MatchPoints Seminar, Aarhus University,12-13 Nov. 2015

Challenges and innovations related to offshore operations in the Arctic

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Norwegian University of Science and Technology (NTNU)

Director of the Centre *Sustainable Arctic Marine and Coastal Technology*

Contents

- Trends in Arctic Marine Activities
- Ice Actions
- Ice Management and Marine Operations

New technologies

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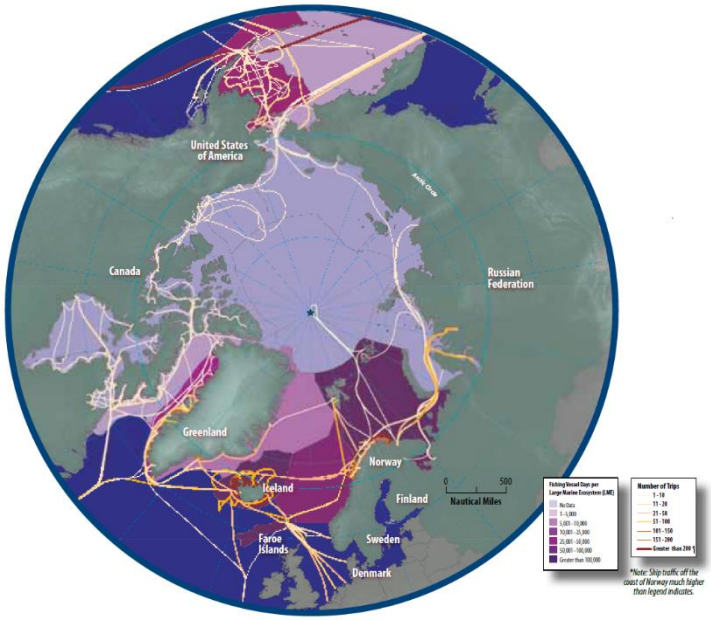
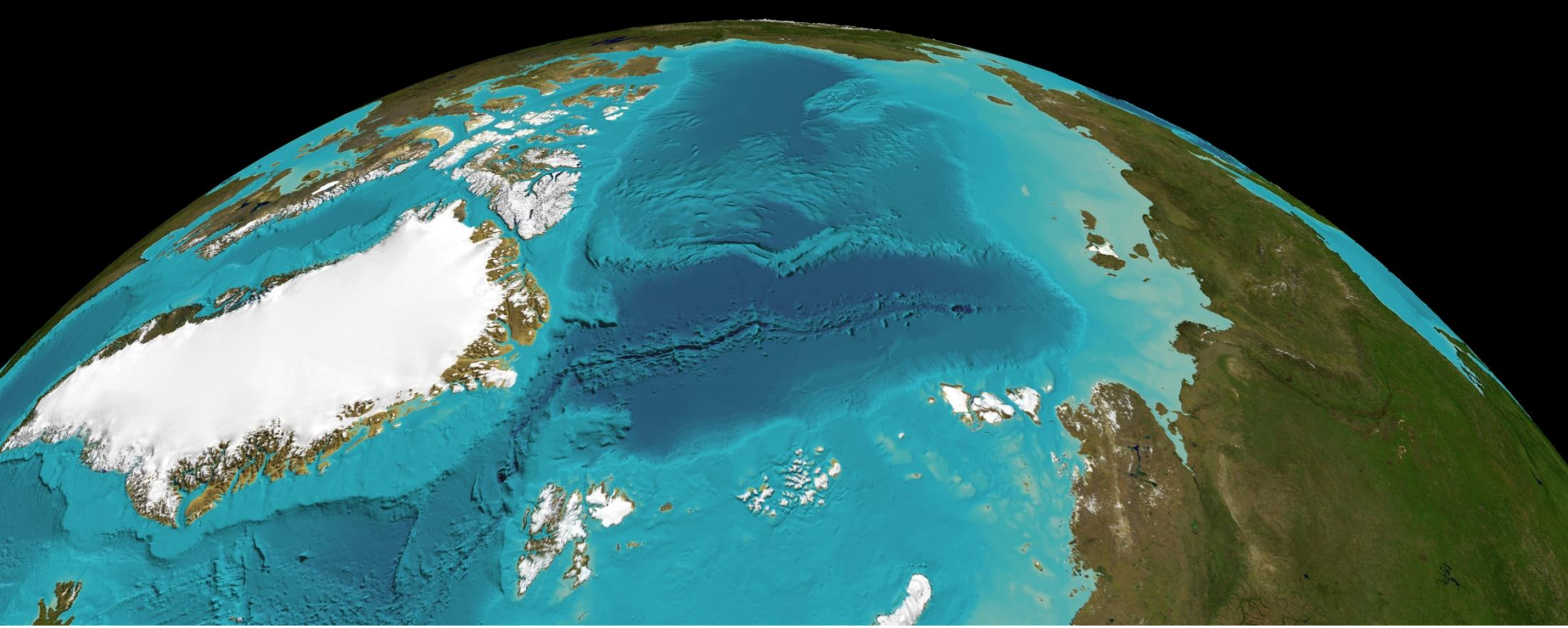
Arctic vessel activity in 2004

Four types of vessel activities as most significant in the Arctic in 2004:

- Community re-supply
- Bulk cargo
- Fishing vessel activity operations
- Tourism

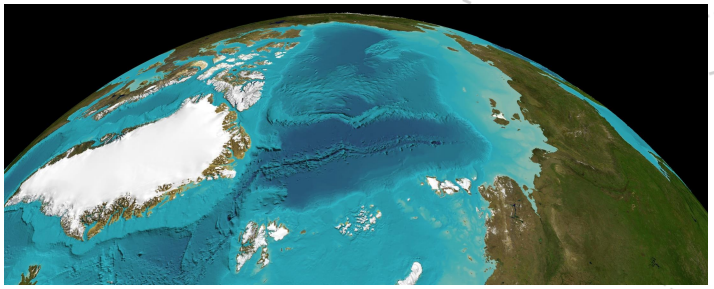


(Arctic Marine Shipping Assessment, 2009a)



What about Future Arctic Marine Activities?

Uncertainties - Future Arctic Marine Activities



- Legal and governance situation
- Degree of Arctic state cooperation
- Climate change variability
- Radical changes in global trade
- Insurance industry roles
- An Arctic maritime disaster
- New resource discoveries
- Oil prices and other resource commodity pricing
- Multiple use conflict (indigenous and commercial) and future marine technologies.

(AMSA, 2009b)

Arctic Marine Infrastructure – Trends (1)

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- Natural resource development and regional trade - key drivers of increased Arctic marine activity:
  - ✓ new Arctic resource discoveries - highly probable
  - ✓ most new developments will require marine transport and operational support.
- Probably a slow movement of Arctic marine ecosystems northward with retreating seasonal sea ice - may open new fishing grounds in higher latitudes in the future.
- Plausible longer seasons of navigation will have significant implications for multiple uses in regional Arctic waterways.
- New Arctic ship technologies will set a norm for more independently operated, icebreaking commercial ships (icebreaker assistance will remain).

Arctic Marine Infrastructure – Trends (2)

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- Increased marine traffic in the central Arctic Ocean is a reality - for scientific exploration and tourism.
- The future holds increasing exploration voyages, plausible increases in tourism and fishing and plausible trans-Arctic voyages in summer on an experimental basis.
- Arctic voyages through 2020 will be overwhelmingly destinational (regional trade), not trans-Arctic, driven by:
  - ✓ natural resource development
  - ✓ marine tourism
  - ✓ supply/import of materials/goods.

Arctic Oil and Natural Gas Provinces

(geology.com, 2013)

Technical Challenges

The activity in the marine Arctic represents a number of new challenges compared to activities further south:

- Navigation
- Communication
- SAR for ship traffic/Escape, Evacuation and Rescue (EER)
- Weather forecast
- Marine icing
- Ice actions
- Marine operations including ice management
- Harbour infrastructure
- Oil spill preparedness and response.

Full-scale data if possible

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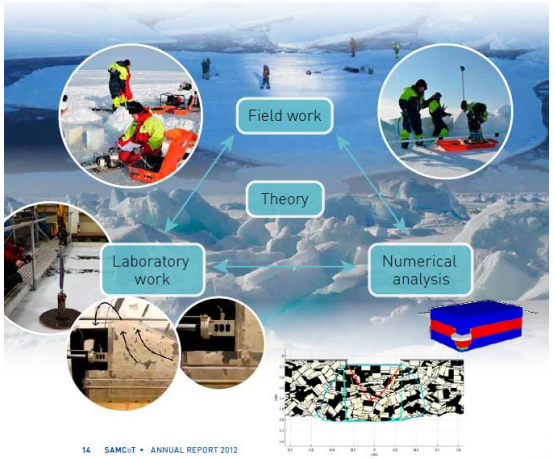

Oden Arctic Technology Research Cruises: 2012, 2013 and 2015

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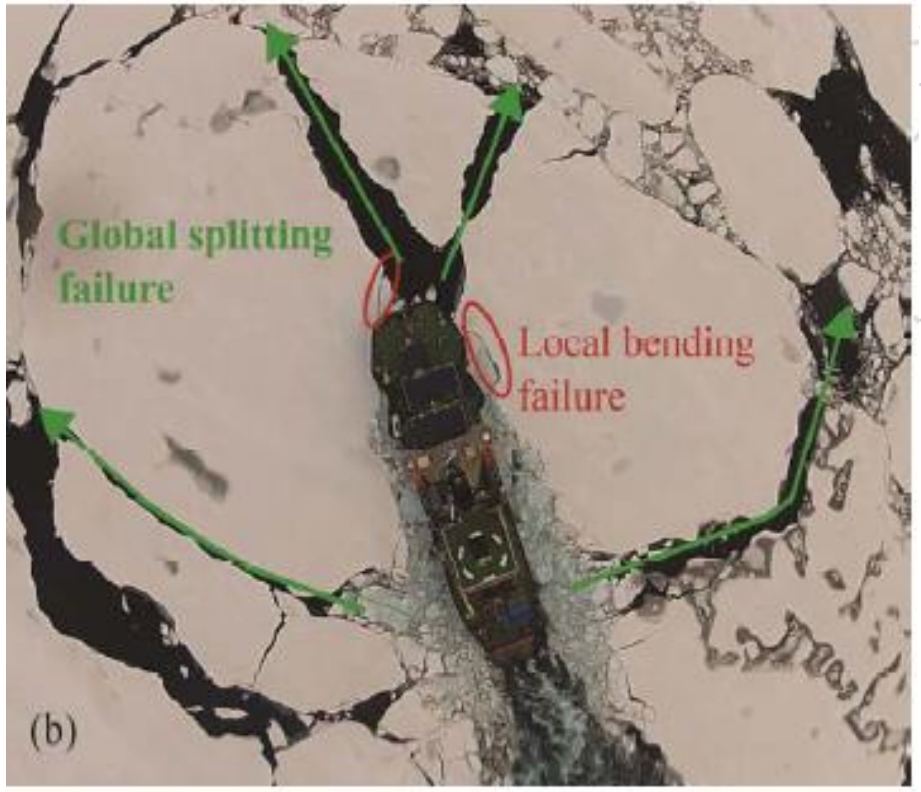
Full-scale observations of interaction processes - modelling

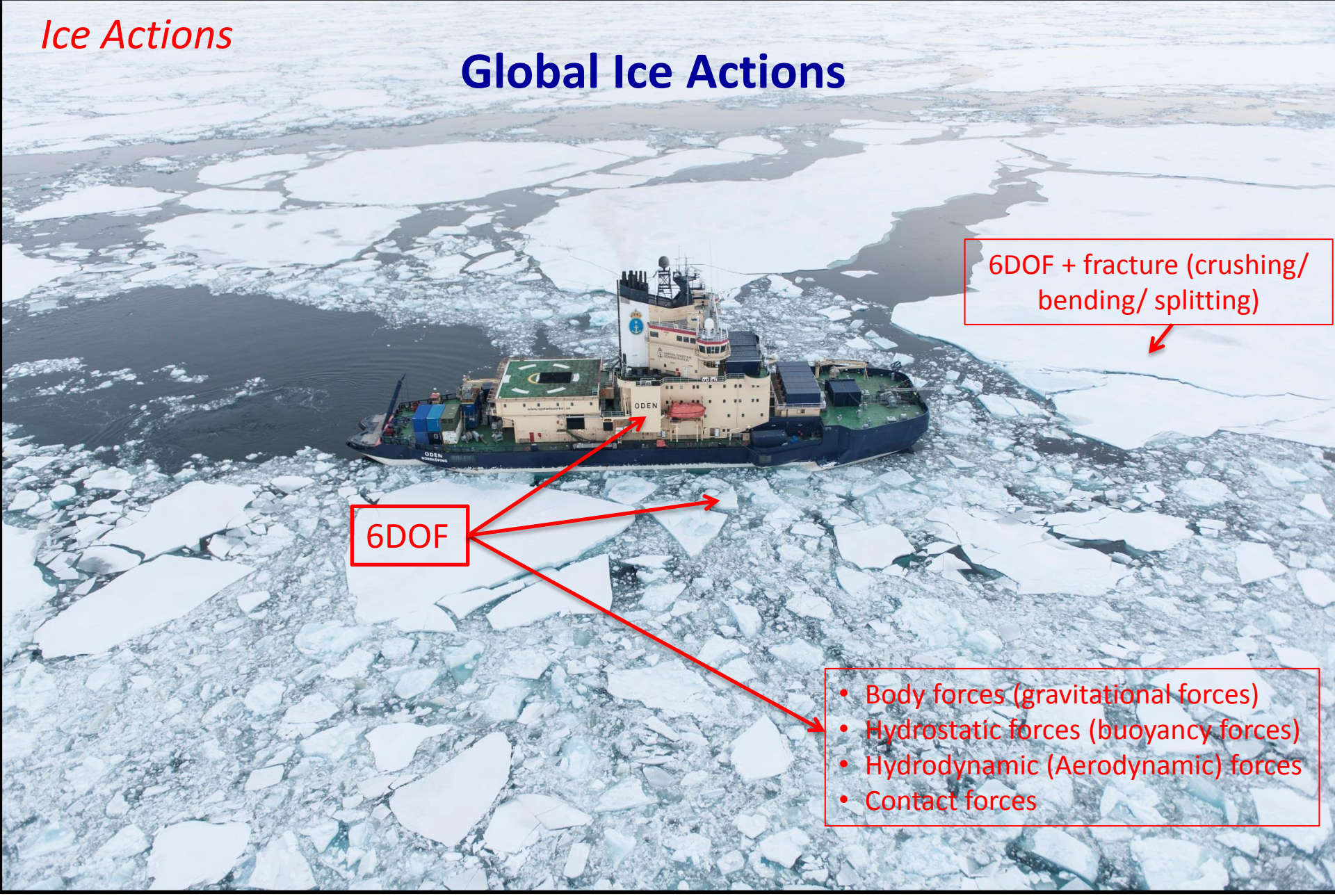


Major physical interaction processes:

- Novel theory developed
- Numerical implementation
- Full-scale data used

Video

Global Ice Actions



Ice Actions

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Ice Actions

Global

The estimate of a time-averaged pressure over a nominal contact area is sufficient

Useful for the design of:
- Foundation
- Moorings/DP systems
- Operations: IM, towing, Prop. wash, etc.

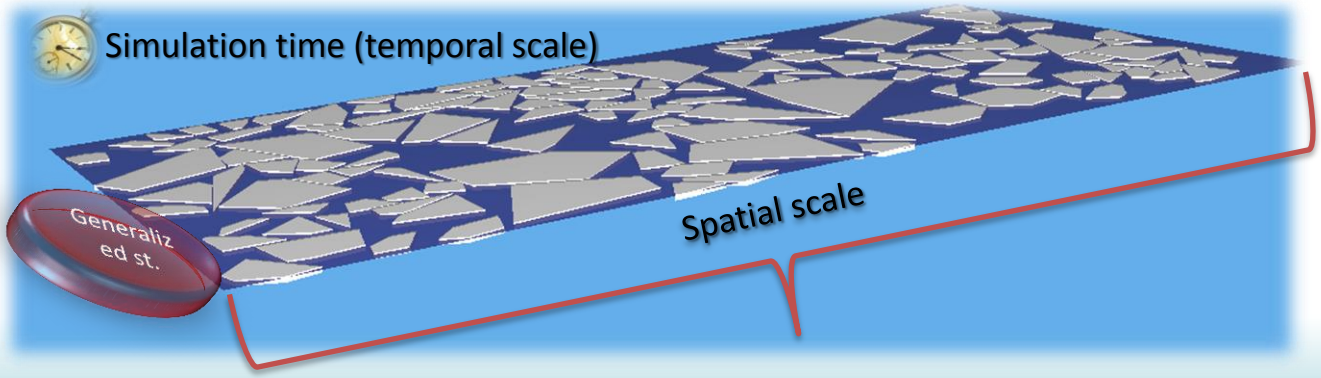
Local

Here, a high resolution image of the pressure over the contact area is needed

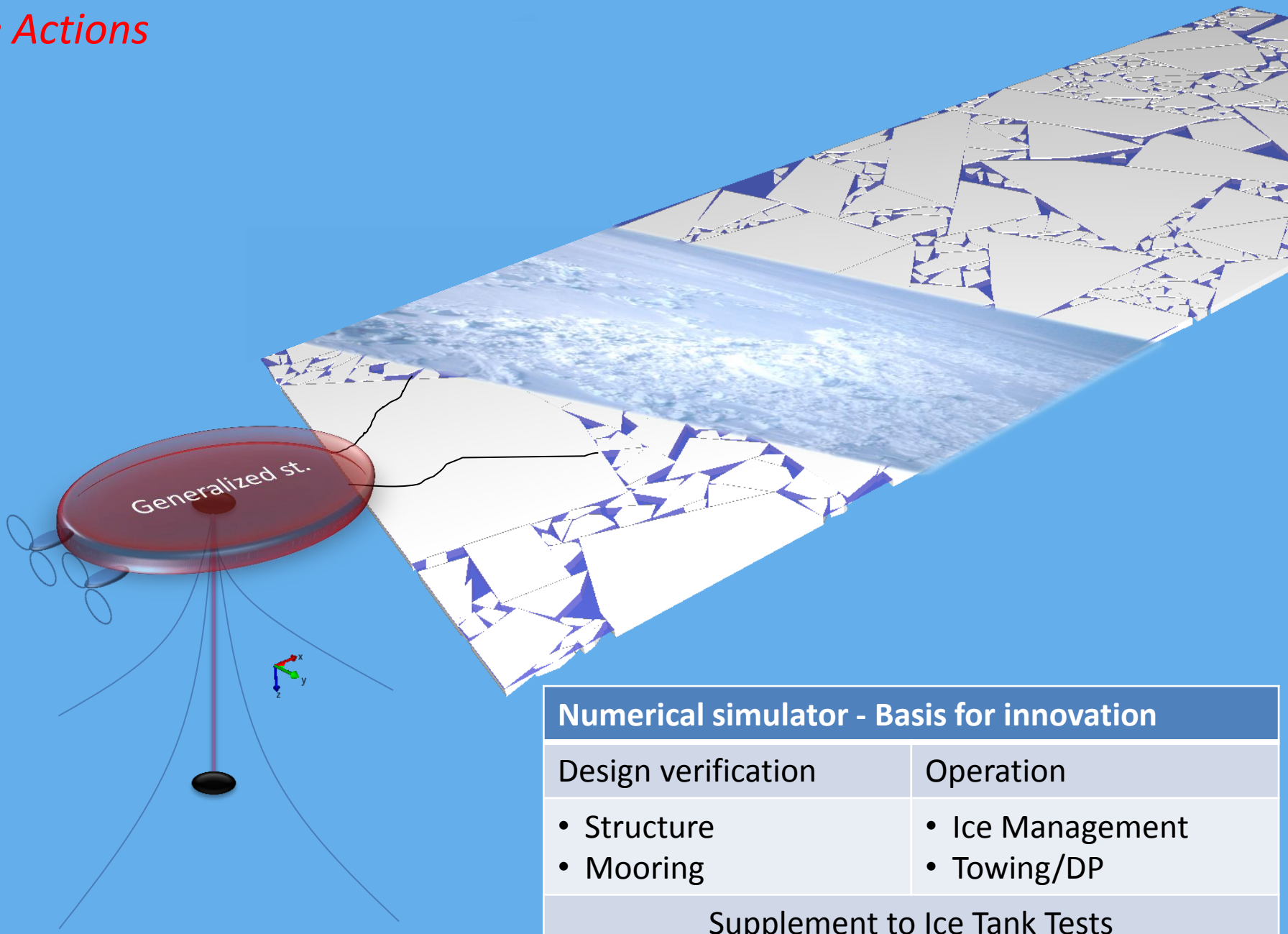
(Kim, 2014)
(Storheim, 2015)

Useful for the design of:
- Structural elements such as plates and beams

The model must be adequate for relatively large temporal and spatial scales



Ice Actions



Numerical simulator - Basis for innovation	
Design verification	Operation
• Structure • Mooring	• Ice Management • Towing/DP
Supplement to Ice Tank Tests	

Modelling of fracture

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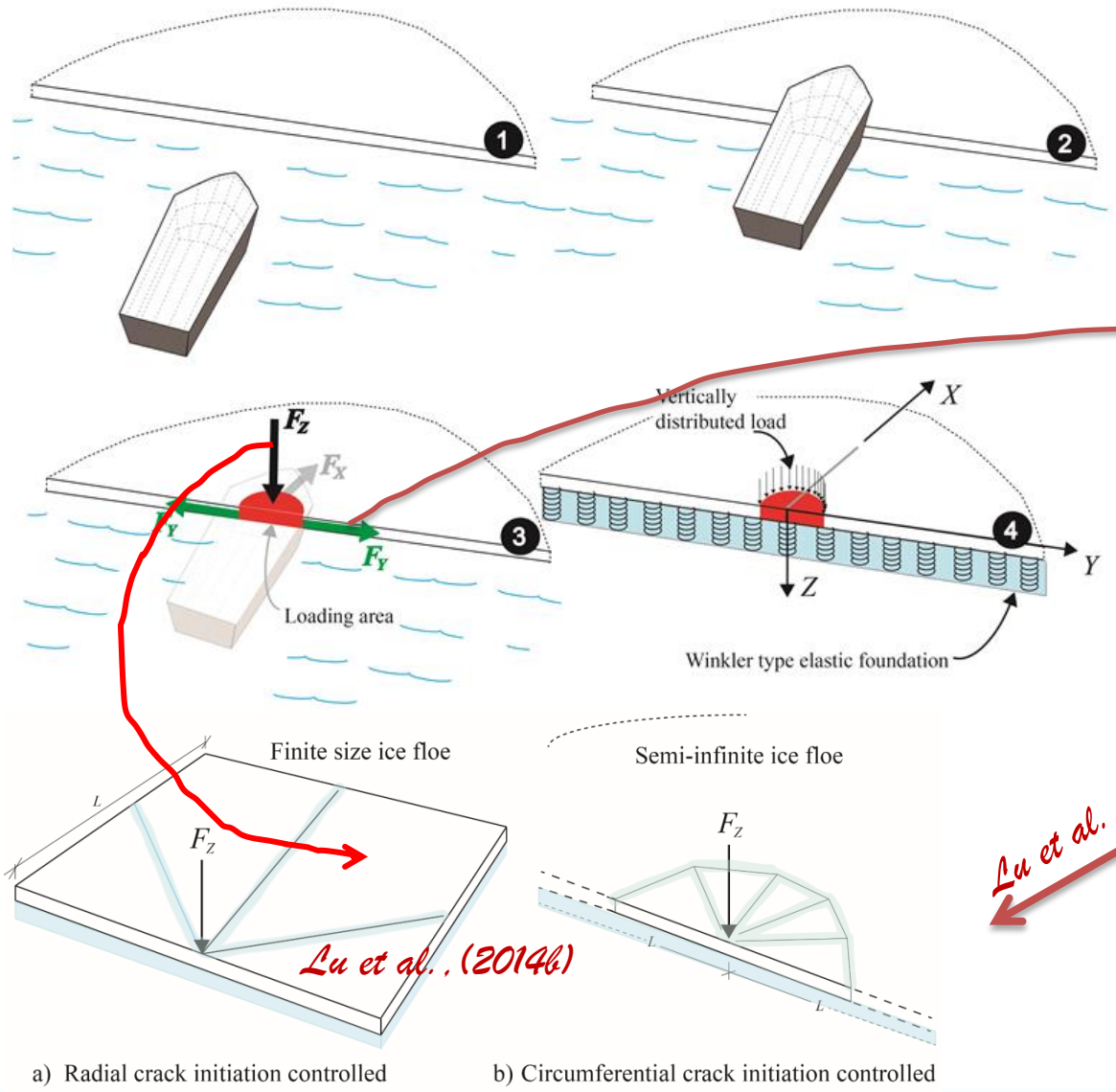

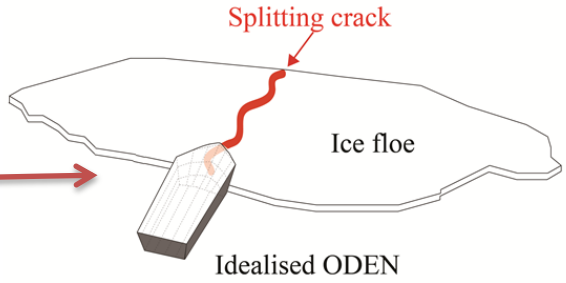

Influence of:

1) floe geometry
2) confinement
3) inertia

Lu et al., (2014a)

Lu et al., (2014c)

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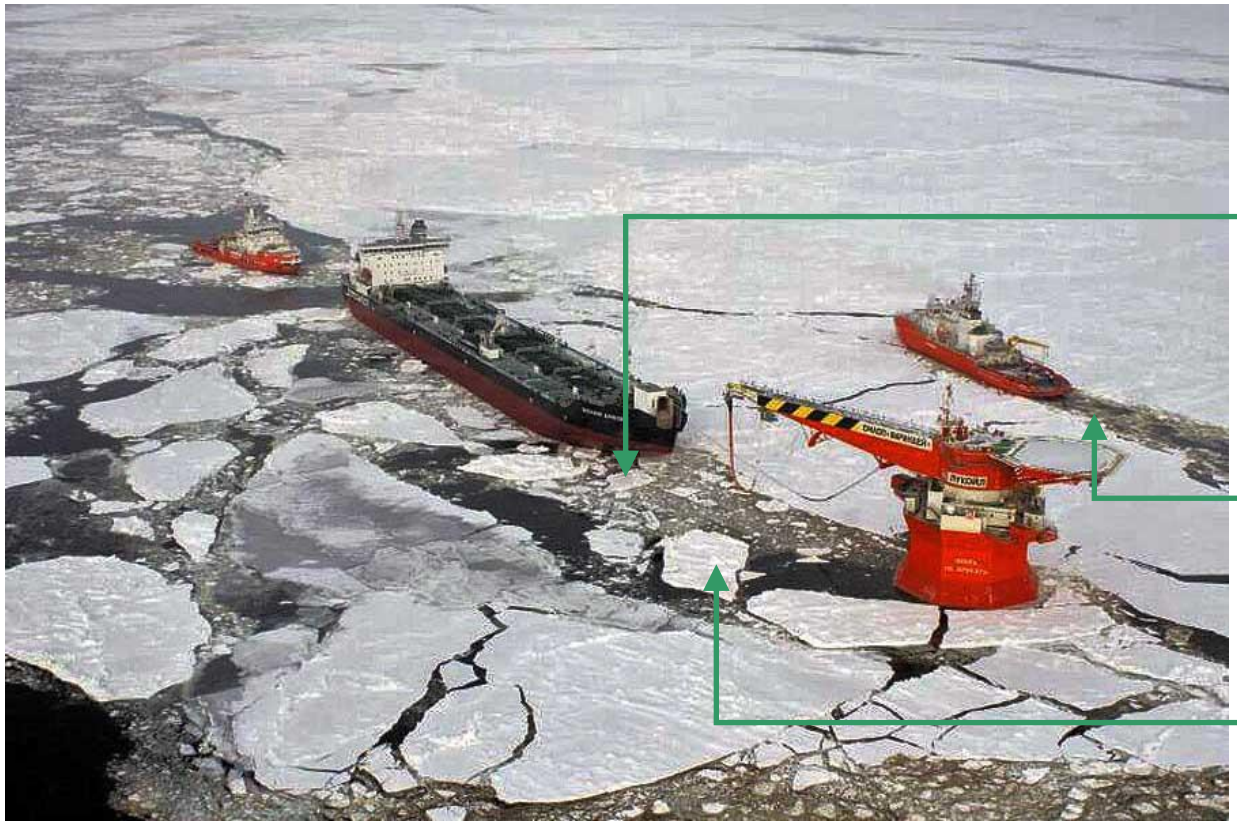
Modelling of hydrodynamic forces



Ice accumulation and clearing upstream of a structure

Propeller wash effect

Wake closing behind a structure

Photo: www.lukoil.com

Integrated simulations

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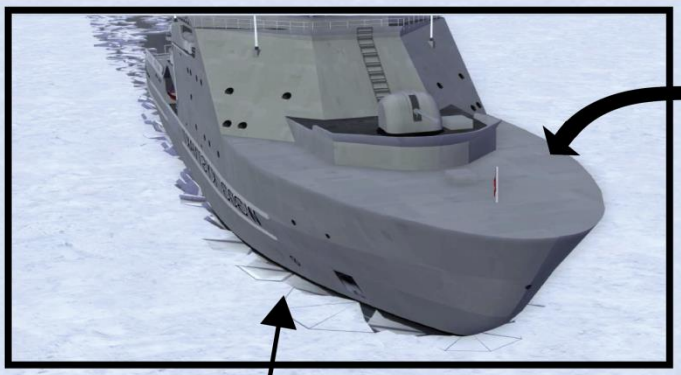

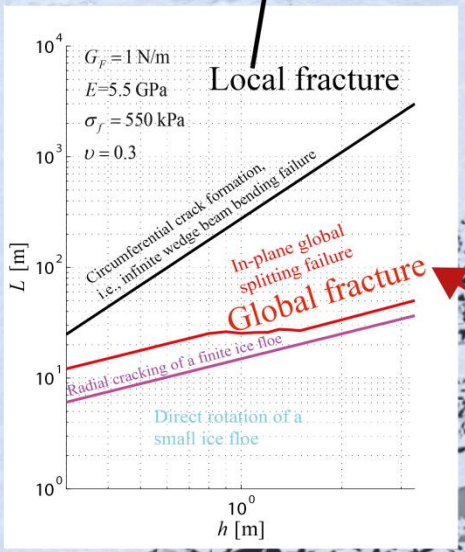

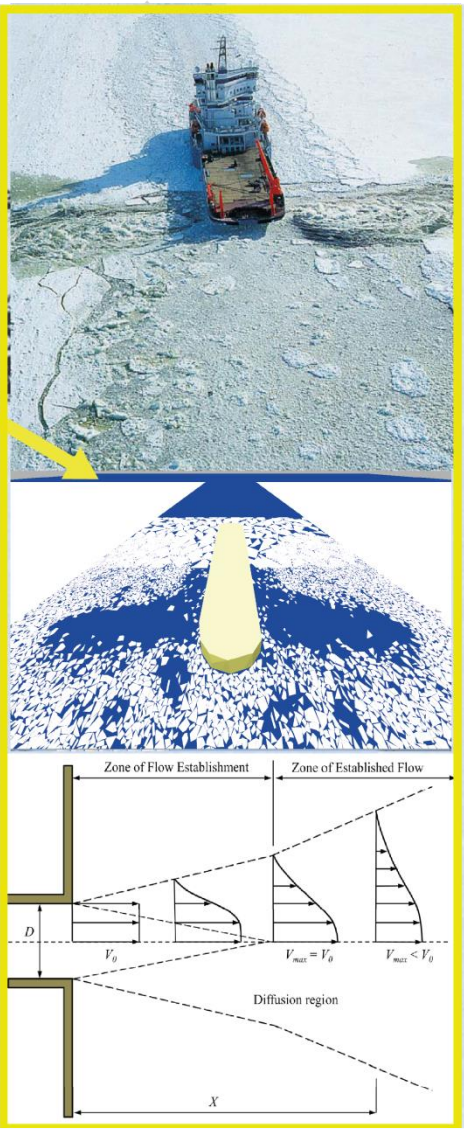

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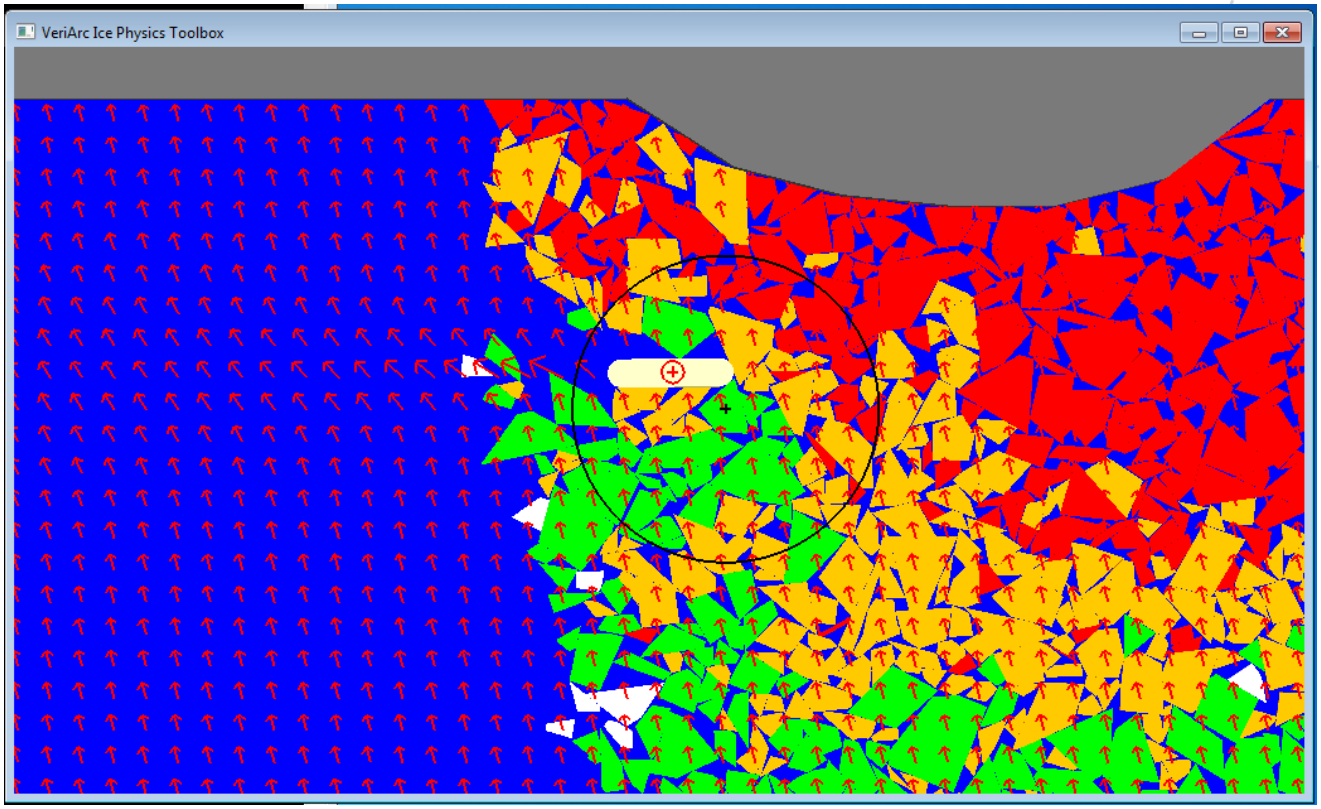
Example: Modelling station-keeping in variable ice drift

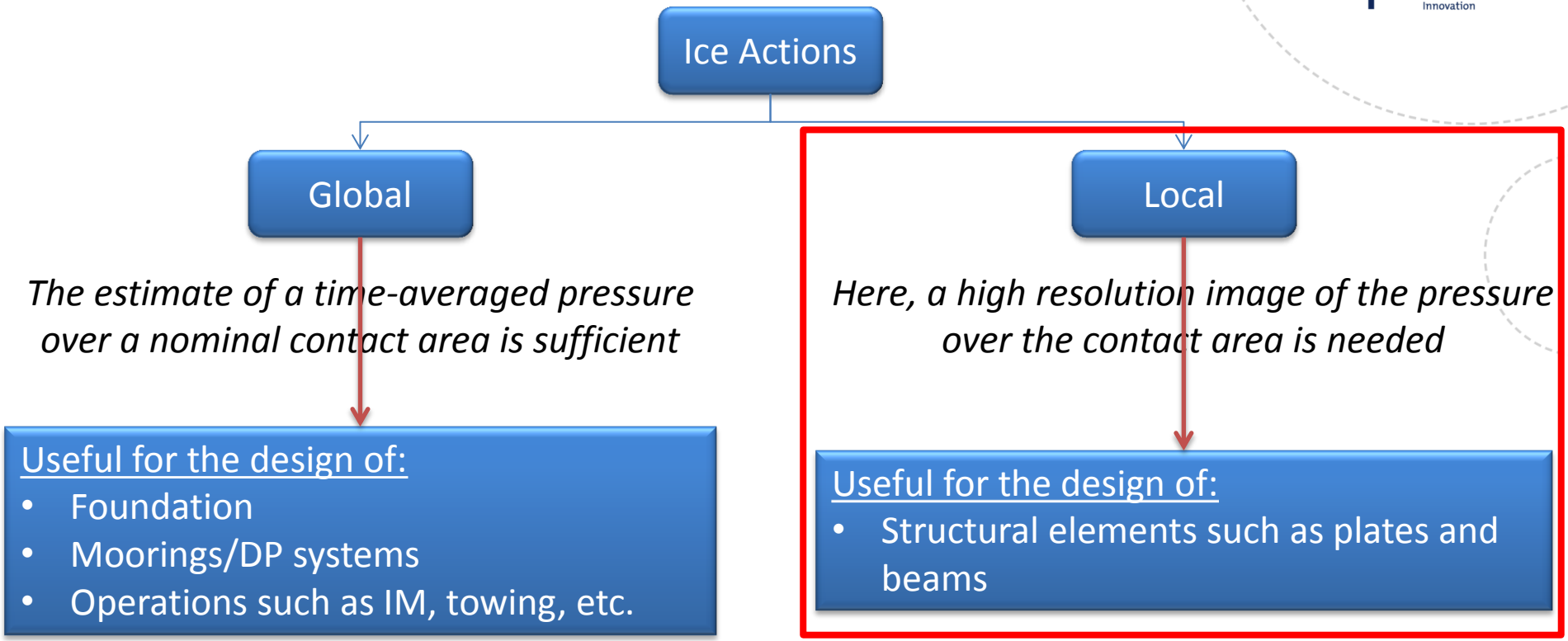
Major features:

- Rigid-body dynamics
- Wind/hydrodynamics
- Pressurized ice
- Moorings



Video

Ice Actions


Ice Actions
Global
Local
The estimate of a time-averaged pressure over a nominal contact area is sufficient
Here, a high resolution image of the pressure over the contact area is needed
Useful for the design of:
• Foundation
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• Operations such as IM, towing, etc.
Useful for the design of:
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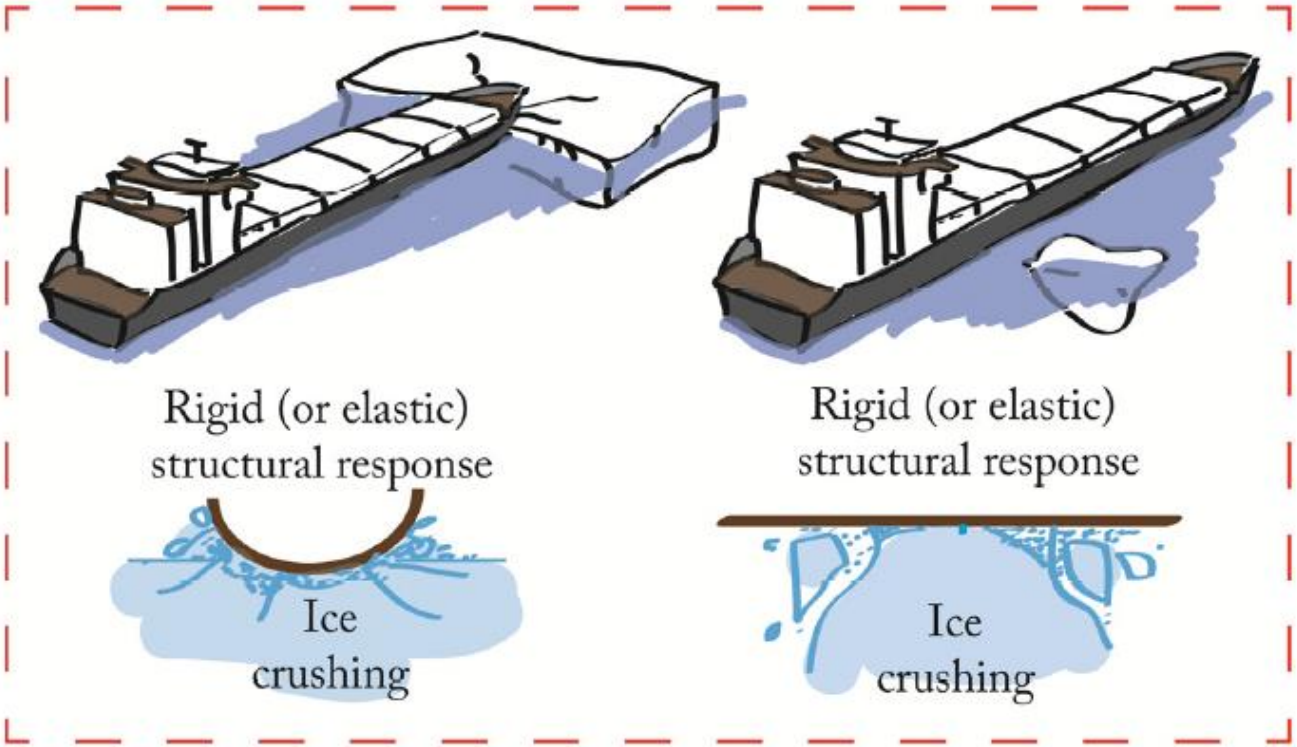
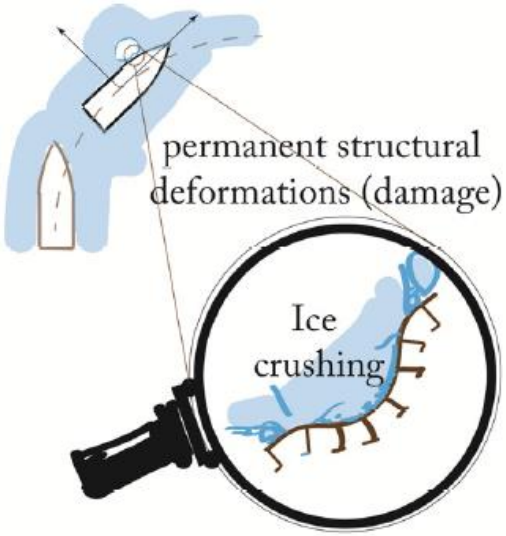
Local Ice Actions



Ultimate Limit State approach

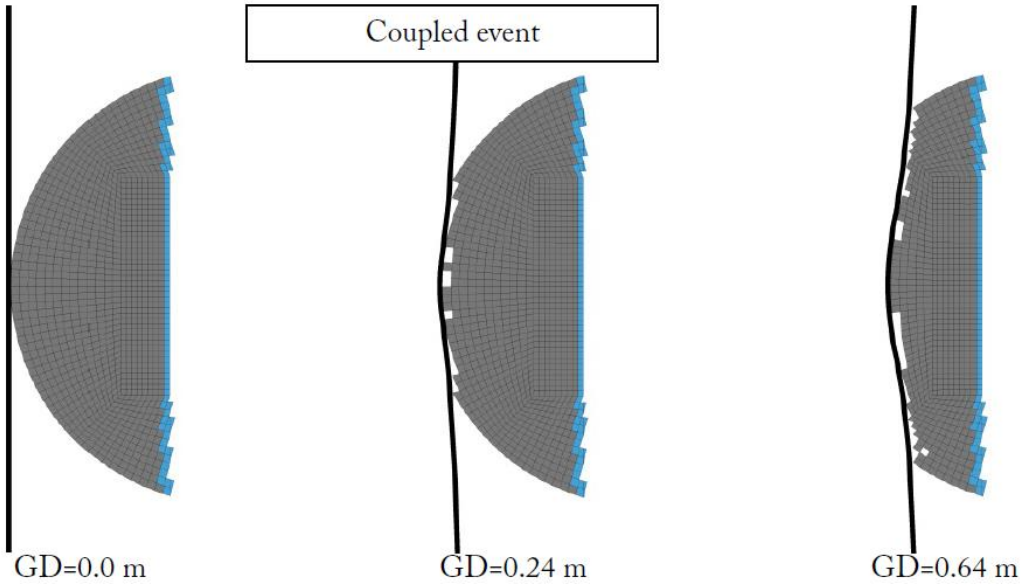


Accidental Limit State approach

(Kim, 2014)

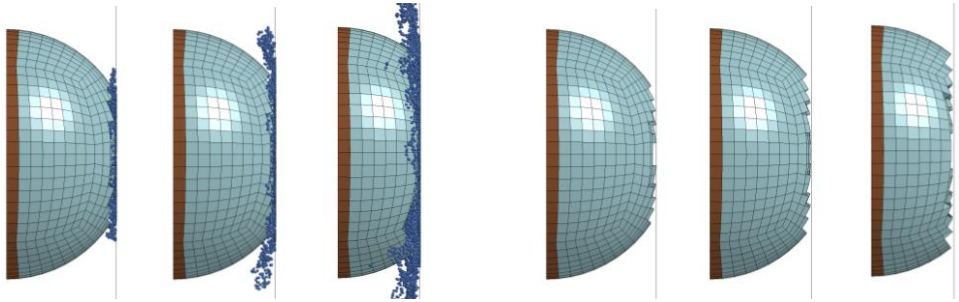
Local Ice Actions

Damage of a chemical tanker's plating caused by multi-year ice (Hanninen, 2005)



(Kim, 2014)

Further Advancements
(SPH vs Element Erosion):



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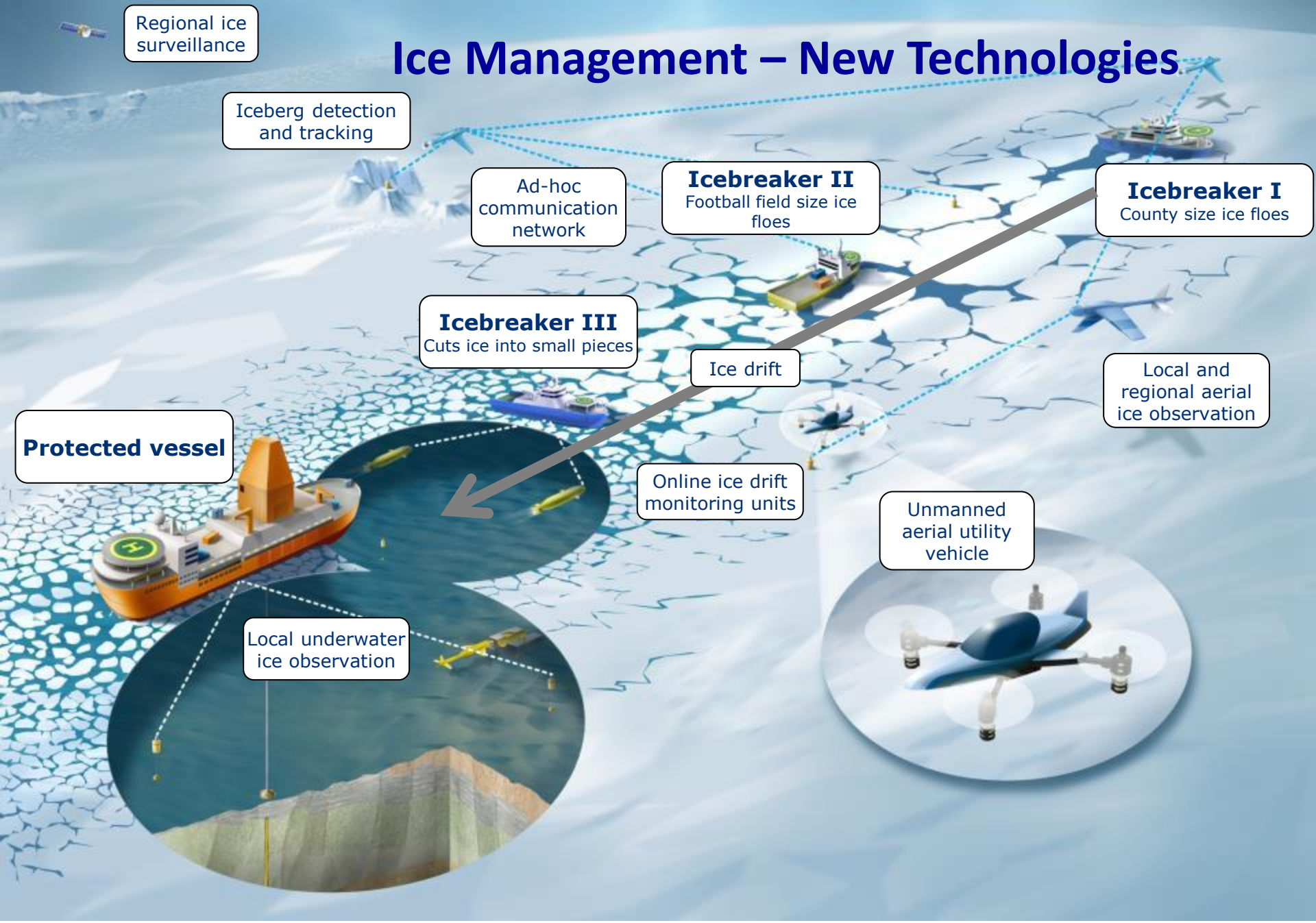
New technologies

Ice Management – New Technologies



(Source: WP5, SAMCoT)

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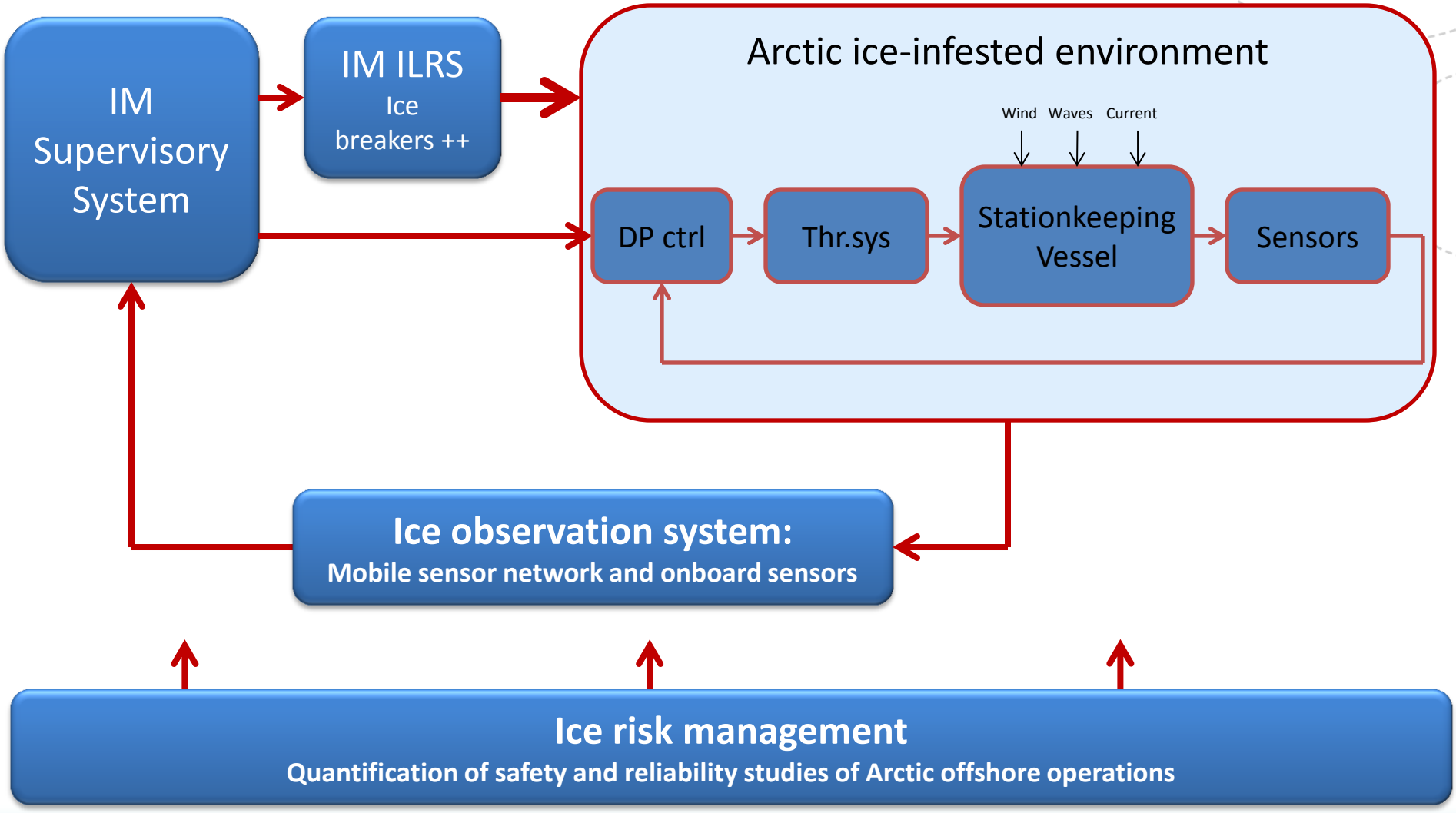
IM: Top-level Feedback System



(Source: WP5, SAMCoT)

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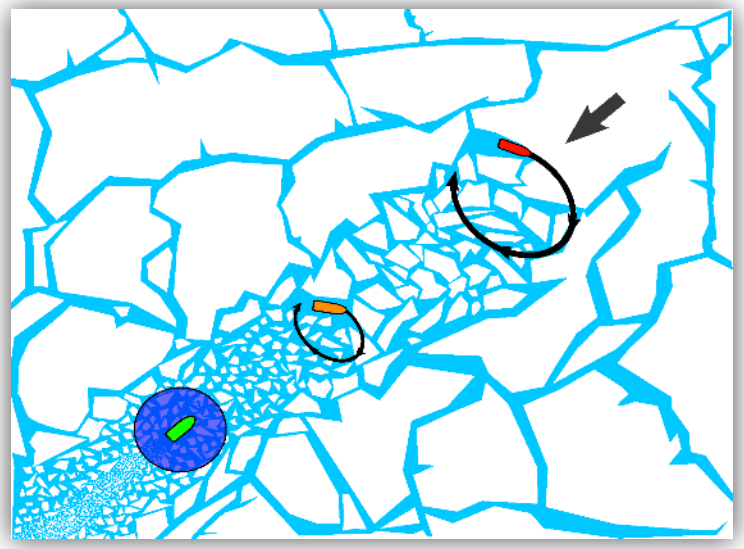
Ice Load Reduction System



Courtesy : Moran

(Source: WP5, SAMCoT)

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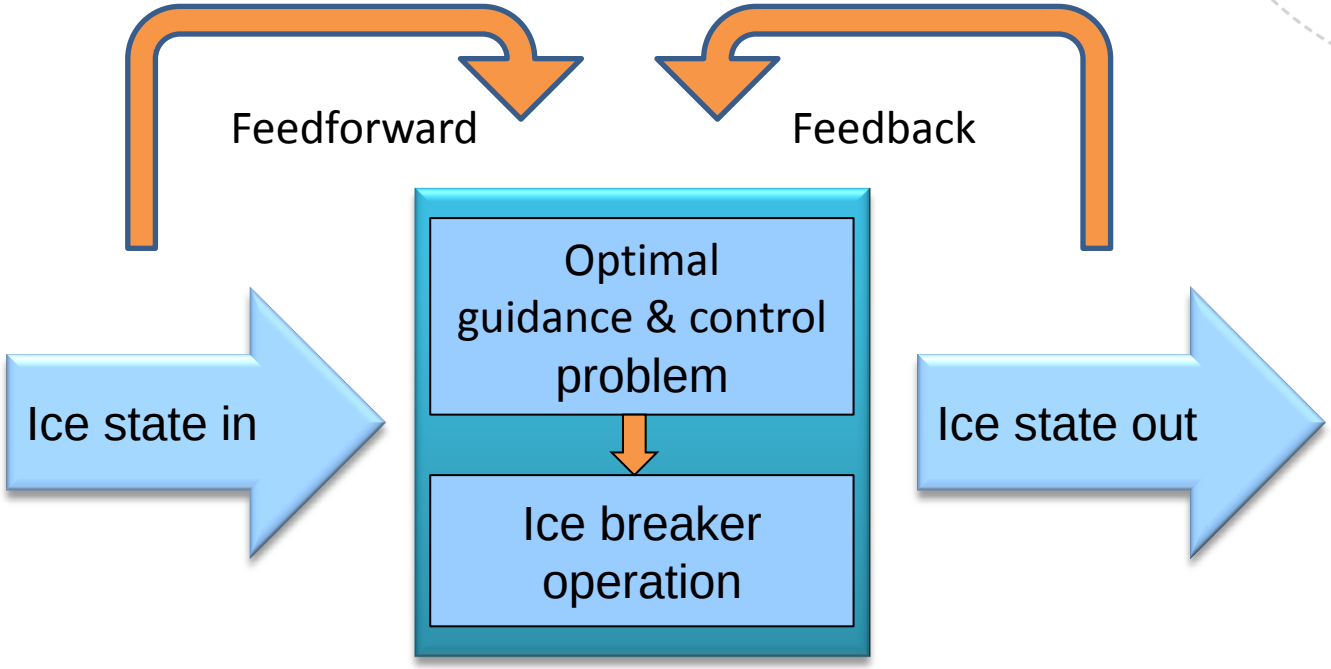
Optimal Ice Load Reduction



Challenges:

- How to measure and estimate relevant ice parameters for “Ice State In” and “Ice State Out”?
- How to model and simulate the behavior of the ice in the field?
- How to model and simulate the effect of ice breaking based on given maneuvers by the ice breaker?
- What to minimize and how to formulate an optimization problem?

(Source: WP5, SAMCoT)

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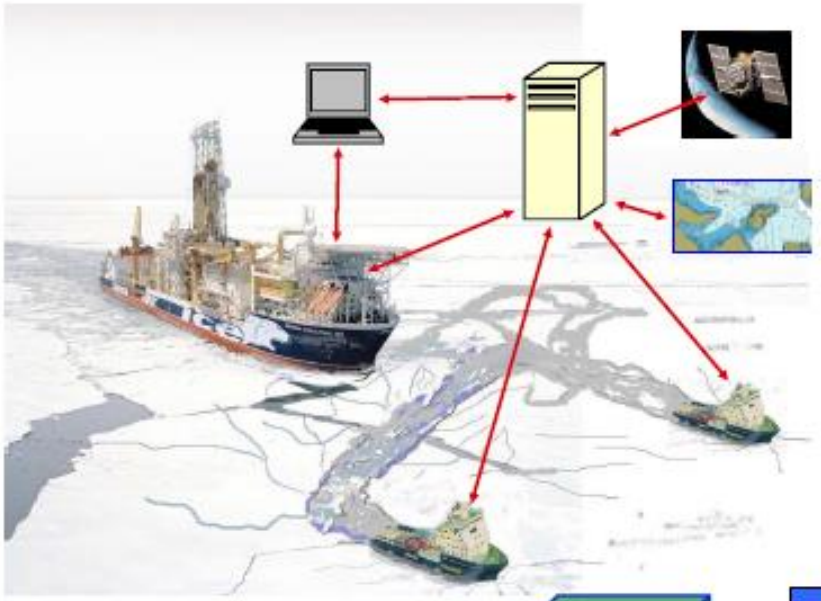
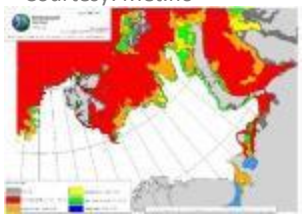
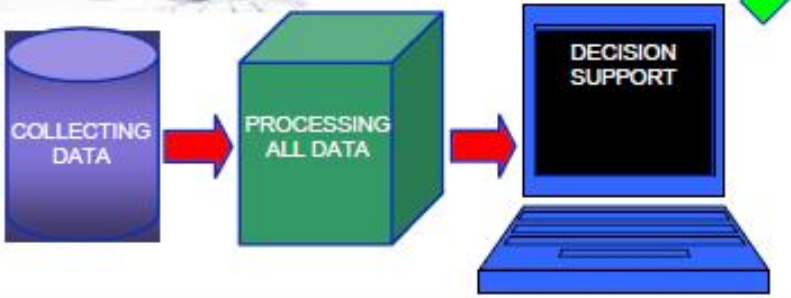
We need a better instrumented Arctic!



Courtesy: Met.no





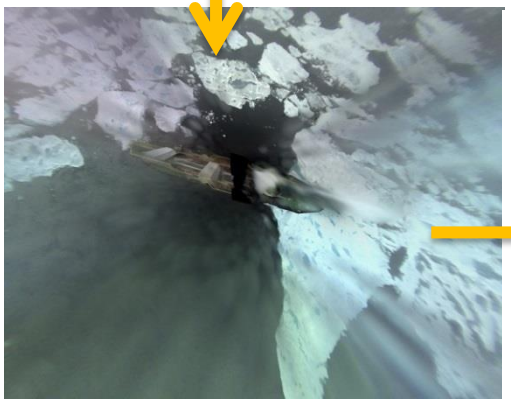
Slide courtesy: Morten Mejlaender-Larsen, DNV

MANAGING RISK DNV

(Source: WP5, SAMCoT)

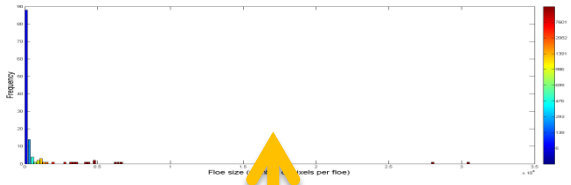
Technologies and methods for sea-ice surveillance

OATRC'13: 360CamSys



Flat image prevailing ice condition

Ice floe size distribution

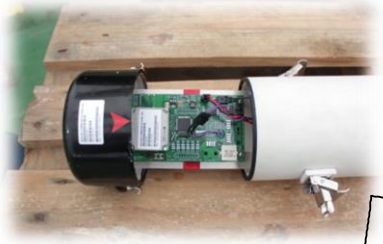


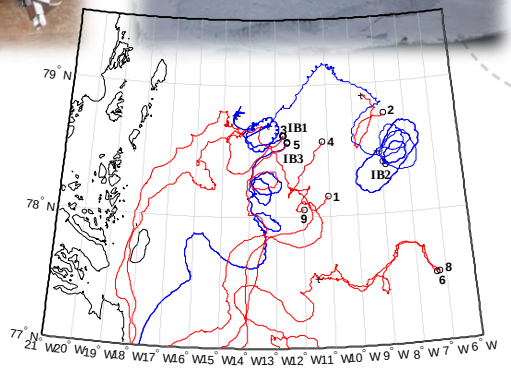
Ice floe identification

Renat Yulmetov

Ice Tracking Drifters

- Best student paper award at IAHR 2014.

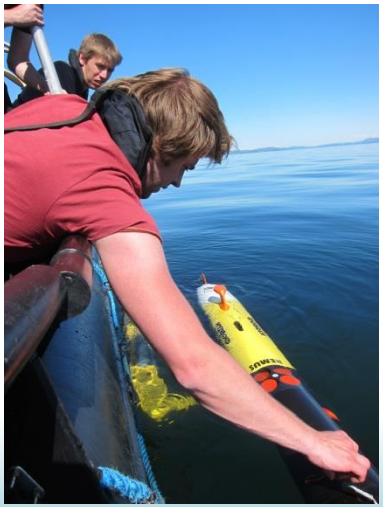




Petter Norgren

AUV Under Ice research

The NTNU AUV – REMUS 100

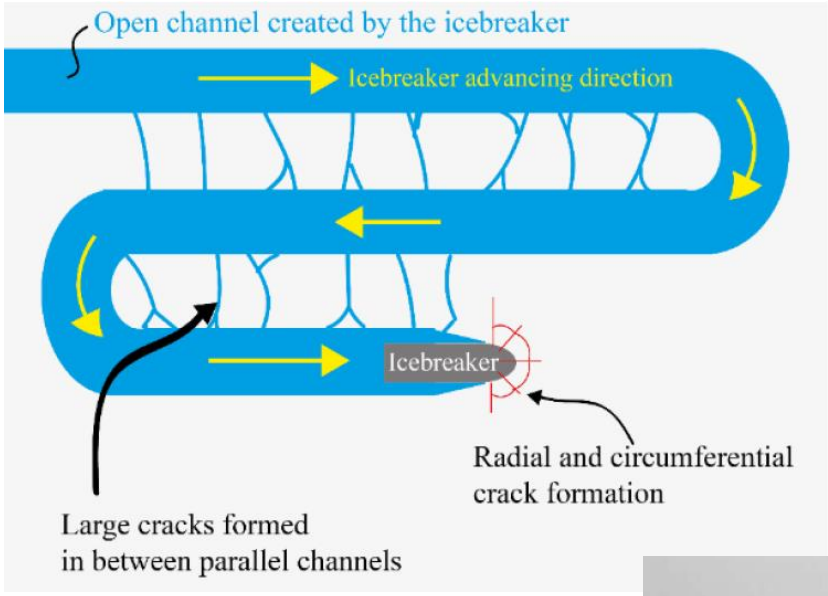


Launch and recovery in nice conditions.

Launch and recovery in the Arctic polar night in January 2015.

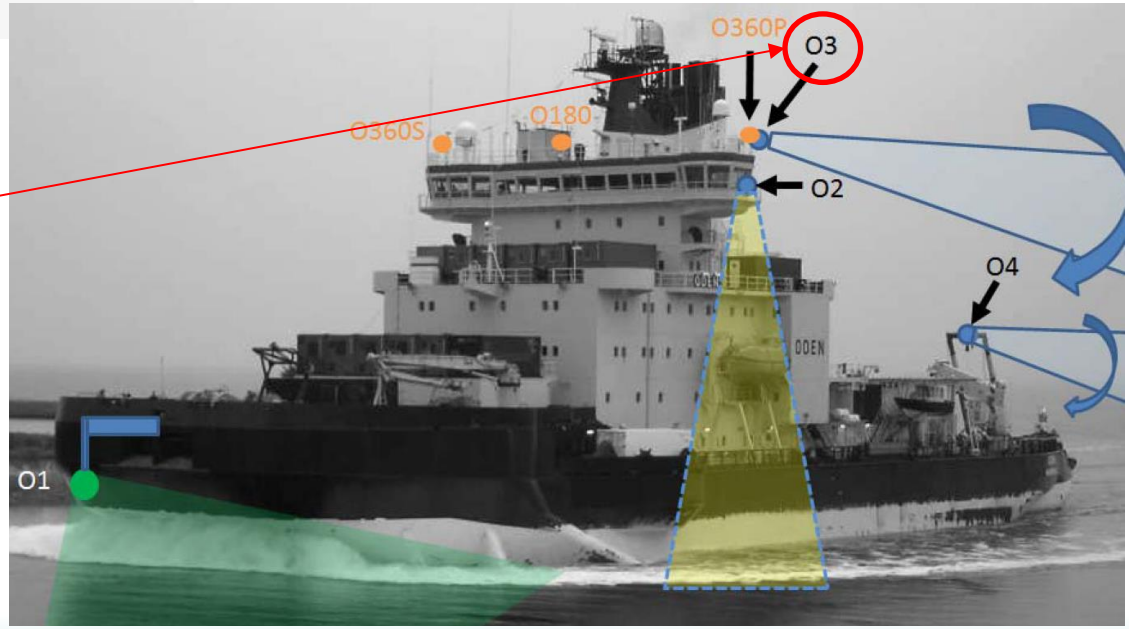
(Source: WP5, SAMCoT)

1. Parallel channel fracturing:

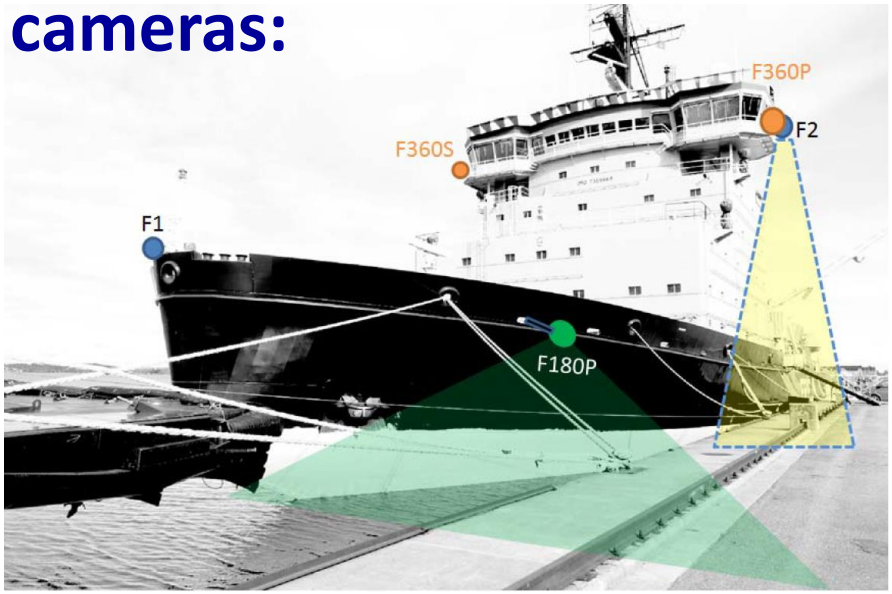


- A paper was presented in June 2015, POAC;
- A tentative theoretical explanation of the observed parallel channel crack was offered;
- Field tests were carried out with IB Oden in September 2015.

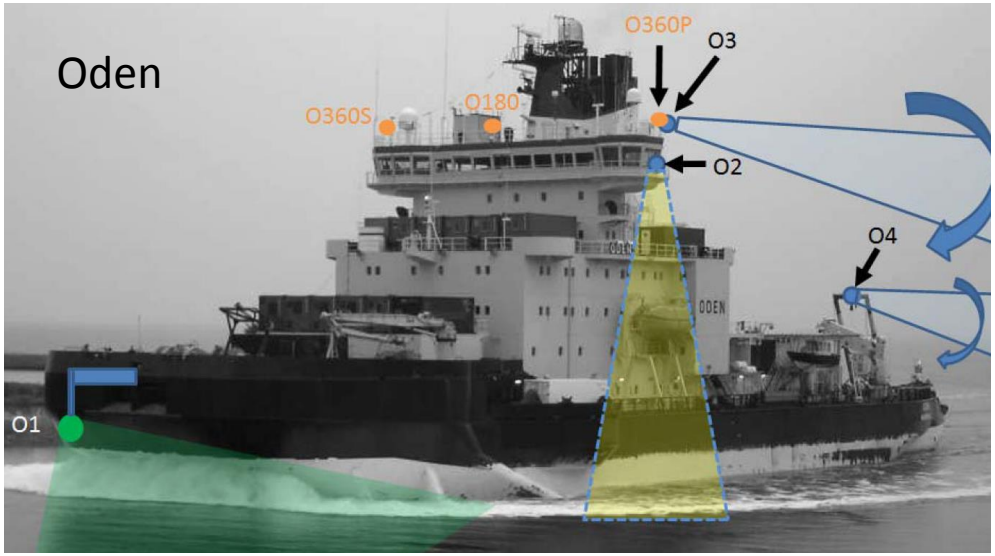
- Several cameras were installed on Oden;
- O3 was used mainly to monitor the parallel channel fracturing events.

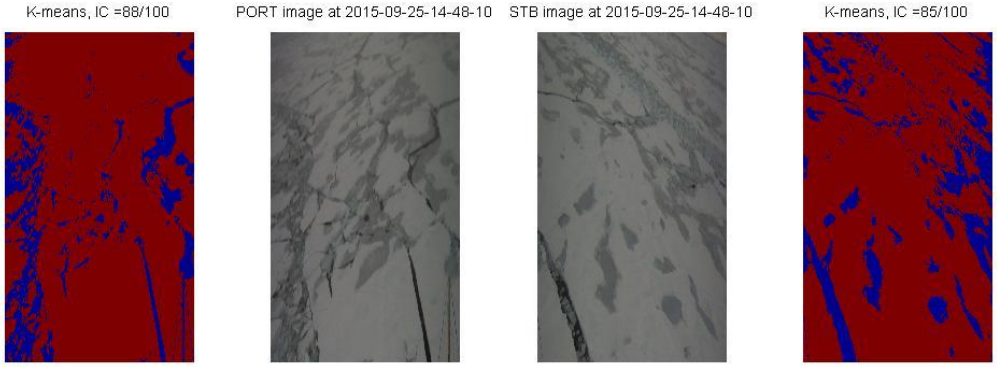


2. Acquiring ice conditions based on optical cameras:

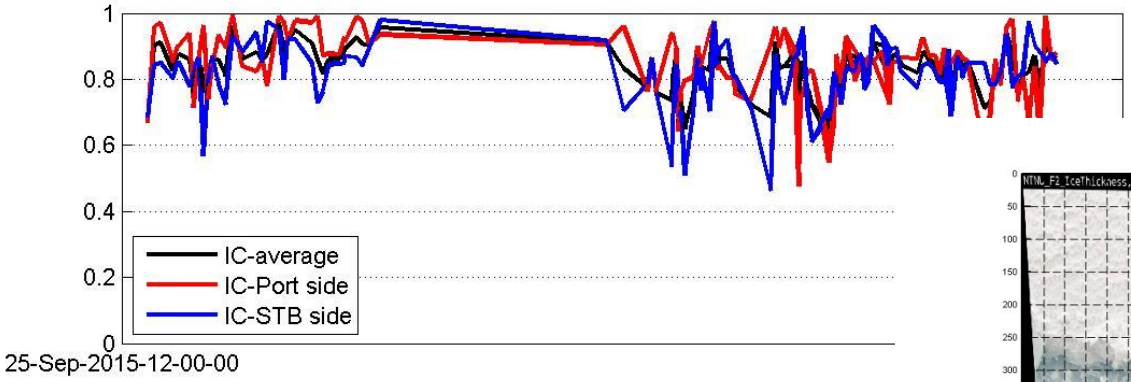


- Both icebreakers were heavily instrumented with different types of cameras;
- **Online analysis** to acquire ice concentration and ice thickness indications are achieved.

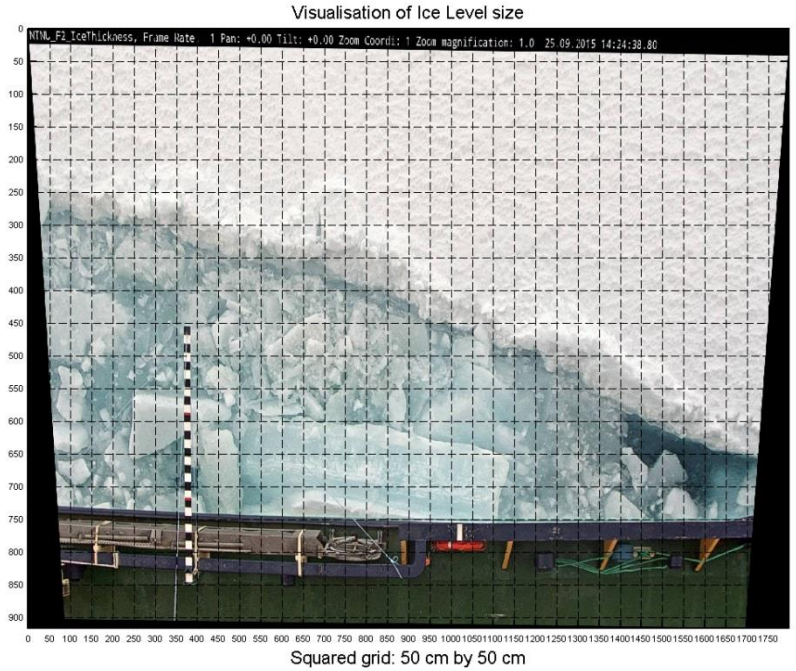




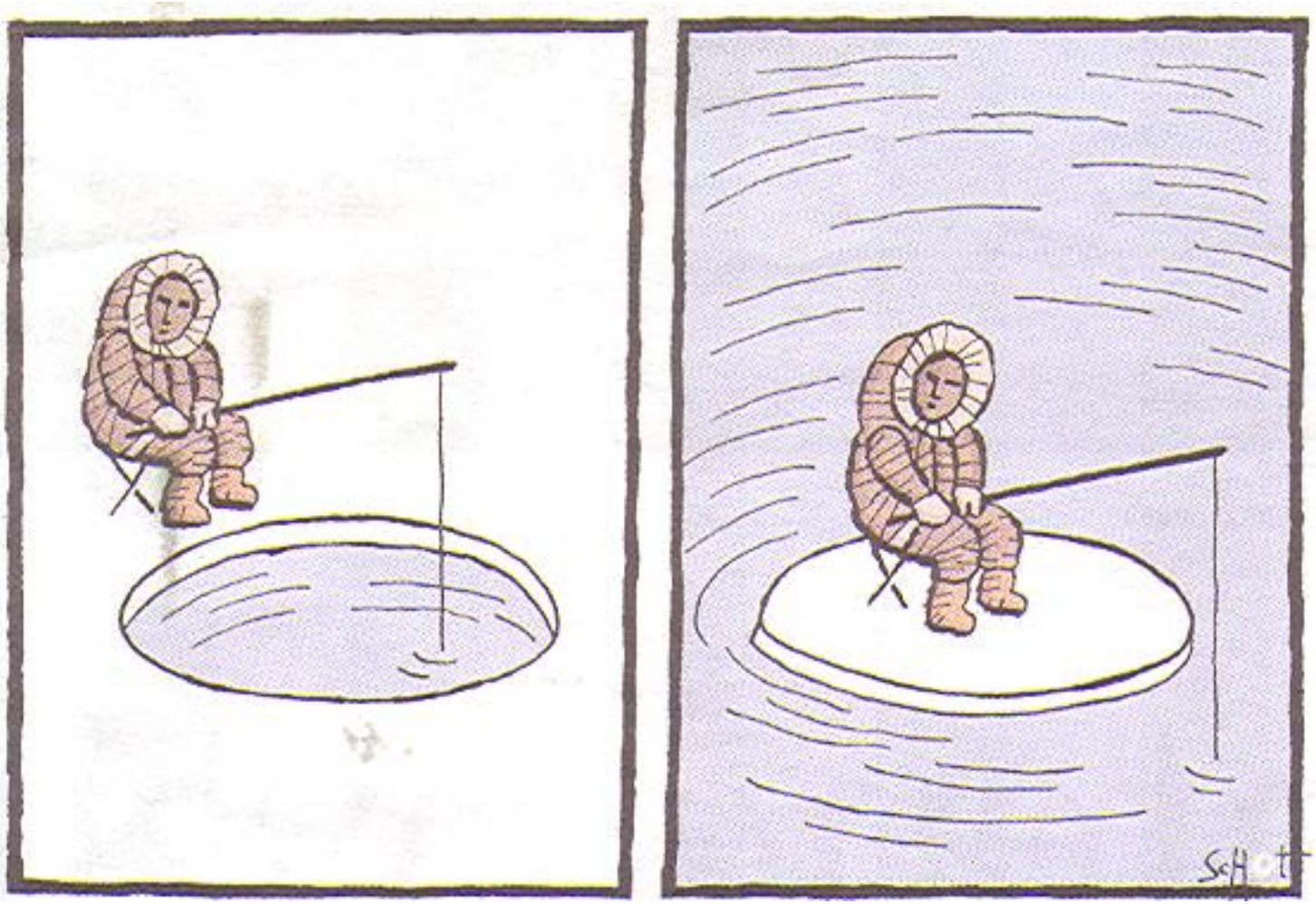
Online analysis of ice concentration based on the k-means method.



Online analysis for exact ice thickness indications



Innovative/New Technologies - Adaption to the Future



Time