Glacial Ice and Offshore Structure Impacts under Wave and Current Excitation

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NTNU

Kunnskap for en bedre verden

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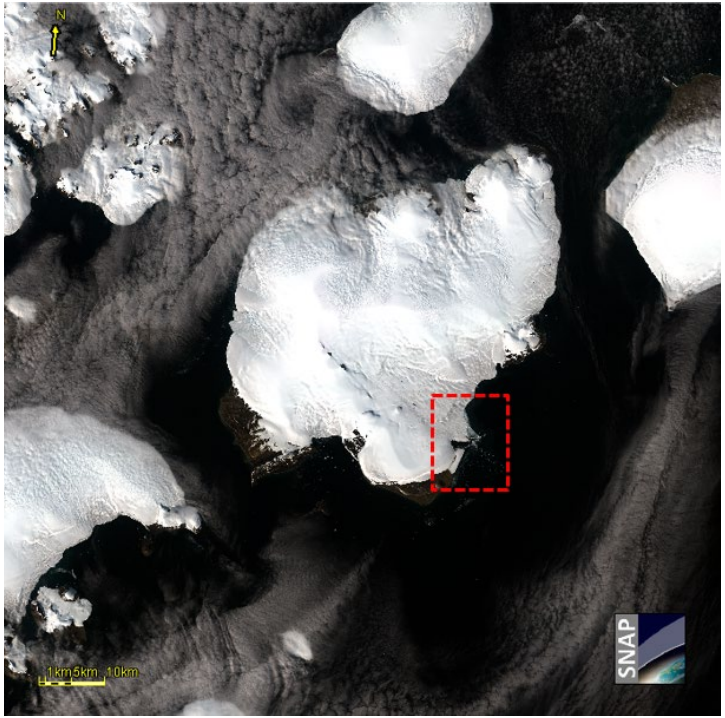
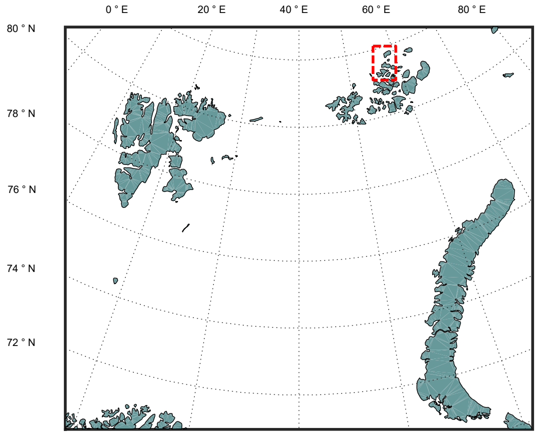
Introduction

Origin

Source

The birth of icebergs





Franz Josef Land (East)

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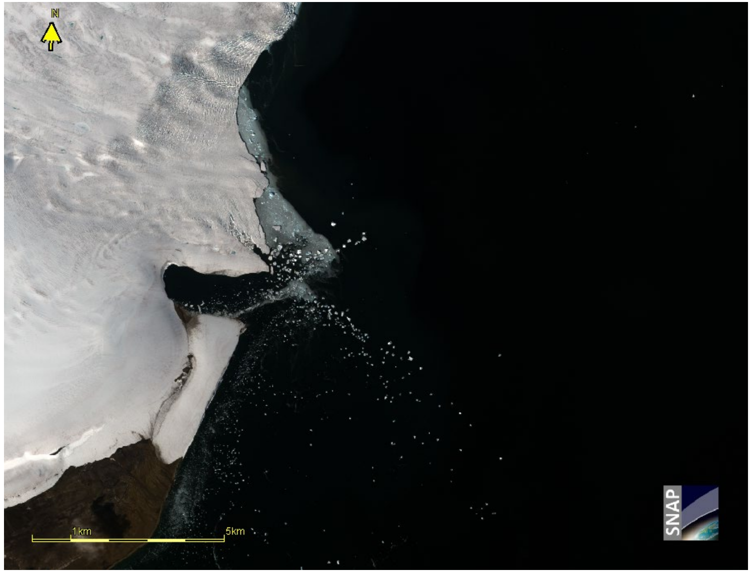

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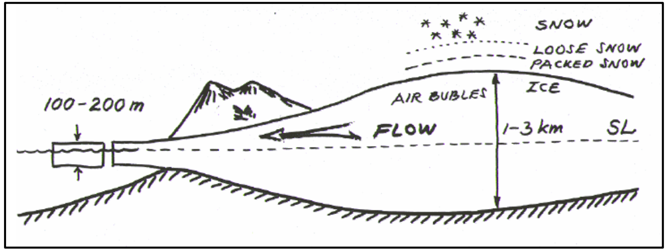

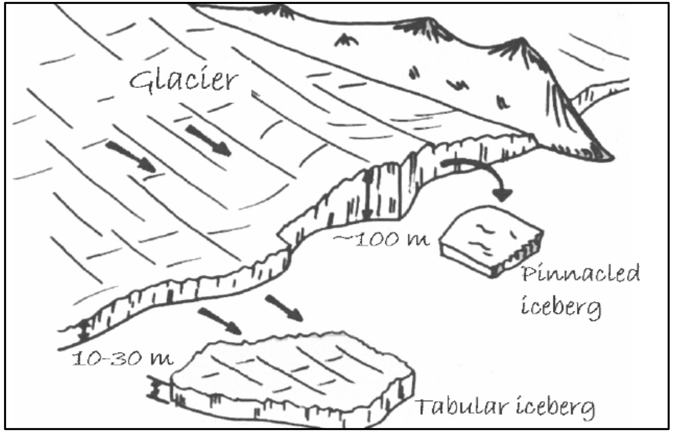

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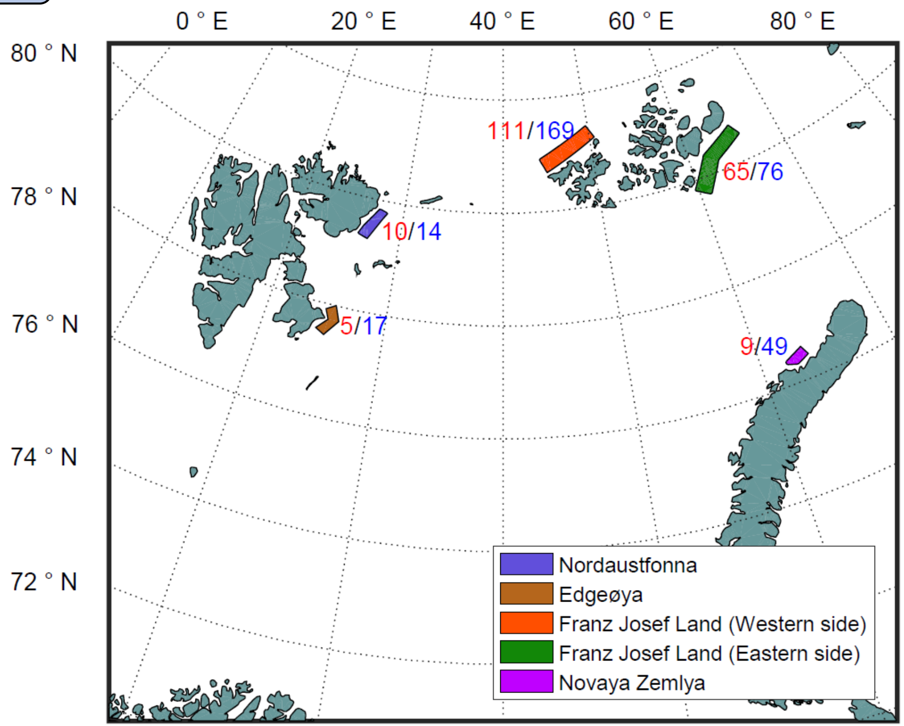
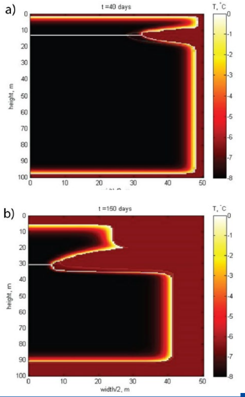
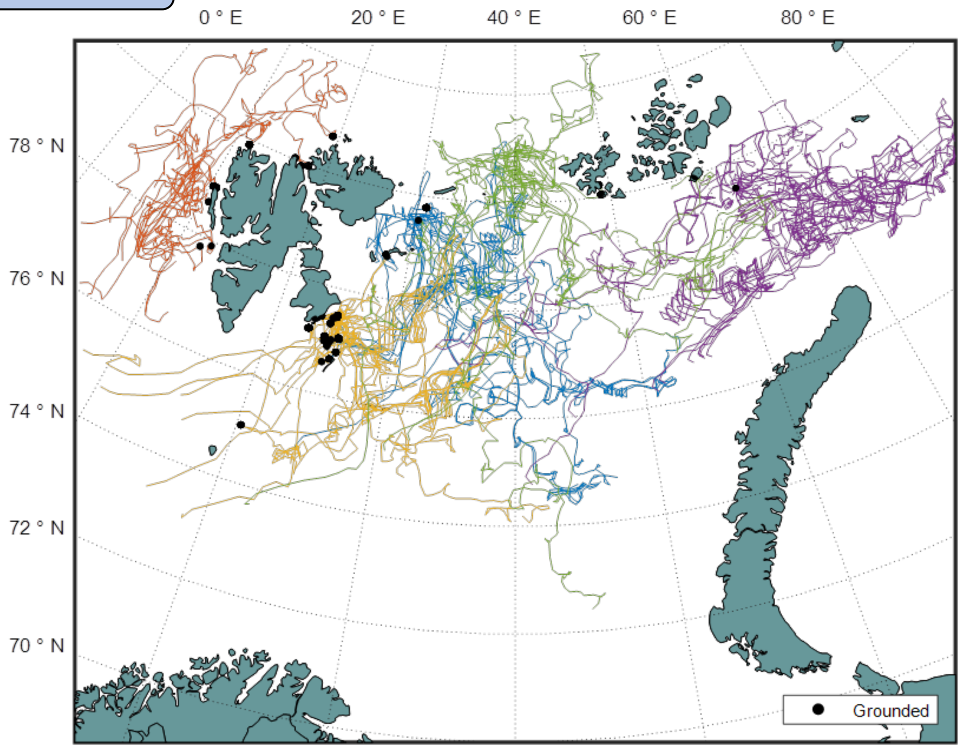


Drift

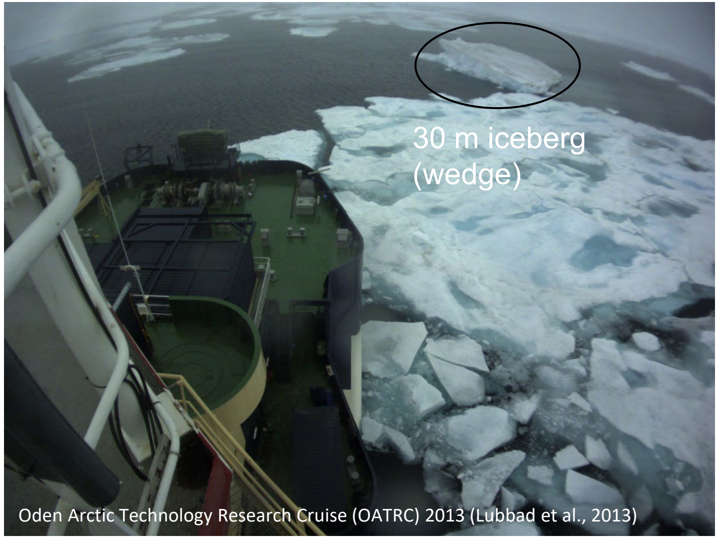
Far-field drift

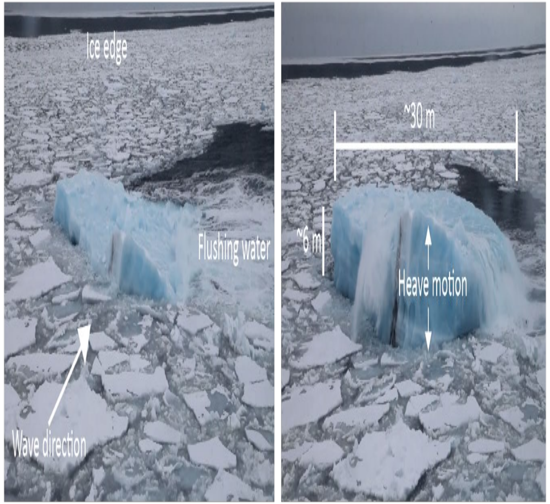




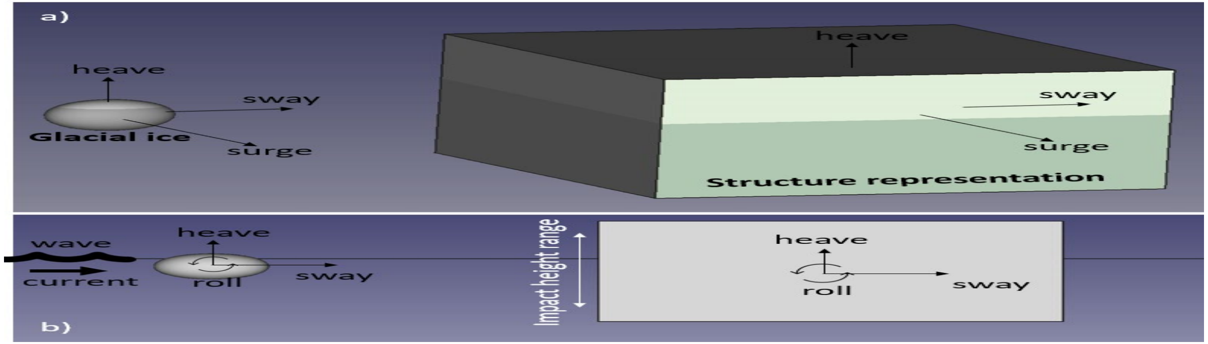
Detection

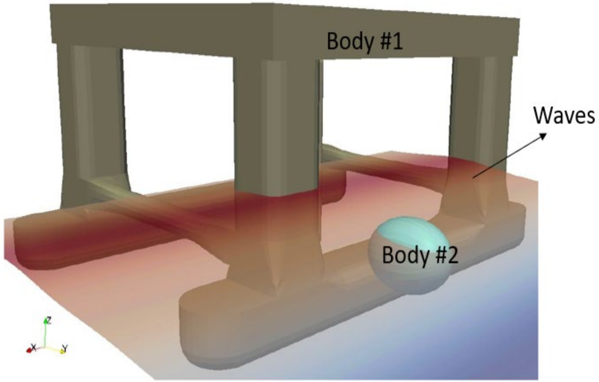
When encounter does happen, we need to find out if we can detect these glacial ice features and thereafter apply ice management operations





Motion in waves

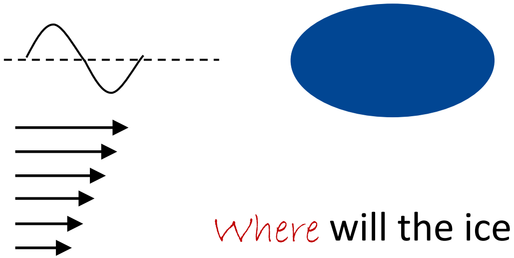




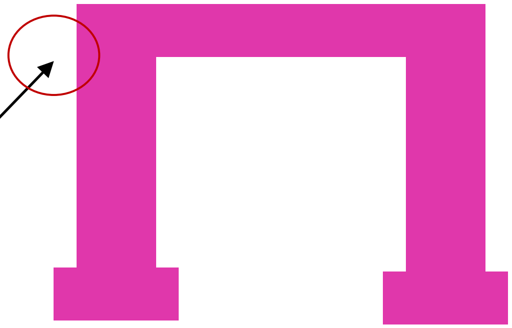
How are we going to solve this problem?

- Small glacial ice features are often interested as they are difficult to detect and manage
- Relative motion between the glacial ice and offshore structure can potentially lead to impact at unstrengthenned location

Principle sketch



Where will the ice feature hit the structure? And at what speed?

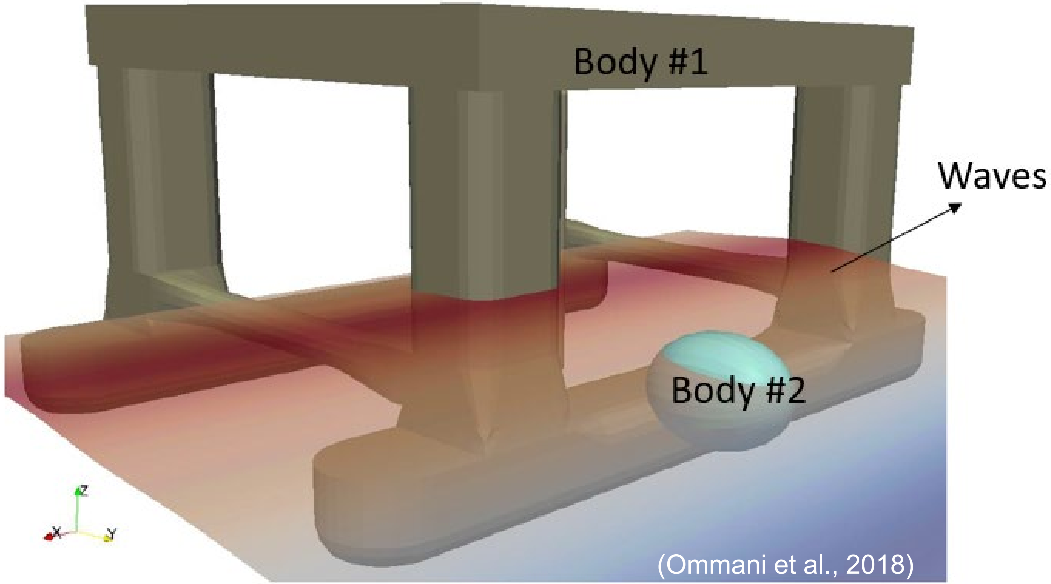


What is the fraction of the total incoming kinetic energy that will be ***dissipated by crushing the ice and deforming the structure.***

We call this part: demand for energy dissipation

The analysis method to estimate this is called External Mechanics

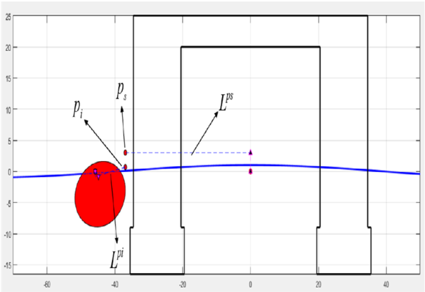
The rest of the incoming kinetic energy will be transferred to rigid body motions



How are we going to solve this problem?

Relative Motions

Wave direction



Wave elevation:

$$\eta_v = \eta_0 \cos(\omega t - kx - \phi)$$

Wave particle horizontal displacement:

$$\eta_h = \eta_0 \sin(\omega t - kx - \phi)$$

Point p_s's heave with reference to structure 'M':

$$\eta_3^{ps} = \left|H_3^{p1}(\omega)\right| \eta_0 \cos(\omega t - kx - \phi) + L^{ps} \left|H_5^{p1}(\omega)\right| \eta_0 \cos(\omega t - kx - \phi)$$

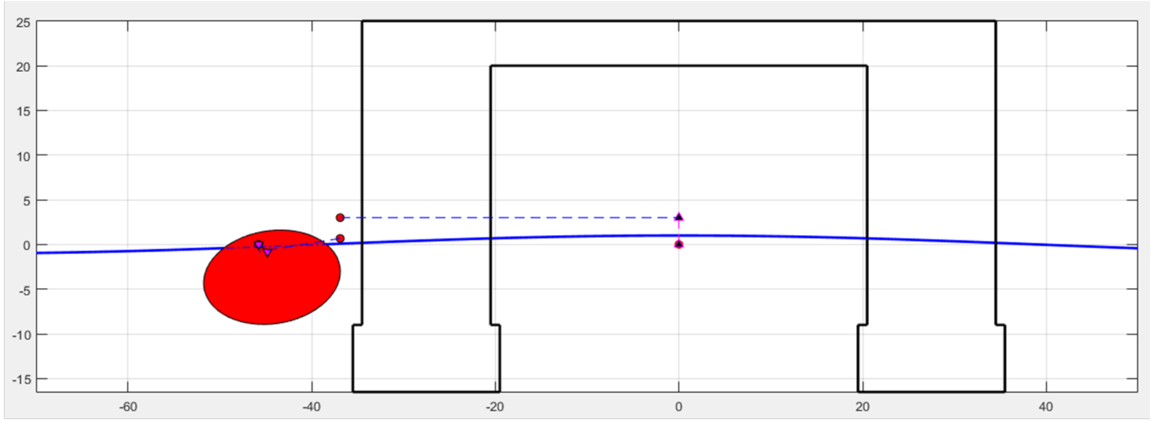
Point p_i's heave with reference to glacial ice 'M':

$$\eta_3^{pi} = \left|H_3^{is}(\omega)\right| \eta_0 \cos(\omega t - kx - \phi) + L^{pi} \left|H_5^{is}(\omega)\right| \eta_0 \cos(\omega t - kx - \phi)$$

- Based on linear wave theory
- Response Amplitude Operators (RAOs) of both the structure and the glacial ice are available

RAOs $H(\omega, \beta)$

Relative Motions



Relative vertical displacement:

$$\Delta\eta = \eta_3^{ps} - \eta_3^{pi}$$

Point p_s 's sway velocity:

$$\dot{\eta}_2^{ps} = \omega \left| H_2^{p1}(\omega) \right| \eta_0 \cos(\omega t - kx - \phi)$$

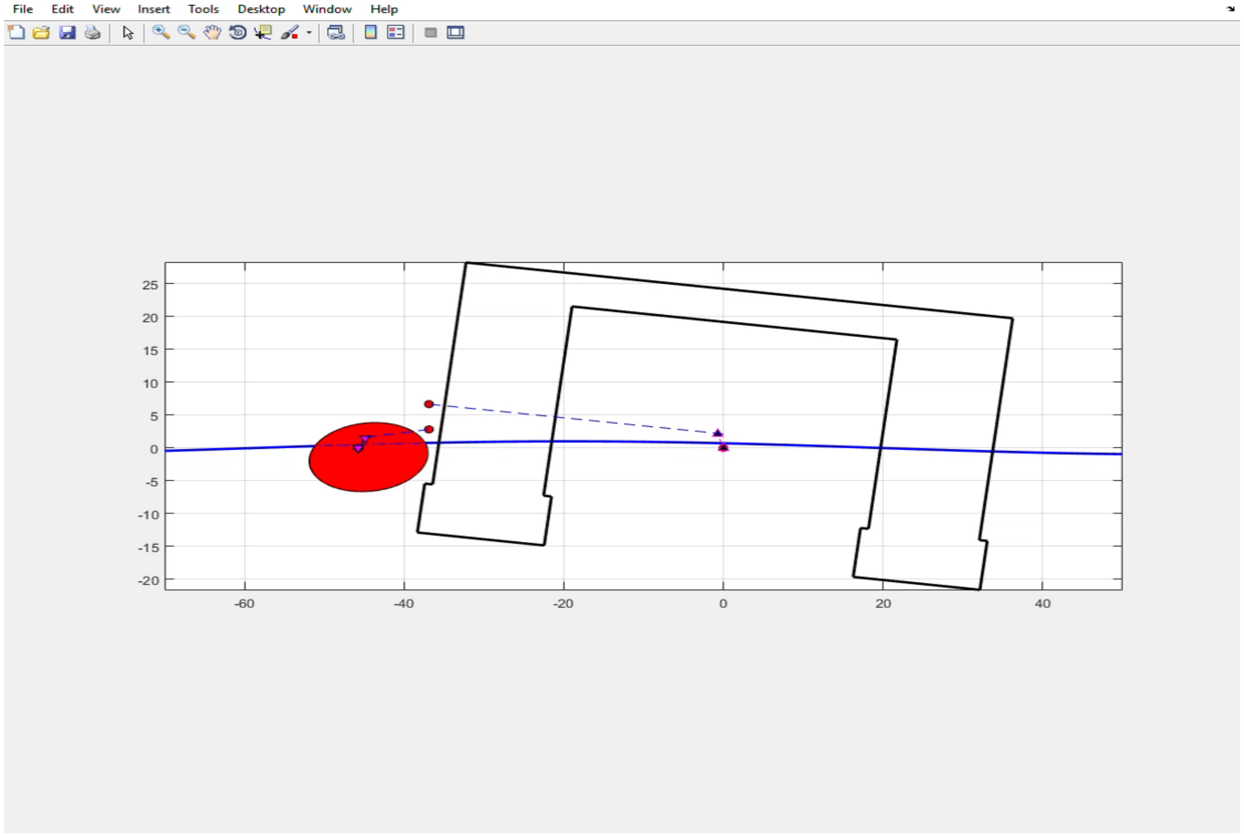
Point p_i 's sway velocity:

$$\dot{\eta}_2^{pi} = \omega \left| H_2^{pi}(\omega) \right| \eta_0 \cos(\omega t - kx - \phi)$$

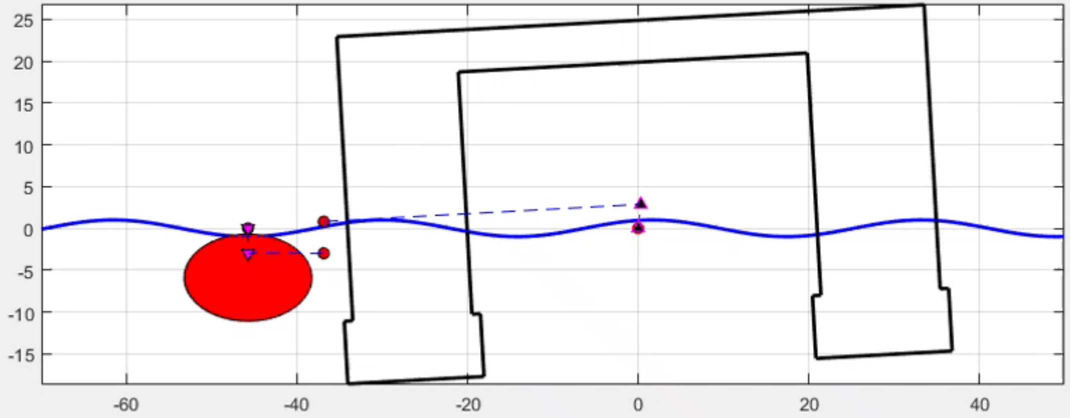
Relative vertical displacement:

$$\Delta\dot{\eta} = \dot{\eta}_2^{pi} - \dot{\eta}_2^{ps}$$

Relative Motions

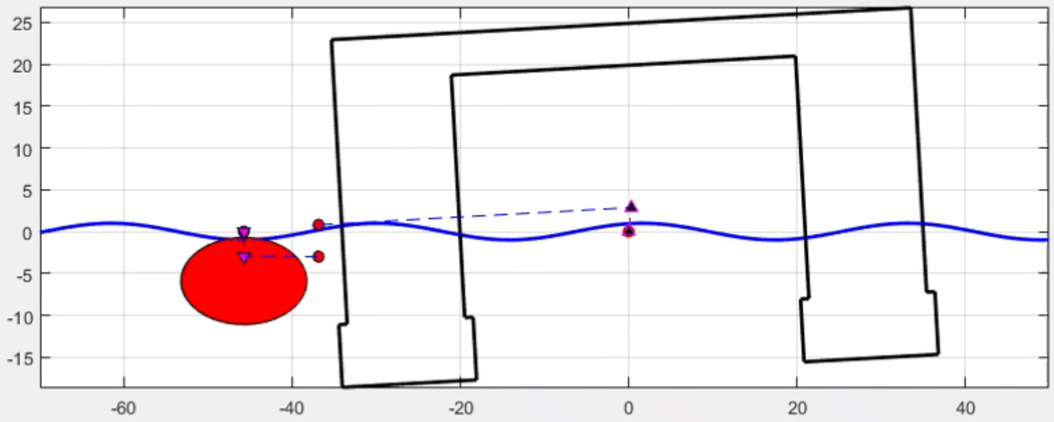


Relative Motions



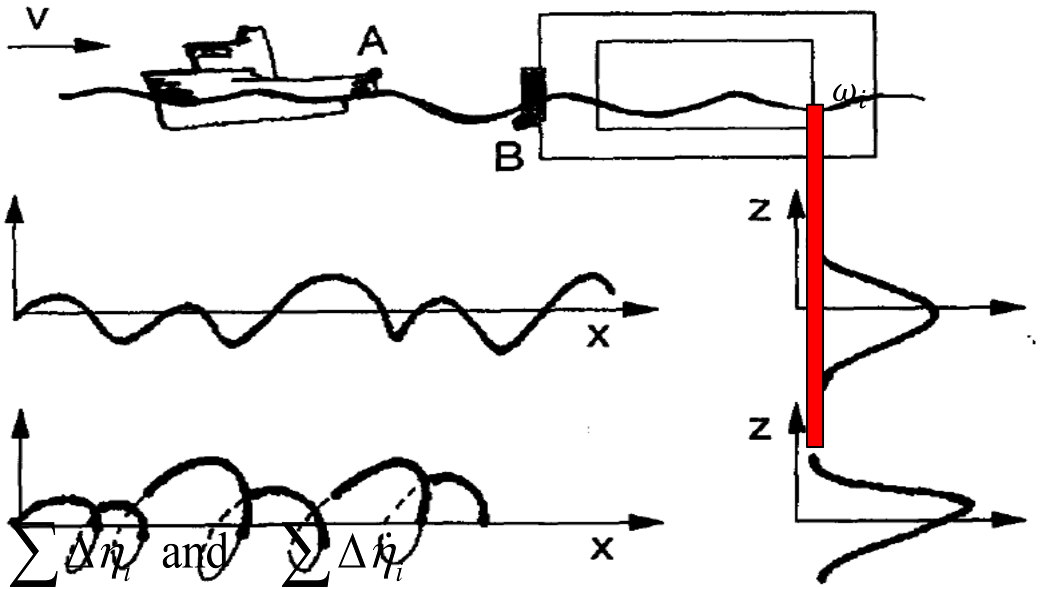
Implementing all previous equations, we can simulate the motion as above 'in time domain' or 'with various phase angle', e.g., a frequency component with a *long wave*

Relative Motions



Implementing all previous equations, we can simulate the motion as above ‘in time domain’ or ‘with various phase angle’, e.g., a frequency component with a *short wave*

Relative Motions



$$S(\omega) \rightarrow \sum \Delta\eta_i \text{ and } \sum \Delta\dot{\eta}_i$$

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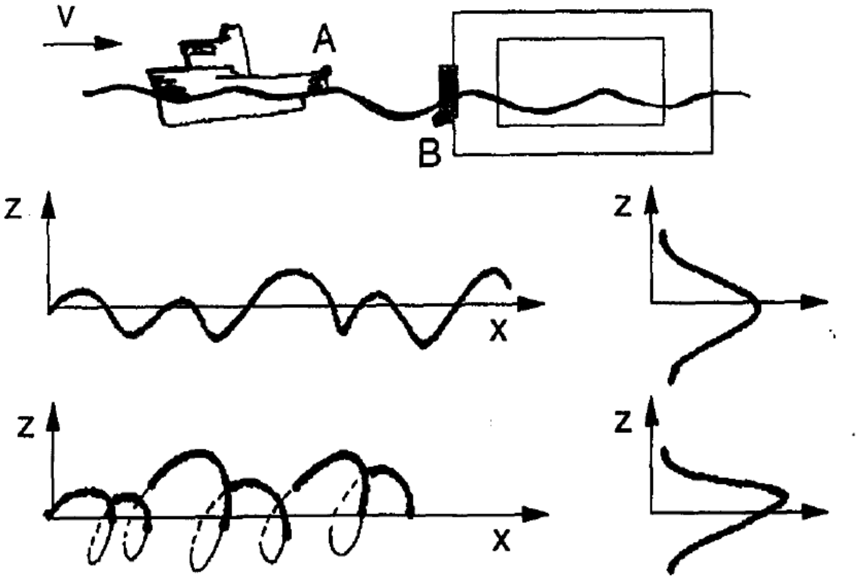
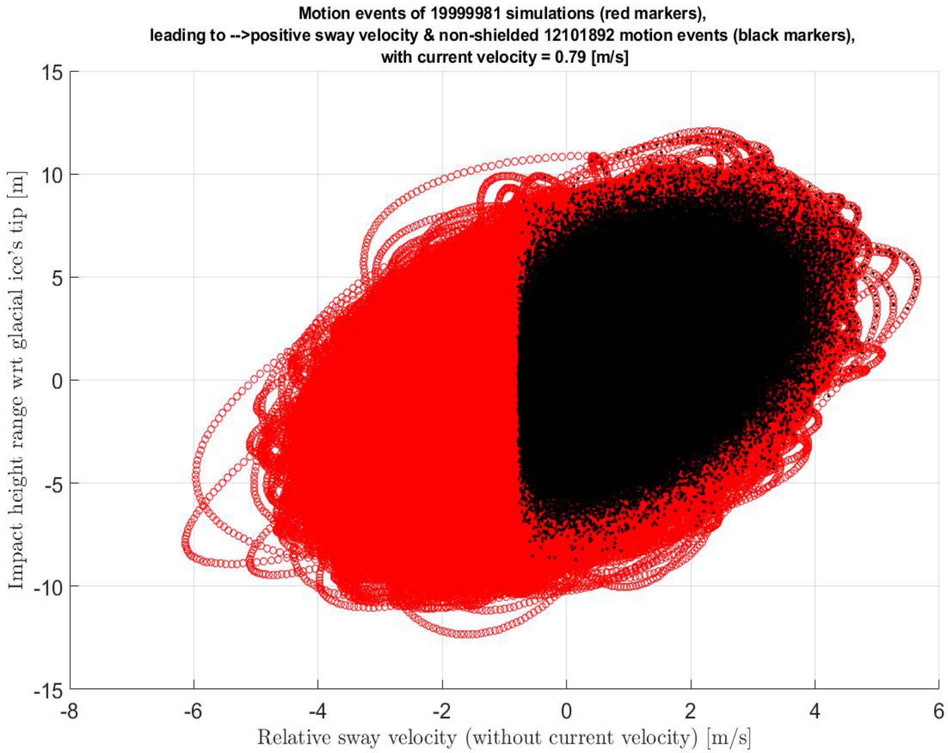
Impact Events Sampling



Fylling (1994)

- Positive impact velocity
- Non-shielded trajectories

Impact Events Sampling



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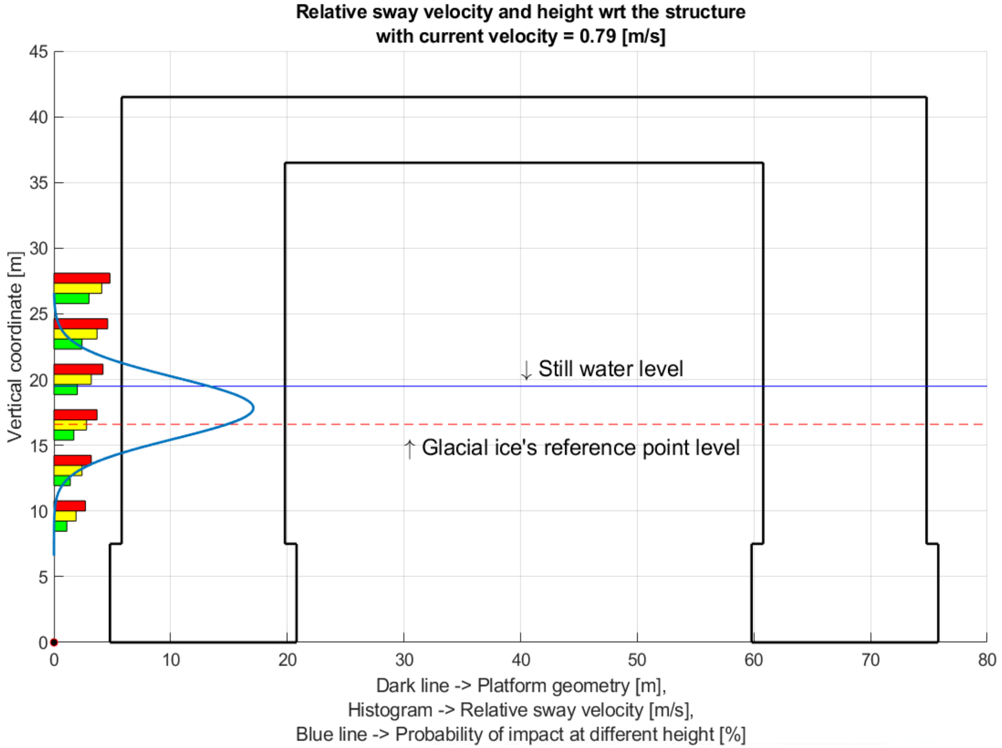
Impact Events Sampling



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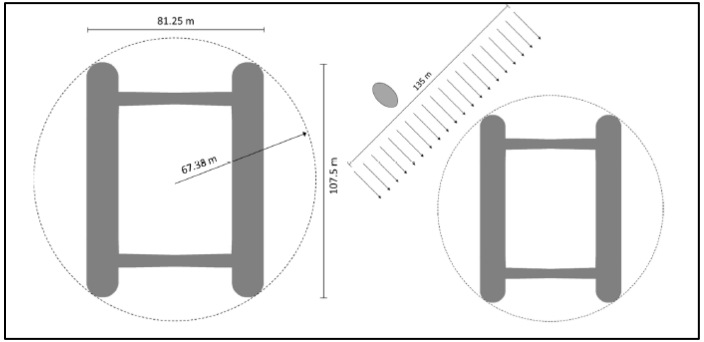
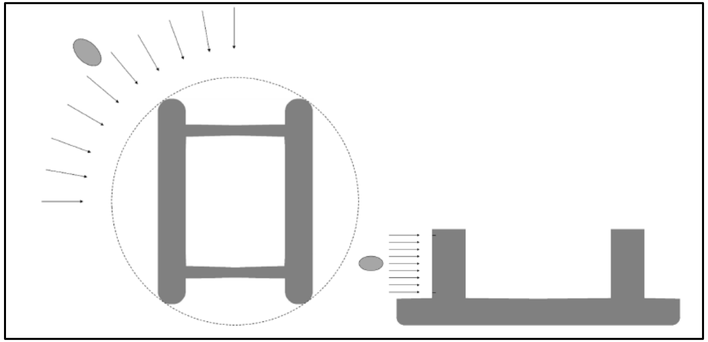
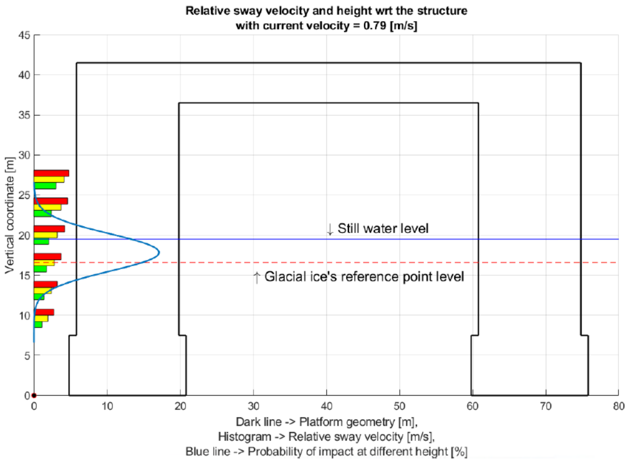
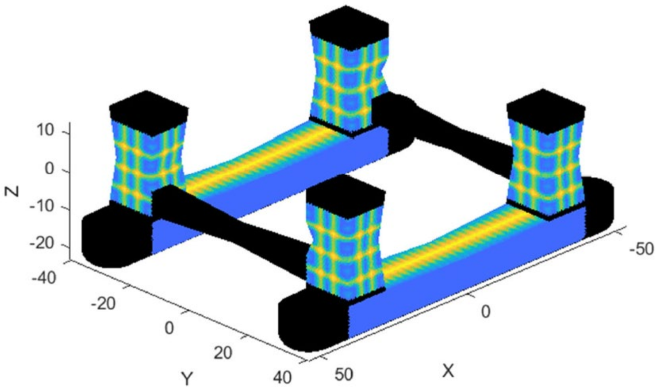
Impact Analysis

A combination of internal and external mechanics

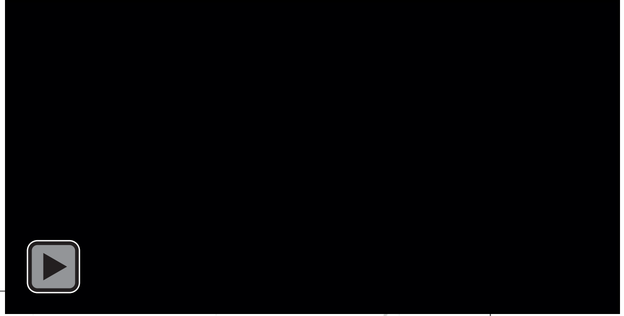


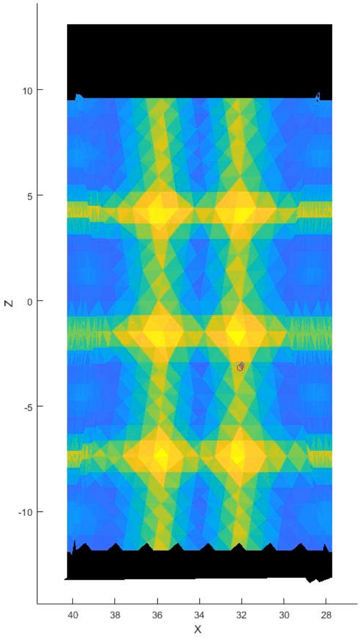


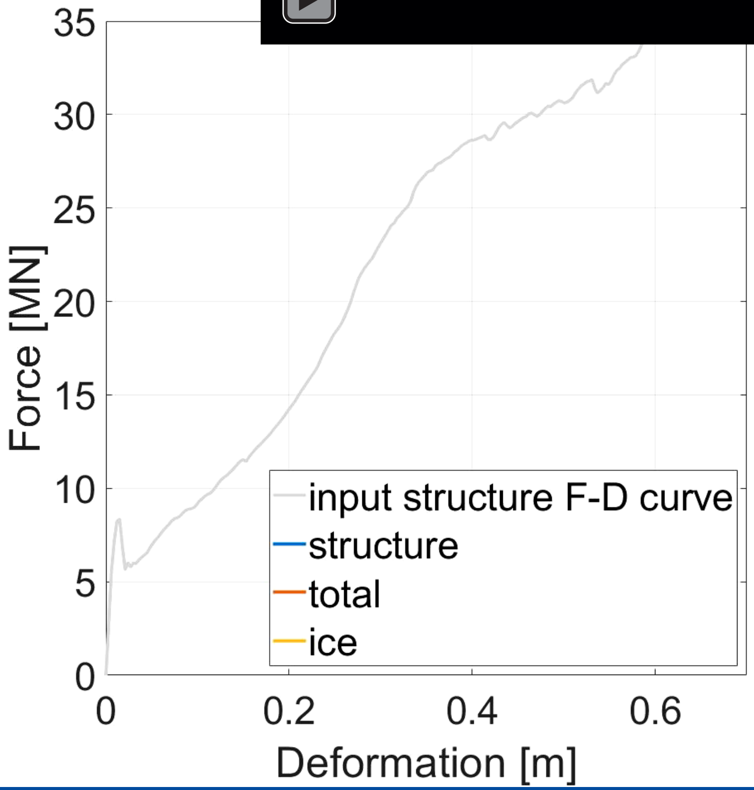




Impact Analysis

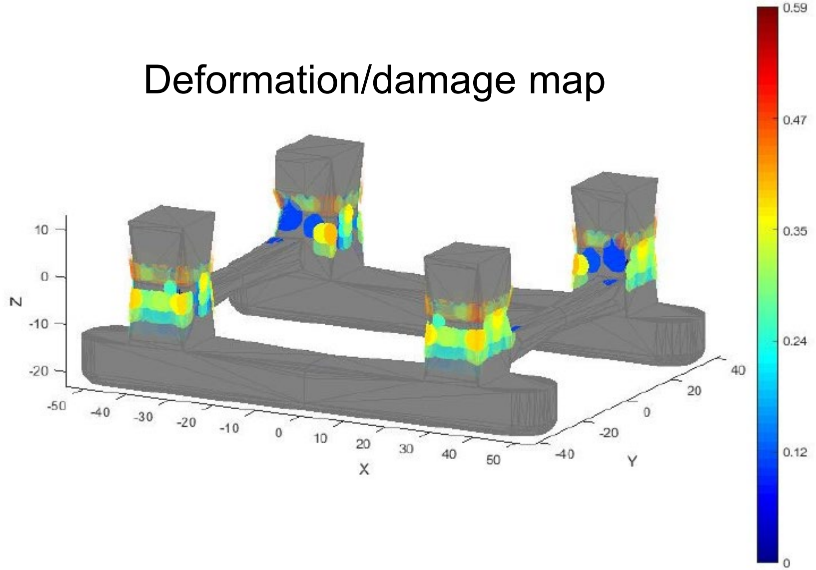






Impact Analysis

Deformation/damage map



- Maximum deformation is around 0.6 m
- 90% of the impact location has a deformation less than 0.36 m

Conclusion

- The horizontal impact velocities increase with the impact height
- The most probable horizontal impact with the ice tip occurs around the SWL

- The proposed method is rather effective in construction a large amount of potential impact events (i.e., in the order of millions) from which, sensible distributions of impact information can be obtained.