



# Unresolved issues in ice-structure interactions

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TU Delft



KIVI NIRIA

■ 170

34<sup>e</sup> lustrum

170 jaar TU Delft

Arctic Battle  
Symposium - 8 March 2012

# Ice-structure interaction: impression



Lunskoye-A gravity based platform

# Ice-structure interaction: impression

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Arctic Battle Symposium 8 March 2012 Delft, the Netherlands

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# Ice-structure interaction: impression



<http://youtu.be/Q6OHHGrVM3g>

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# Ice-structure interaction: impression



Oil rig Kulluk

# Ice-structure interaction: impression



Artist impression of a dynamically positioned semi-submersible rig

# Ice-structure interaction: applications

## 1. Bottom founded structures: oil/gas rigs, offshore wind turbines



# Ice-structure interaction: applications

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# Ice-structure interaction: applications

## 2. Floating structures: moored rigs, dynamically positioned vessels, icebreakers



# Ice-structure interaction: applications

## 3. Artificial islands



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# Ice-structure interaction: applications

## 4. Protection of pipelines



# Ice-structure interaction: applications

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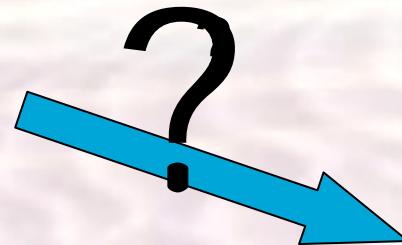
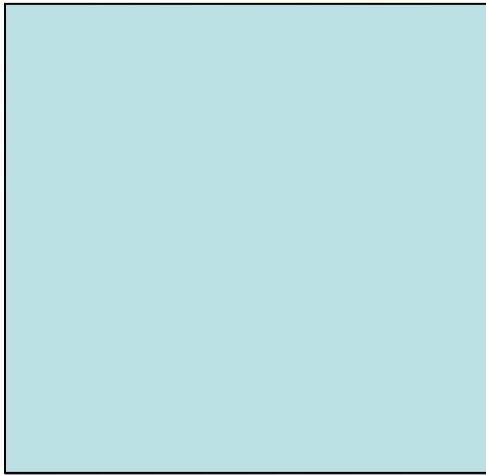
- 5. Pile driving in permafrost
- 6. Pipe laying in permafrost
- 7. Rescue vessels for the platforms in Arctic
- 8. Roads and railways in Arctic conditions

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# Unresolved Issues: Scaling

Small scale tests

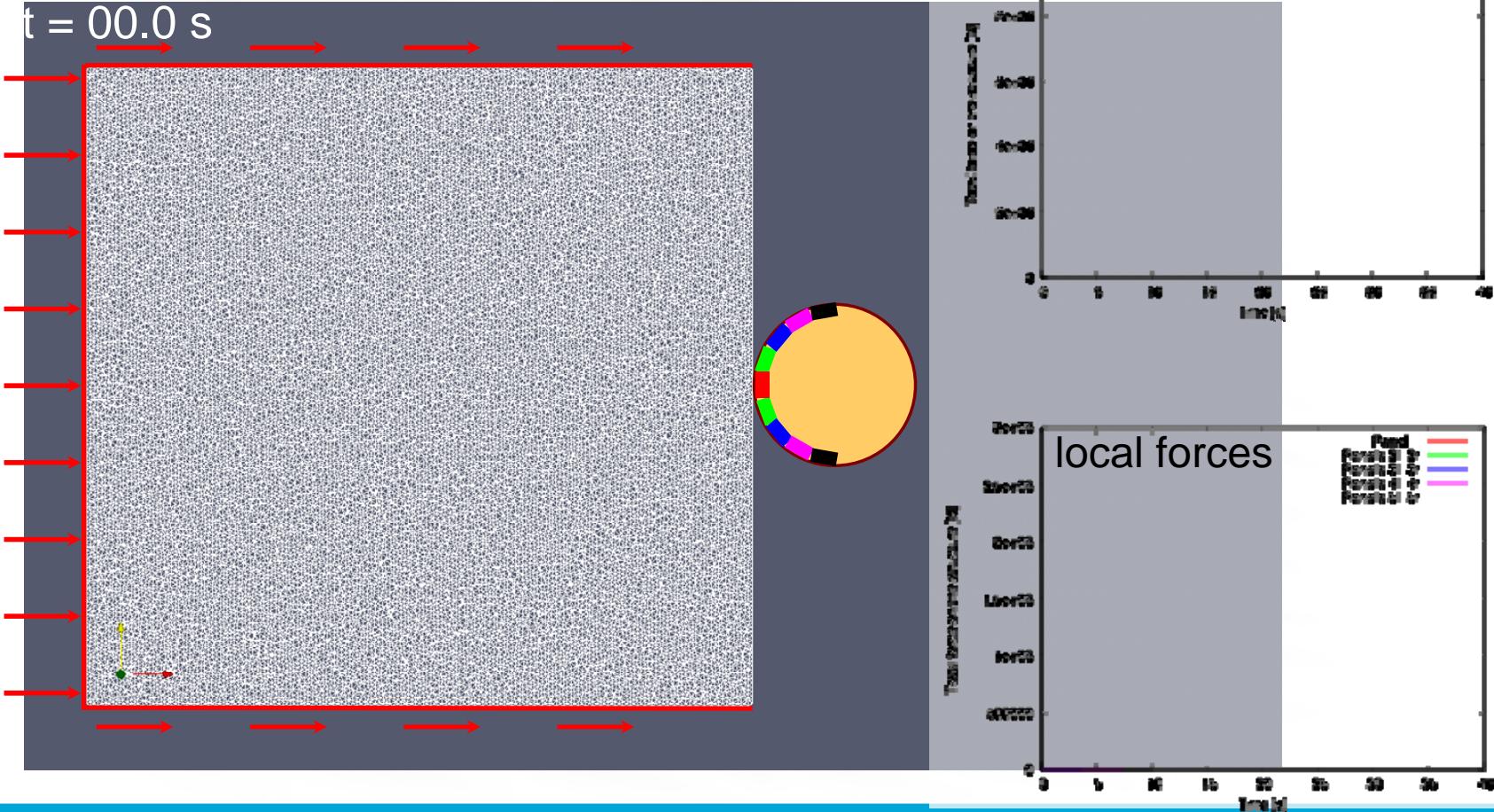


The upscaling is very (VERY) difficult because of the size effect

Actual scale



# Unresolved Issues: Scaling



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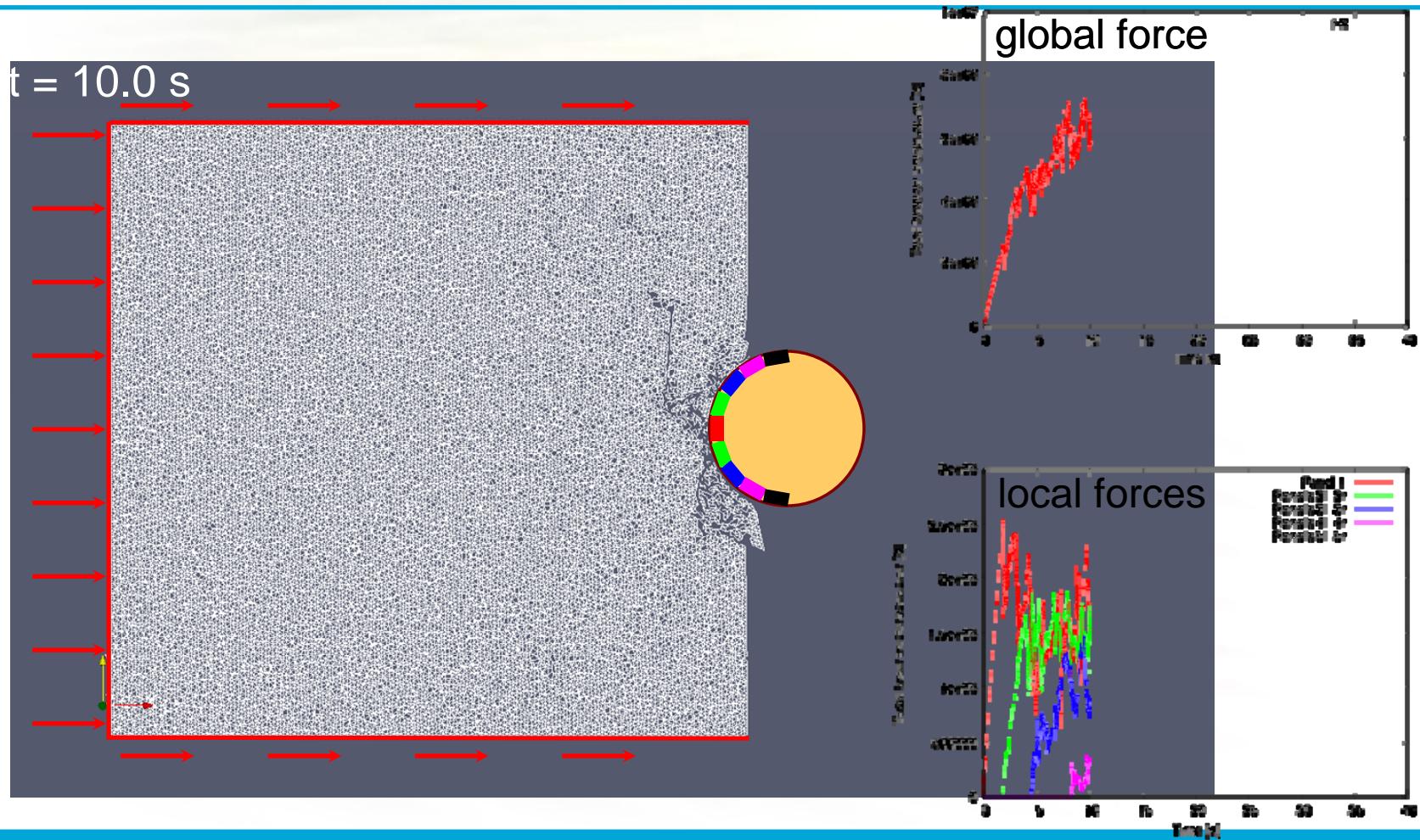
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# Unresolved Issues: Scaling



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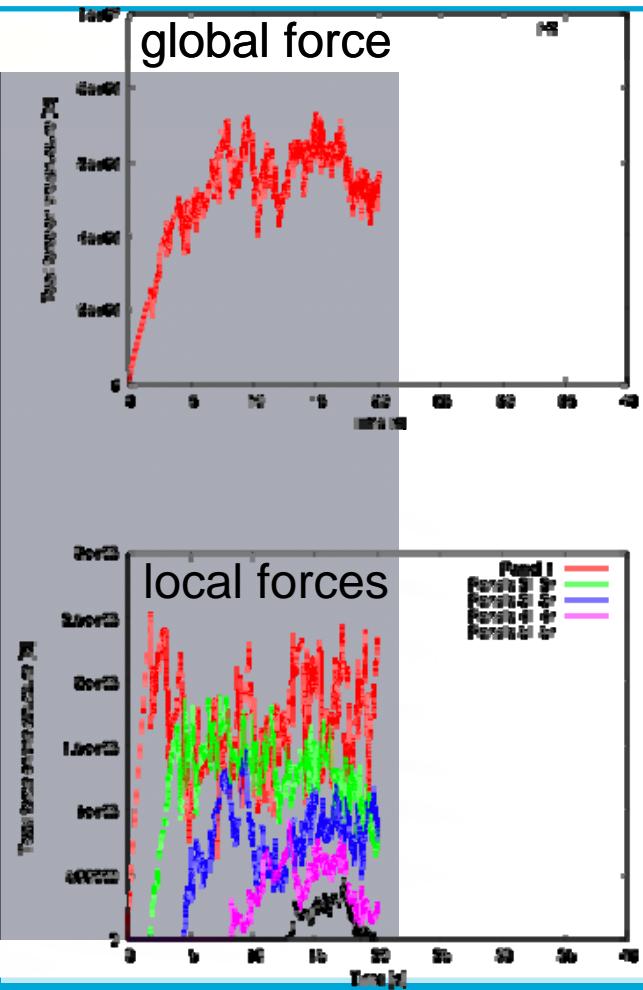
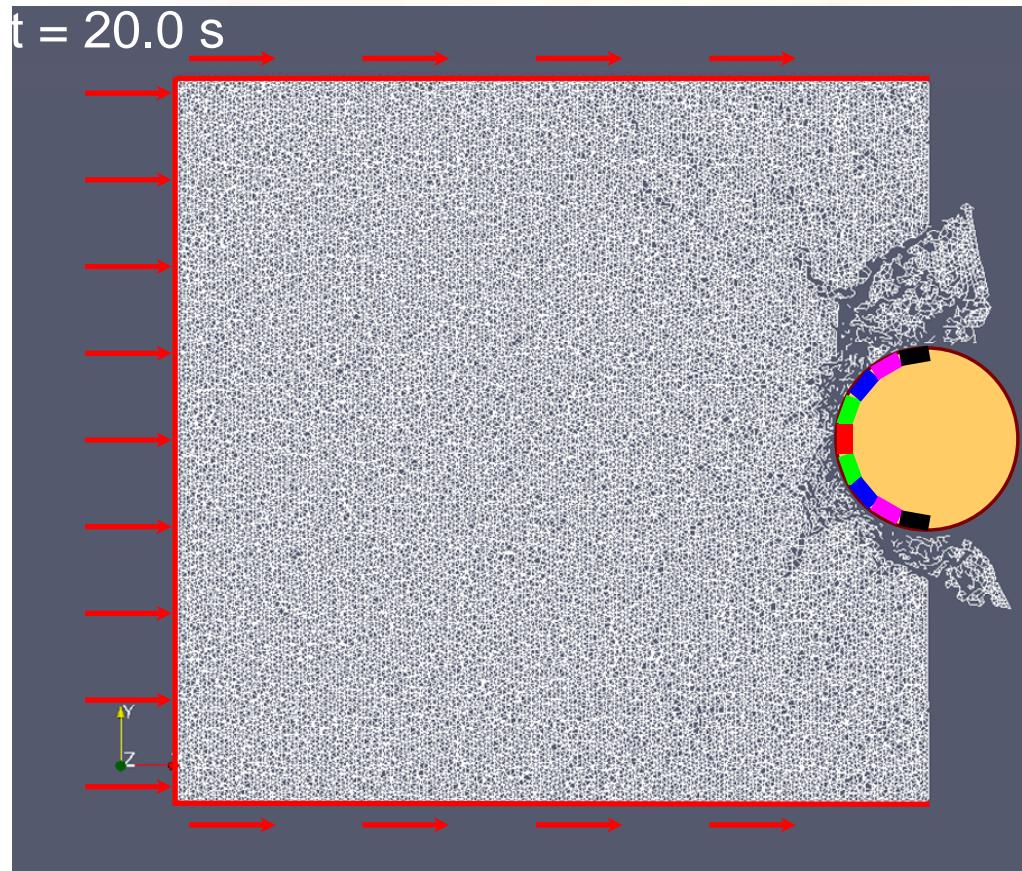
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# Unresolved Issues: Scaling



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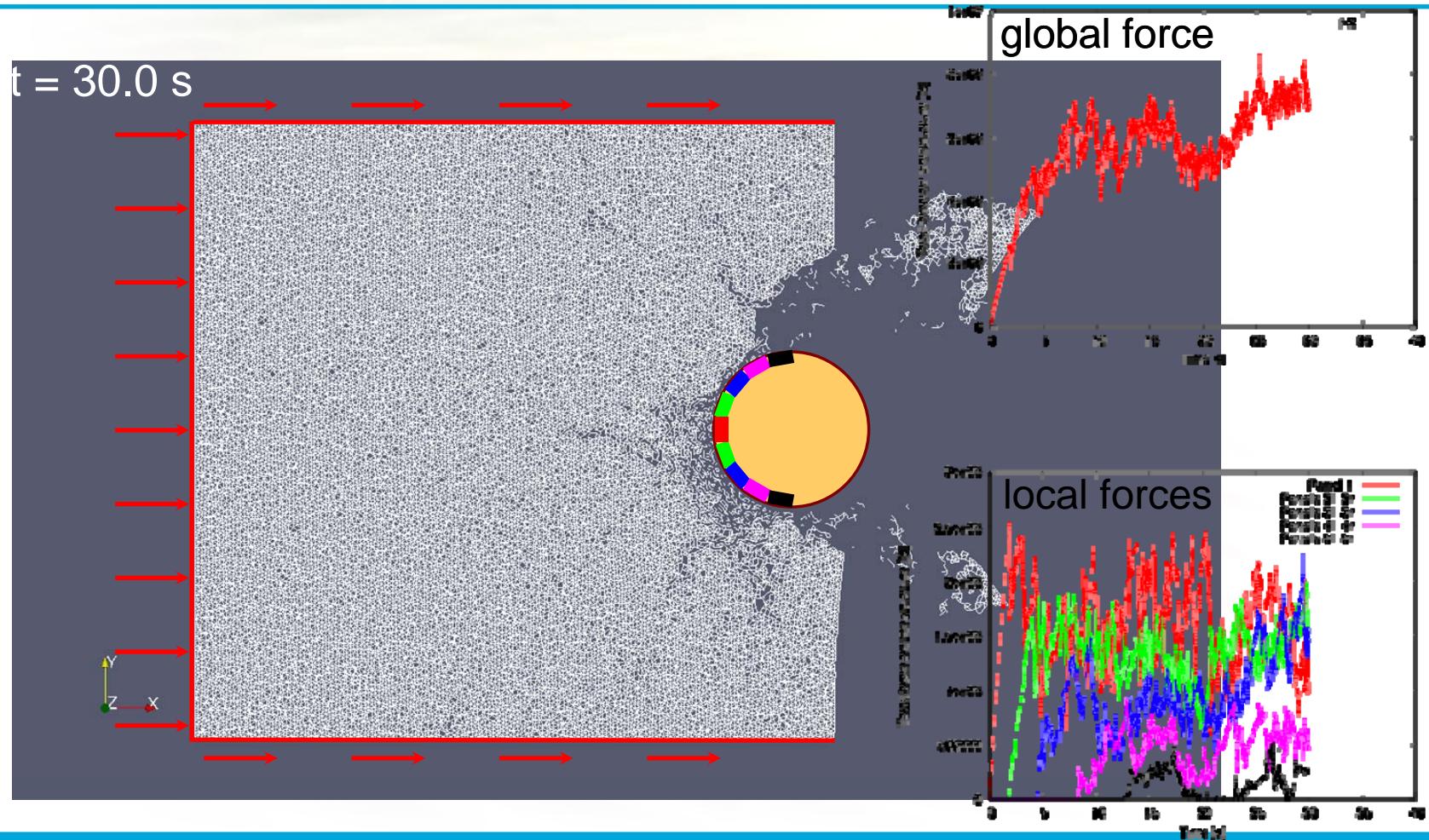
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# Unresolved Issues: Scaling



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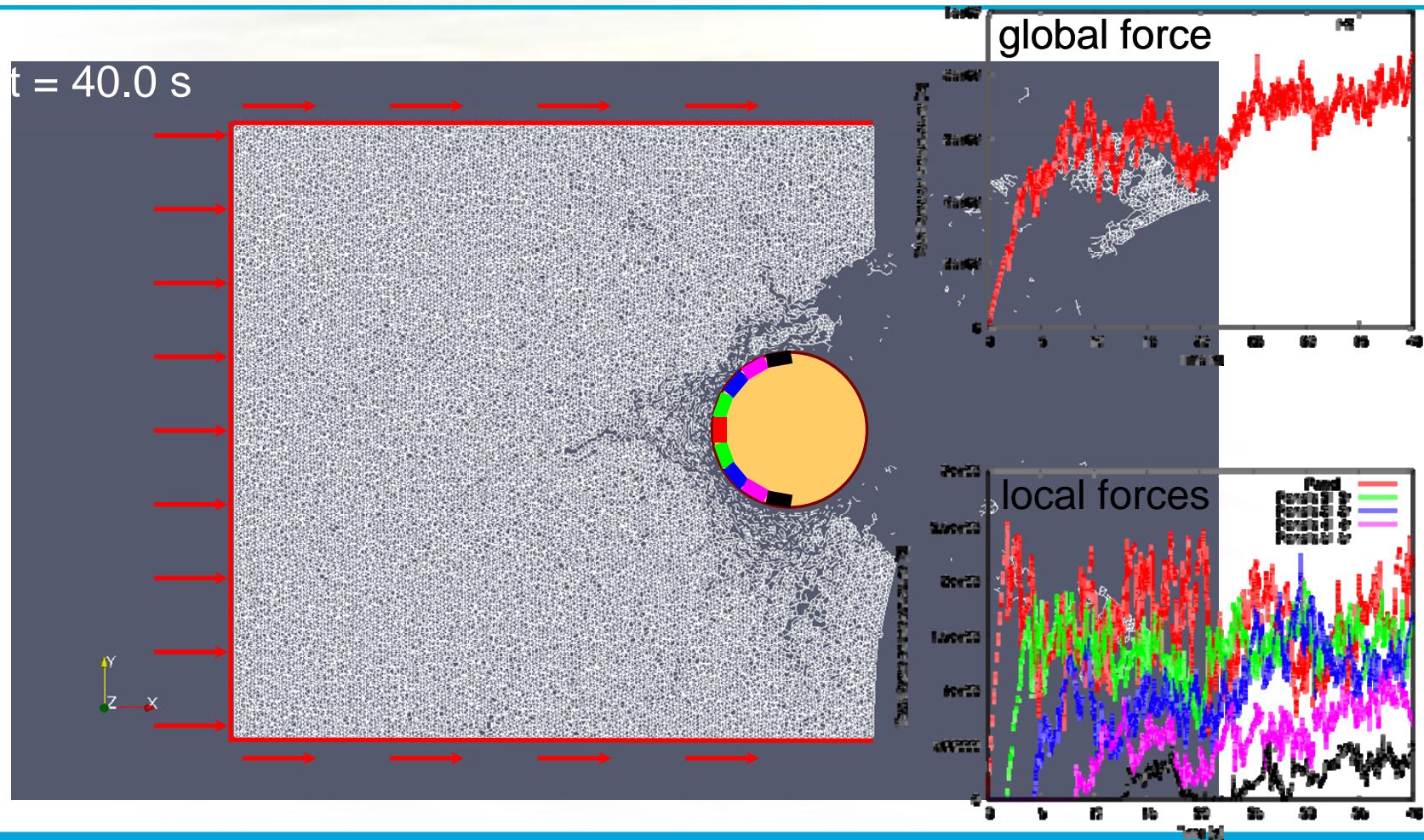
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# Unresolved Issues: Scaling



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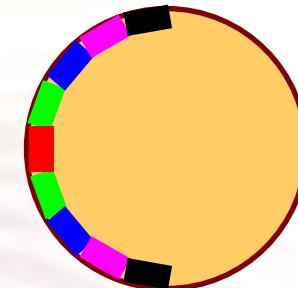
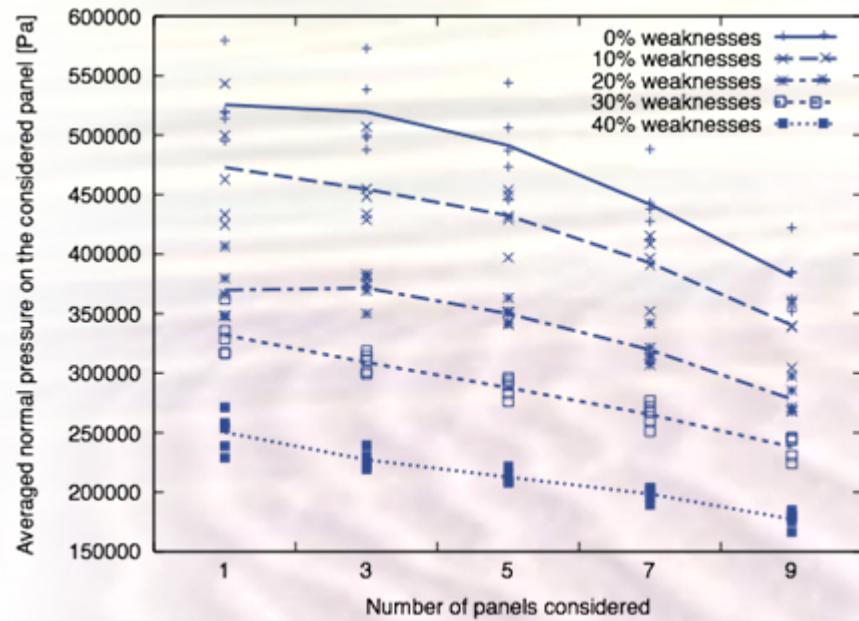
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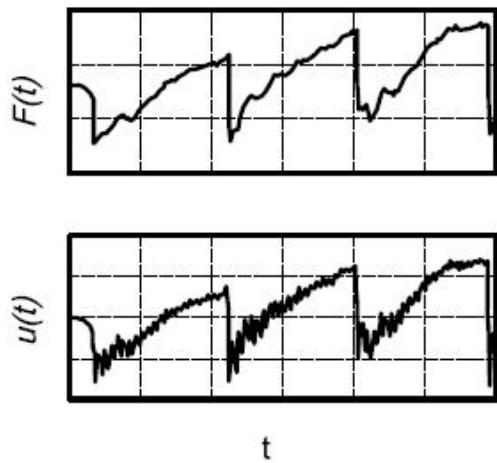
# Unresolved Issues: Scaling



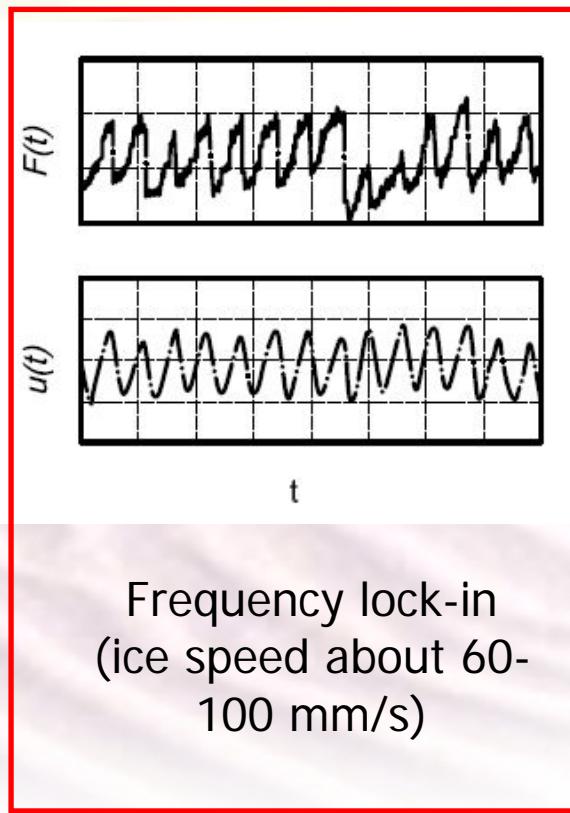
Average pressure decreases as the number of considered pressure panels increases. However, what is the decay rate???

# Ice-structure interaction: vertical structures

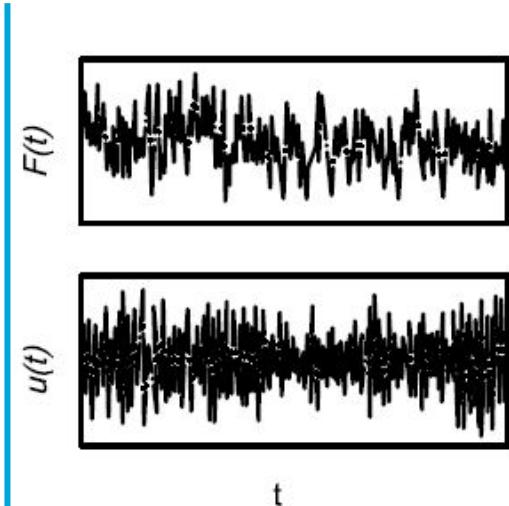
ISO 19906



Intermittent crushing  
(low ice speed)



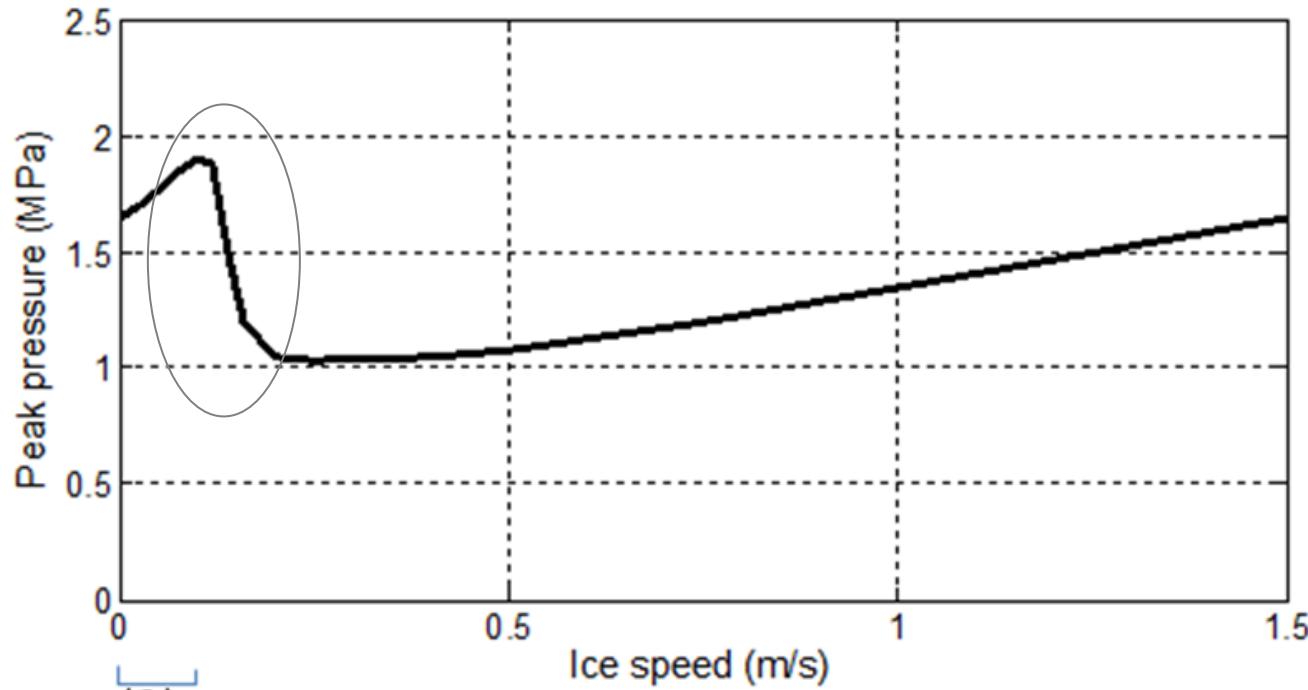
Frequency lock-in  
(ice speed about 60-  
100 mm/s)



Continuous brittle  
crushing (ice speed >  
100 mm/s)

# Ice-structure interaction: vertical structures

A theory of ice-induced vibration based on the idea of negative viscous damping



# Ice-structure interaction: vertical structures

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HYDROLAB test August 2011

Deciphering Ice-Induced Vibration

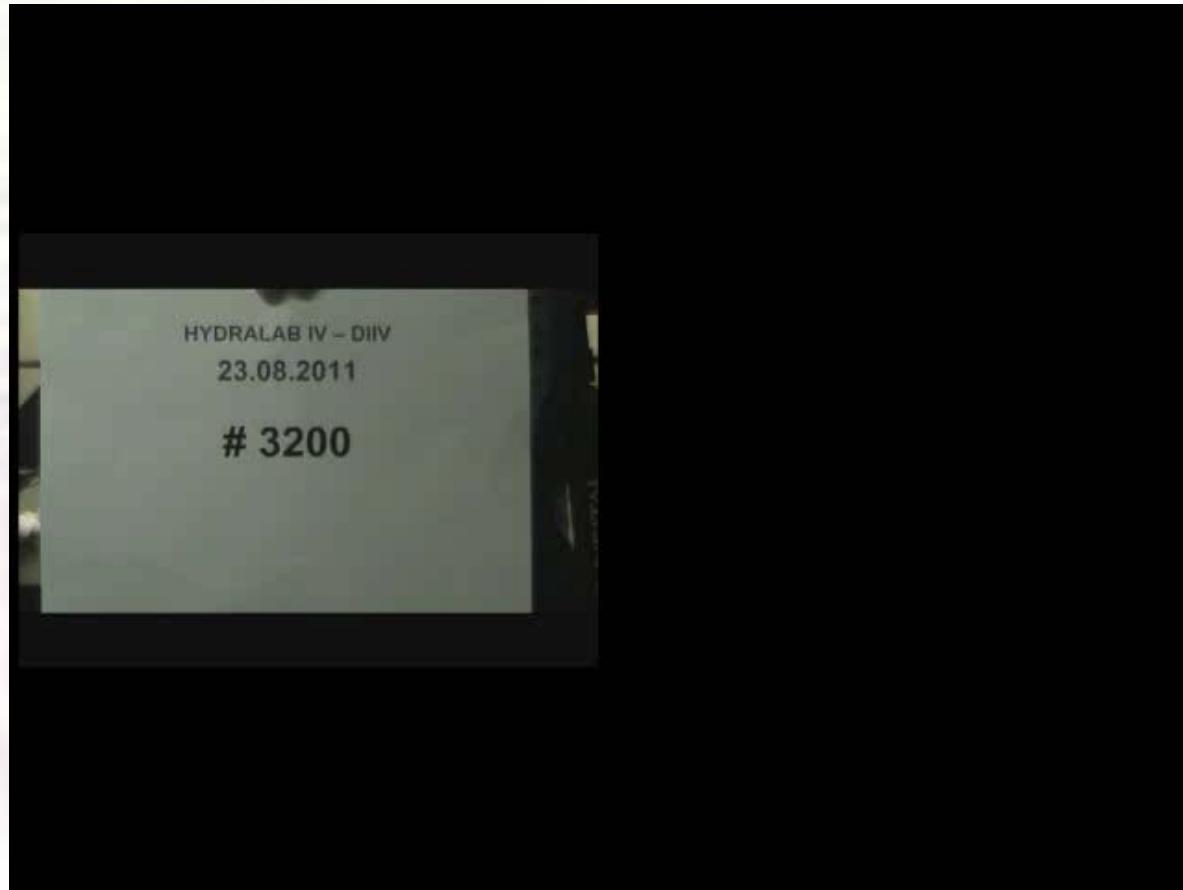
Joint effort by Helsinki University,  
NTNU and TU Delft

Movie

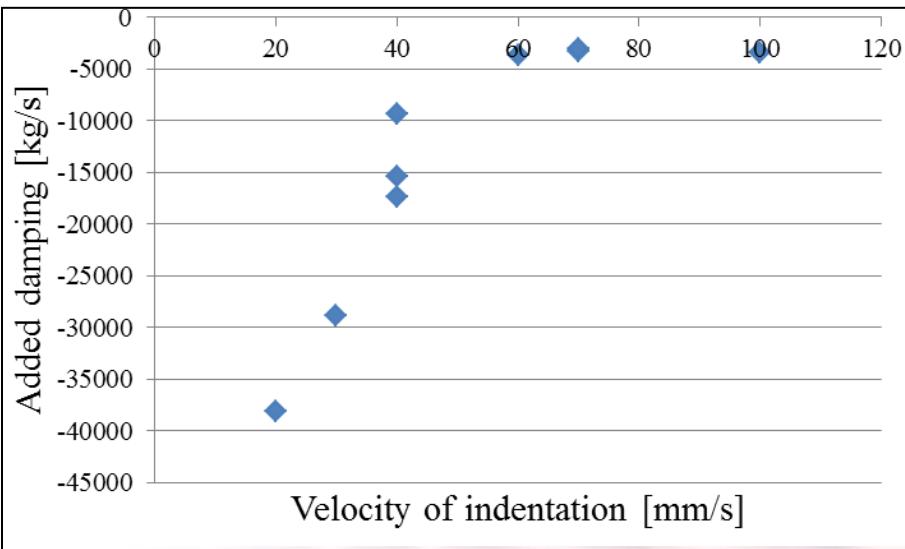


# Ice-structure interaction: vertical structures

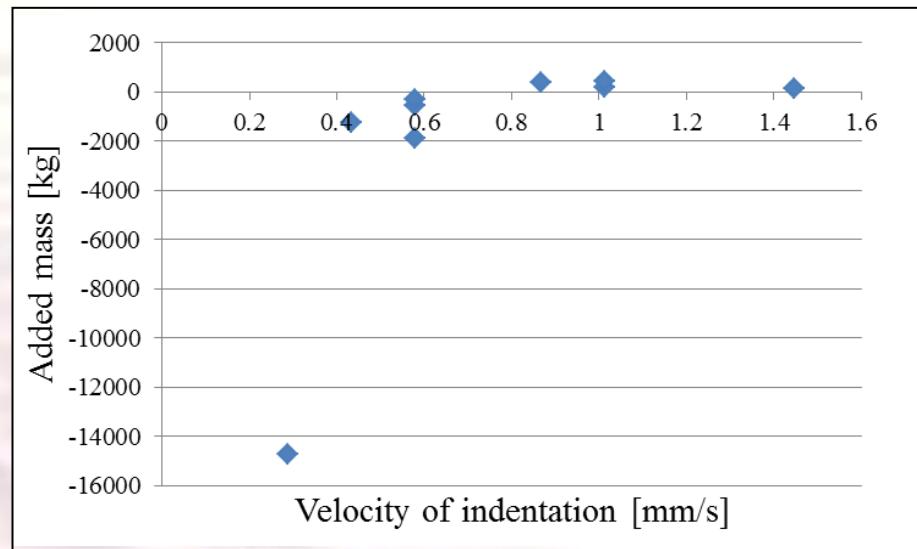
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# Ice-structure interaction: vertical structures



Added damping: negative

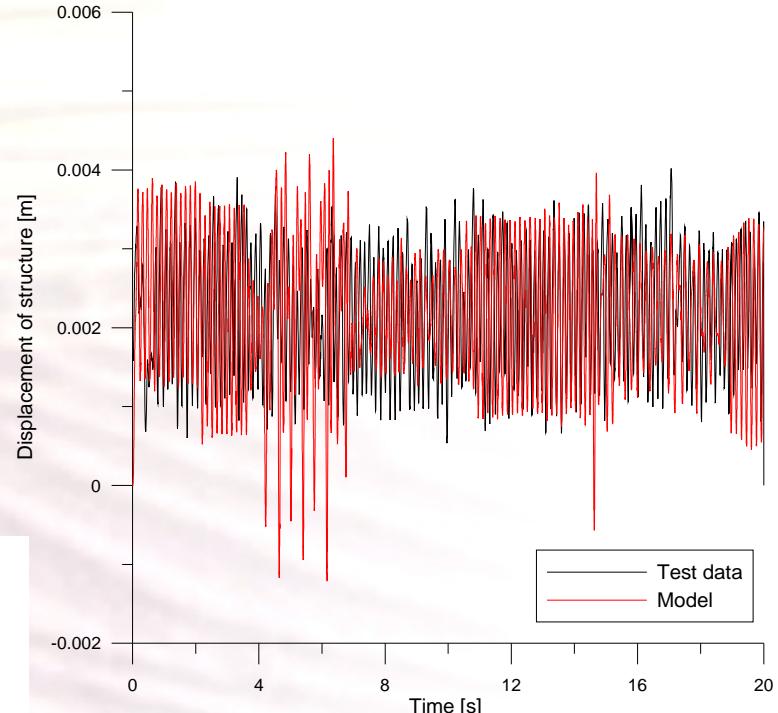


Added mass: significant and negative  
at low velocities

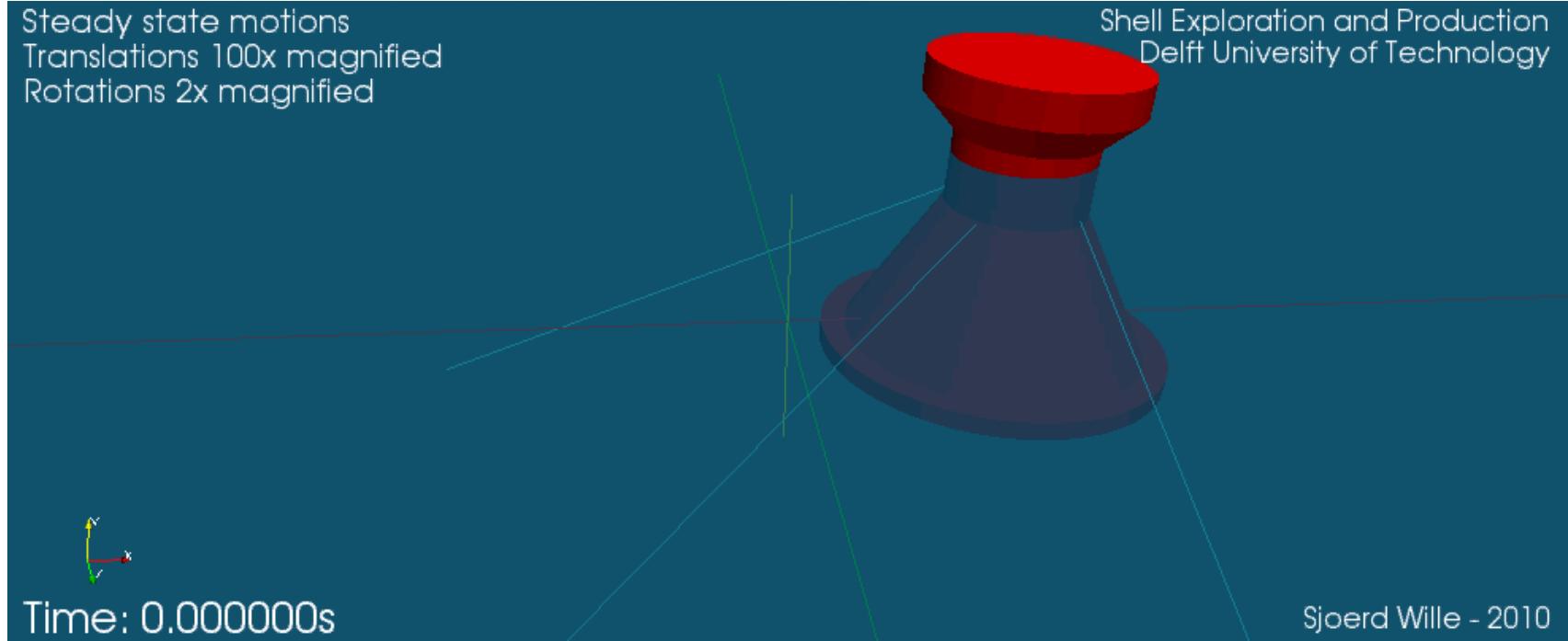
# Ice-structure interaction: vertical structures



TU Delft model is being considered as 1 of 3 remaining candidates to be used by the oil majors

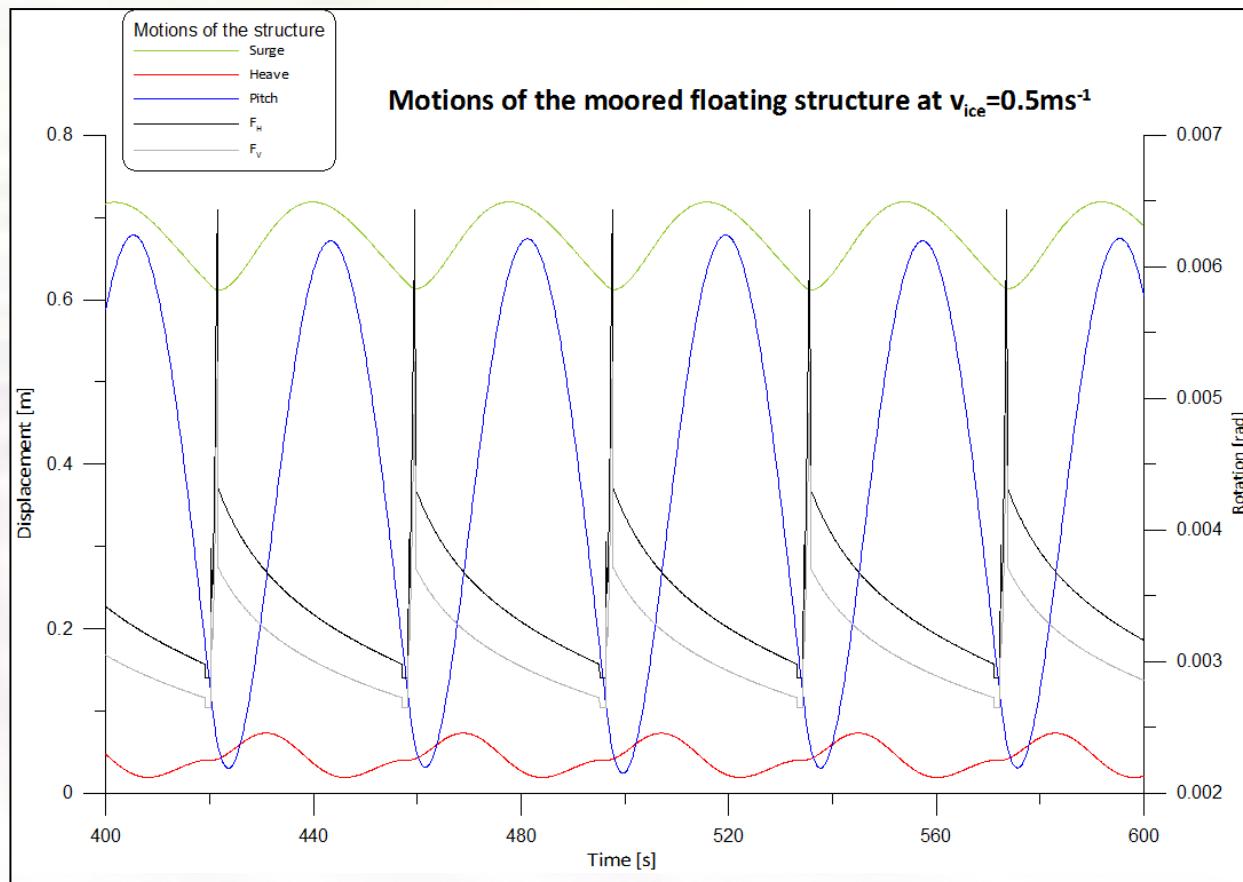


# Ice-structure interaction: conical structures



Courtesy of Ir. Sjoerd Wille

# Ice-structure interaction: conical structures

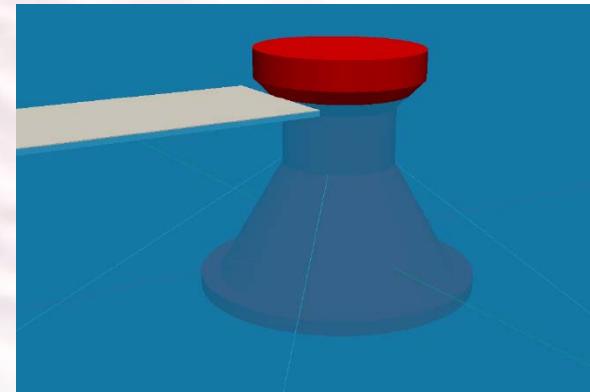


# Ice-structure interaction: conical structures

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Challenges:

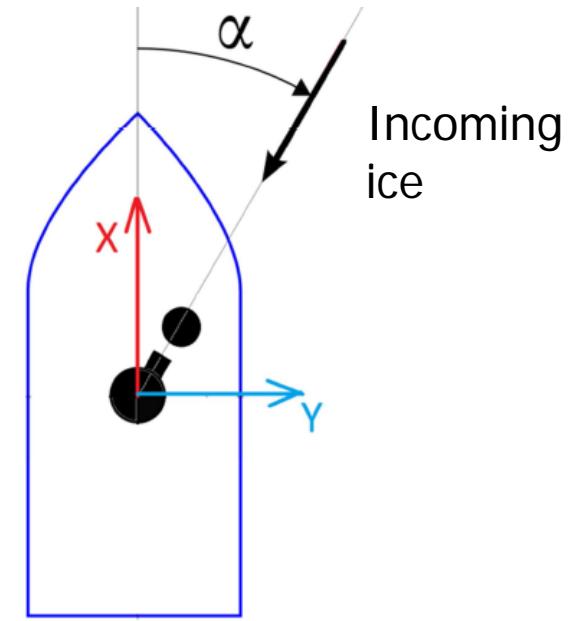
1. Pile up and ride-up/down (are there some stable accumulation patterns? Are they breathing? )
2. What kind of cracks (radial or circumferential) appear first?



# Ice-structure interaction: dynamic positioning

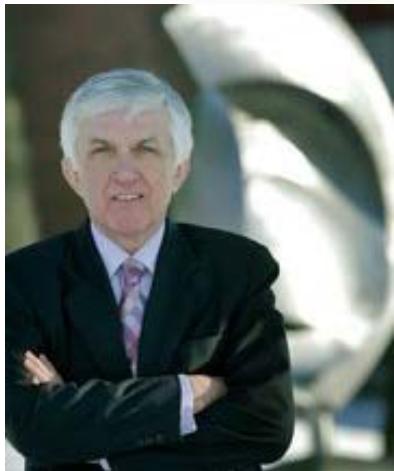
Challenges:

1. Time of flight load estimation
2. Controllability



if  $\alpha > \alpha_{\text{critical}}$  – uncontrollable

# Ice-structure interaction: team



**Gus Cammaert**



**Jeroen Hoving**



**Hayo Hendrikse**



**Andrei Metrikine**

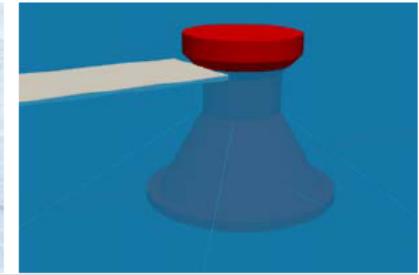
# Ice-structure interaction: team



Adriaan van Tets

## *2D Approach to Modelling of Level Ice in Interaction with a Conically Shaped Offshore Structure*

Sponsor: Shell

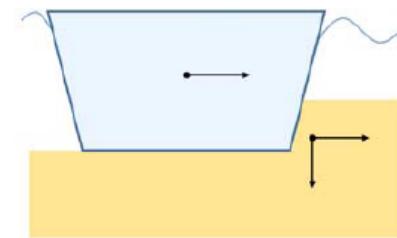


# Ice-structure interaction: team



## *Numerical analysis of soil displacements under gouging ice keels*

Sponsor: **Shell**



Alex Goeijenbier

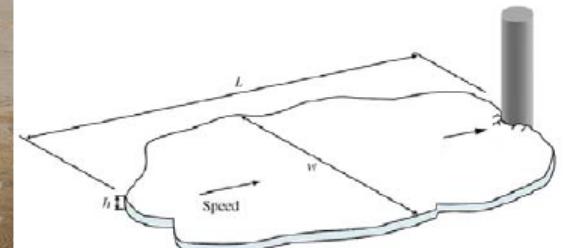
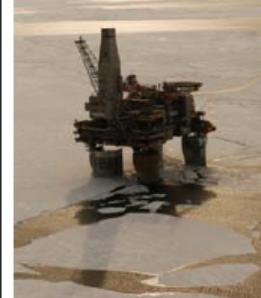
# Ice-structure interaction: team



Jan Willem Thijssen

## *Numerical analysis of floe ice loads on a four leg structure*

Sponsor: GustoMSC



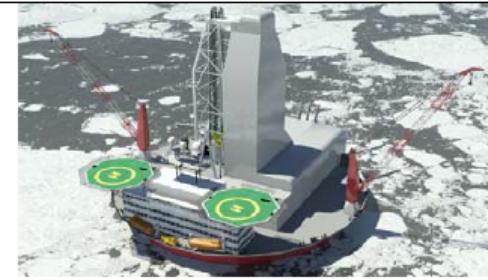
# Ice-structure interaction: team



Chris Keijdener

## *Dynamics of JBF Arctic drilling unit moored in ice*

Sponsor: **Huisman**



# Ice-structure interaction: team



María Calero

## *Dynamics of conical structures interacting with level ice*

Sponsor: MARIN



# Ice-structure interaction

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Thank you for your  
attention!

