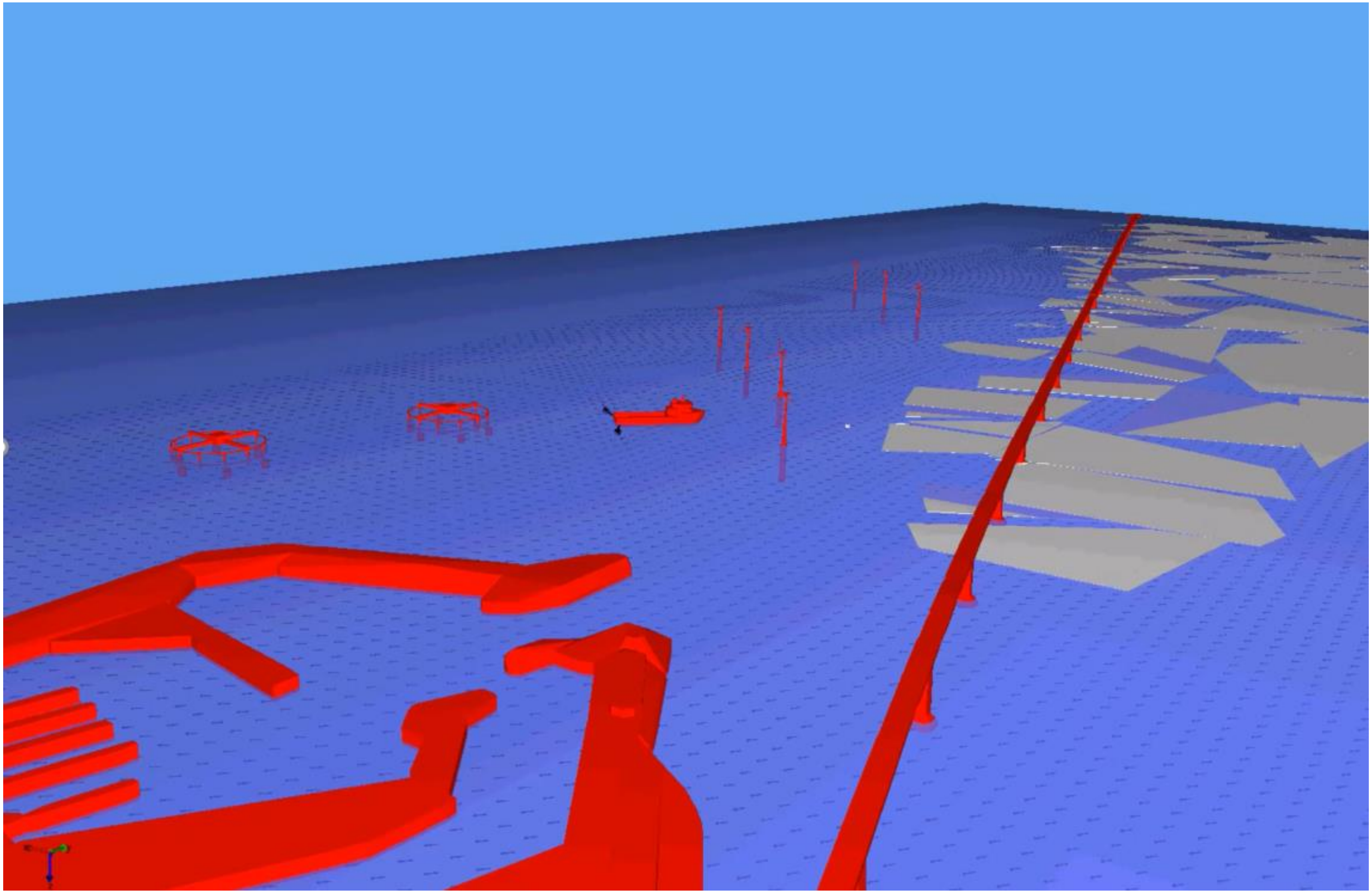
Aside from the basic buoyancy of all bodies, the hydrodynamic forces, including the force due to the propeller flow, upon each individual ice floe and the structure are assigned explicitly, and ice drift simulations are possible given wind and/or current conditions.

The total hydrodynamic force on a rigid body is considered here as a combination of the so-called form drag and skin-friction drag.

$$\mathbf{F}_h = \sum_{k=1}^{M} \left[\rho_w C_f S^k \, | \mathbf{U}_{\parallel}^k | \, \mathbf{U}_{\parallel}^k - \left(\frac{1}{2} \rho_w C_d S^k \left[(\mathbf{U}^k \cdot \mathbf{n}^k) \right]^2 \mathbf{n}^k \right) \Big|_{(\mathbf{U}^k \cdot \mathbf{n}^k) < 0} \right]$$



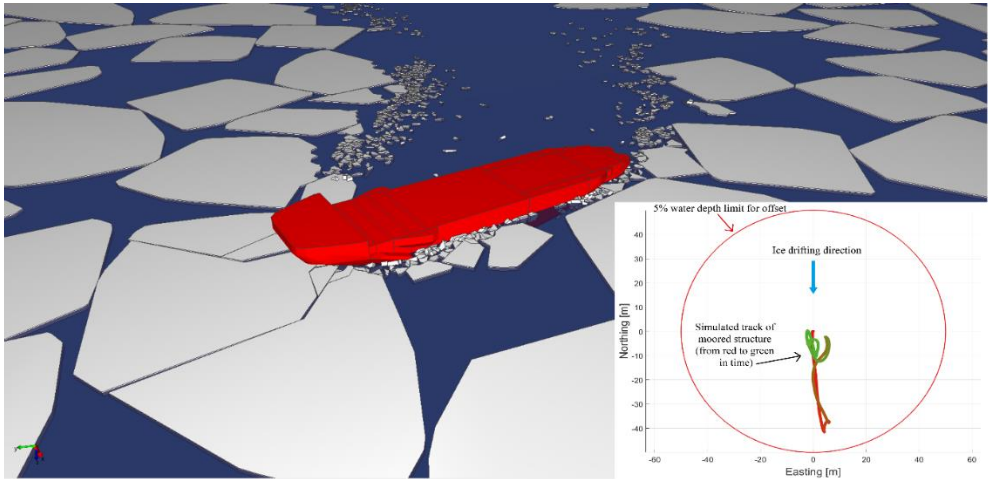
Capabilities of SAMS



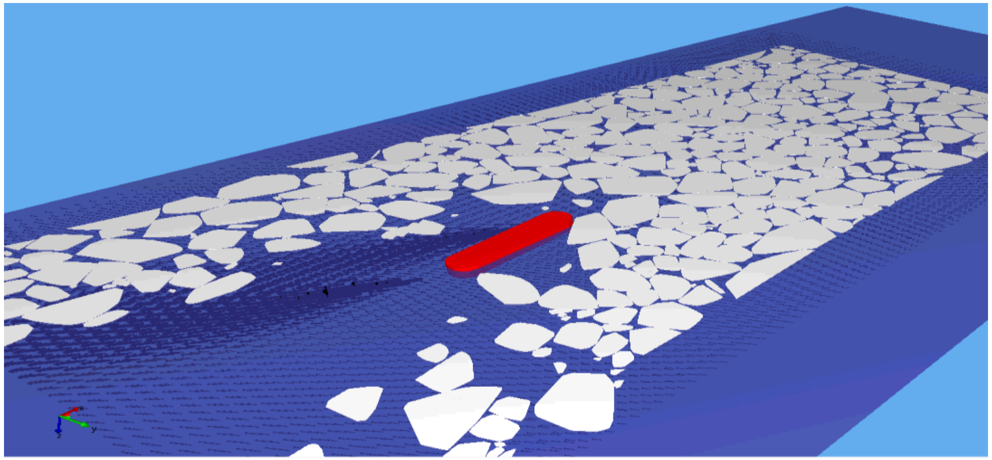
Simulator for Arctic Marine Structures (SAMS)

Current capabilities

- Self-propelled vessels
- Station keeping (DP)
- Station keeping on mooring
- Fixed structures
- Towing carriage
- Ice tank
- Coastal structures
- Ice drift due to wind and current
- Floe ice, level ice, rubble



Moored vessel in broken ice during a change in ice drift direction.



Simulation of the propeller wash of a ship in ice.

Simulator for Arctic Marine Structures (SAMS)

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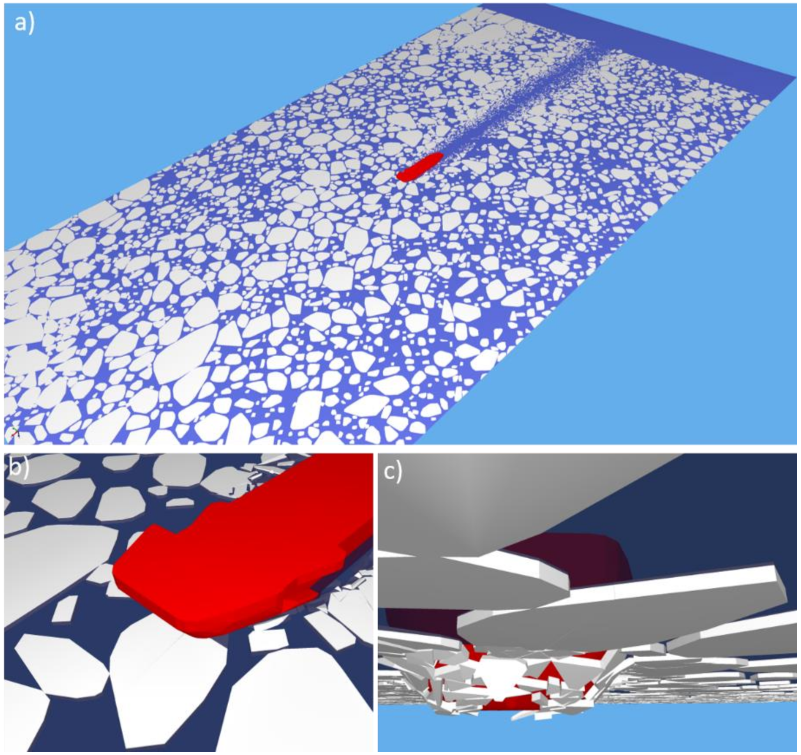

Ship transit simulation

Simulator for Arctic Marine Structures (SAMS)

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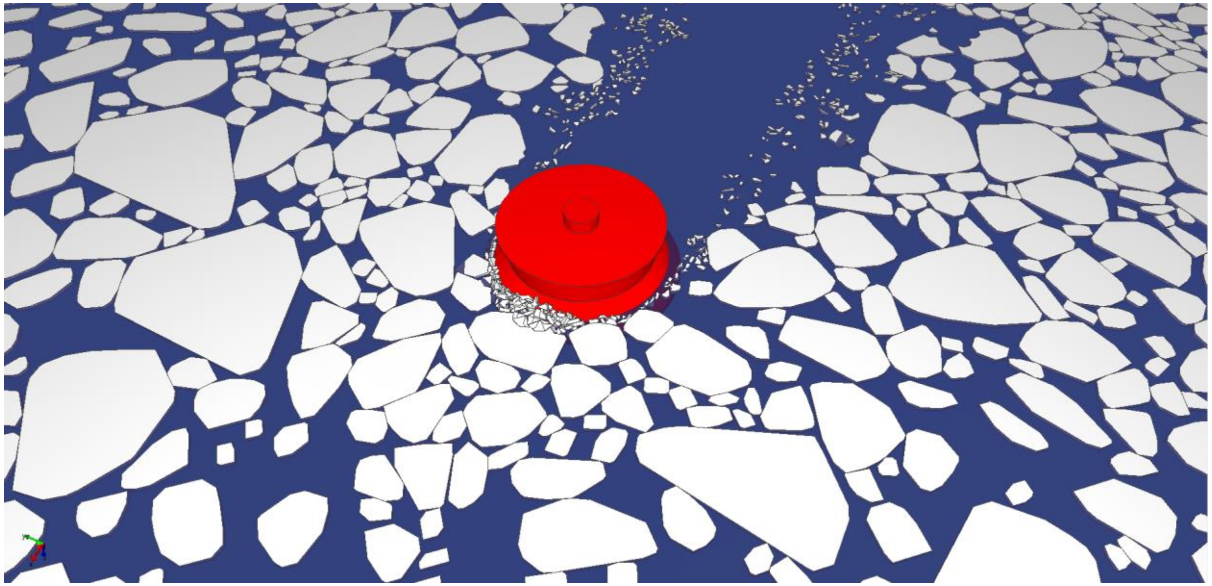

Bending failure of ice against a structure with an upward-sloping waterline.

Simulator for Arctic Marine Structures (SAMS)

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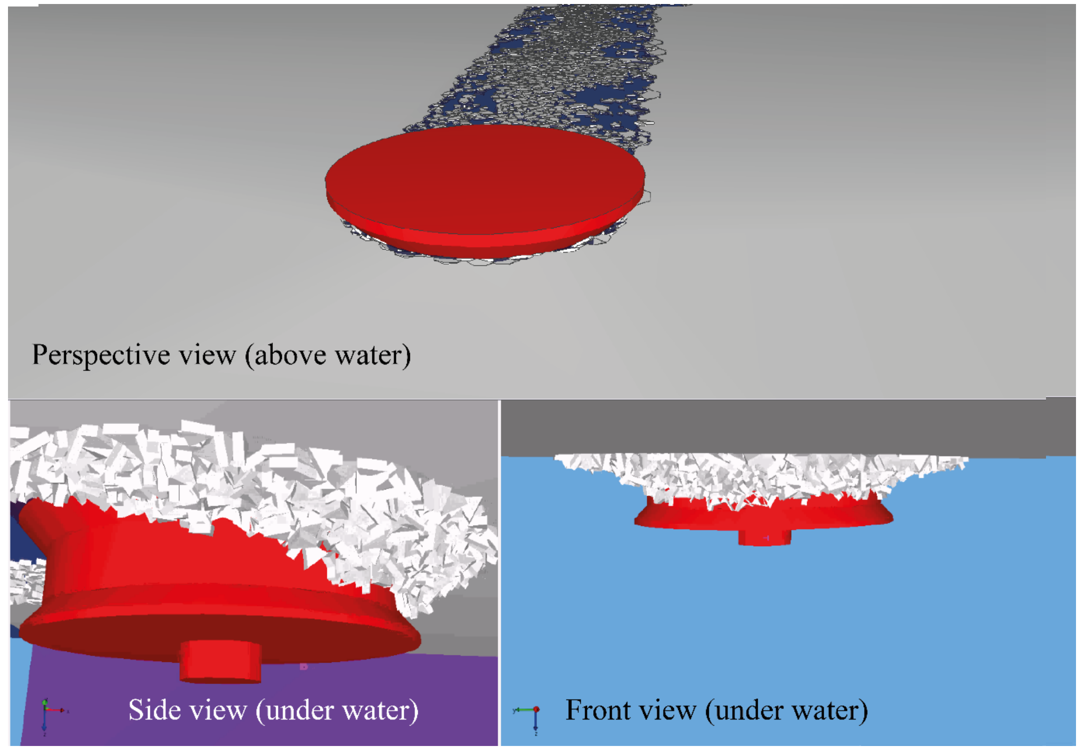

Moored conical structure in level ice

Simulator for Arctic Marine Structures (SAMS)

Current capabilities

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- Station keeping (DP)
- Station keeping on mooring
- Fixed structures
- Towing carriage
- Ice tank
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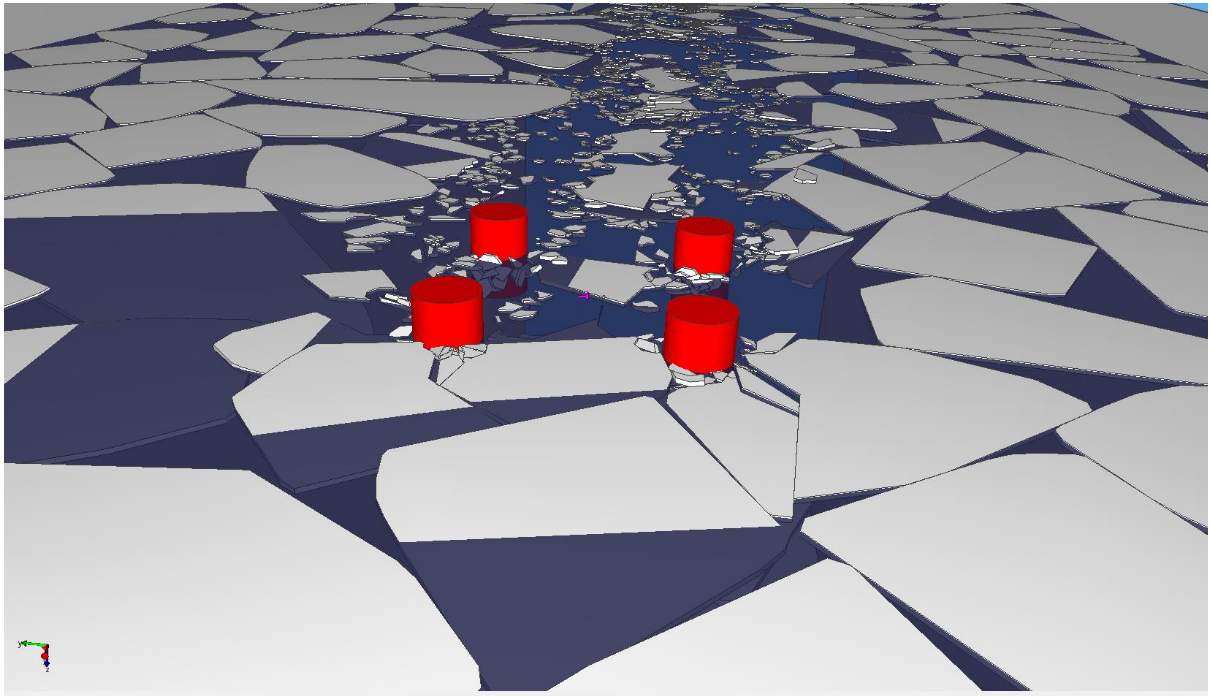
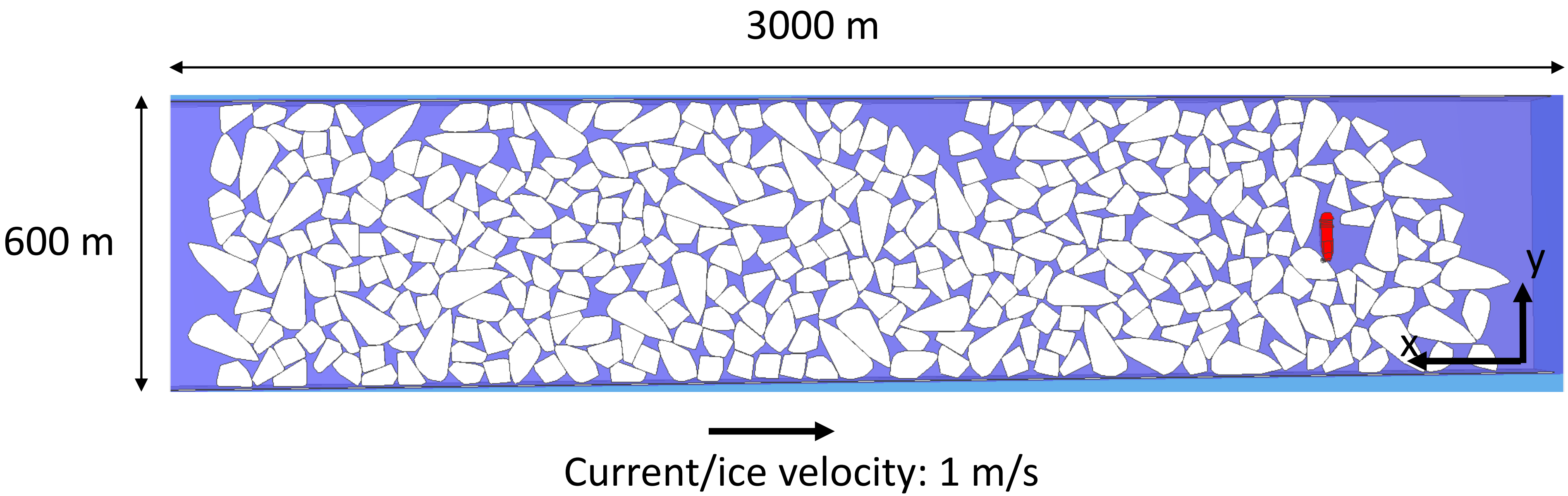
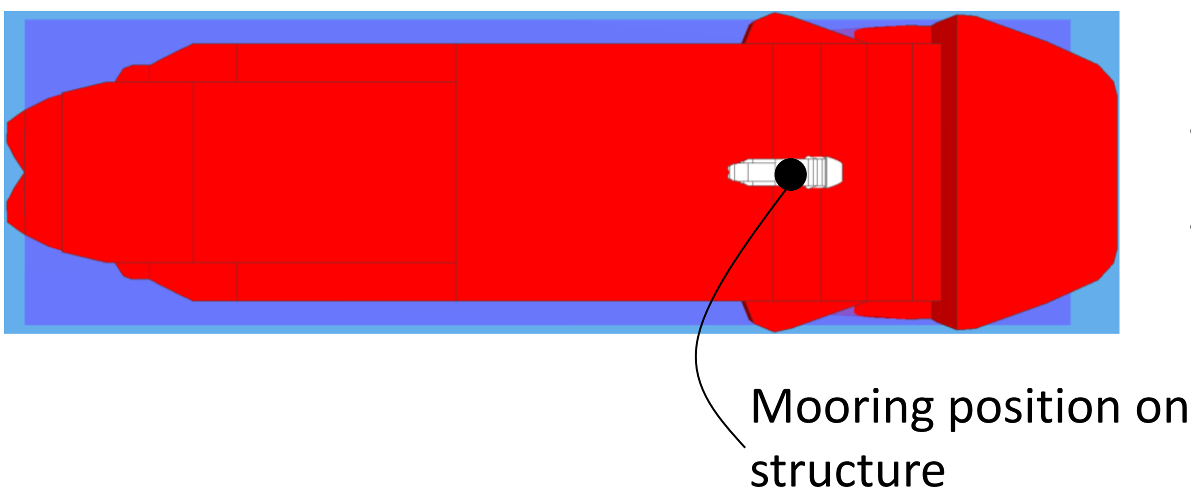


Multi-leg structure interacting with broken ice

Ship on Mooring in Broken Ice

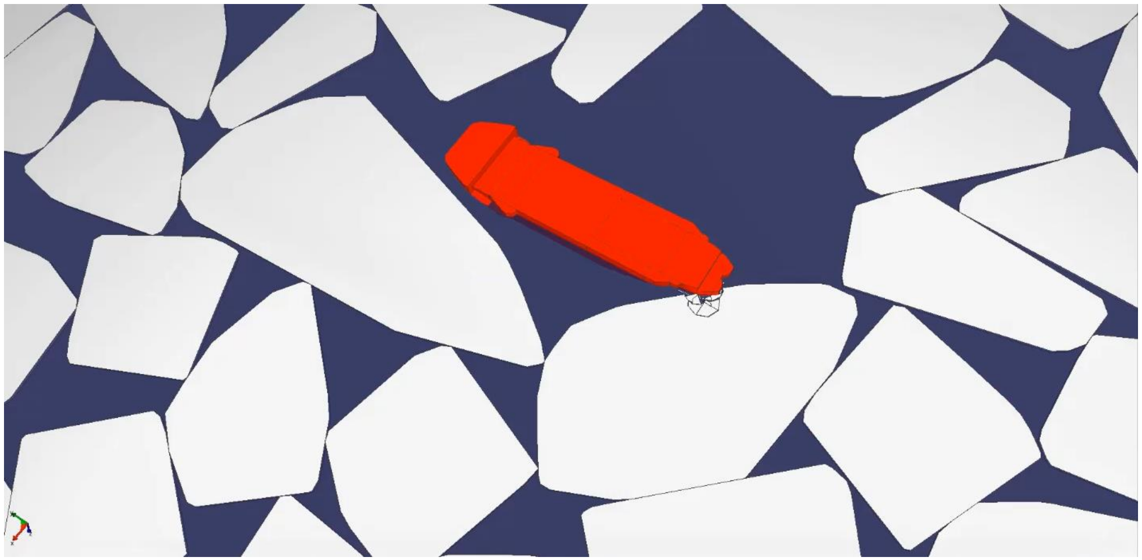


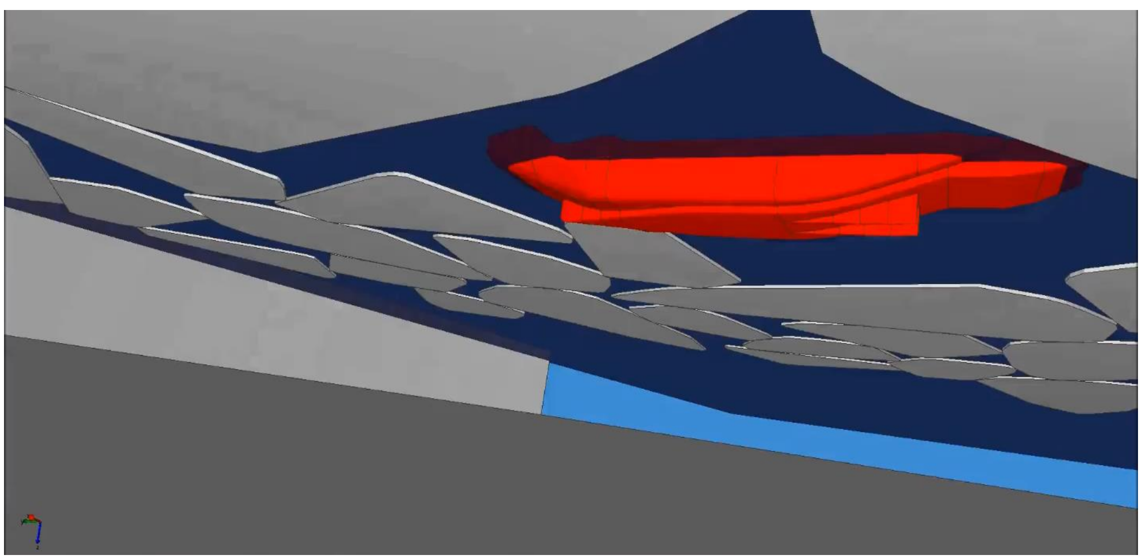


Linear) mooring properties:

- 100 kN/m surge/sway
- 0.1 damping coefficient

Ship on Mooring in Broken Ice





- ✓ Splitting and bending failure
- ✓ Good rubble clearing by ice-'knife'
- ✓ Rotation of structure due to ice loads

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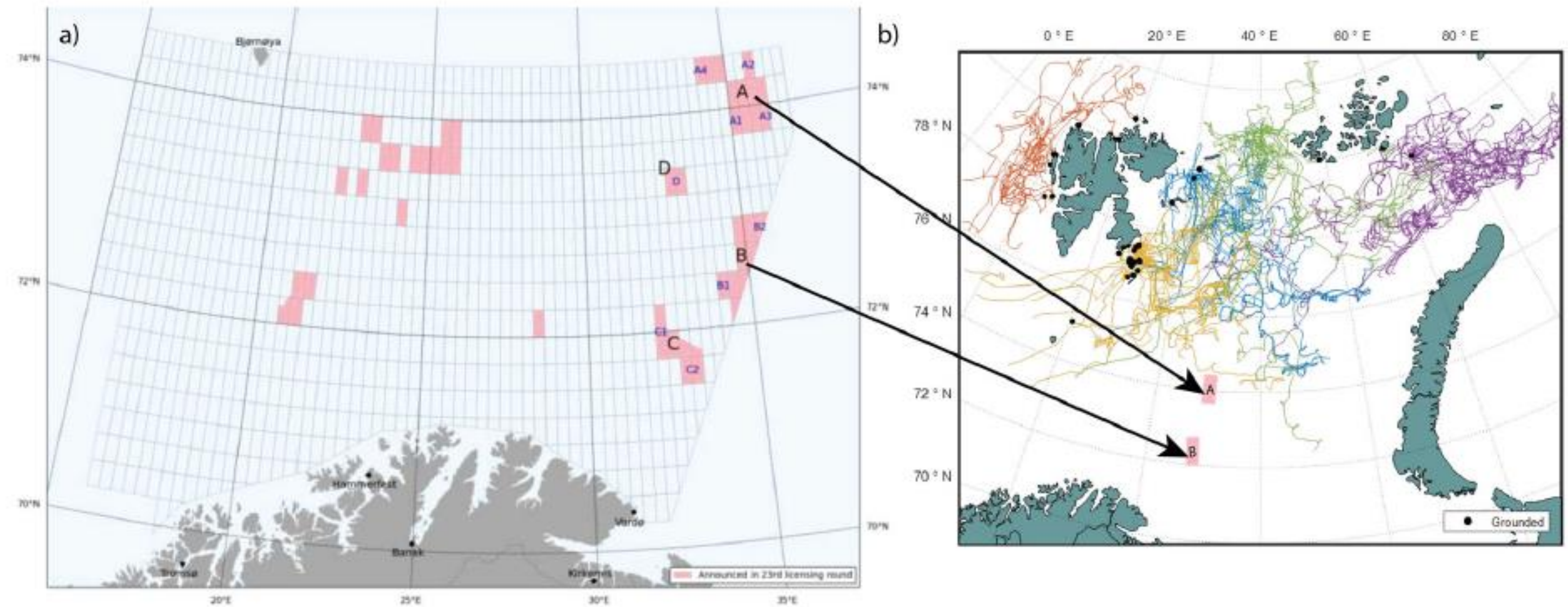
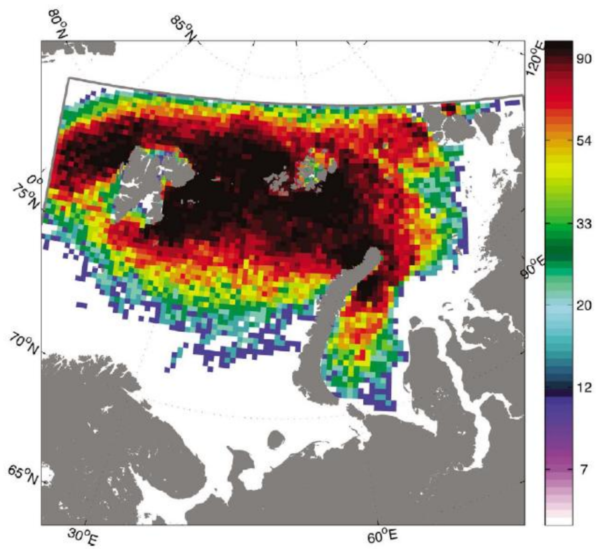


Figure 3. a) Blocks in the 23rd licencing round; b) an example of icebergs' (in black dots) drifting track (curvature lines) simulations and with rough locations of Blocks A and B from the 23rd licensing round.



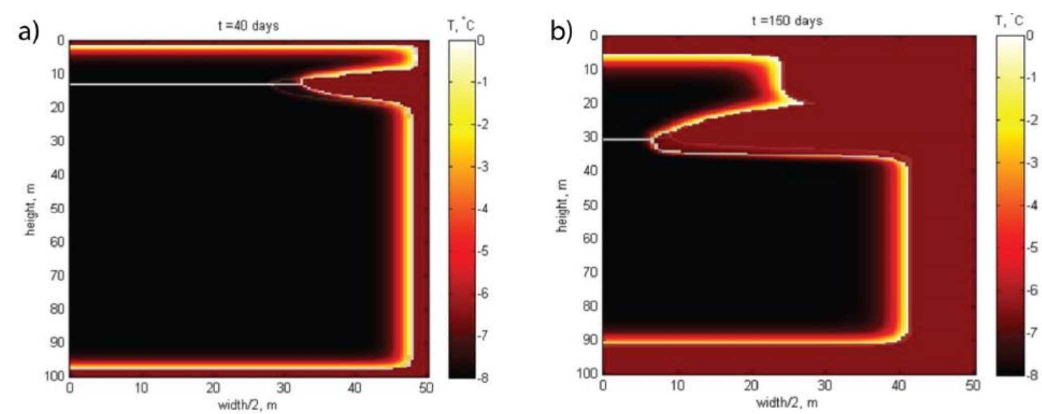
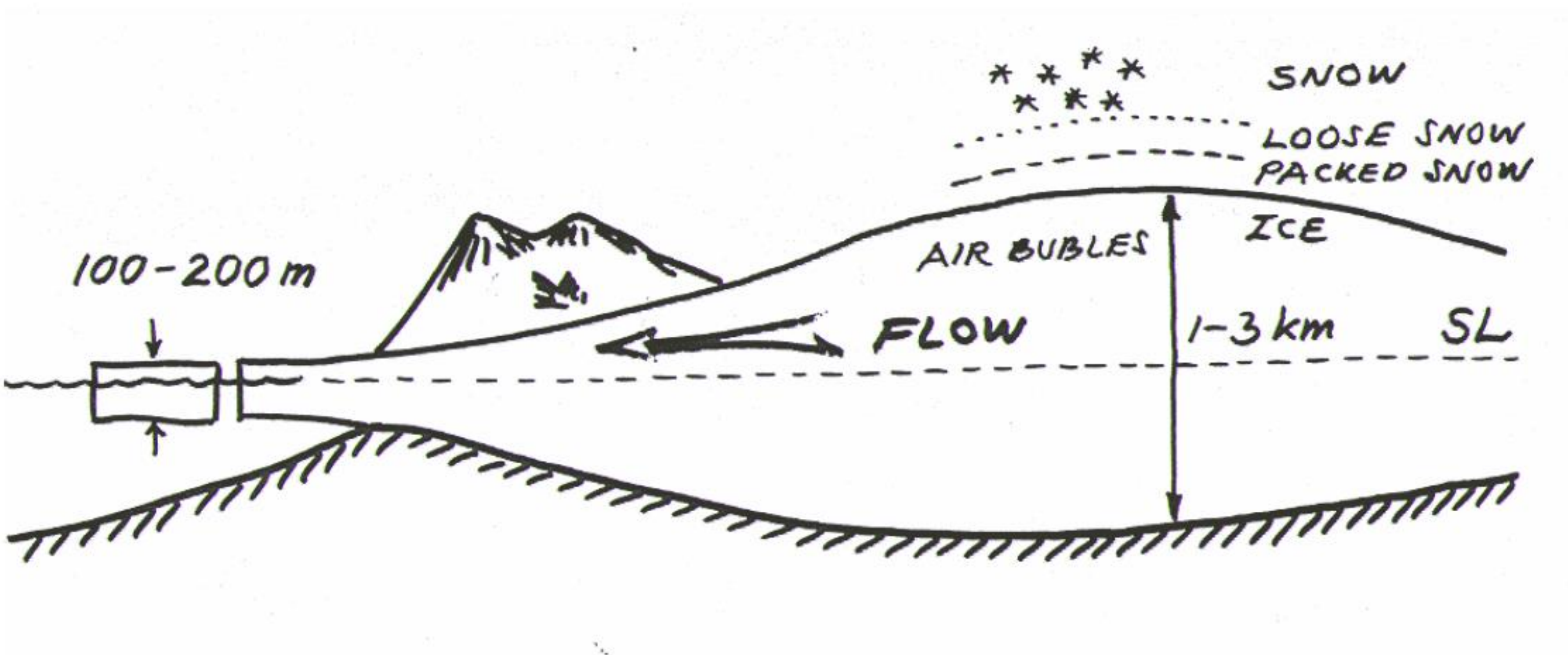


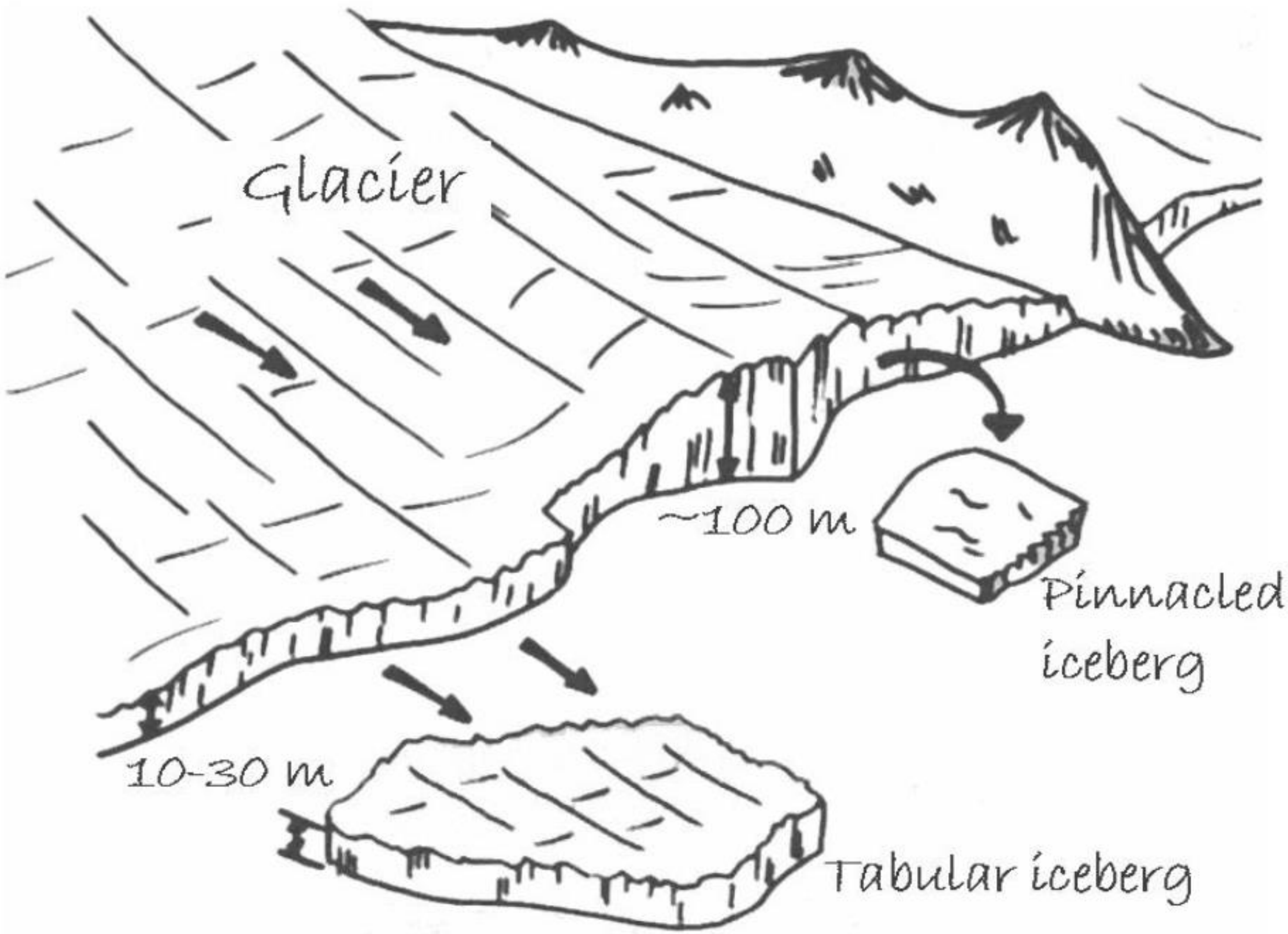
Figure 4. An example of thermal and wave erosions of an originally tubular iceberg after 40 days and 150 days (waterline is labelled with the 'white horizontal line') (Løset, 1993, Løset, 2018)

Formation process of glaciers and icebergs



(Løset et al., 2006)

Boundary Conditions



(Løset et al., 2006)

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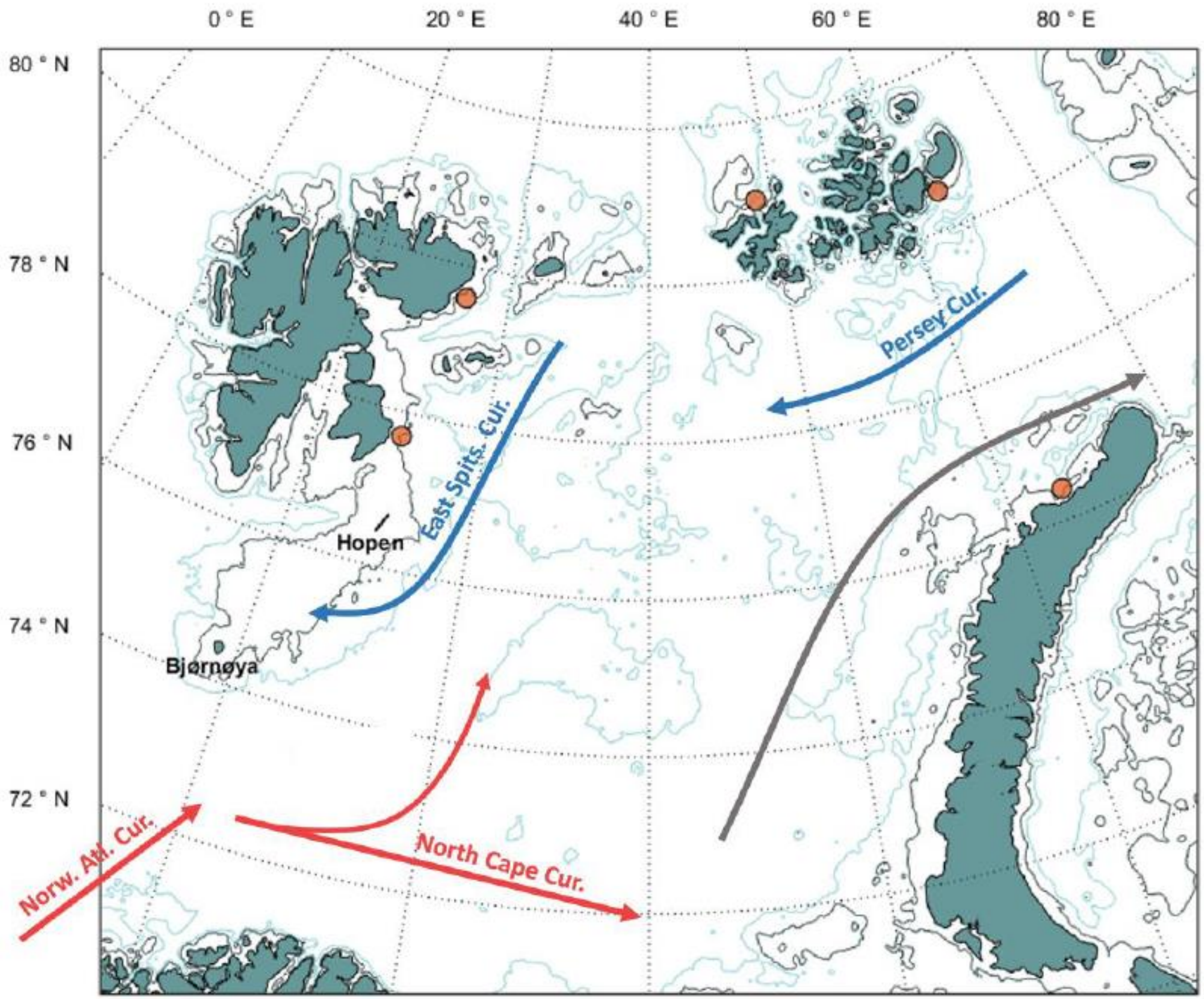
Barents Sea – Major iceberg sources



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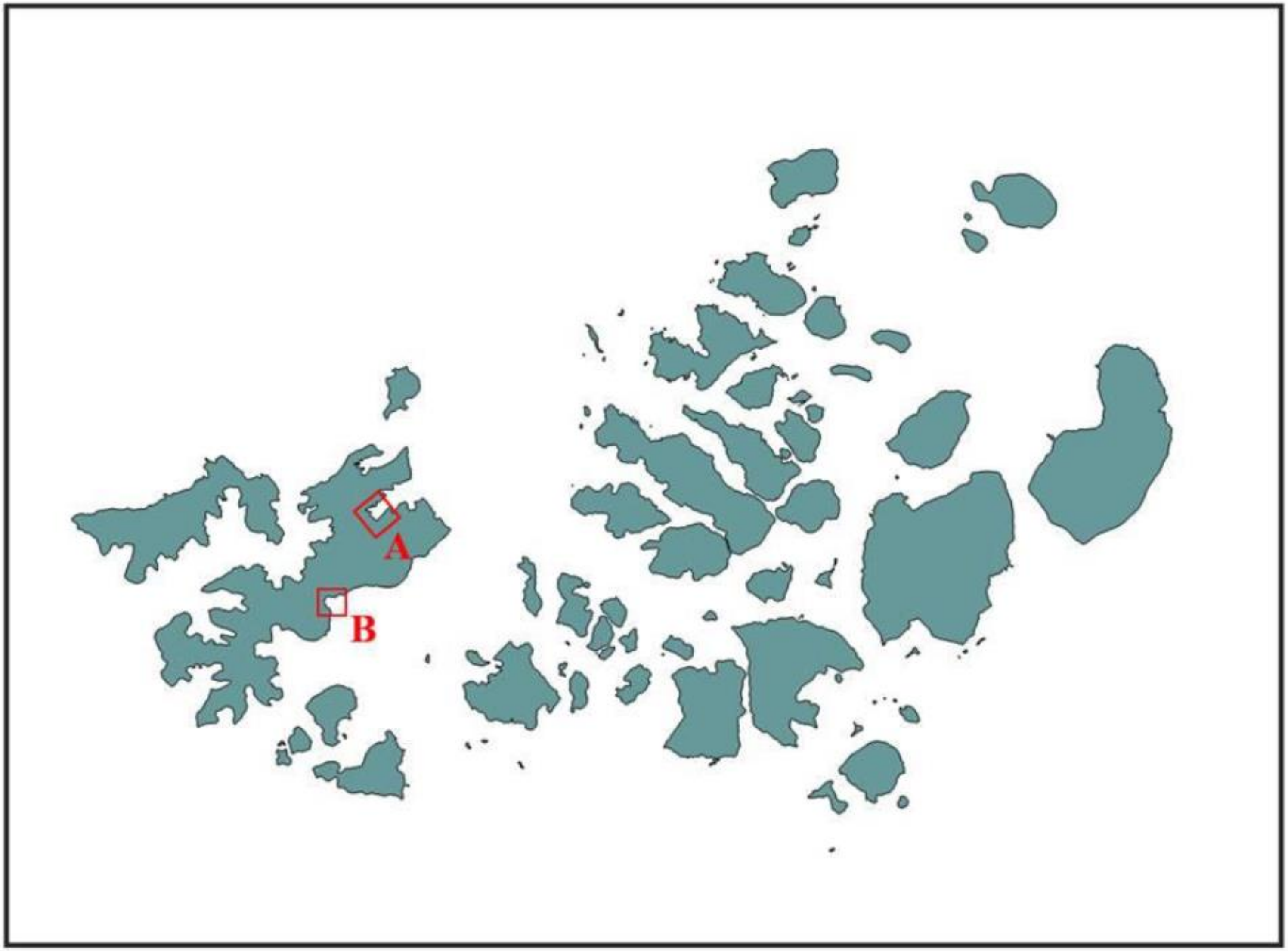
Franz Josef Land



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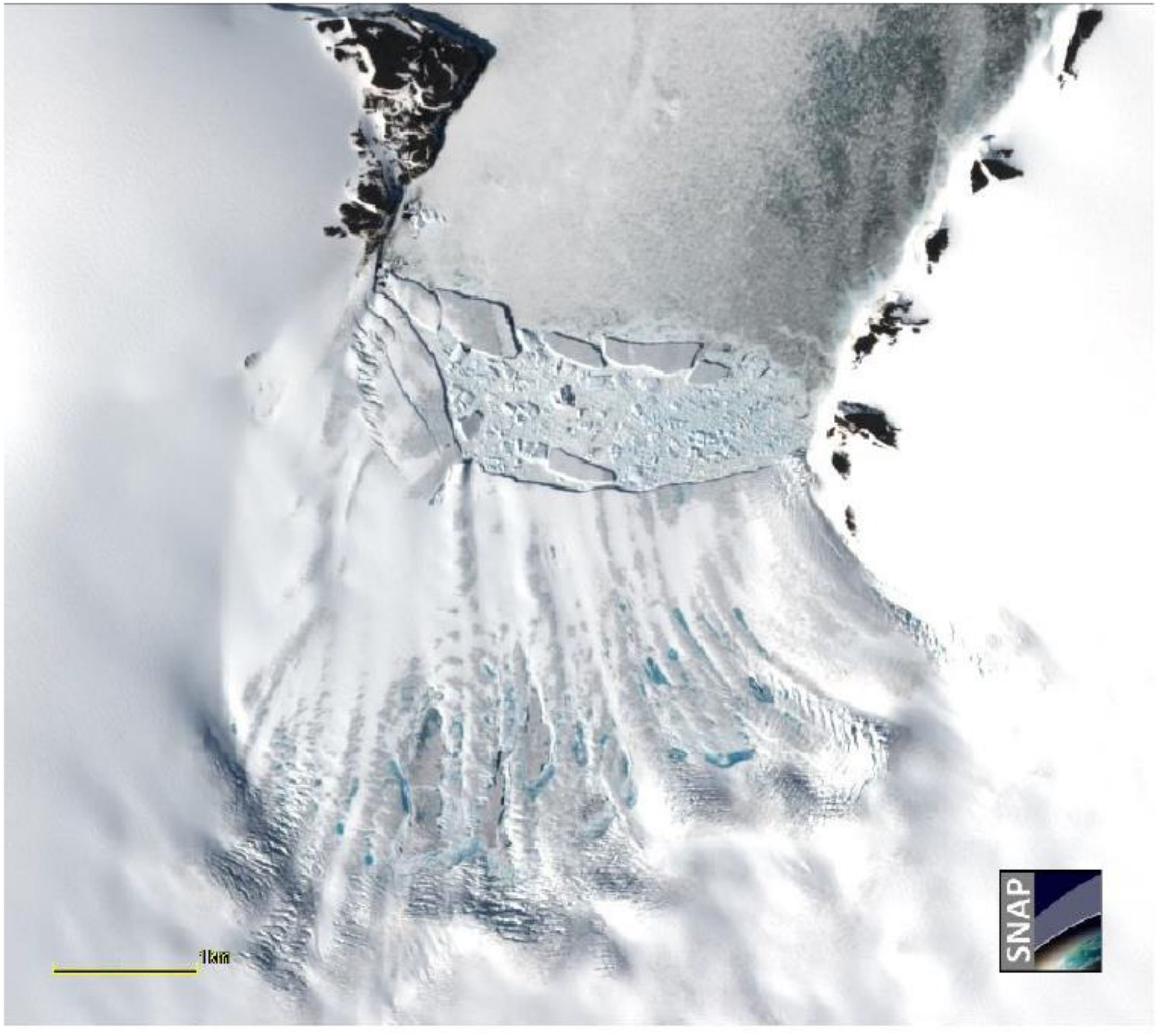
Franz Josef Land - A



Franz Josef Land, Location A, 19.06.2018.
(Source: Sentinel 2, resolution 10 m).

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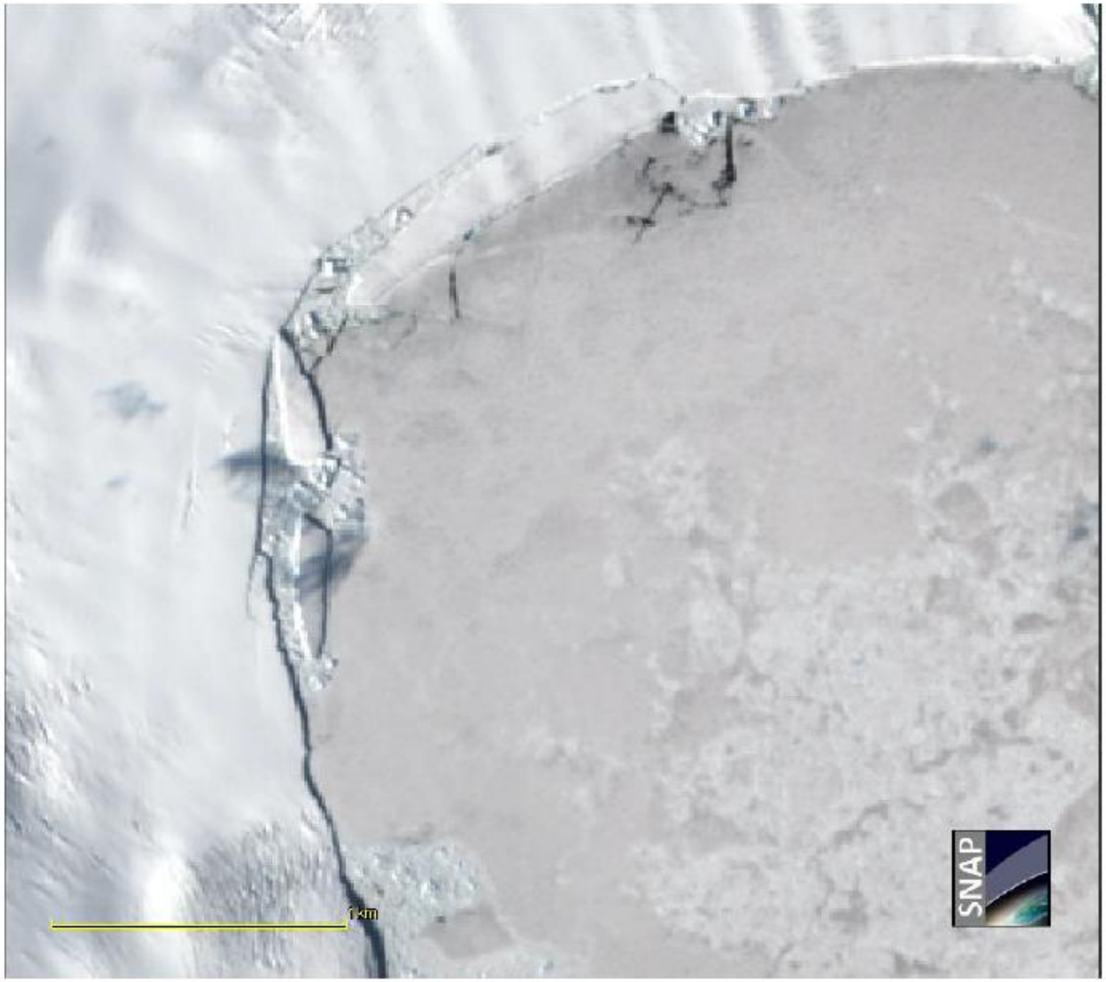
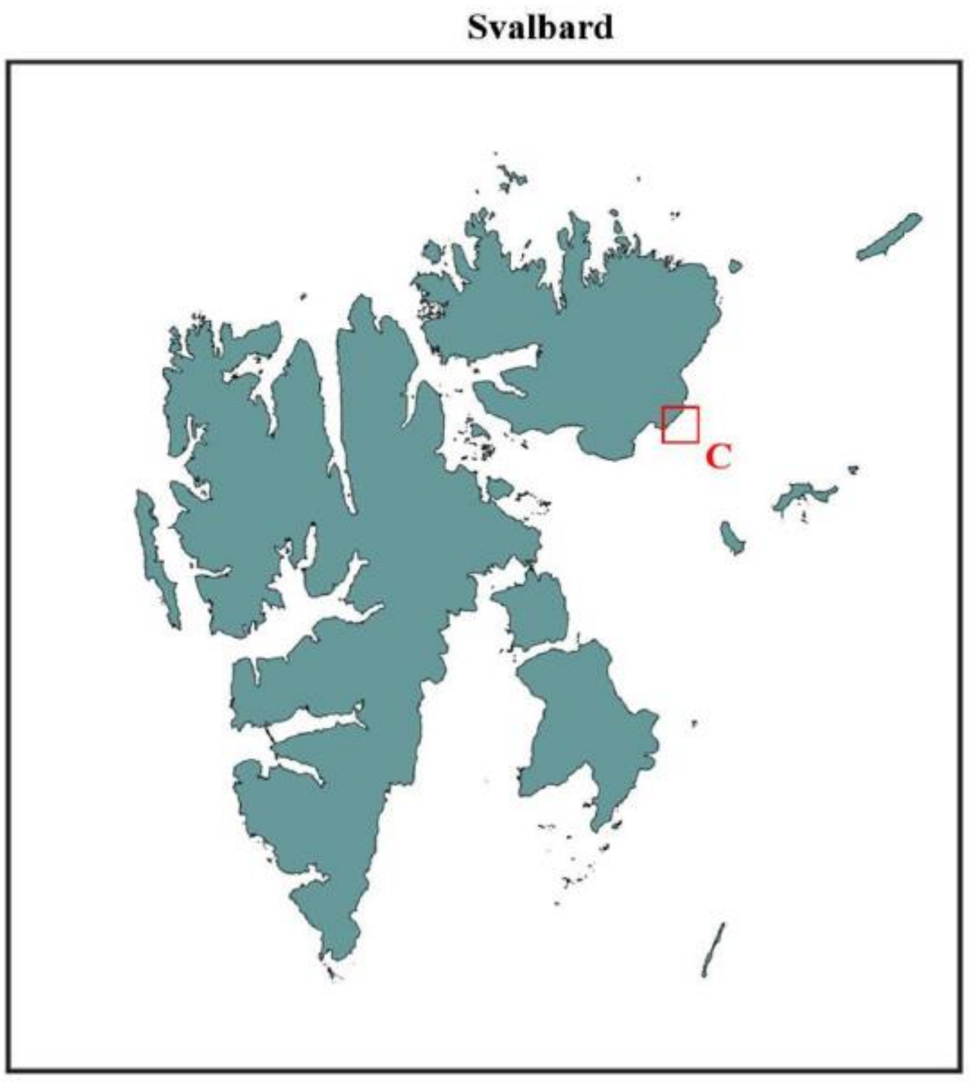
Franz Josef Land - B



Franz Josef Land, Location B, 19.06.2018.
(Source: Sentinel 2, resolution 10 m).

Nordaustfonna - C



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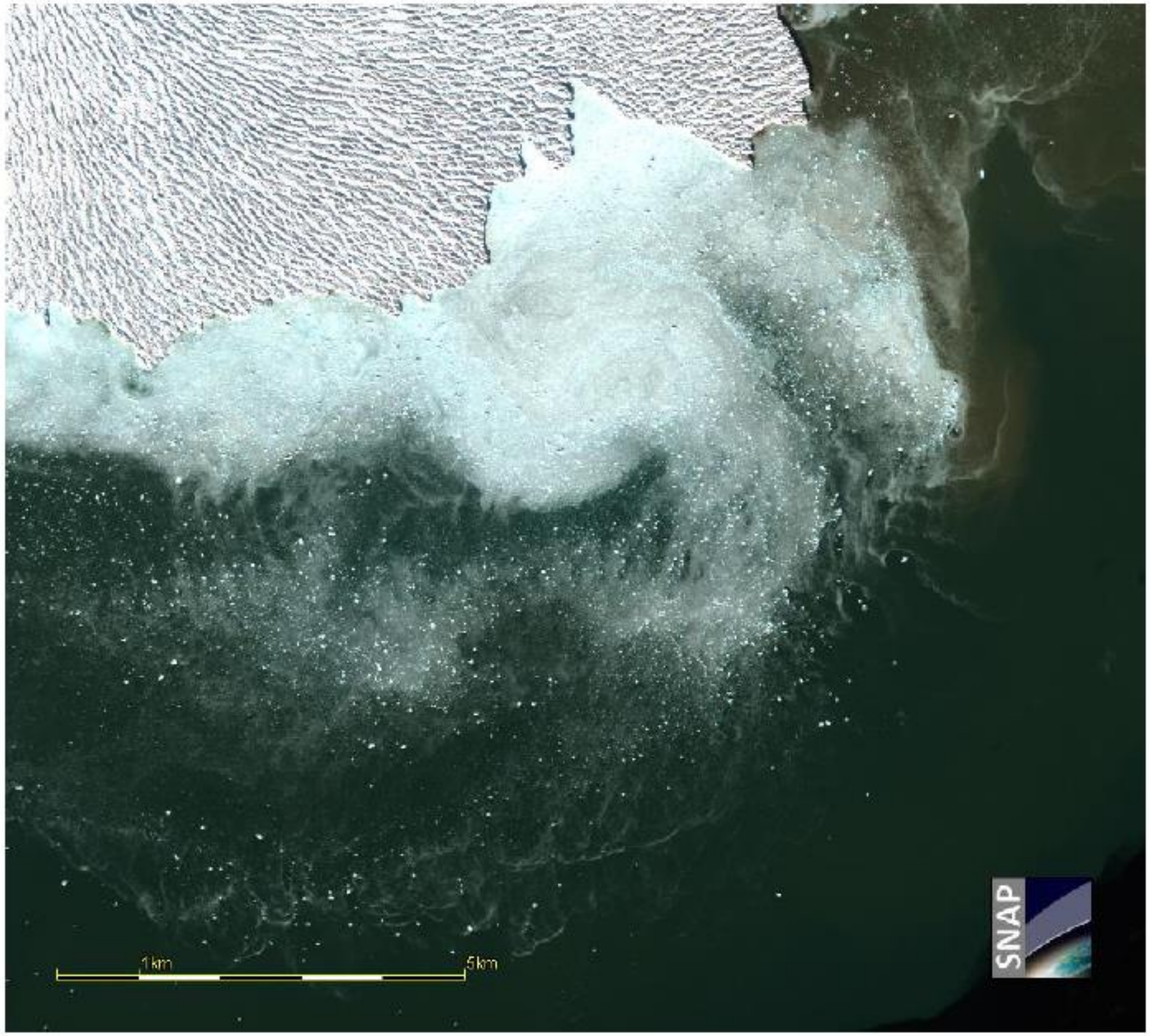
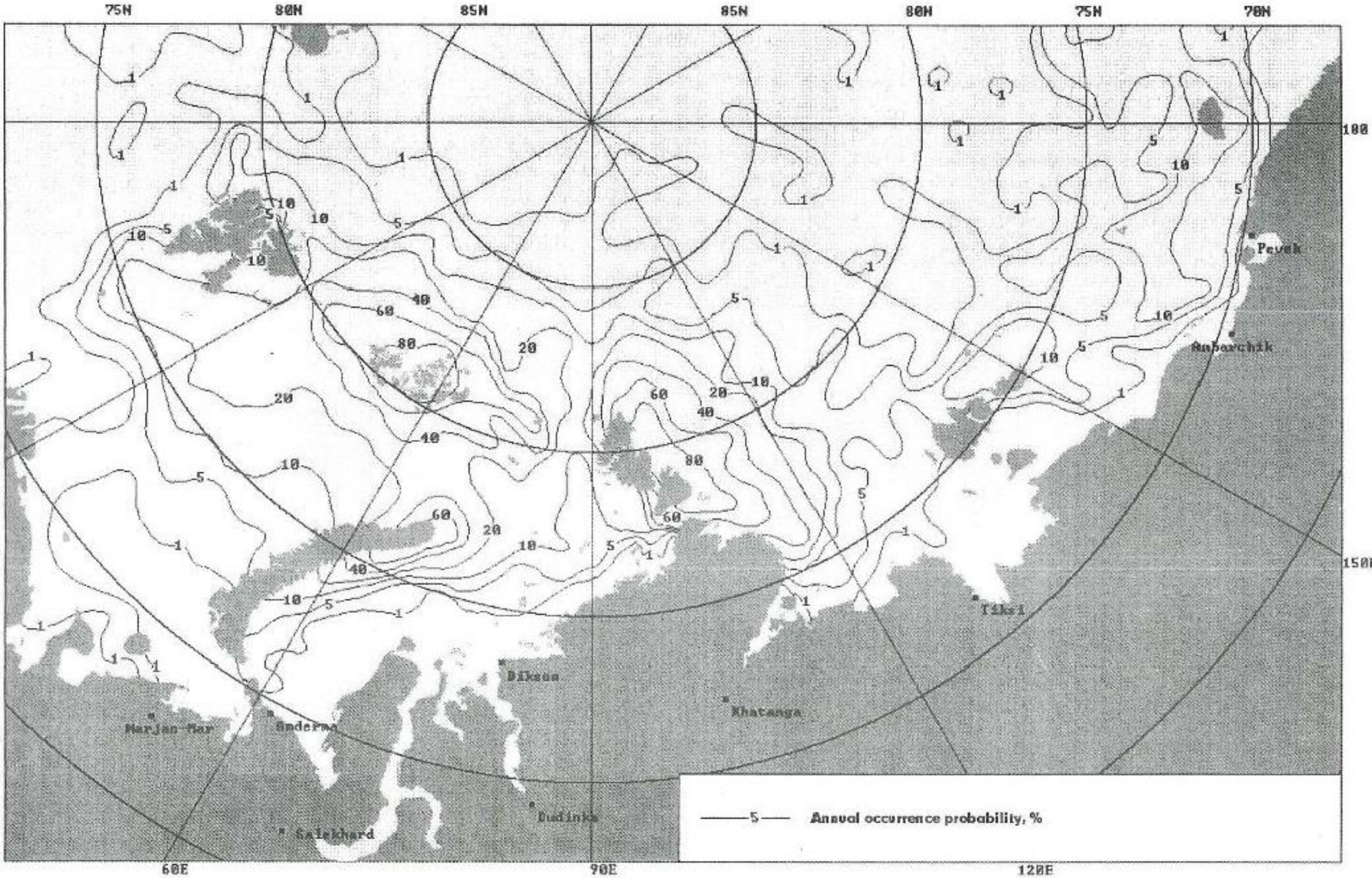
Nordaustfonna - C



Location C, 24.08.2018. (Source: Sentinel 2, resolution 10 m).

Arctic Iceberg Atlas



Abramov and Tunik, 1996

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Iceberg Drift Equations

$$m \cdot (1 + C_m) \frac{d\mathbf{v}_i}{dt} = \mathbf{F}_a + \mathbf{F}_w + \mathbf{F}_c + \mathbf{F}_{wd} + \mathbf{F}_{si}$$

m - iceberg mass,

C_m- added mass coefficient,

$\boldsymbol{V}_i$ -iceberg velocity,

$\boldsymbol{F}_a$,$\boldsymbol{F}_w$ - air and current form drag,

$\boldsymbol{F}_c$ - Coriolis force,

$\boldsymbol{F}_{wd}$ - mean wave drift force,

$\boldsymbol{F}_{si}$ - forcing from sea ice.

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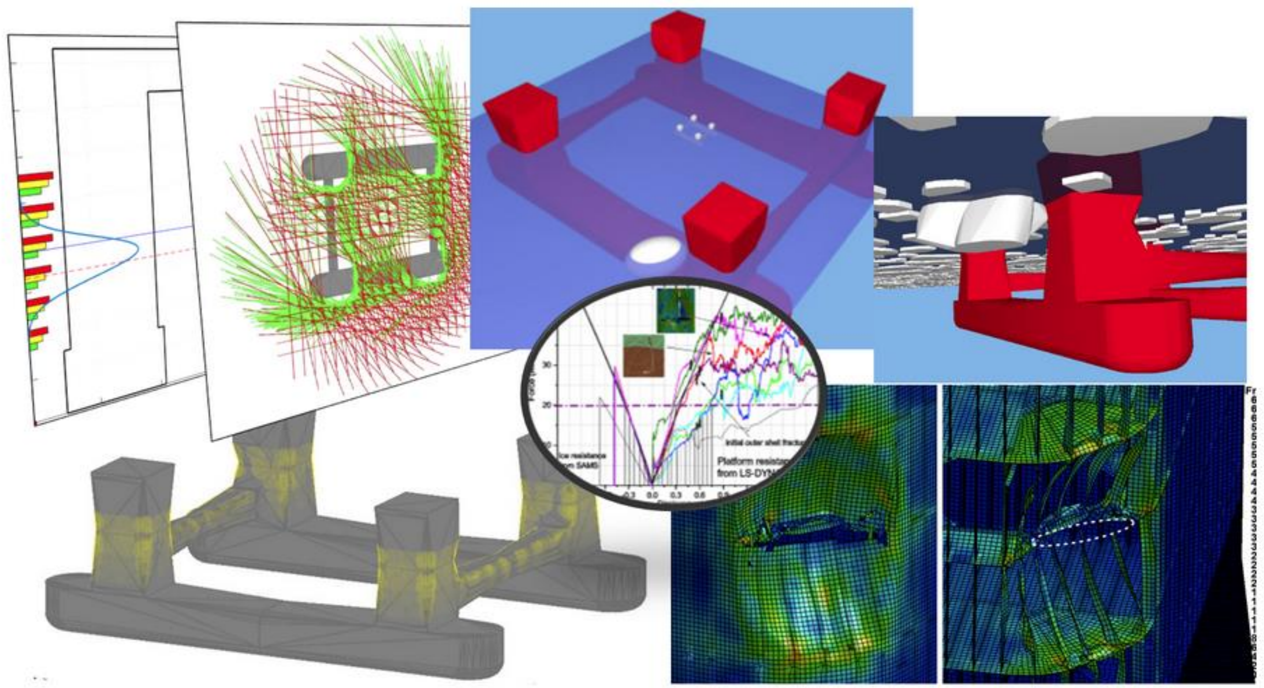
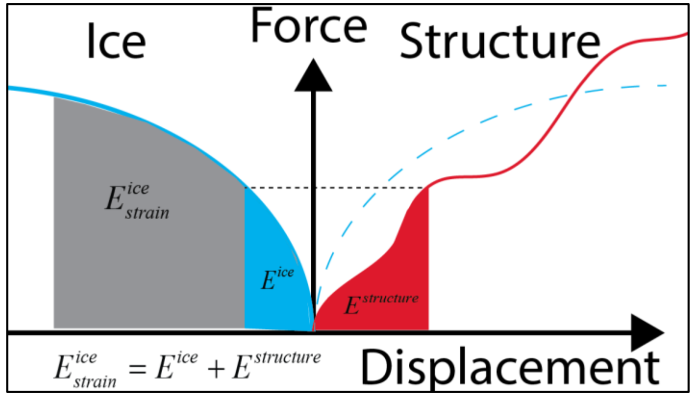
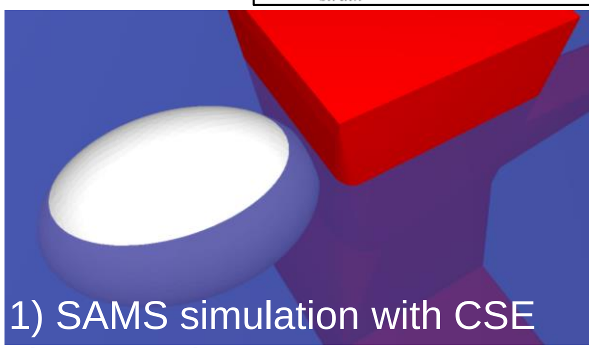
Recent Projects with SAMS

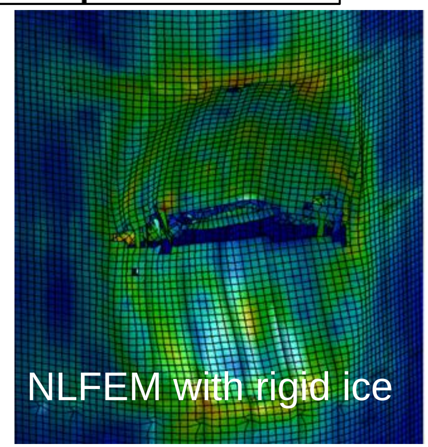


Integrated Damage Assessment





1) SAMS simulation with CSE
2) Alternatively: Process P-A curves



NLFEM with rigid ice

SAMS simulations results are integrated with NLFEM analysis to perform local damage assessment in accordance to the 'shared energy approach'.

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Figure 1: EXWAVE semi-submersible 1:50 scaled model.

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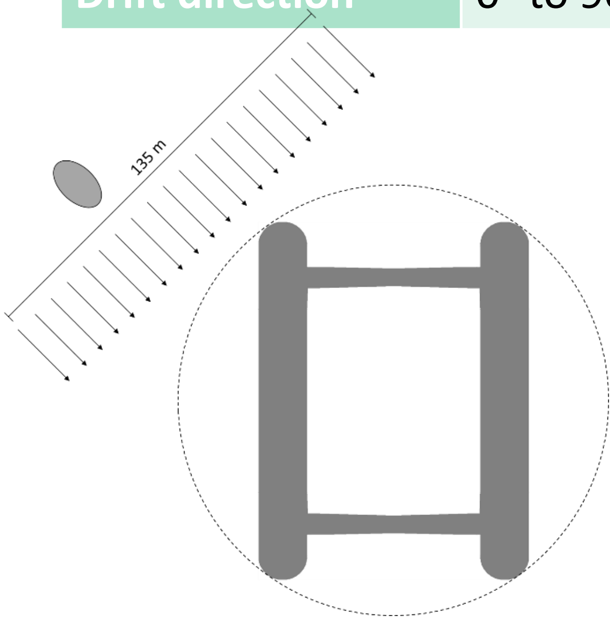
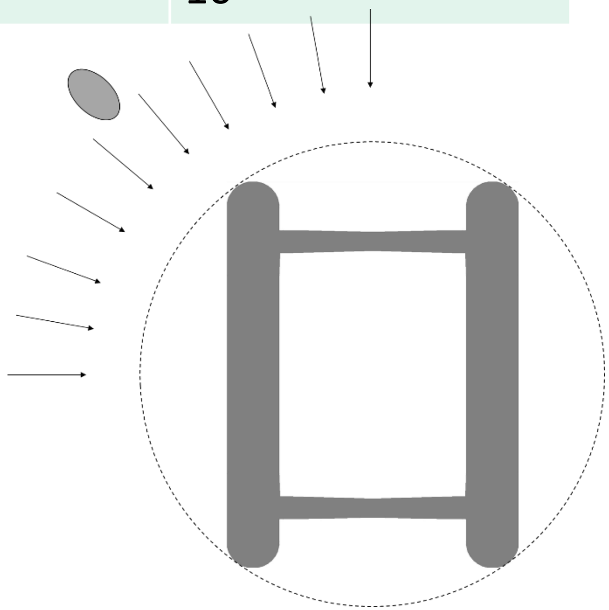
Test Matrix

Glacial ice	Range	Number of values
Vertical offset	-10.8 to 10.8[1]	9
Horizontal offset	-67.5 to 67.5	20
Drift direction	0° to 90°	10





Total: 1800 simulation

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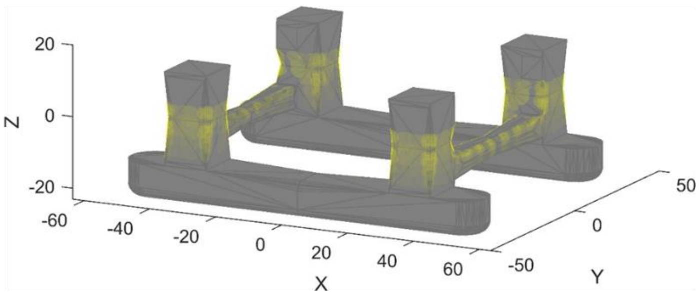
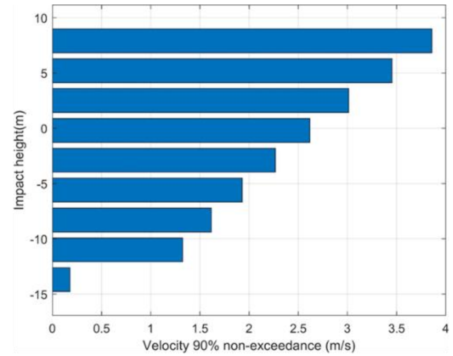
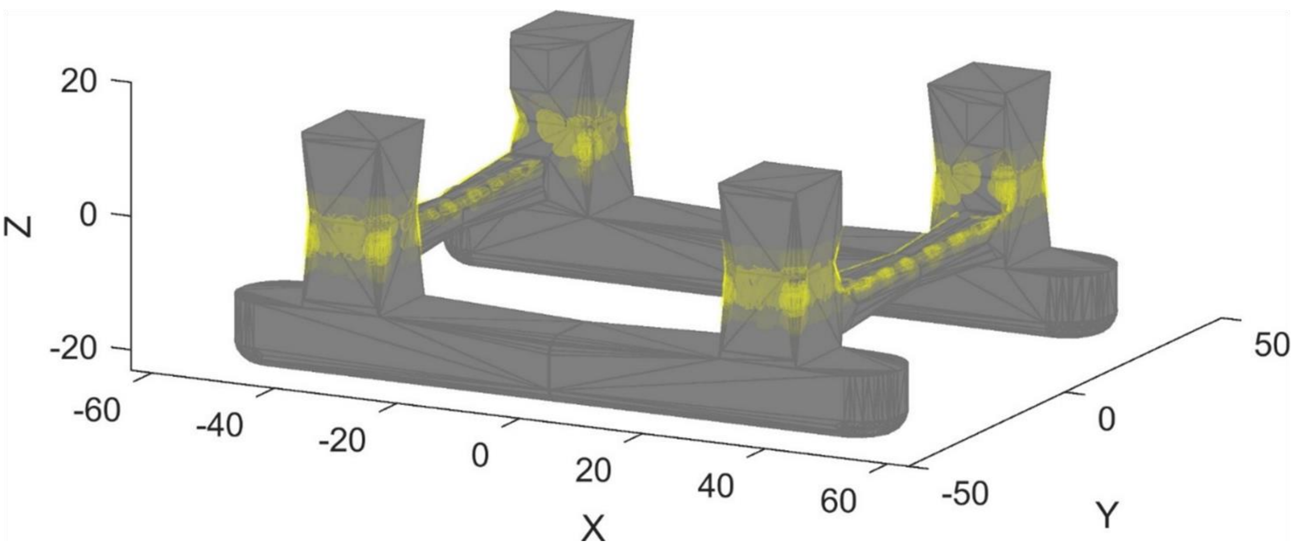
Simulation results

Energy map scaled according to collision probability and collision velocity as a function of height.







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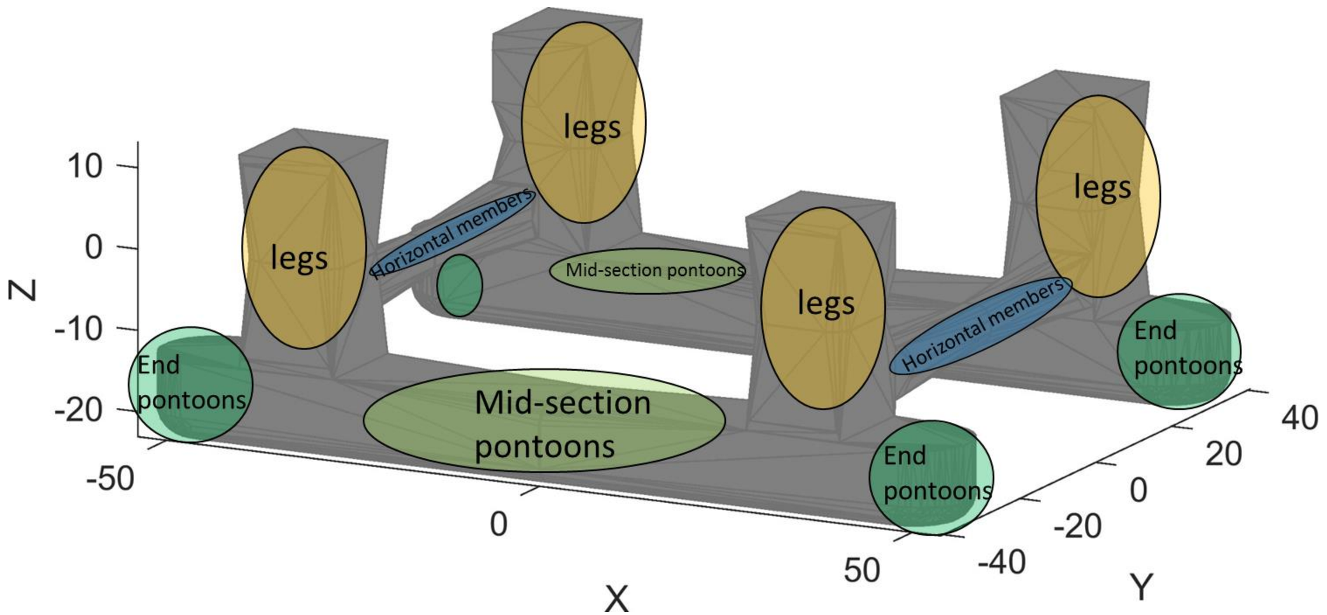
Simulation results

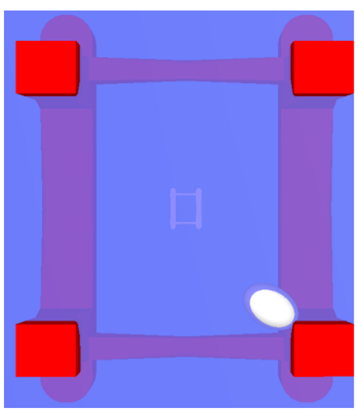
Collision probability on structure sections

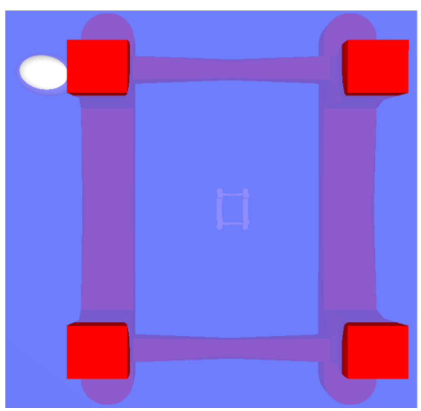


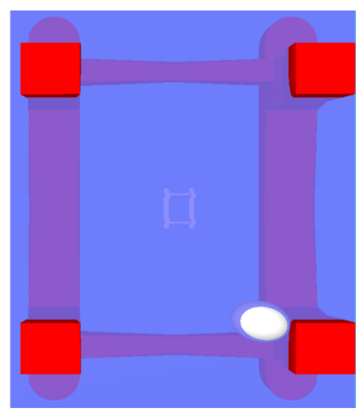
Section	Impact probability (% of all impacts)
Legs	68.8%
Horizontal members	30.6%
Mid-section pontoons	0.3%
End-sections pontoons	0.3%

Critical impact scenarios

Scenario	Ice feature drift velocity (m/s)	Maximum load[1] (MN)	Collision energy (MJ)	Impact location
1	3.4	22.0	7.32	Corner of structure leg
2	3.4	29.7	7.25	Side of leg
3	3.4	28.3	7.30	Side of leg, near corner







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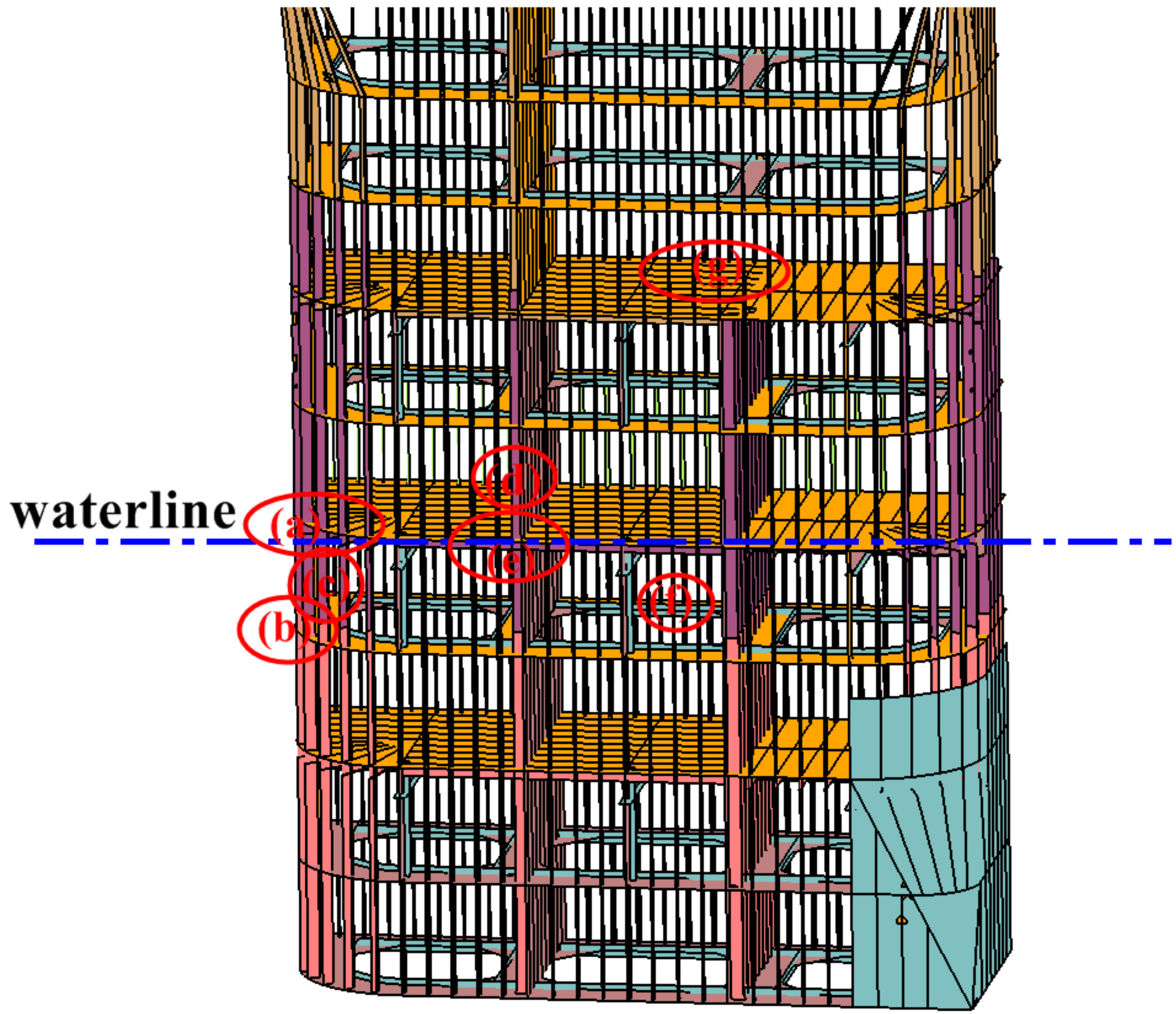
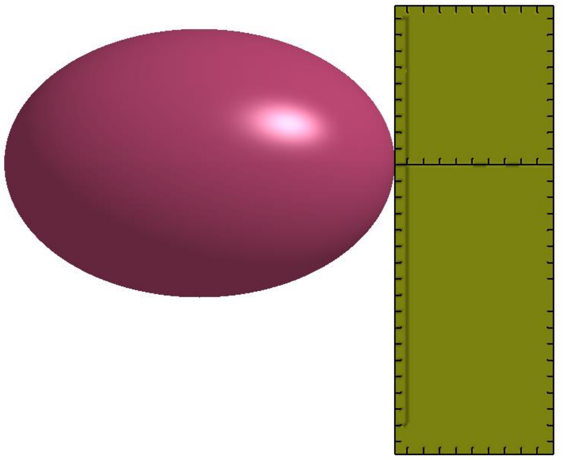
Rigid ice
(Collision location)

An energy of 7.5 MJ is considered critical from probabilisic analysis

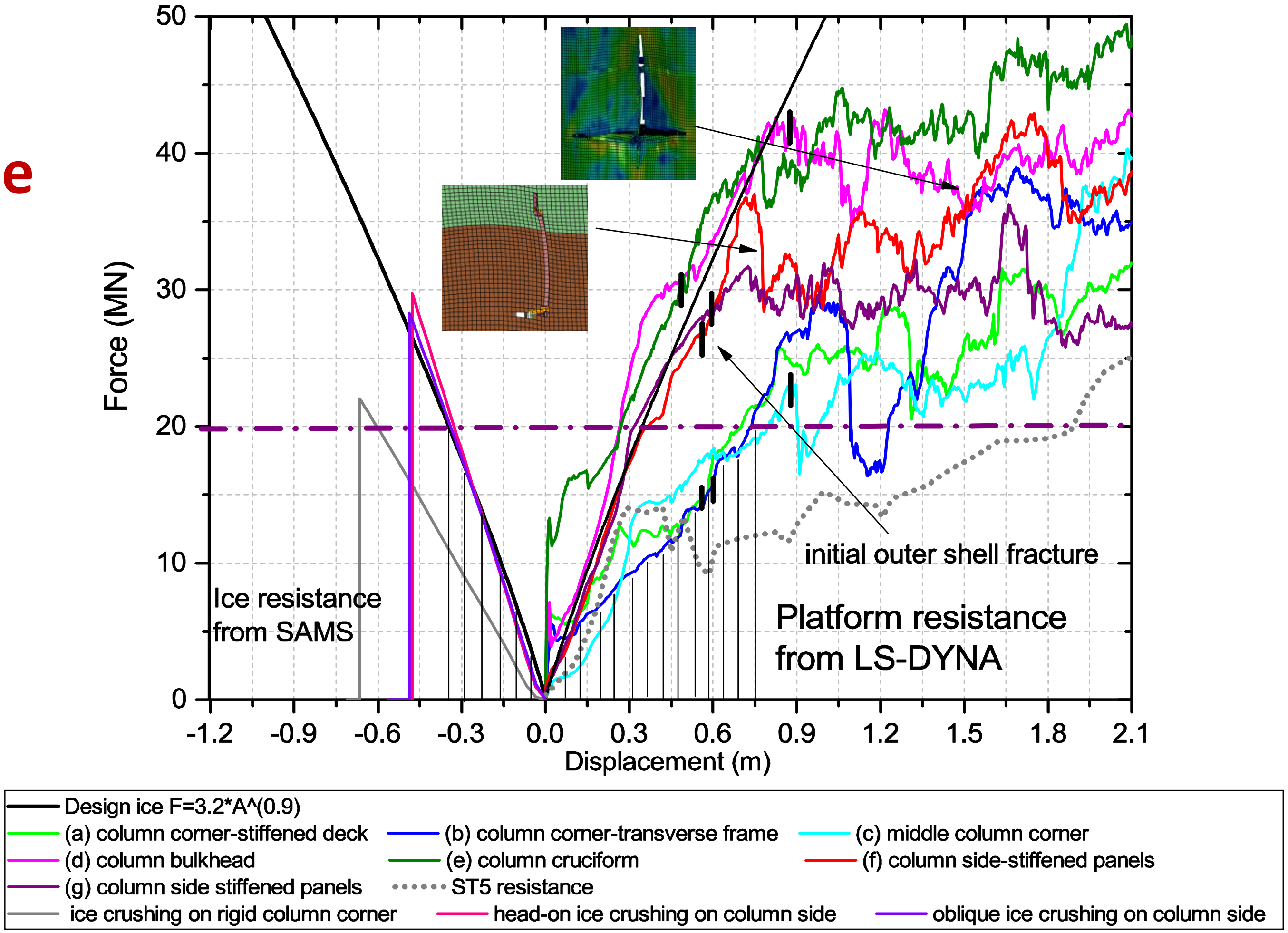


(a): column corner with the stiffened deck
(b): column corner with the unstiffened transverse ring frame
(c): middle column corner (d): stiffened bulkhead
(e): cruciform (f, g): confined stiffened panel

An example collision case on the bulkhead



Collision resistance of ice and structure



1. Stronger points: bulkhead, intersection between bulkhead and the transverse frame
2. Shared energy: column front stiffened panel
3. Weak part: column corner

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Recent Projects with SAMS

Havari Northguider, Hinlopen

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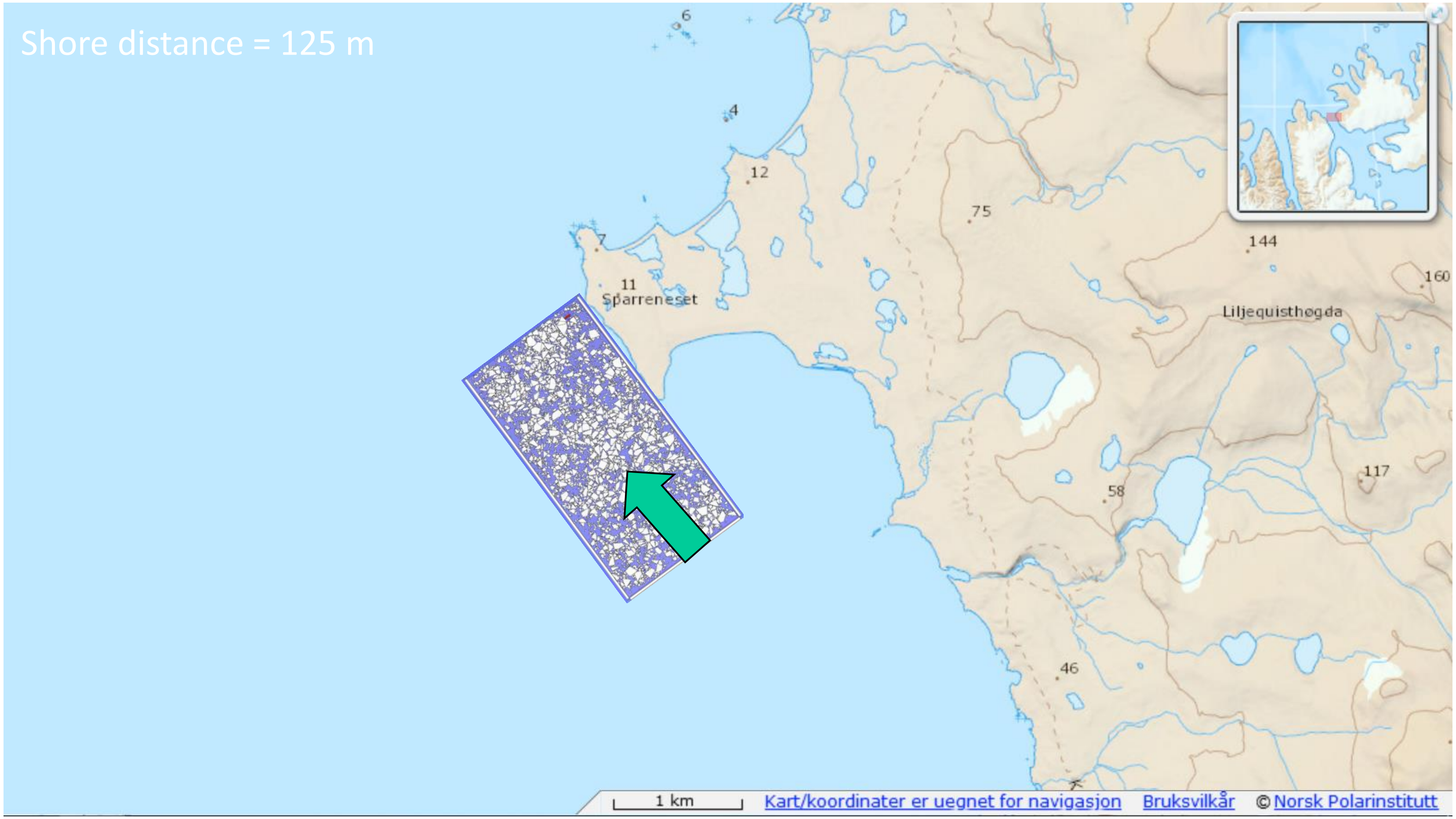
Simulations

Advanced simulation set-up



ArcISo

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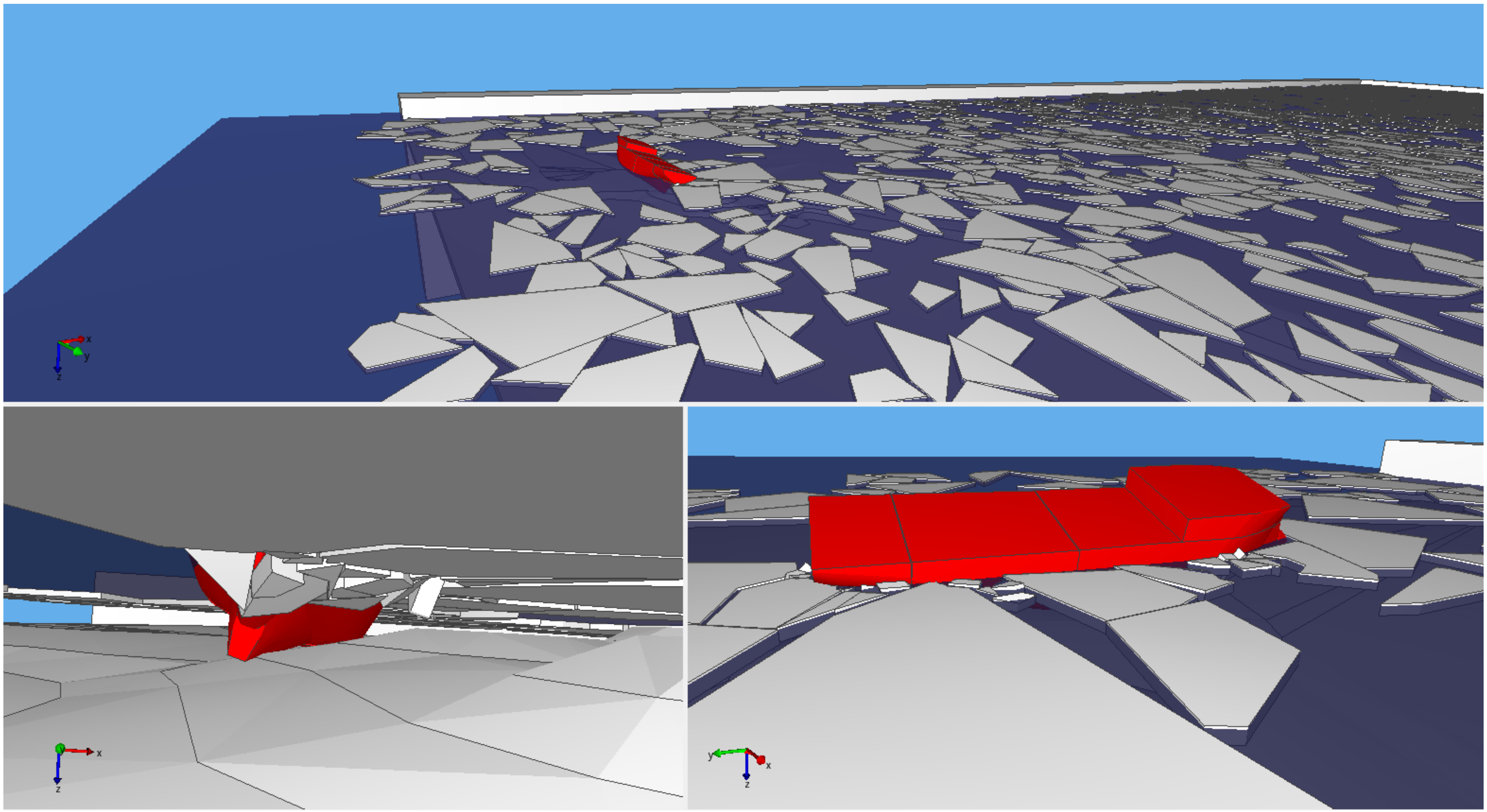
More Simulation Scenarios

Ship listing 17°



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