Simulation tool for winter navigation decision-support in the Baltic Sea

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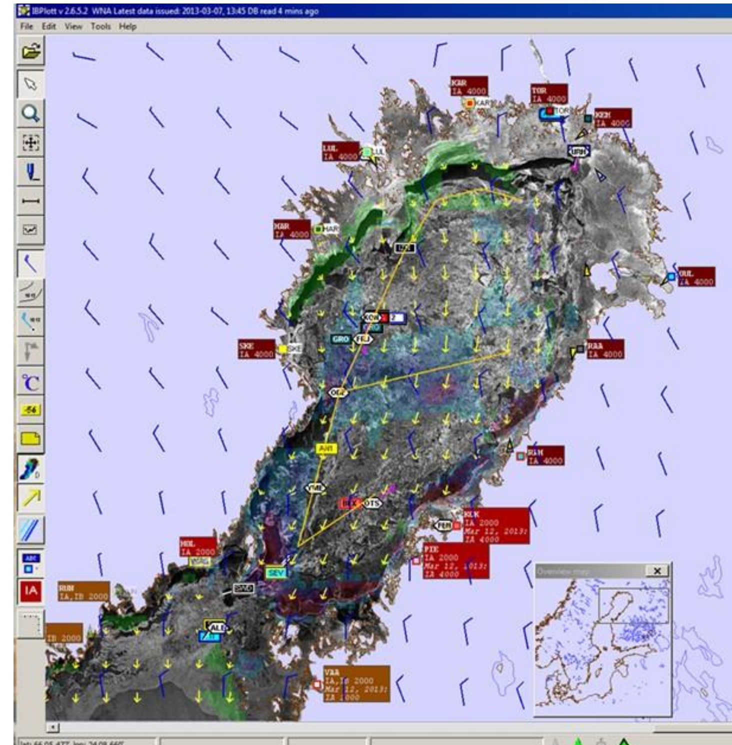
WINMOS II

Simulation model, Motivation

- An example of fairways on the Bothnian Bay
- Aim of the model:
- Predict the performance of the winter navigation system in future
- Climate change
- EEDI ships

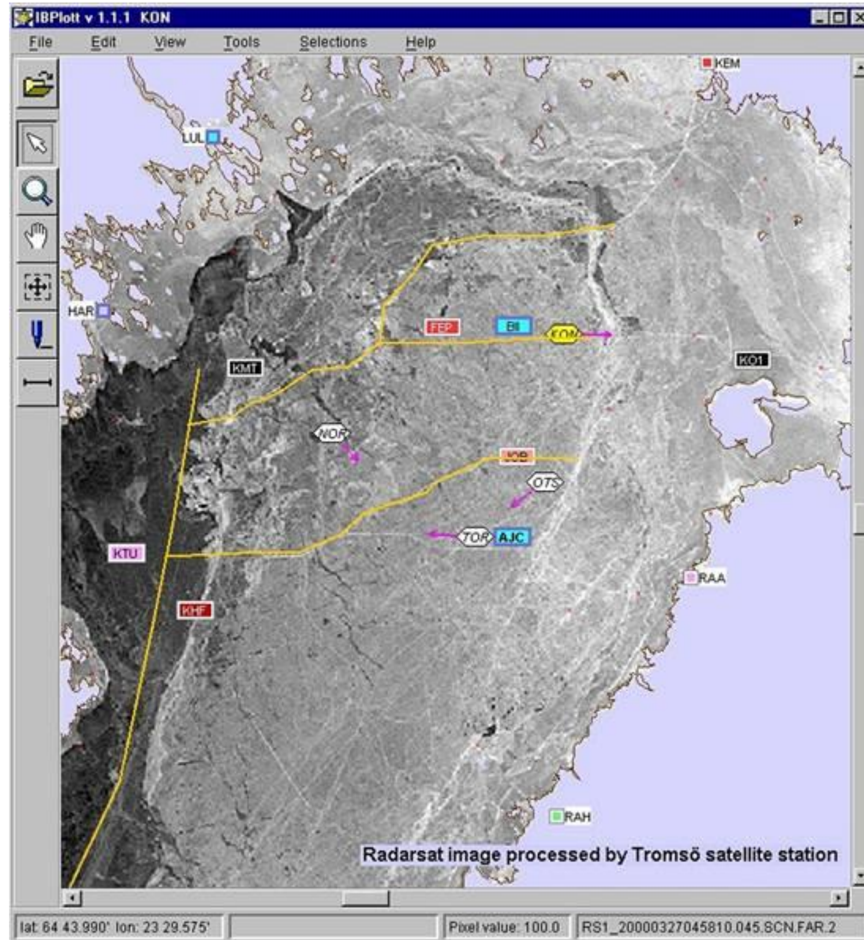


IB NET

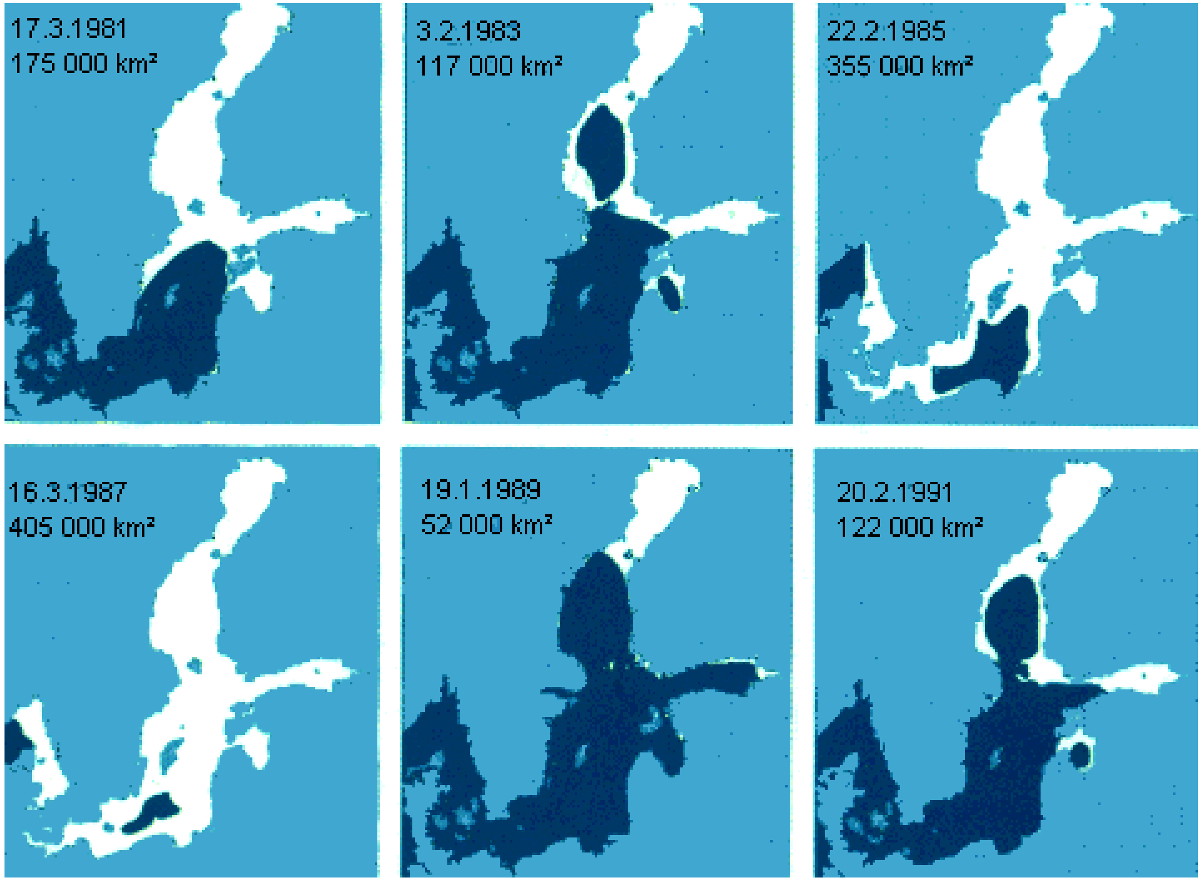
Practical coordination of ice-breaker assistance by IB-Plott system

Different color for various ship types and destinations

In use between Finnish and Swedish icebreakers



Ice extent in the Baltic Sea is varying annually



Simulation model

- Agent-based, discrete-event simulation
- Changing ice conditions, dirways
- Entire winter traffic can be simulated
- Icebreakers with dynamic speeds
- Simulation model validated as standalone functionality

Finnish IB Fleet

IB Urho/Sisu, 1976

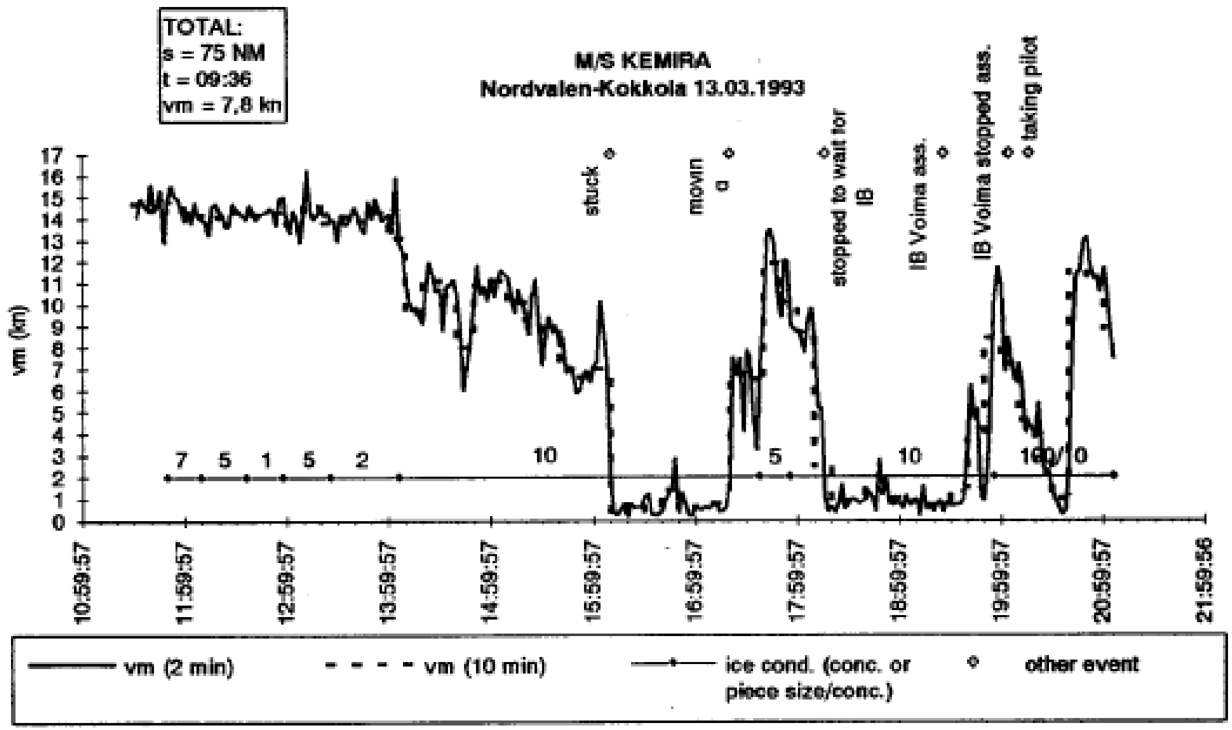
IB Otso/Kontio, 1986/1987

IB Nordica/Fennica, 1993/1994

Newest IB: Polaris

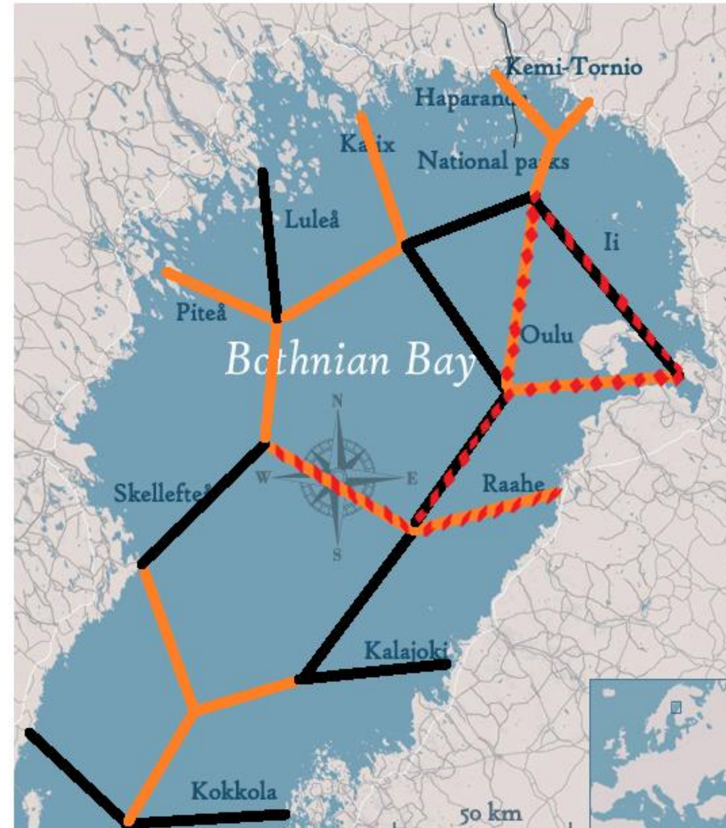
- **3 x** AZIPOD (1 bow+2 x aft)
- **LNG powered**
- **Built in** Arctech Helsinki Shipyard, 2016

The navigation in ice means large variation on the average speed

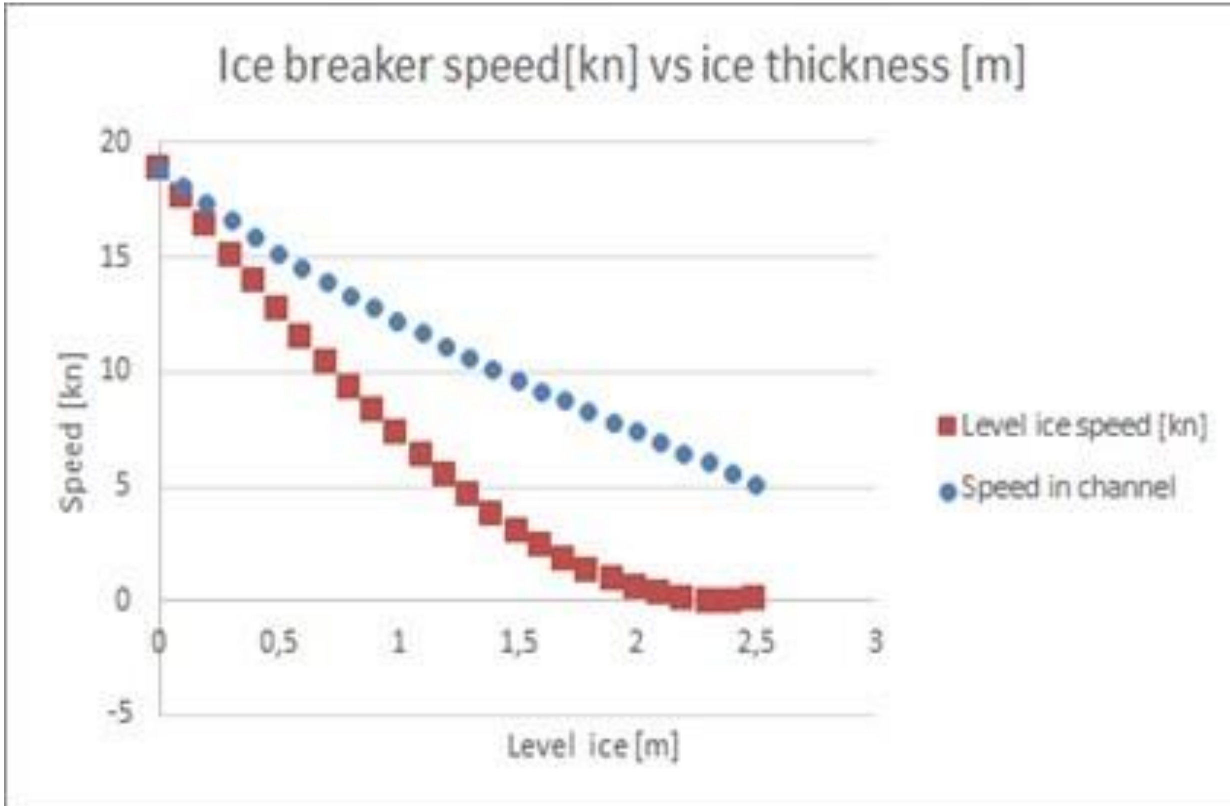


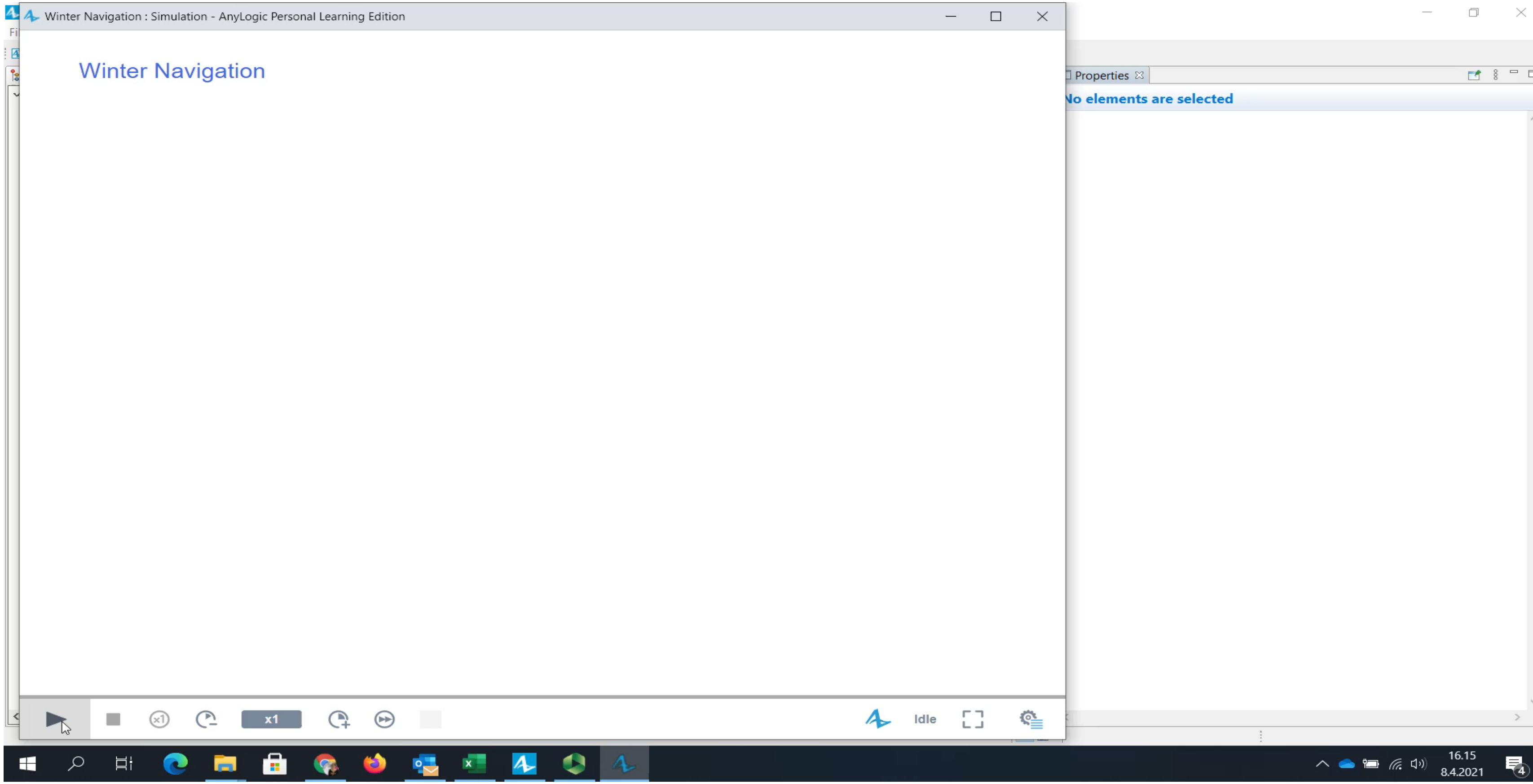
Simulation model, assumptions

- The model consist of dirways
- Icebreakers operate on these lines
- H-V curves determine the ship specific speed as a function of ice thickness, independent navigation and navigation behind an icebreaker
- Various ice conditions are included as an equivalent level ice thickness
- Assistance in convoys and towing, towing starts when the weakest ship speed drops below 6kn



Example of H-V curves





Visualization

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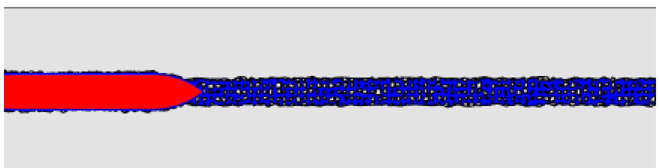
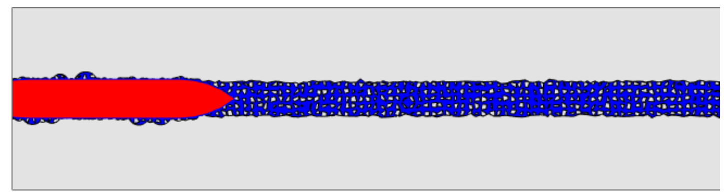
Aalto Ship Operation in Ice Simulator (ASOIS)

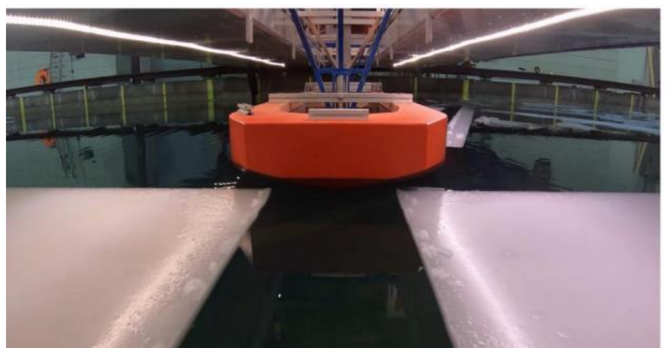
Numerical simulation program capable of simulating ship operation in various ice conditions

Ship in narrow ice channel



Ship in closing ice channel

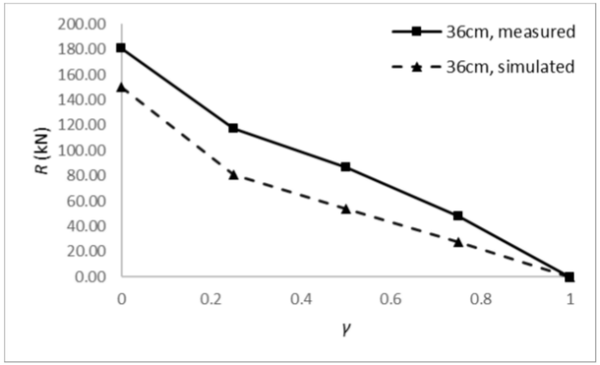


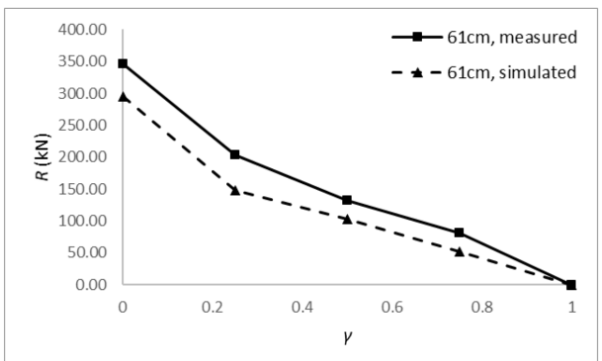


Model scale testing in Aalto ice and wave tank

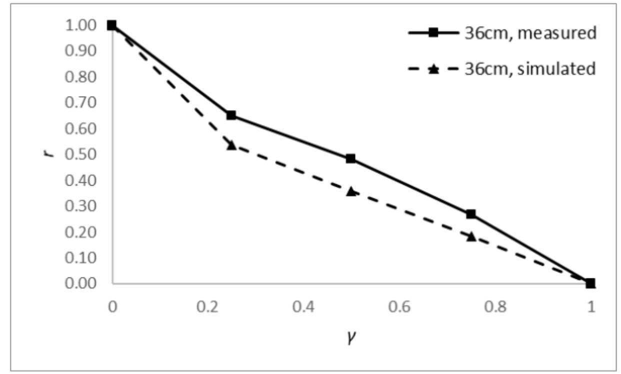
Simulation results

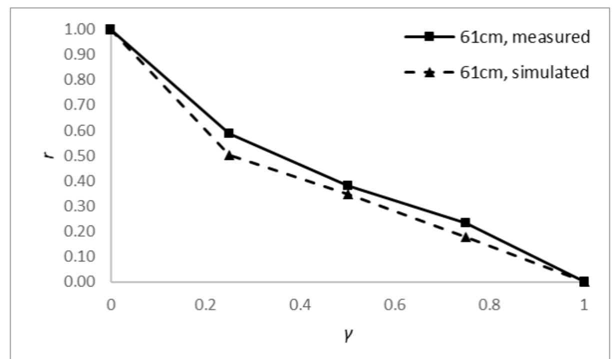
Resistance comparison





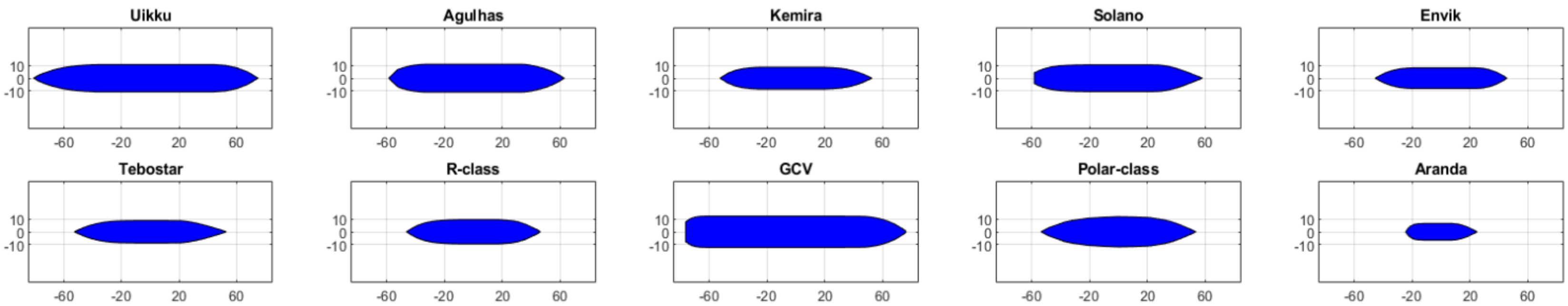
Normalized resistance





Simulation with more ships

Ship name	Length (m)	Breadth (m)	Draught (m)	Block coefficient
Envik	96	16.5	5.2	0.68
Kemira	105	17	8.1	0.74
Solano	116	21	6.2	0.69
Tebostar	106	17.6	6.6	0.63
Uikku	156	21.5	9.5	0.71
Agulhas II	126	22	7.65	0.64
R-class icebreaker	93	19.2	7.2	0.63
Polar-class icebreaker	107.3	23.8	9.1	0.57
General cargo vessel	149.3	24.6	9.4	0.80
Aranda	51.2	13.8	4.6	0.56



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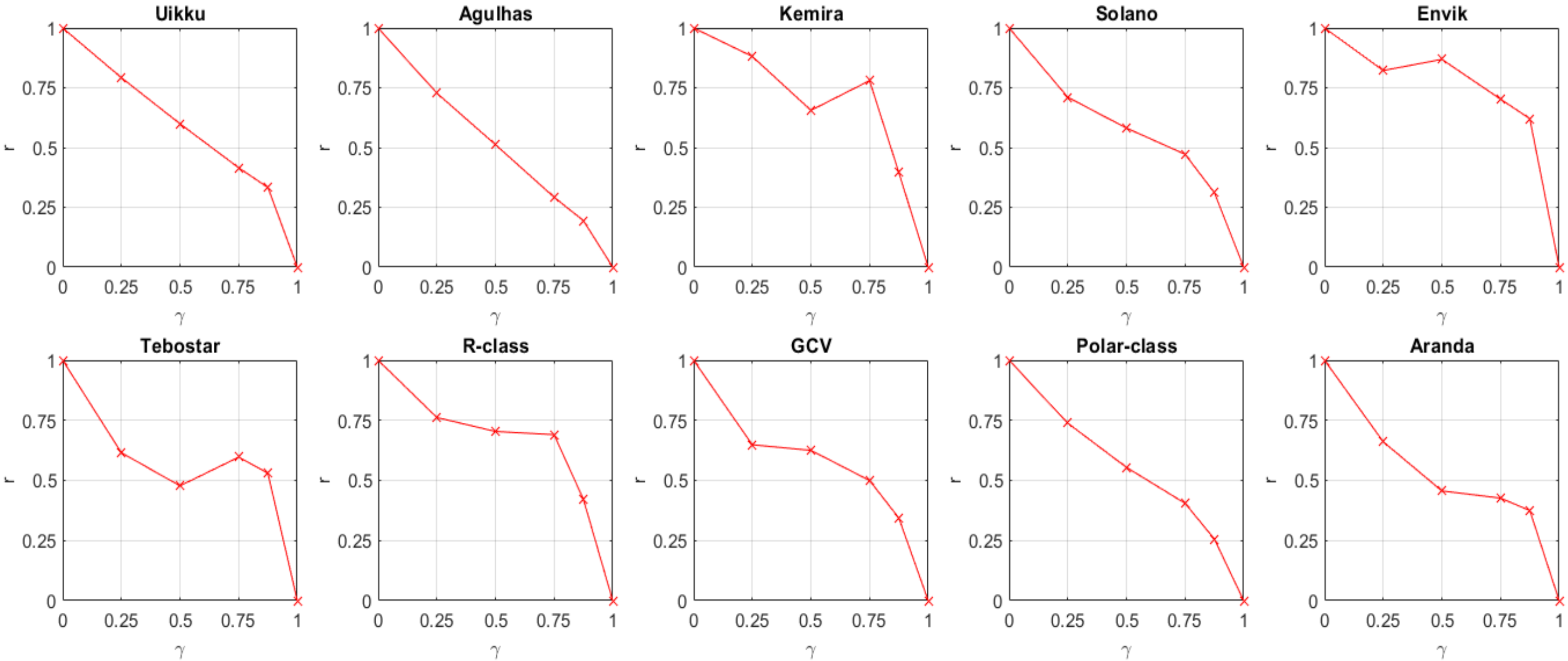
Simulation results



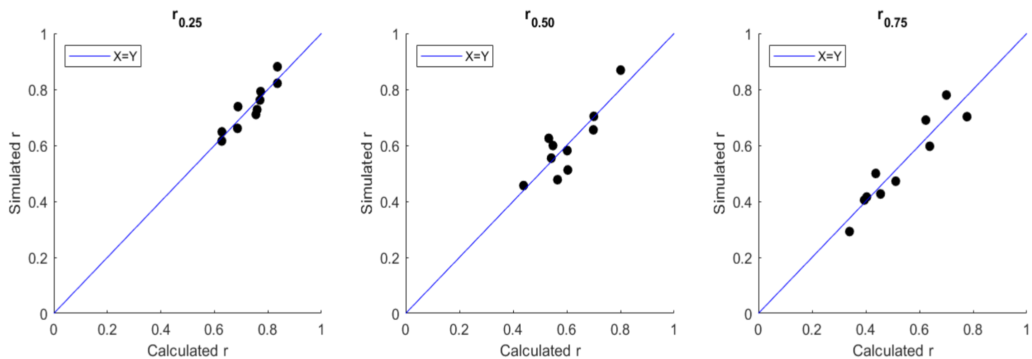
X-axis: channel width/ship width
Y-axis: resistance/level ice resistance

Regression formulas

- $r_{0.25} = 0.8048 - 0.4710 \tan \phi_1 + 0.8421 \tan \phi_2 - 0.6101 \tan \phi_3 + 0.1075 \tan \phi_4$
- $r_{0.5} = 0.6136 - 0.4700 \tan \phi_1 + 0.7100 \tan \phi_2 - 0.6790 \tan \phi_3 + 0.1801 \tan \phi_4$
- $r_{0.75} = 0.2128 - 0.4531 \tan \phi_1 + 0.7164 \tan \phi_2 - 0.5611 \tan \phi_3 + 0.1990 \tan \phi_4$

- Resistance as functions of hull angle and channel width

verific
ation

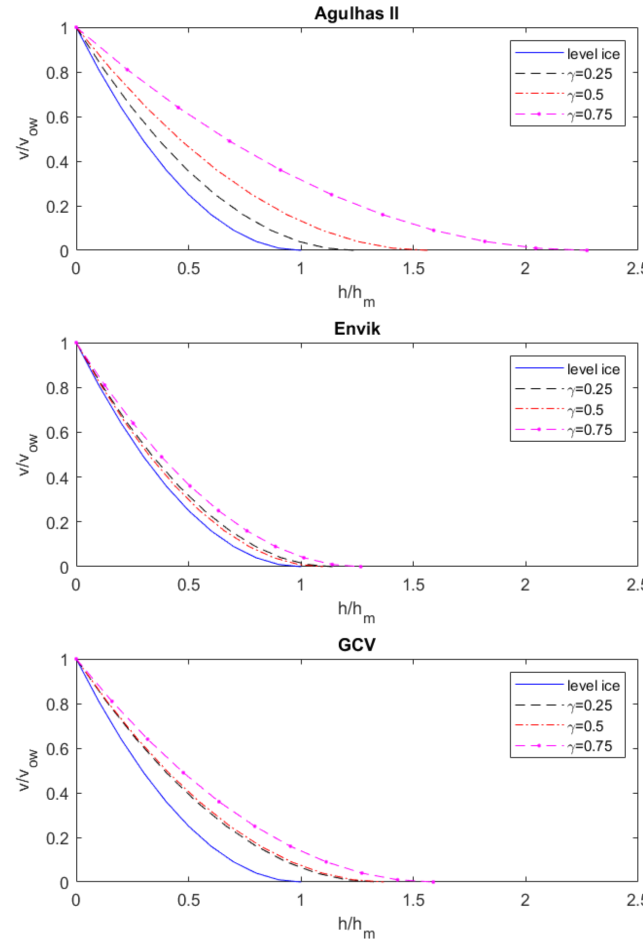


Influence on h-v curves

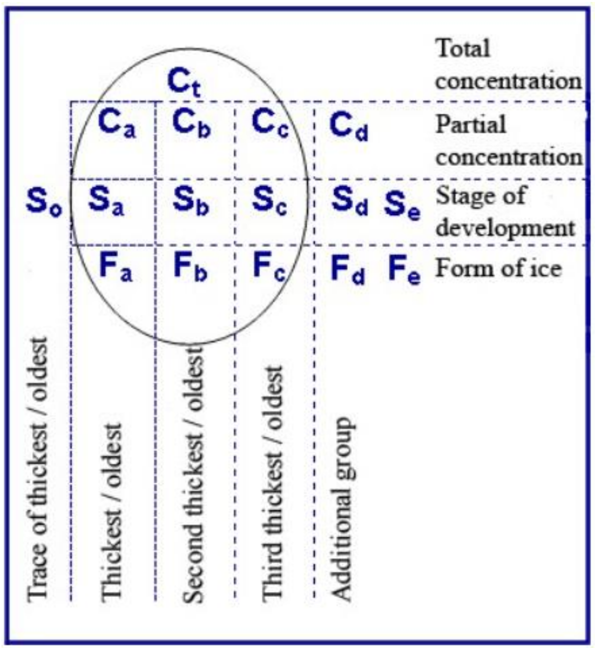
Type I vessel: efficient escort in narrow ice channel

Type II vessel: Inefficient escort in narrow ice channel

Type III vessel: effective escort in narrow ice channel, but not sensitive on channel width



Equivalent ice thickness based on ice data



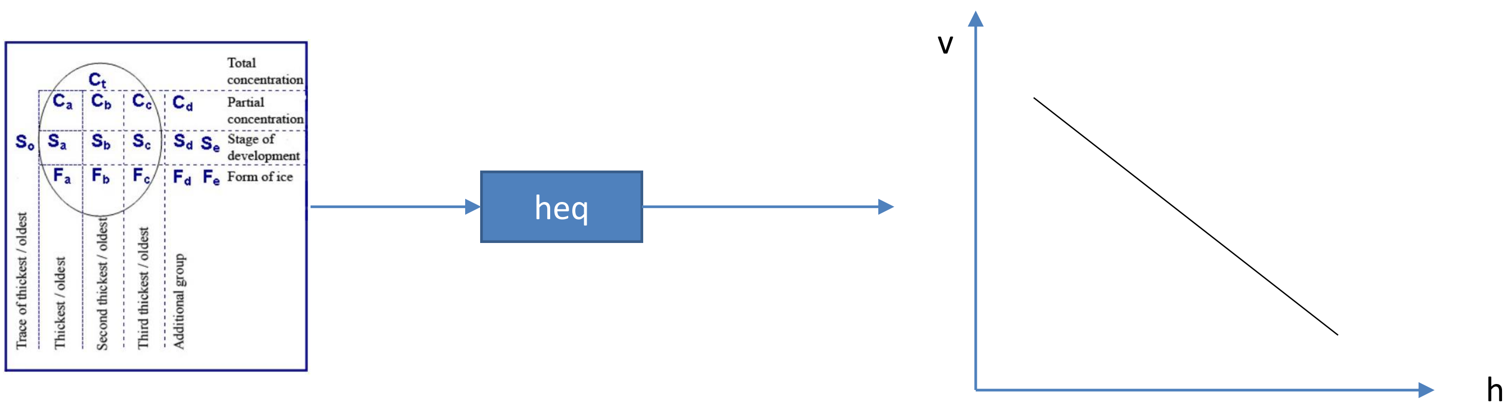
- Mandatory fields
  - Concentration
  - stage of development (thickness)
  - form of ice (floe size)
- Optional fields
  - Ridge density
  - And many other fields
- In the data we have, over 10 parameters relevant to ship performance

Simplify ice parameters into a single thickness parameter

h_{eq} = f(Ct,Ca,Cb,Cc,Sa,Sb,Sc,Fa,Fb,Fc,Ridge density)

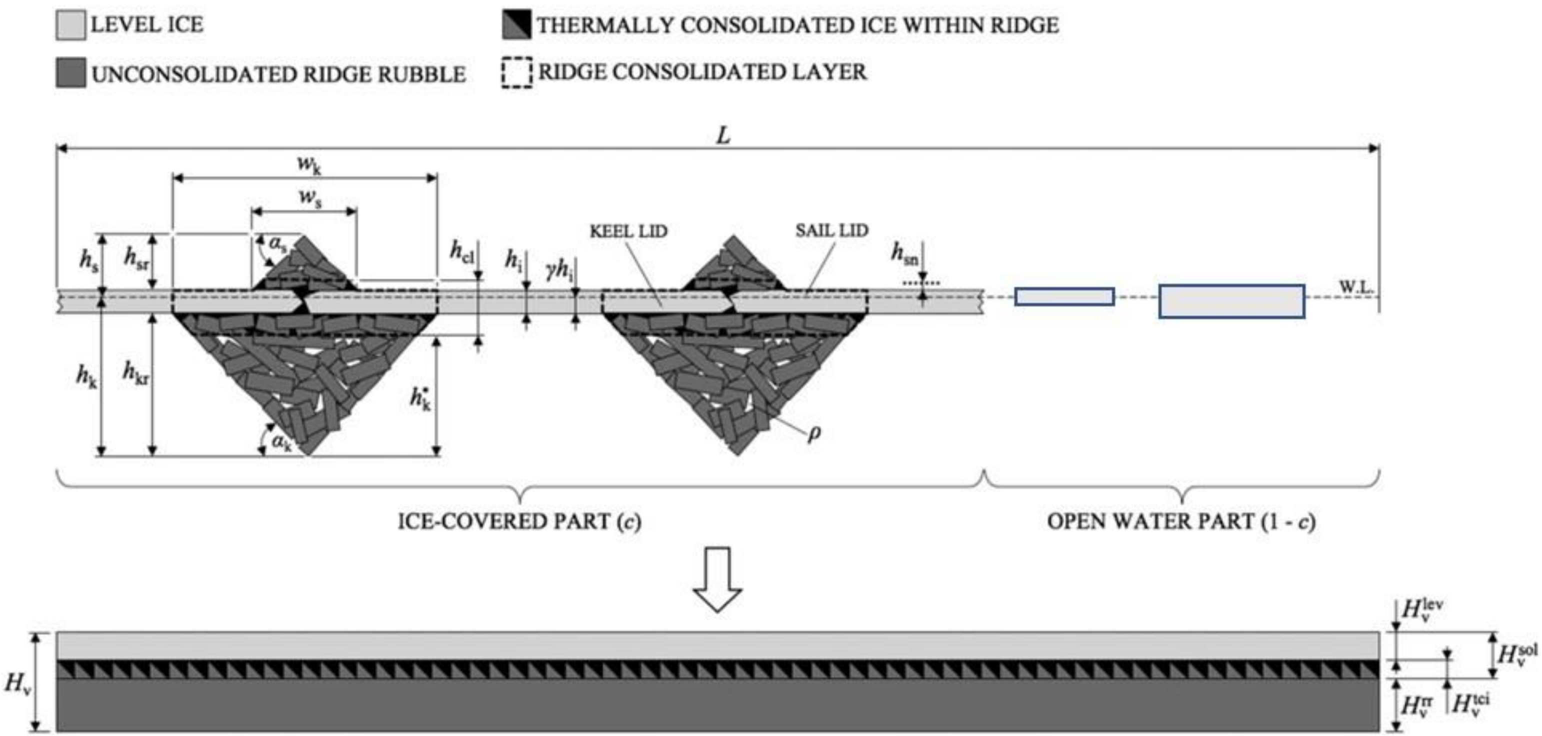
So that the resistance is equivalent to level ice resistance with h_{eq}

$R_{levelice}(h_{eq})$ = R(Ct,Ca,Cb,Cc,Sa,Sb,Sc,Fa,Fb,Fc,Ridge density)

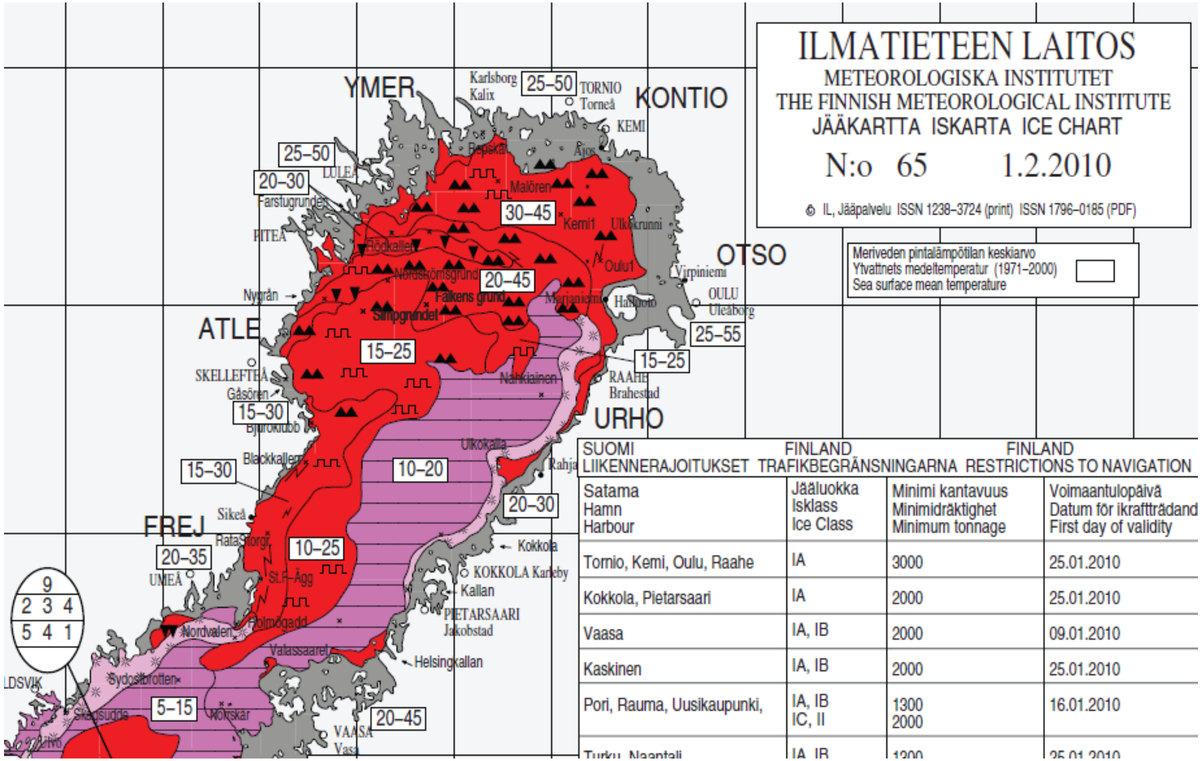


Equivalent-volume thickness

- Volume-conservative
- Commonly adopted

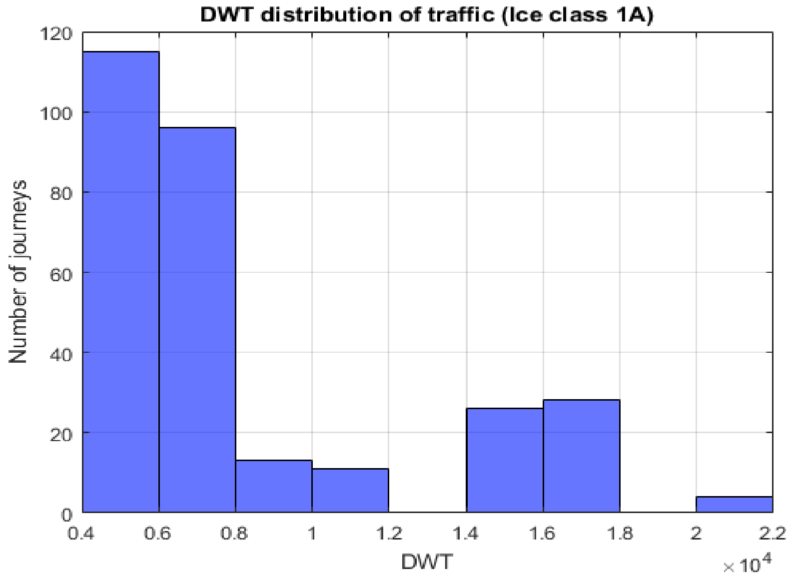


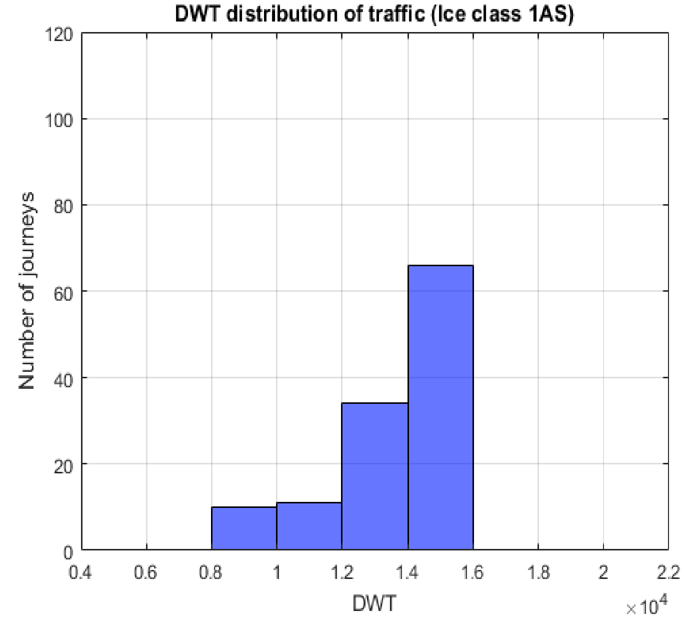
Case study 1



- 15 Jan- 15 Feb, 2010
- Close to normal winter

Number of cargo ships on the studied area





Ice class IA

Ice class IAS

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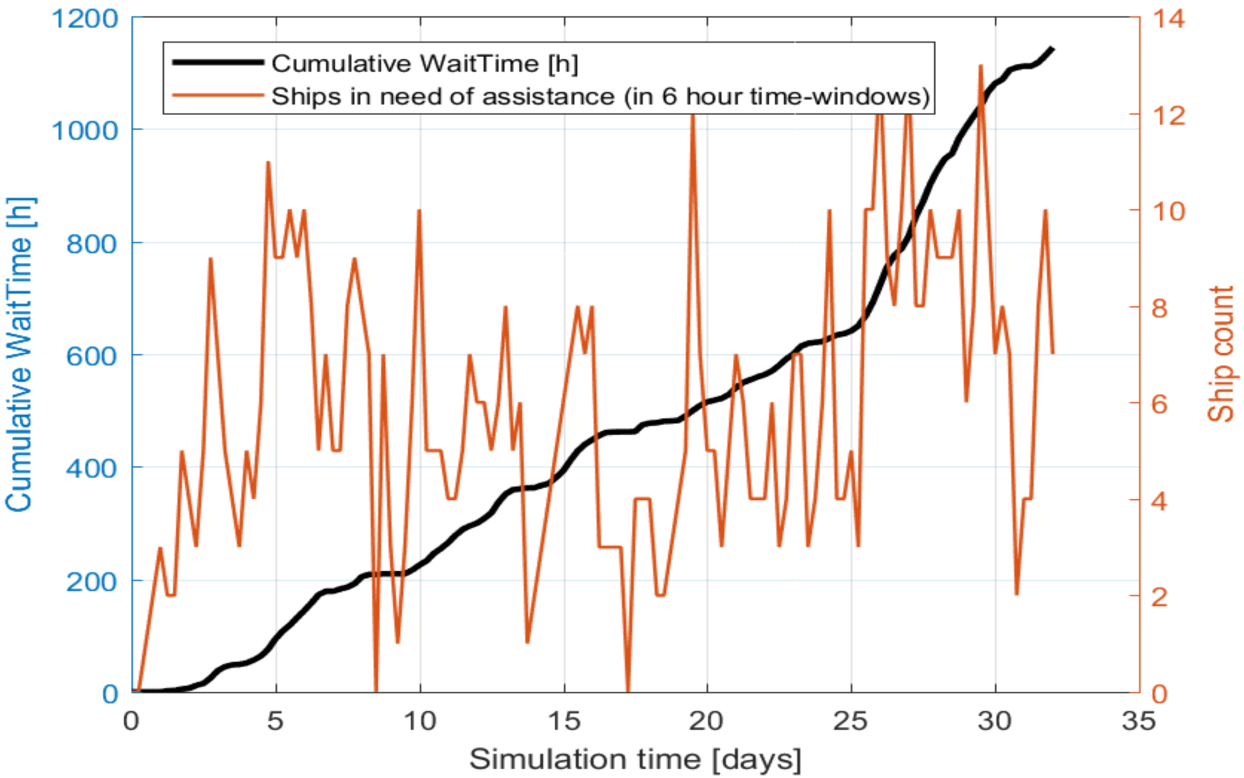
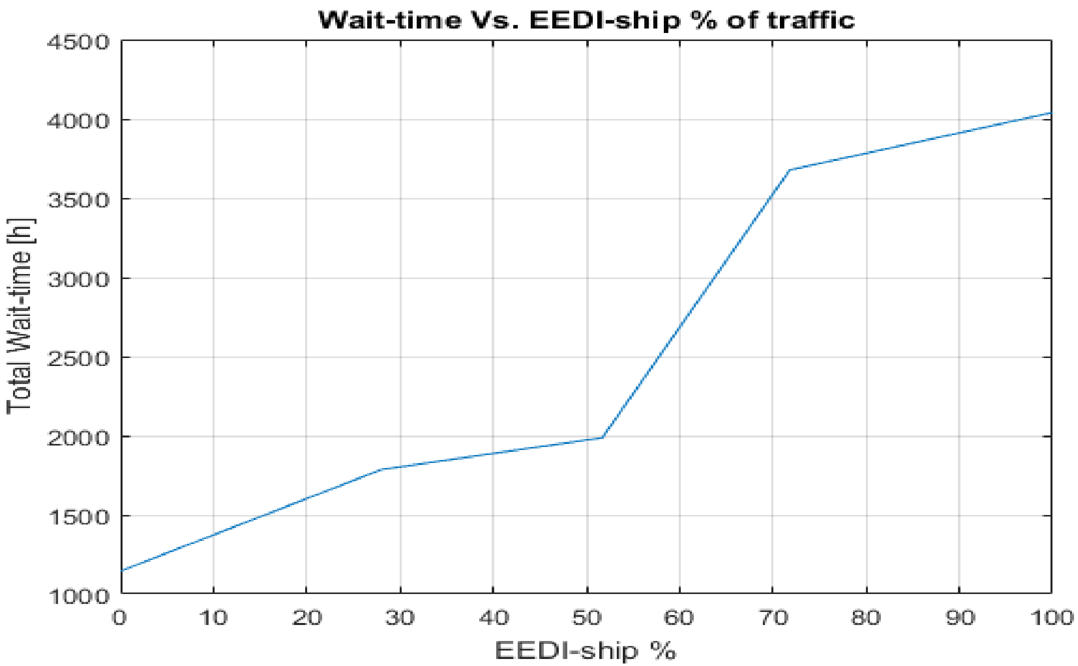
Simulated results (Waiting time)



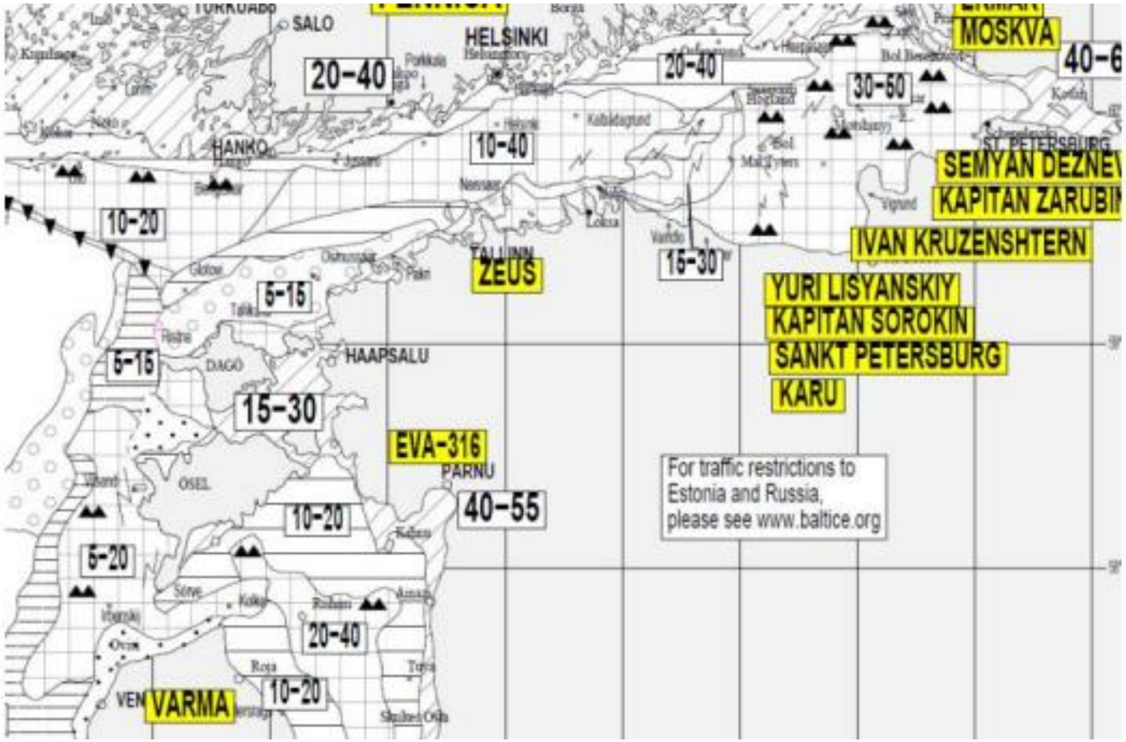
- Cumulative waiting time
- Ships needing assistance in 6 hour time windows
- The simulated waiting time compared with the real data and the resulsta are comparable within 1.7 % margins

Possible effect of EEDI ships on the waiting time



- 50 % EEDI ships will double the waiting time
- 100 % EEDI ships will trible the waiting time
- This indicates that Finnish IB fleet may not be enough once number of EEDI ships increase even though winter are getting milder

Case study 2



- **IB Needs for Estonia until 2050**

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THE MODEL USED TO SIMULATE THE ESTONIAN WINTER NAVIGATION

- AIS data from winter 2018 used to describe the marine traffic
- Ice conditions based on the data by TalTech Meresüsteemide Instituut
- IB decision making principles:
  - Each icebreaker maintains a list of assistance requests received;
  - The icebreaker assists the vessel that has been waiting for the longest;
  - The icebreaker checks if any other vessel can be assisted along with the chosen vessel as part of a convoy;
  - If an icebreaker is not busy, it may assist vessel requests belonging to a neighboring operating zone of another icebreaker.

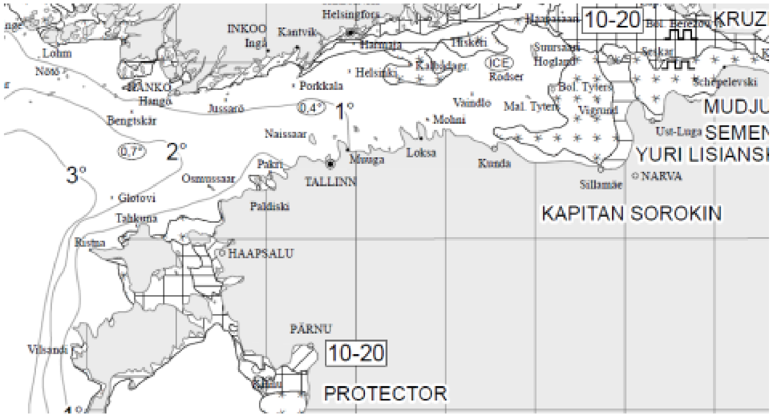
STUDIED SCENARIOS FOR MILD, NORMAL AND HARD WINTER

Table 21 Icebreaker scenarios

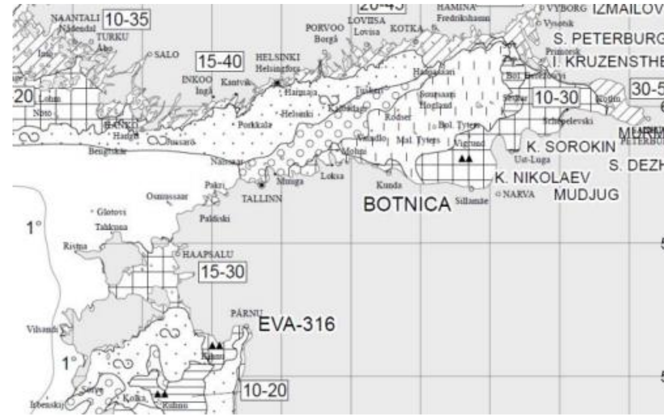
Icebreakers	ME Power (kW)	Shaft Power (kW)	IB Scenario 1	IB Scenario 2	IB Scenario 3
Gulf of Finland primary IB	13000	10000	+	+	+
Gulf of Finland secondary IB	9100	7000		+	+
Gulf of Finland third IB	6250	5000			+
Gulf of Riga IB	5500	4400	+	+	+

Note: '+' means the IB is included in the scenario

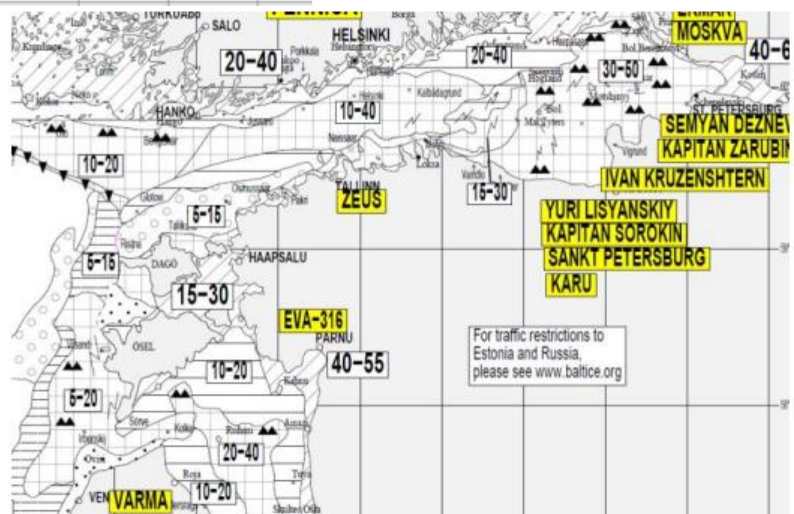
DEFINITION OF THE MILD, NORMAL AND HARD WINTER



MILD



NORMAL



HARD

SUMMARY OF THE RESULTS, AVERAGE WAITING TIME

Table 34 Summary of the main KPI-average waiting time (mins) for all scenarios

	Mild winter	Average winter	Severe winter
IB Scenario 1	~130	~500	~1000+
IB Scenario 2	~110	~160	~400
IB Scenario 2*	-	-	~470
IB Scenario 3	~110	~140	~150
Low Traffic		~150	
No Icebreaker		N/A	

- Average waiting time: the total waiting time of the all assisted vessels divided by the number of assisted vessels
- In addition, fuel consumption for IBs has been calculated and this has been used by Aker Arctic in their analysis

Conclusions

- A new simulation modeled developed to study the Baltic Sea winter navigation system
- The simulation model validation indicate that the system is well comparable with the real data
- The model can be used to plan for the future need of icebreakers
- The model can also be used to analyse the effect of future environmental regulations on the need of IB fleet
- The model extended to study the winter traffic in GUF and to evaluate the IB needs of Estonia

Questions ?