On-line ice resistance survey for the ships supporting winter navigation in ice channels of the Baltic Sea

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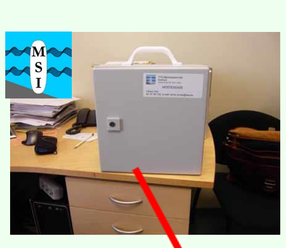
PREFACE: the idea of this work is to combine different datasets (sat imagines, *in situ* measurements and model forecast data) in added value form into web based user interface to support safe navigation in sea ice.

INTRODUCTION: Wintertime navigation is specific and risky as ice resistance can reduce ships speed and maneuvering capacity. The on-line knowledge of ice resistance and its forecast will help to avoid ships stack in ice, to organize accordingly the ship traffic, to improve safety of the winter shipping, to lower fuel consumption of the fleet and to plan a ship time.

1

• A ship stuck in compressive ice (red arrows) and needs the icebreaker assistance to proceed further

MEASUREMENTS: Ship hull vibration intensity characterizing the ice resistance



2

• Hull of the ship proceeding in ice, vibrates because of resistance from ice. There are other sources for vibration - engines, waves etc but these can be detached from ice resistance caused vibrations.

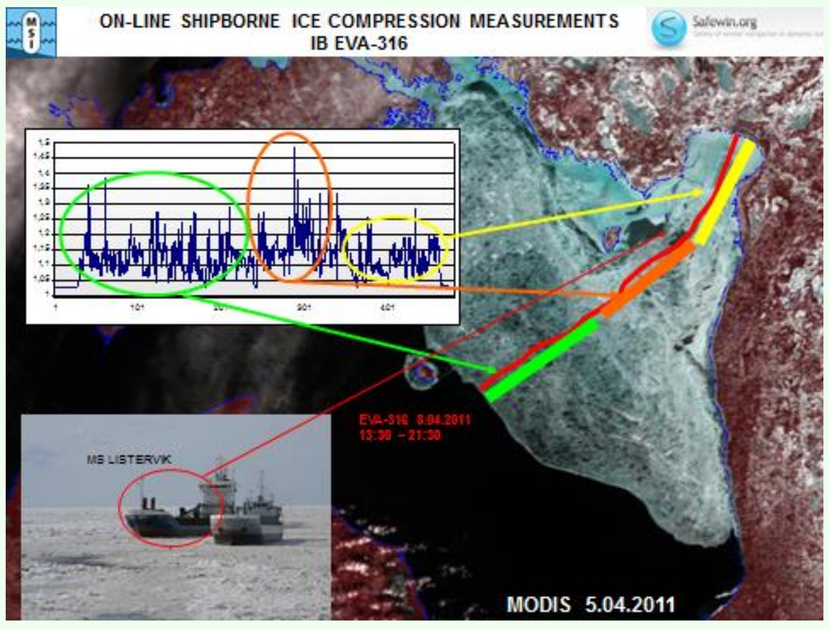
• Harder ice resistance (severe ice conditions/compression) cause more (intensive) vibrations.

• Shiphull vibrations are measured in terms of 3D acceleration, sensor tied to ship hull.

• Obtained vibration data (1 minute max) stored and transmitted in real time to shore.

• Ice resistance parameter calculated and related to other parameters – ship speed, actual ice conditions, forcing conditions etc

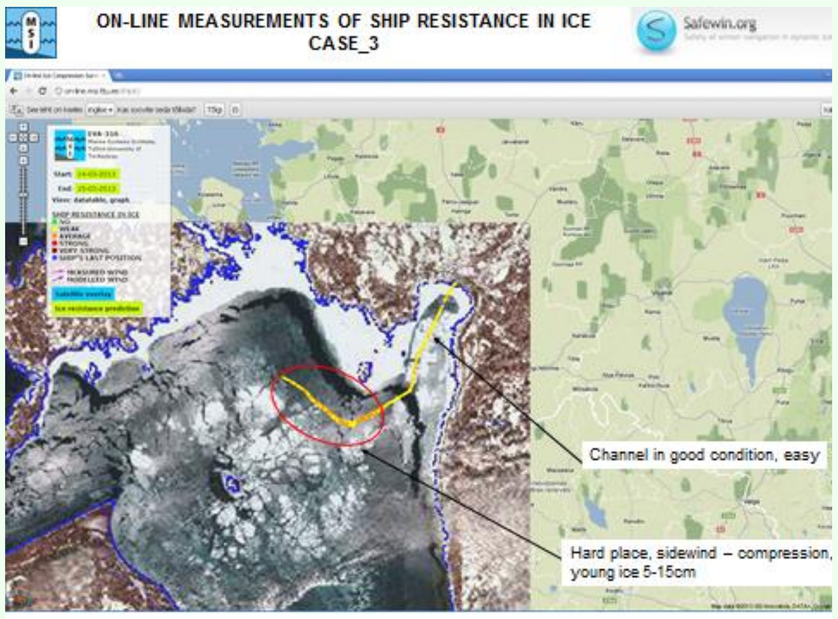
3



•The ship hull vibration data were converted to color-coded ice resistance index

- no
- weak
- average
- strong
- very strong

4



•The angle between the wind direction and ship course is one of the important factors determing the ship resistance in ice channel

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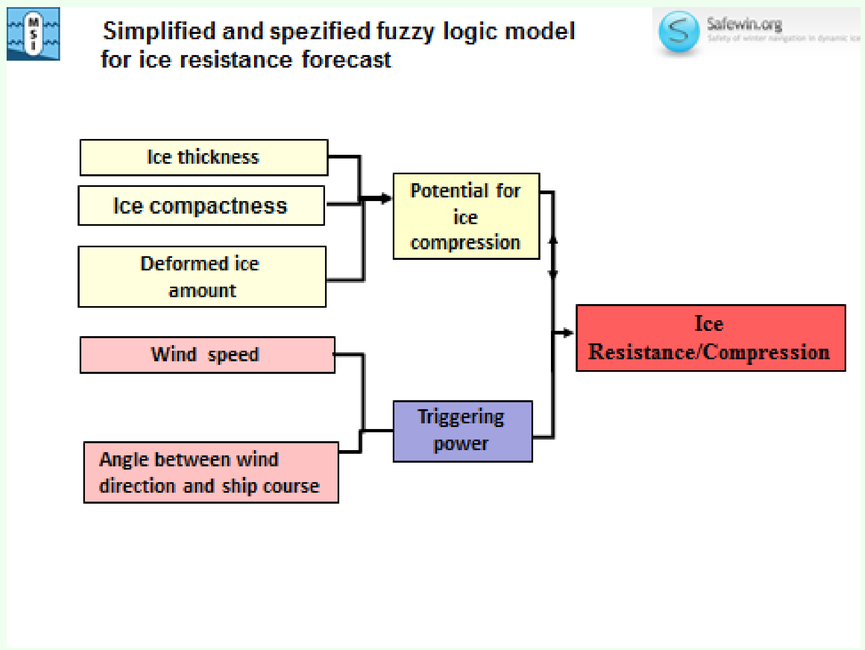
MODEL: Fuzzy logic expert system. The model produces 48 hours forecast of ice resistance along the fairway to Pärnu Harbour, Gulf of Riga, the Baltic Sea (colored boxes in figure 6). Forecast calculations were based on weather forecast (HIRLAM, 48 h forecast of wind) and ice data deduced from MODIS satellite images, from ice charts as well communication with icebreaker crew.

5



The model considers that ship speed depends on:

- ice characteristics (ice thickness, deformed ice amount and ice concentration)
- and wind and ship characteristics (wind direction and speed , ship course)

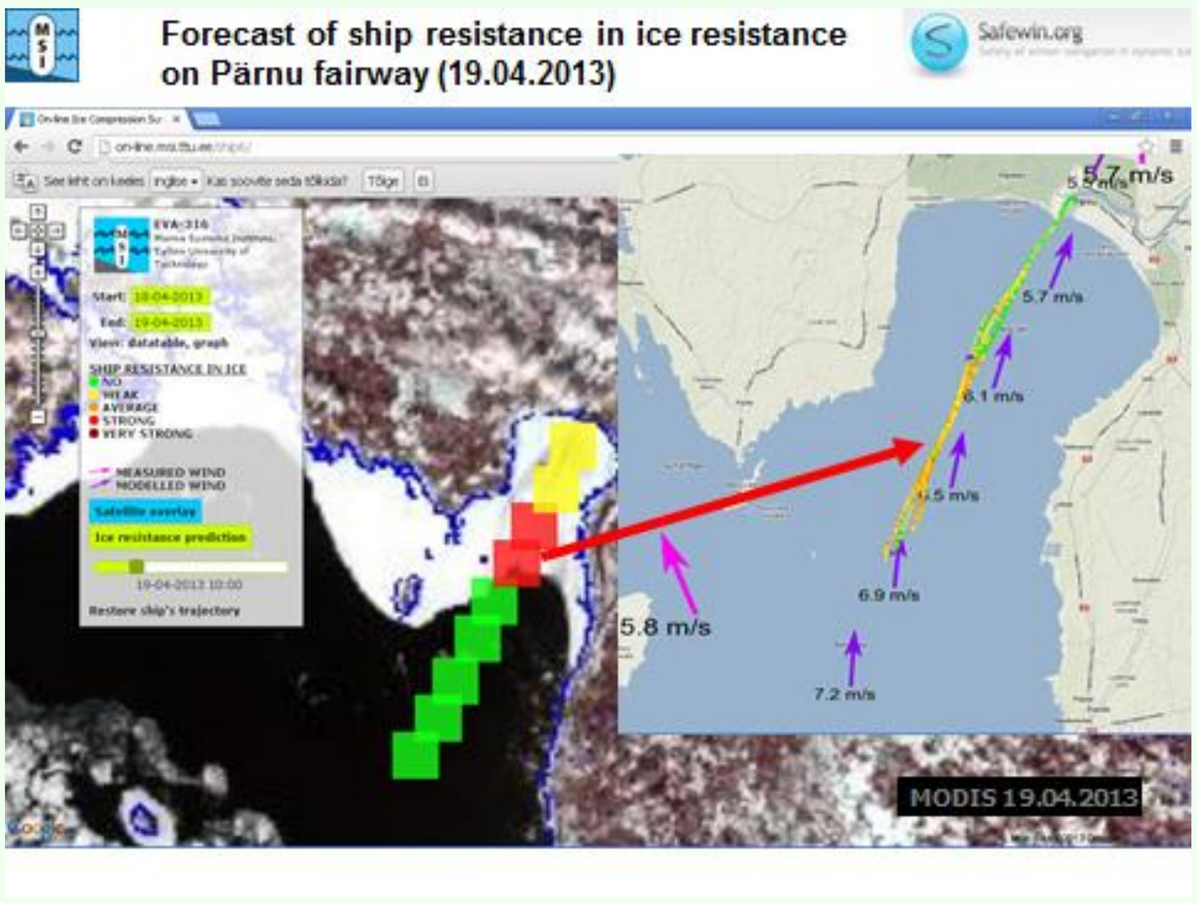
The model forecast was converted to color-coded ice resistance index:

- no
- weak
- averaged
- strong
- very strong

Look figure **6**

6

LOOK OF WEB-BASED USER INTERFACE (operates only at winter)
http://on-line.msi.ttu.ee/ship6/:



Screenshot of web based user interface for forecast of ice compression hazard (ship resistance in ice) implemented in fairway into Pärnu Harbour, Gulf of Riga. MODIS satellite data were used to give ice situation as background and different colors show grading of ship resistance forecast, hourly for 48h ahead. The pasted figure shows the *in situ* measurements of ice resistance index (one option of web based user interface).

SUMMARY

- Method to evaluate the ship resistance in ice channels is developed, tested and implemented in fairway into Pärnu Harbour, the Gulf of Riga.
- Ice resistance data made available for on-line use and applications via web-based user interface, as well for statistical analysis and post-processing.
- Together with ship resistance the forcing parameters (wind, sea levels, etc.) and their forecasts made available through same user interface.
- Forecast method of ship resistance in ice, based on fuzzy logic, was developed and applied on Pärnu Harbour fairway, realized as web based service complimentary to resistance monitoring data.
- Validation of the system is made during IB season 2012/2013 on fairway into Pärnu Harbour, based on board observations of IB EVA-316

http://on-line.msi.ttu.ee/ship6/: