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METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Variability of sea ice thickness in the Baltic Sea

Jari Haapala, Mikko Lensu, Byoung Woon An,
Jonni Lehtiranta and Iina Ronkainen
Marine Research Unit
Finnish Meteorogical Institute

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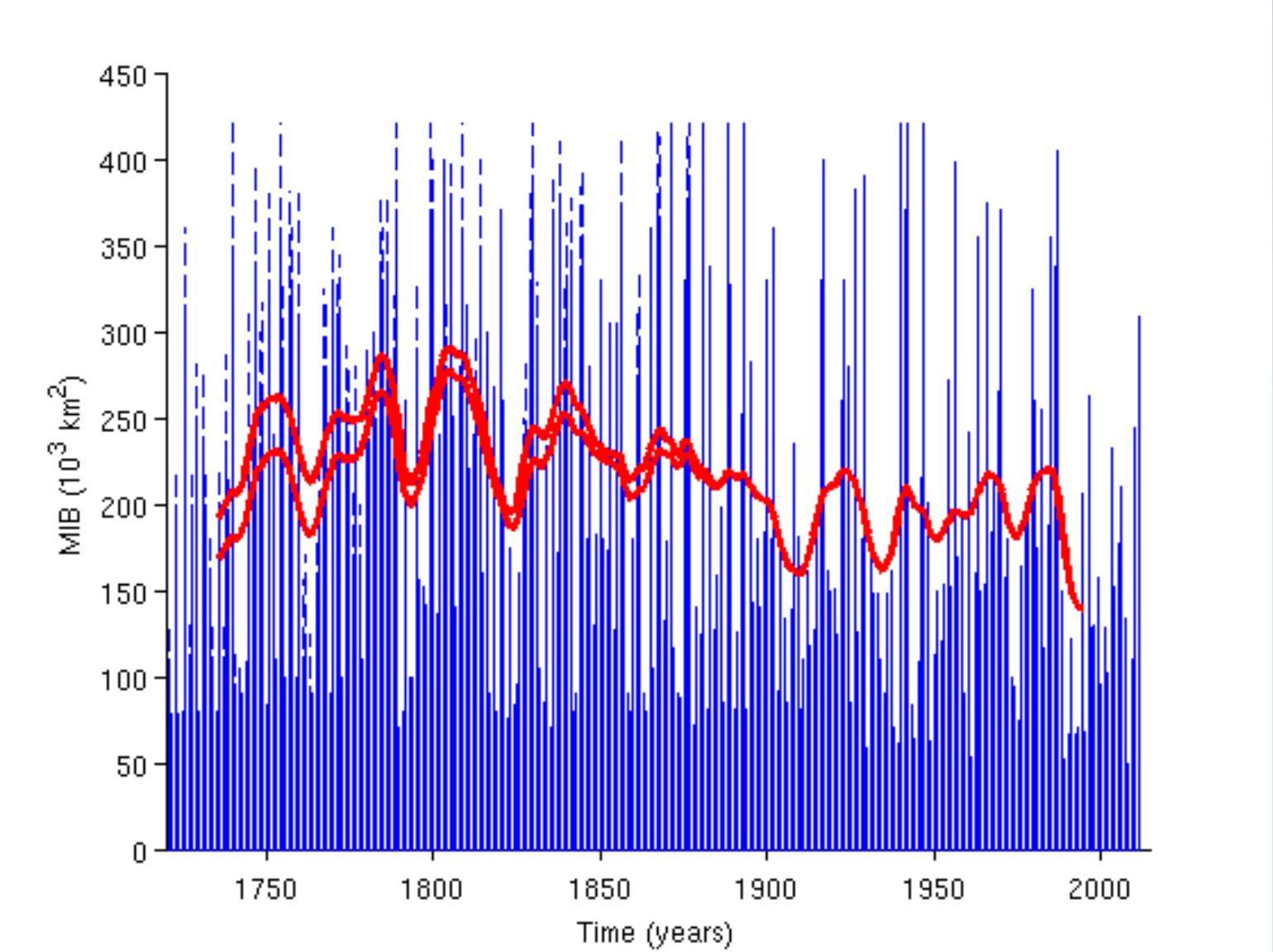
Christian Haas, York University, Canada

OUTLINE

- Short introduction of the long term sea ice observations in the Baltic Sea.
- Description of sea ice thickness measurements in the Baltic.
- Introduction of the HELMI model for numerical investigations of ridged ice production.

ANNUAL MAXIMUM ICE EXTENT OF THE BALTIC (MIB)



Coastal observations

Drift ice thickness measurements

SEA ICE IS STILL THICK AND HAZARD FOR SHIPPING

2010

of ships freed from Baltic Sea ice - Mozilla Firefox

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http://news.bbc.co.uk/2/hi/8550687.stm

ships stuck ice baltic

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Dozens of ships freed from Baltic Sea ice

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Over 1000 trapped as ships stuck in Baltic ice

Nearly 1,100 people were trapped on two passenger ferries and two stuck in ice in the Baltic Sea.

Dozens of merchant vessels stuck in packed ice in Gulf of Bothnia

Getting ships detached from the ice will take at least a week

Owing to the strong winds and the difficult ice situation, almost all ship traffic to and from harbours has come to a halt in Northern Finland. Ships cannot get to the harbour through the ice without the help of

2011

at Sotheby's »

60 ships trapped in Baltic Sea Ice on Sunday: 5 icebreakers at work

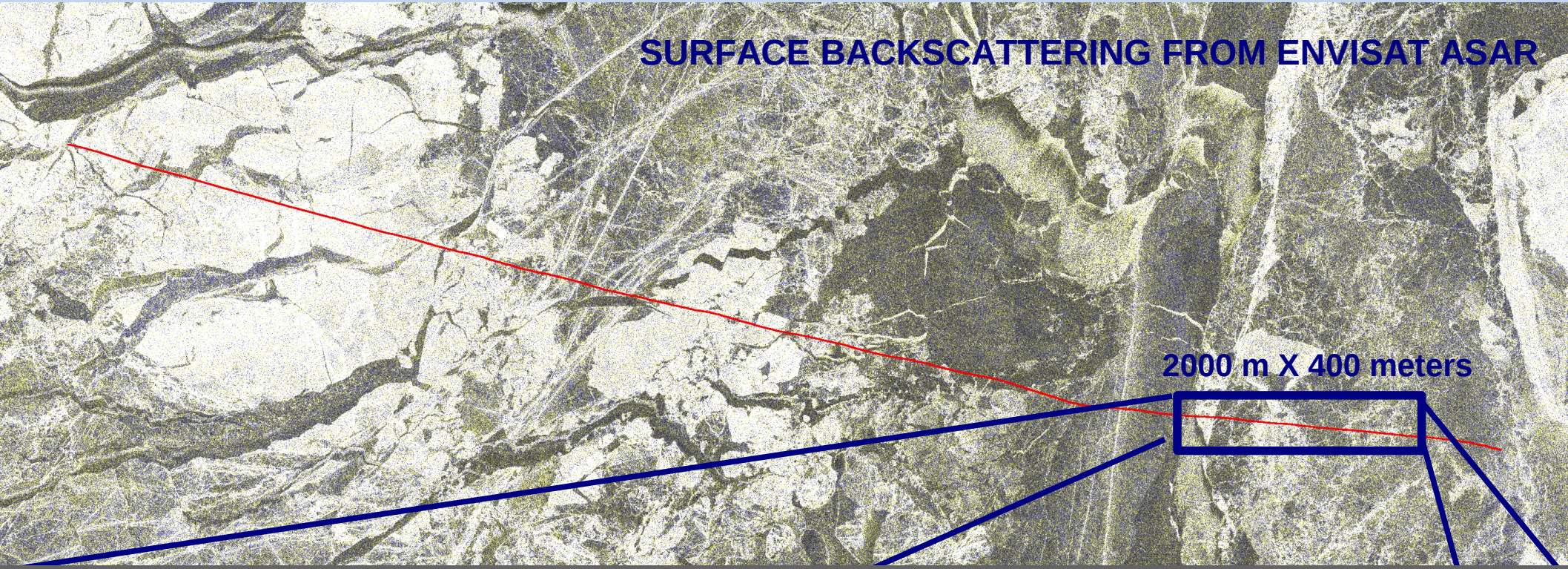
By ktwop

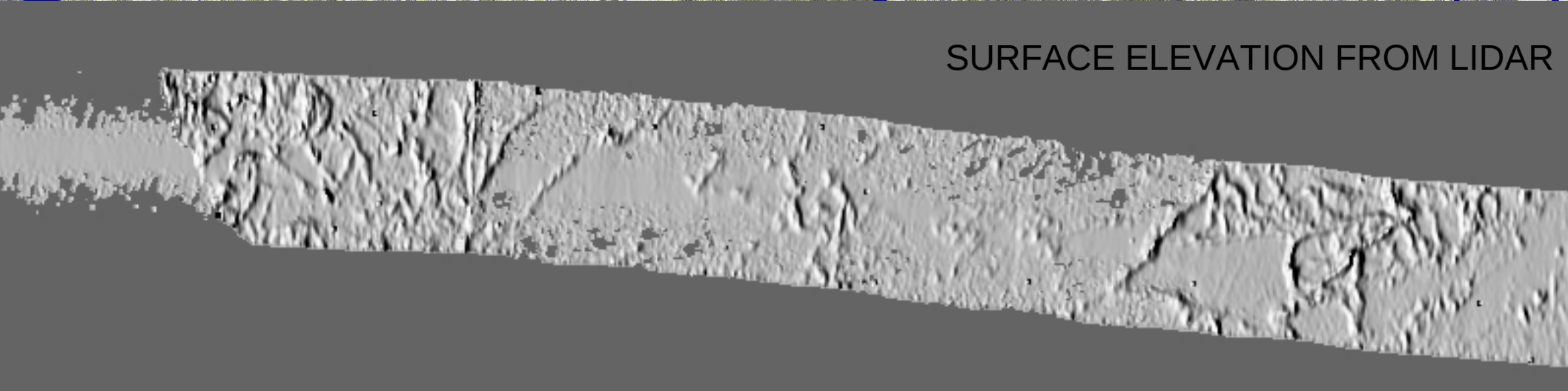
2011

Ships stuck in Baltic Sea ice

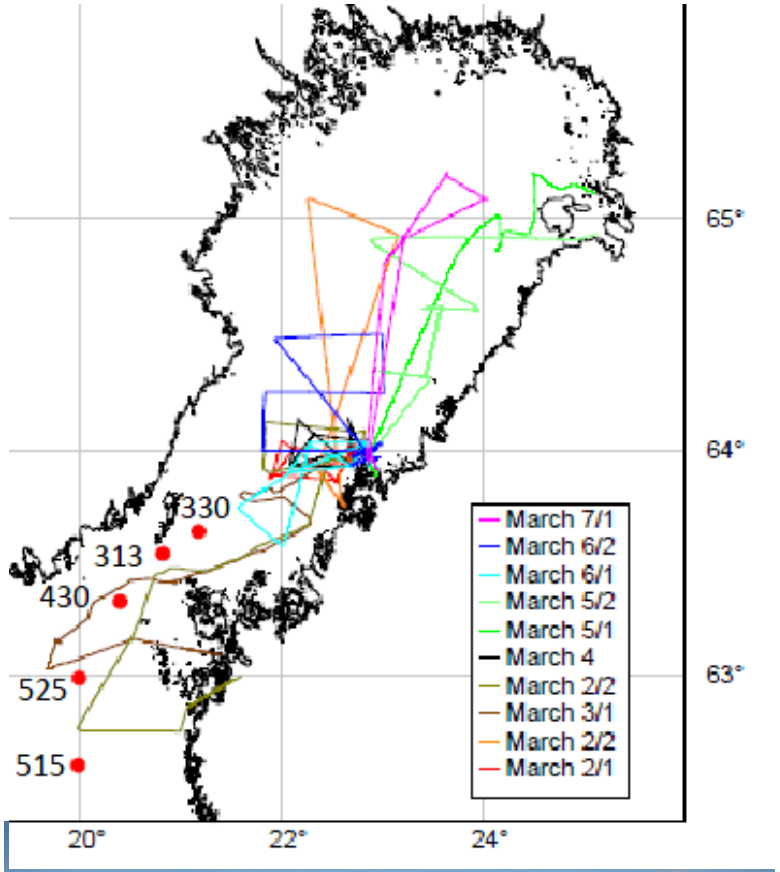
05/03/10 07:31 CET

VARIABILITY OF SEA ICE CHARTERISTICS IN GEOPHYSICAL SCALE





NEW DATA SET OF ICE THICKNESS



- Alfred Wegener Institute (AWI) has performed HEM measurements in the Bay of Bothnia and the Gulf of Finland in 2003, 2004, 2005, 2007, 2010, 2011.
- Activites funded by the IRIS and SafeWin EC projects
- HEM measurements validated by extensive drillings
- The most extensive dataset of ice thickness in the Baltic.
- Problems : weather, shallow water, large open water areas

HEM campaing 2-7 March 2011

Almost 3000 km of profile data

HELMI – Helsinki Multi-category sea-Ice model

- open water
- five undeformed ice categories
- one rafted ice category
- one ridged ice category

Model resolved ice motion and evolution equation for each ice category (Haapala et al. 2005)
Equations solved
1) Ice momentum balance equation
2) Rheological equation
3) Continuity equations for ice concentration and thickness categories

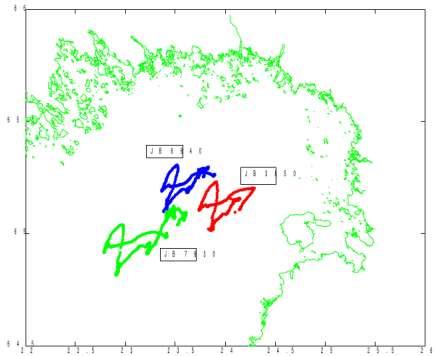
Assumptions :
- Viscous-plastic rheology (Hibler 1979; Zhang & Hibler 1997)
- Ice strength proportional to energy consumption in ridging (Rothrock, 1975)
- Ridging function r=r(h,A,g(h))
- rectangular ridges
- Model constants based mainly on Arctic models (Flato & Hibler,1995, Bitz et al.,2001)

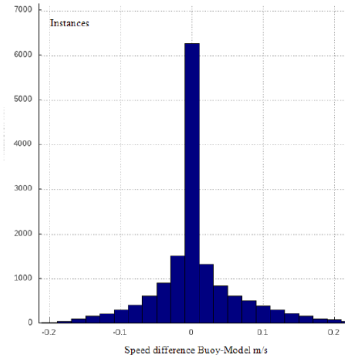
Hindcast simulations

- Simulation period : 2005-2011
- Atmospheric forcing : HIRLAM reanalysis
- Prescribed SST from ice charts

Model validation and sensitivity studies

- Buoy observations : 2010, 2011
- HEM data : 2005, 2007, 2010, 2011
- Sensitivity studies of ice strength which describe dissipation of the kinetic energy due to the deformation → optimized value





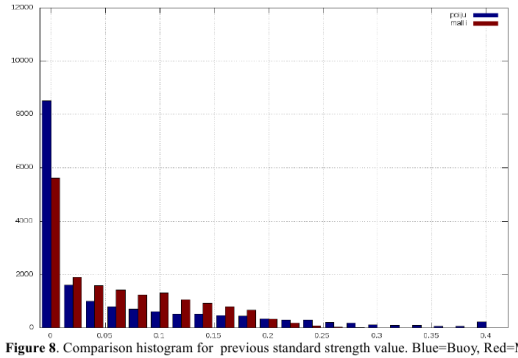
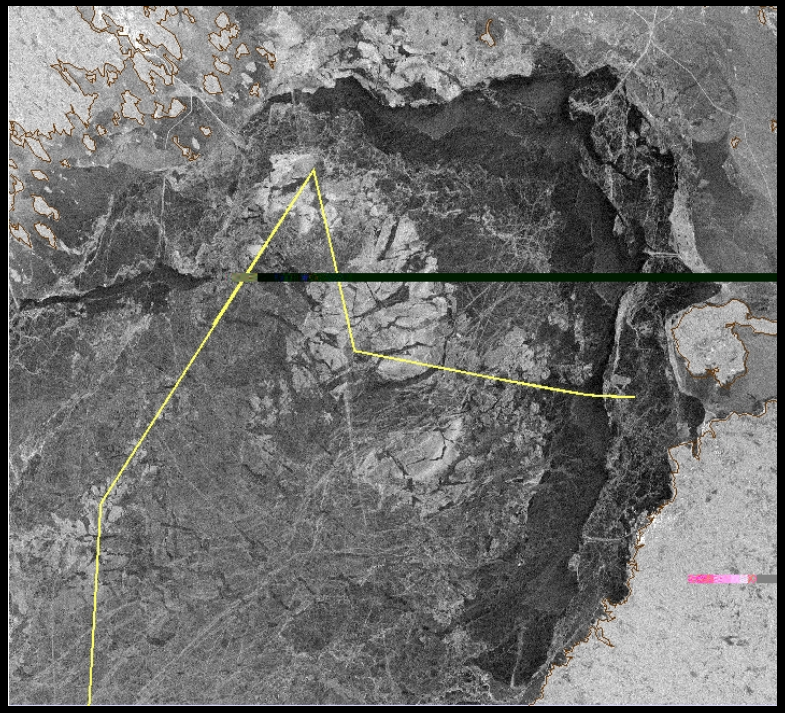
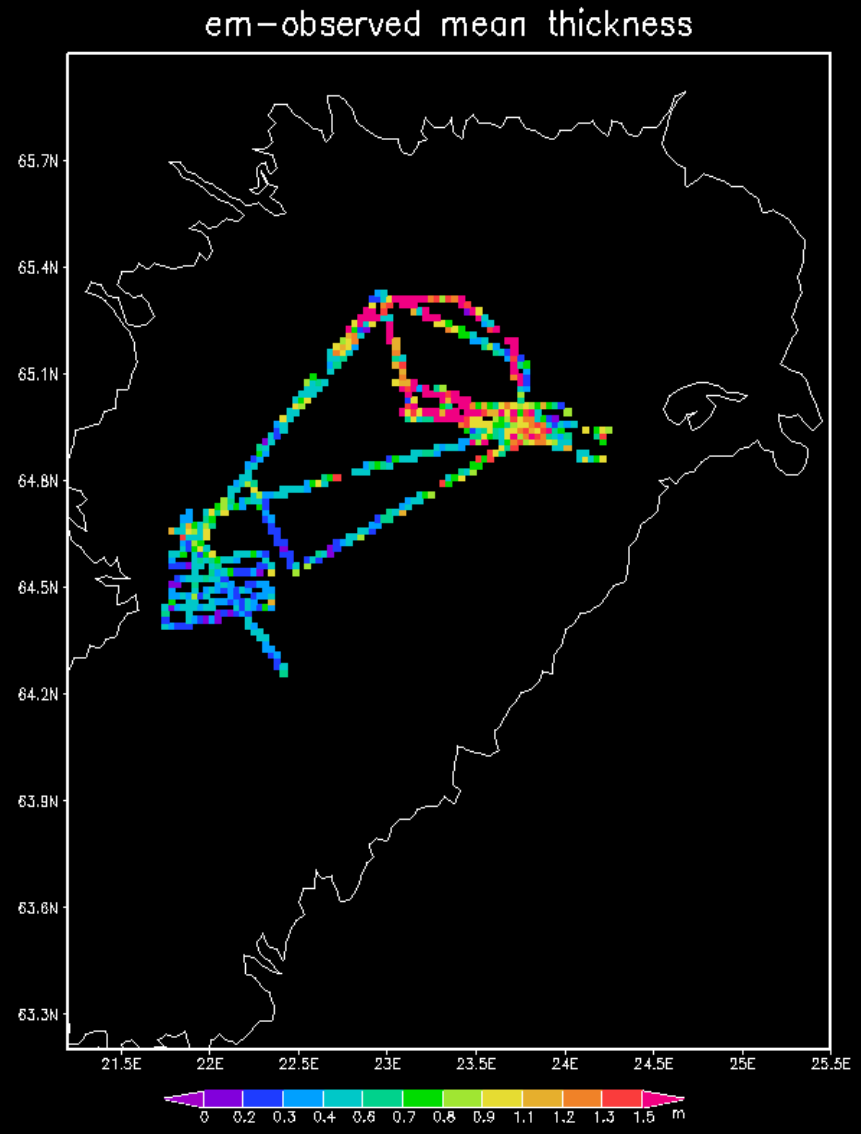


Figure 8. Comparison histogram for previous standard strength value. Blue=Buoy, Red=Model.

HEM MEASUREMENTS IN 2005, AVERAGED ON MODEL GRID

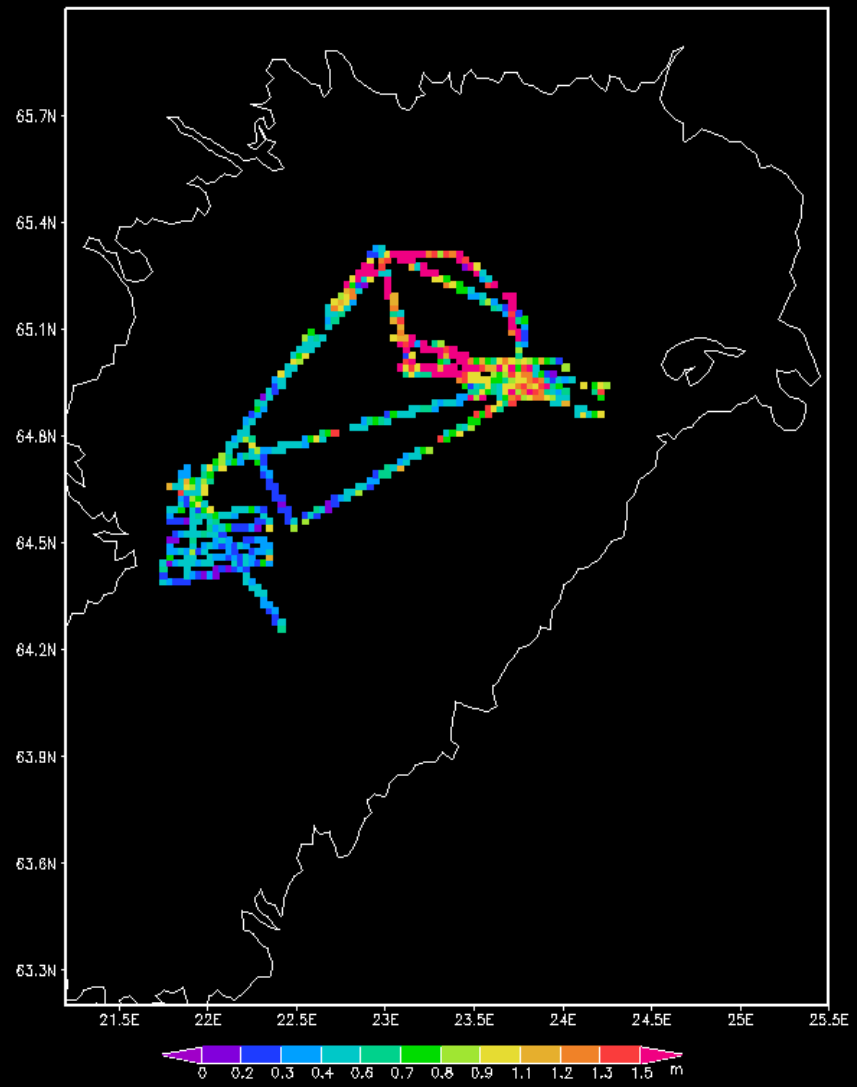
RadarSat image



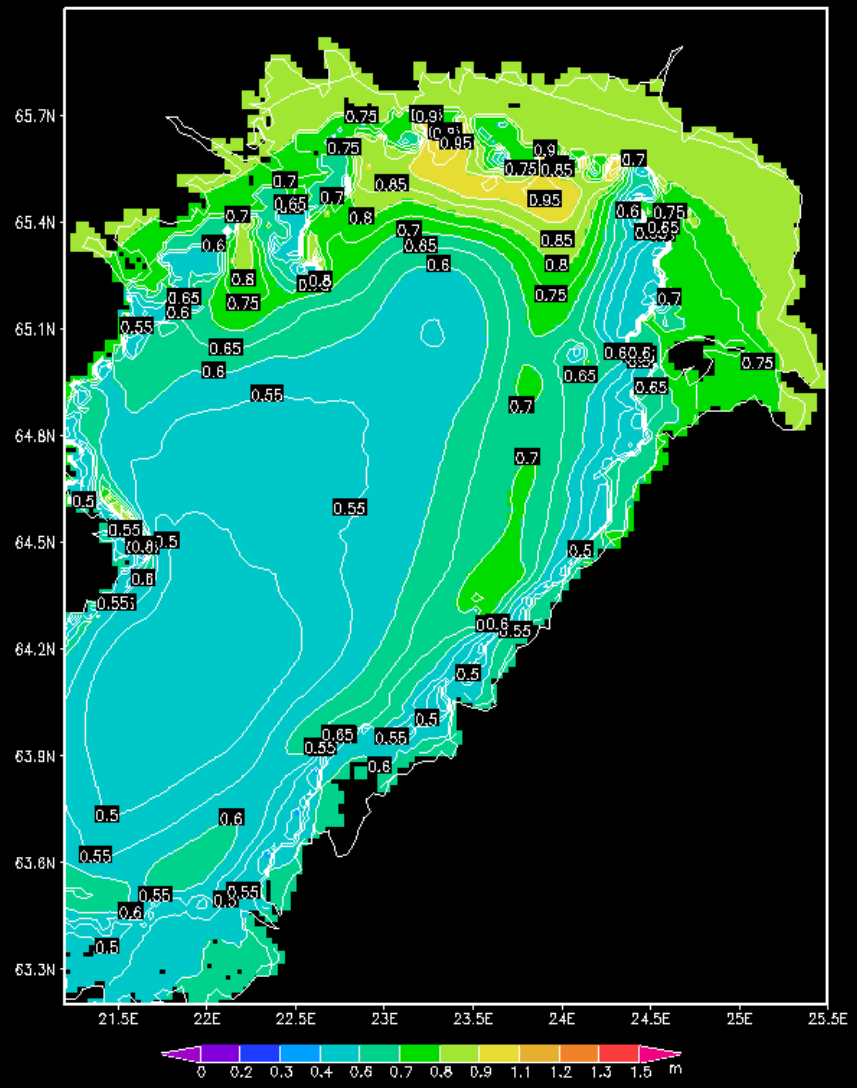


HEM MEASUREMENTS VS. MODELLED ICE THICKNESS

em-observed mean thickness

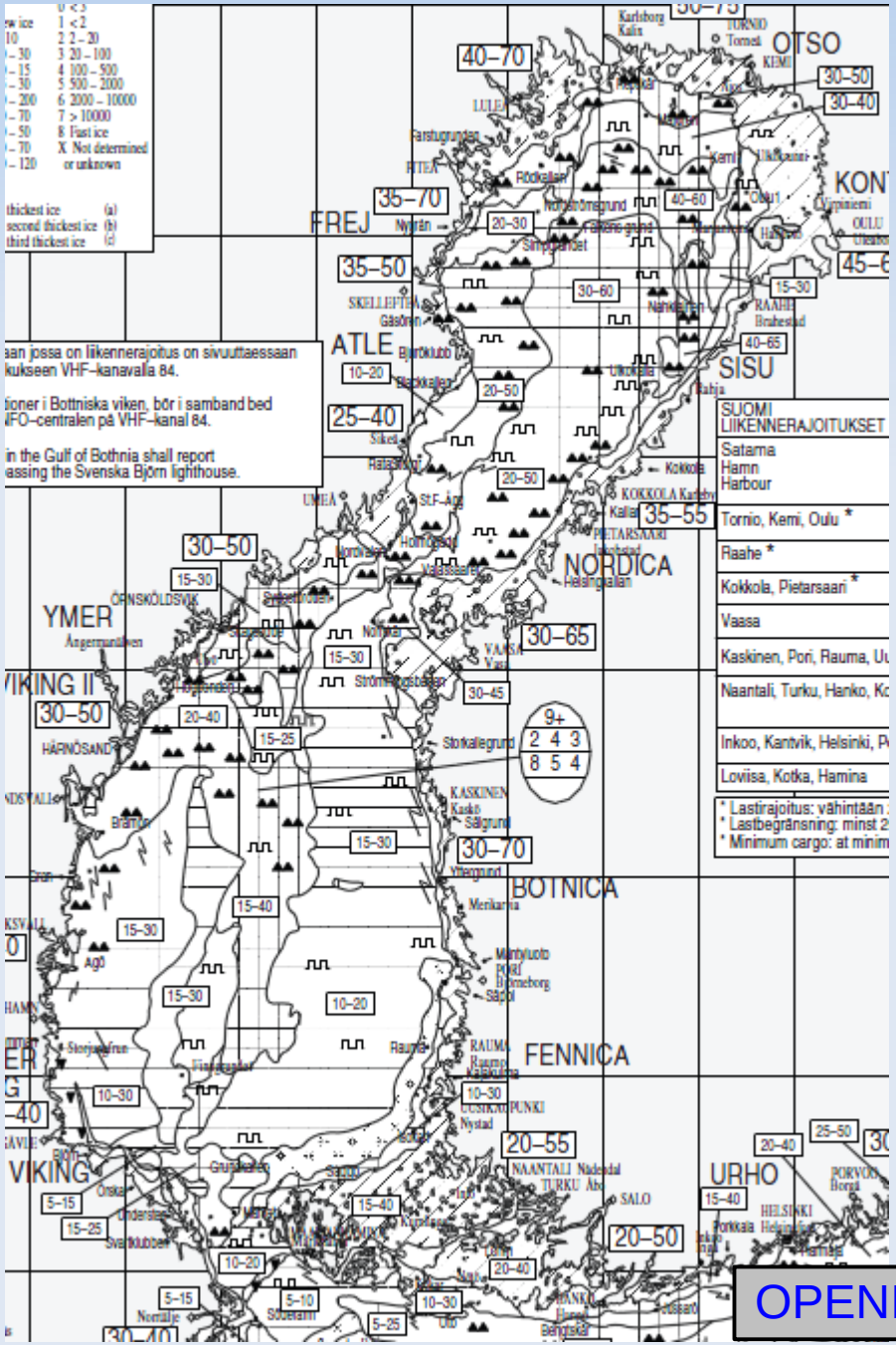


modelled mean thickness

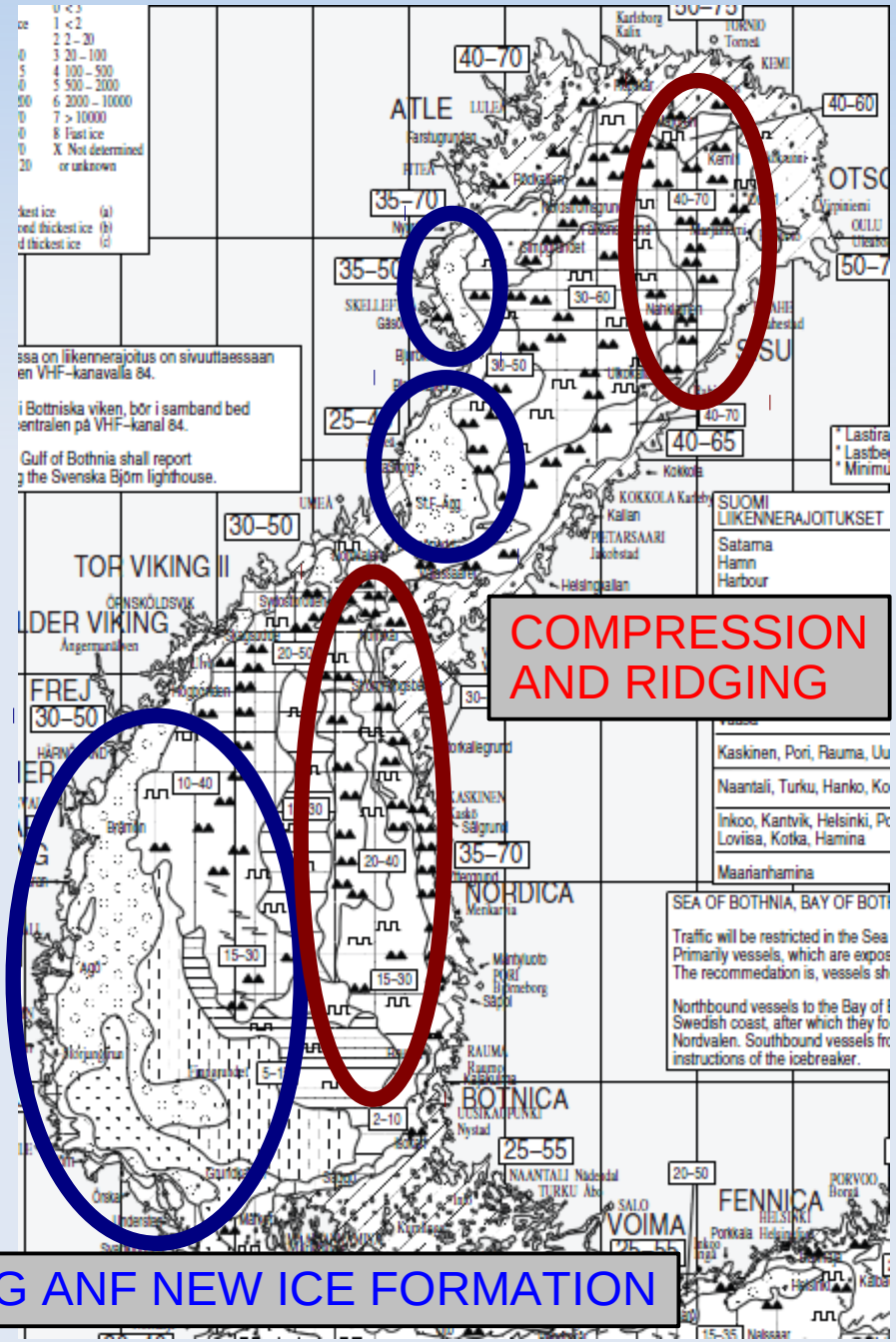


EXAMPLE OF DEFORMATION EVENT

22 Feb 2011

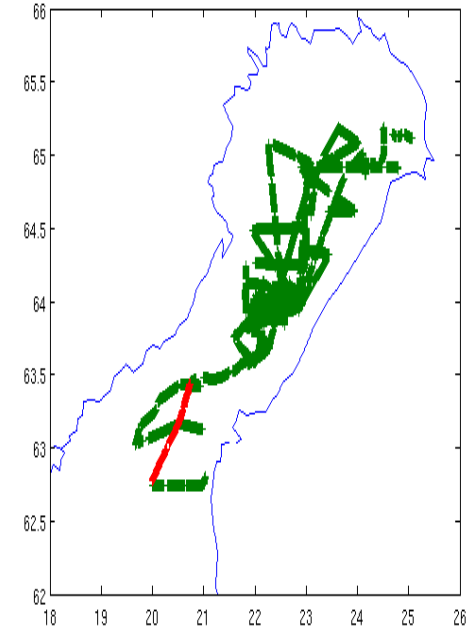


3 Mar 2011

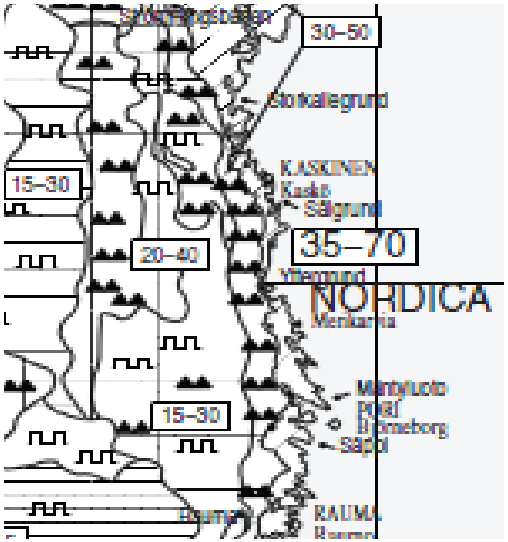


HEM ICE THICKNESS DATA

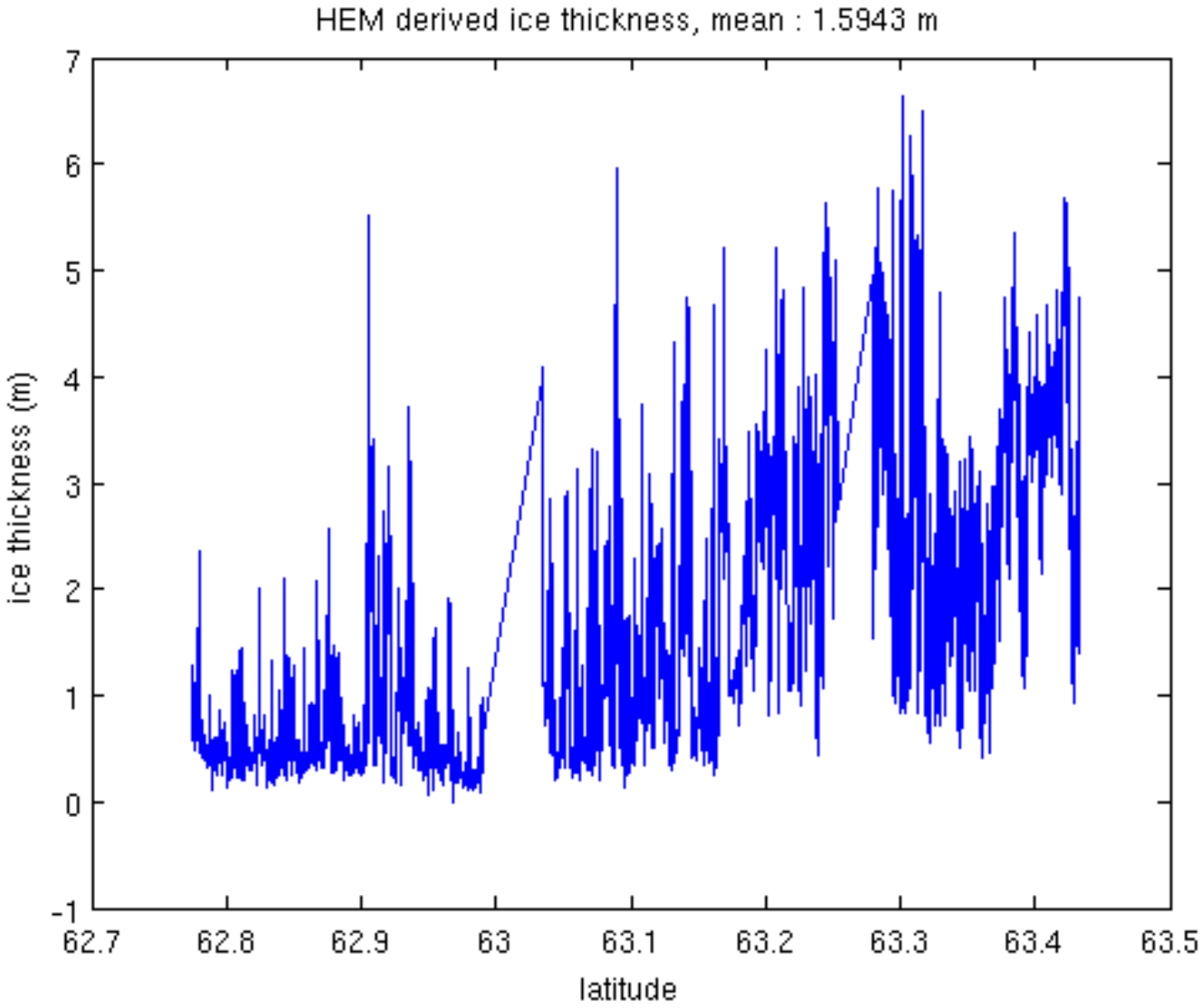
MEASUREMENT TRACKS



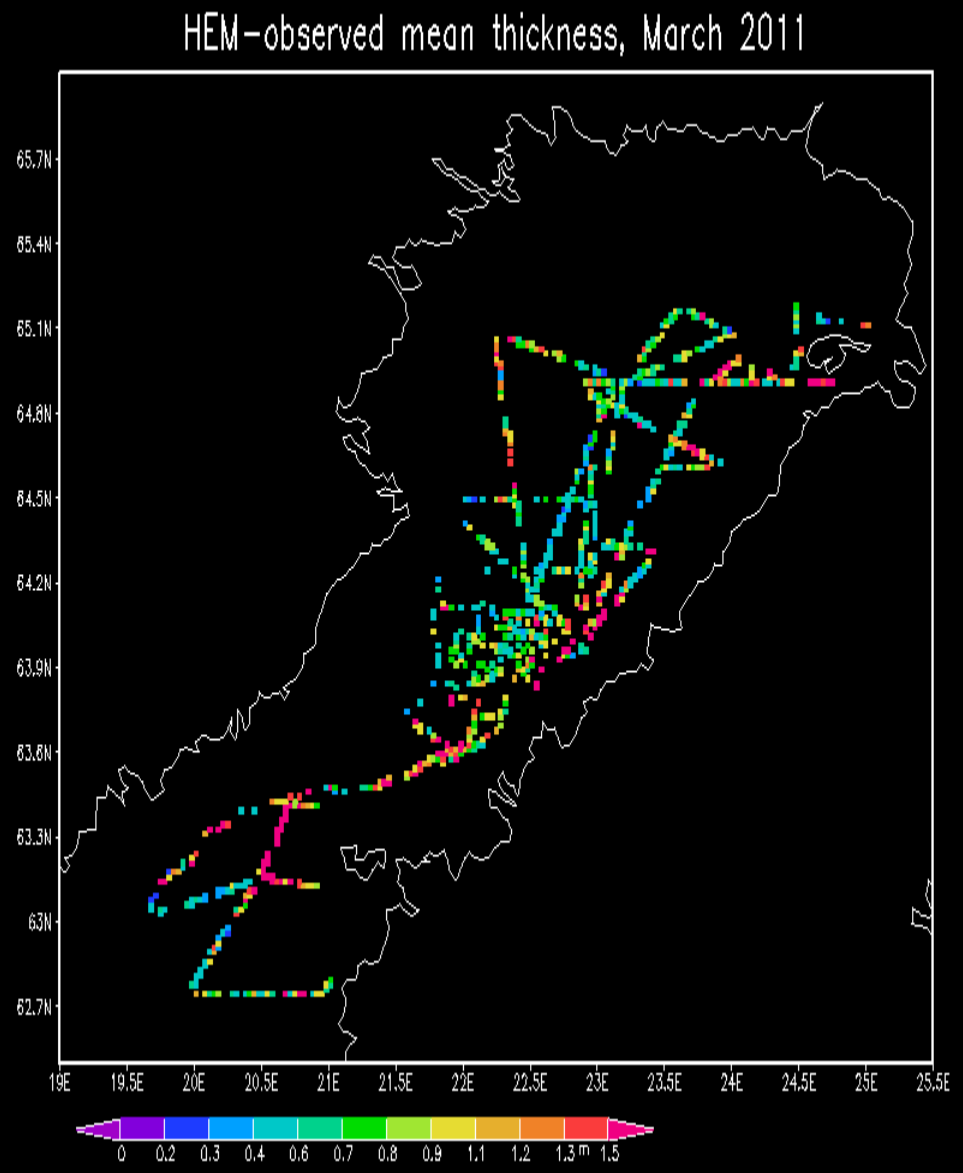
ICE CHART THICKNESS

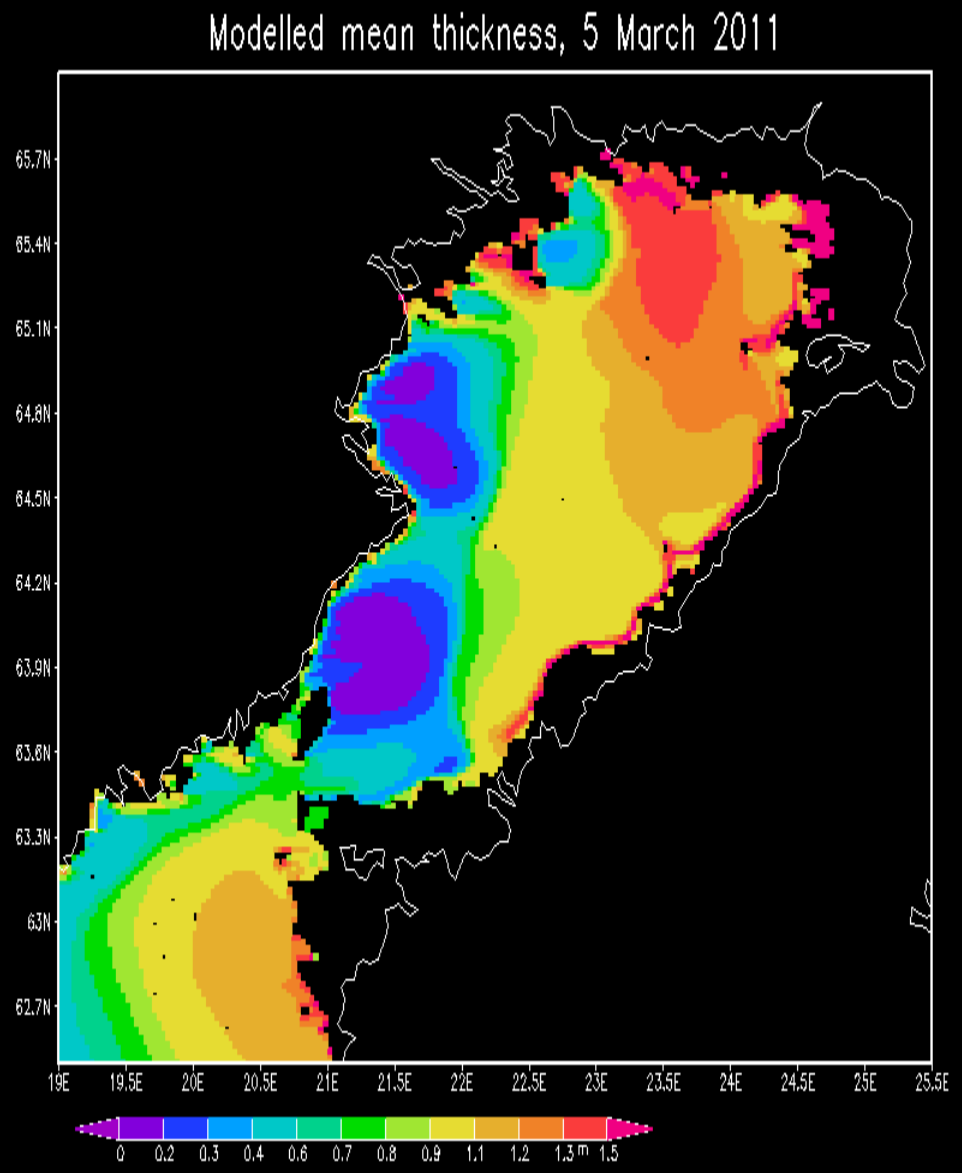


ICE THICKNESS (RED SECTION)



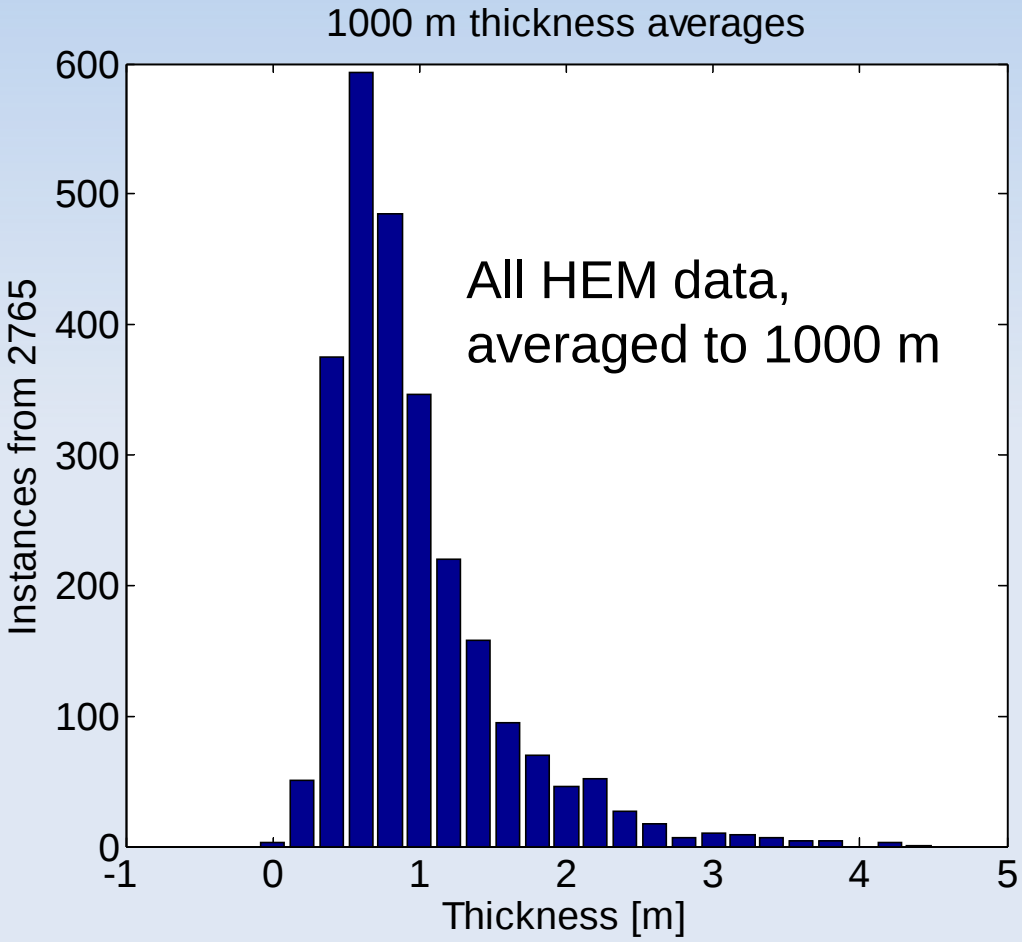
HEM MEASUREMENTS VS. MODELLED ICE THICKNESS





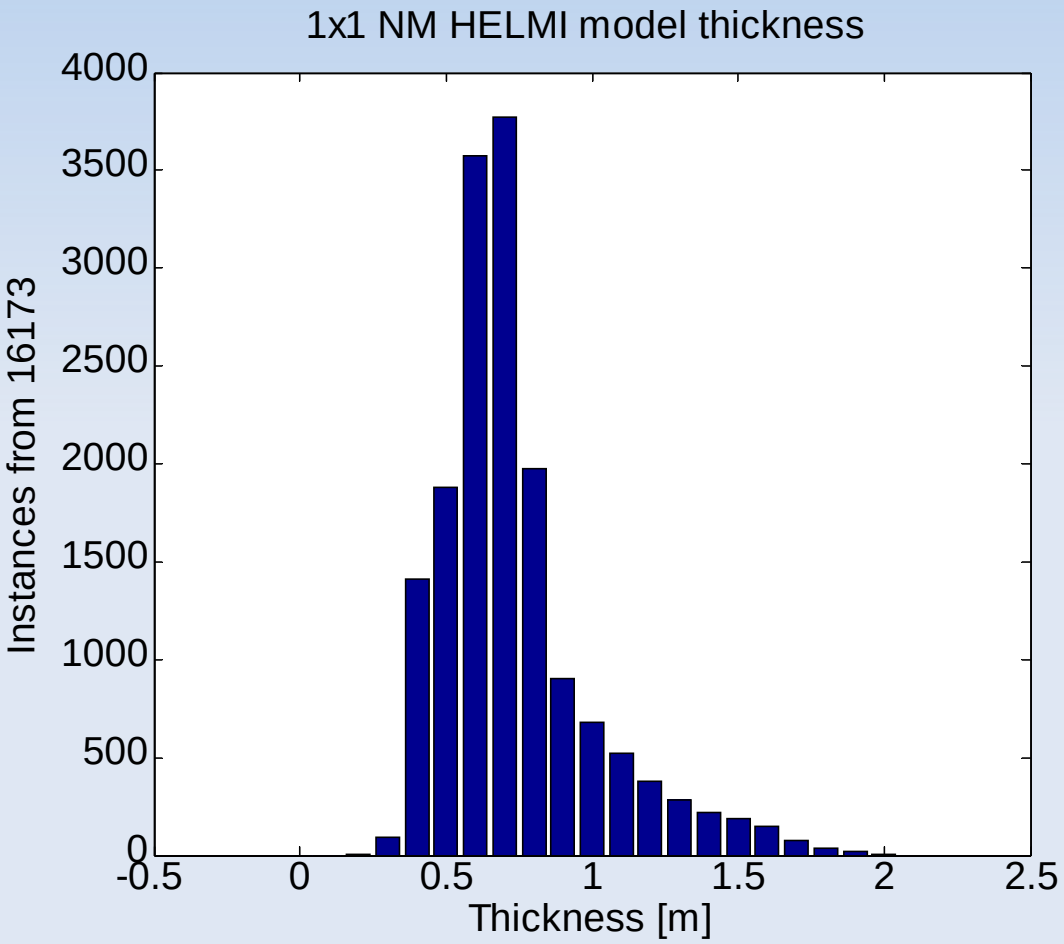
PDF'S OF ICE THICKNESS

OBSERVATIONS



Mean 0.95 m, mode 0.6 m

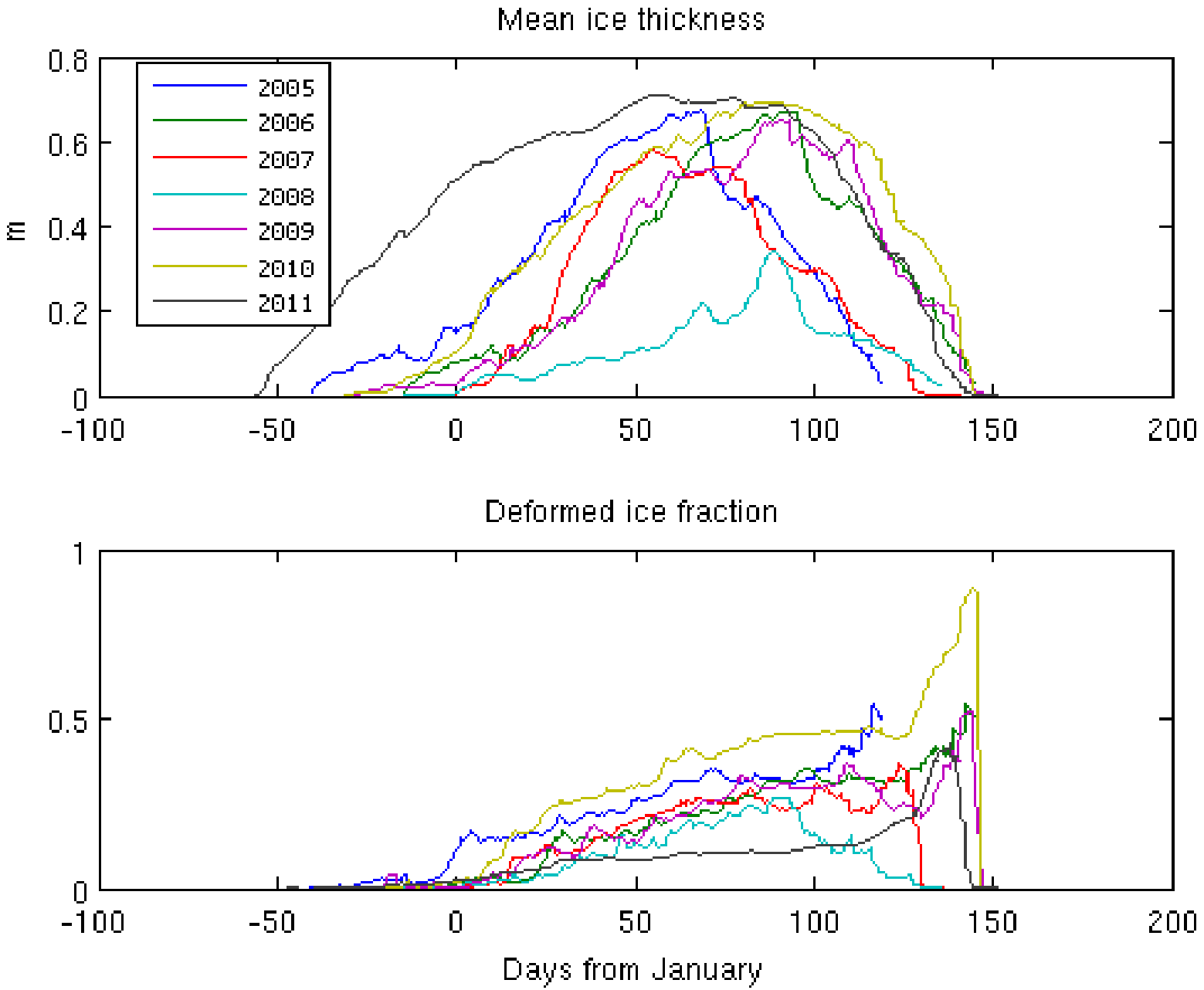
MODEL



Mean 0.73 m, mode 0.65

The fraction of 1-km segments thicker than 2 m is 6%. For 1-NM segments = 5%

INTER-ANNUAL VARIABILITY OF SEA ICE MASS IN THE BAY OF BOTHNIA



CONCLUSION

- HEM observations show that the mean ice thickness could be even 1-3 meters at 5 - 50 km^2 scale in the Baltic Sea. HEM is the best method for large scale ice thickness mapping, but the success of measurement campaigns depends on weather conditions.
- Multi-category sea ice model produce thicker ice conditions than classical two-level approach due to the explicit calculation of mechanical ice growth, but the present model underestimate mean ice thickness in heavily deformed regions.
- Inter-annual variability of basin scale mean sea ice thickness in the Bay of Bothnia is 30 – 70 cm. Deformed ice fraction increase during the season, in mid-winter it's inter-annual variability is 10 – 50 %.
- Possible reason of the underestimation of deformed ice growth are underestimation of wind speed during storms and underestimation of small scale differential ice motion and deformations.