



Ocean and sea ice modeling for Arctic shipping

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Ocean modelling at DMI

- Operational modelling and hindcasts
 - Arctic and Atlantic, including nestings: HYCOM-CICE
 - European shelf seas: HBM
- Climate research with coupled modelling
 - Global: EC-Earth with NEMO
 - Regional: HYCOM-CICE and HBM coupled with HIRHAM5 atmospheric climate model
- All models are also used for process studies



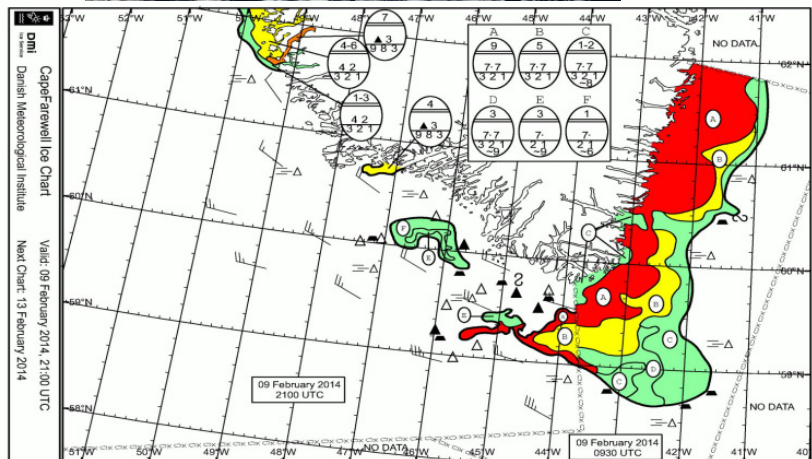
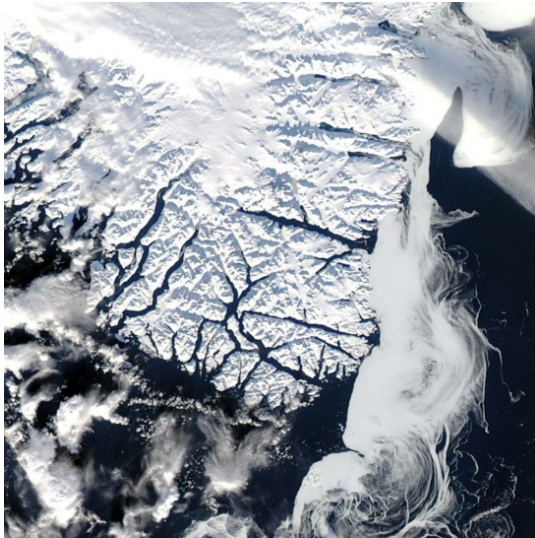
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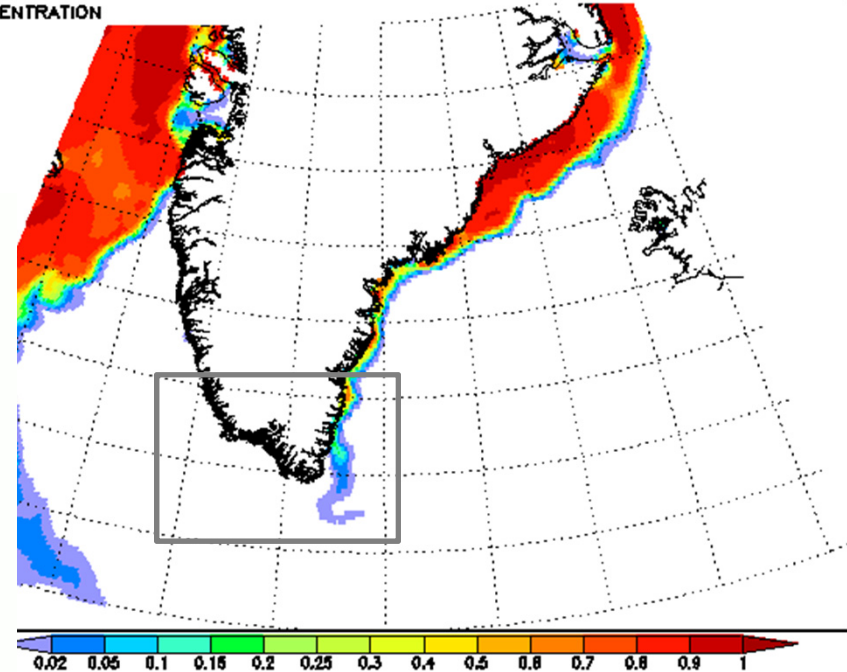
Why ocean/sea ice modelling at DMI?

- Support DMI Ice charting ... with forecasts



ISCONCENTRATION
ICE CONCENTRATION

2014 FEB 09 12GMT



Why ocean/sea ice modelling at DMI?

- Support DMI Ice charting ... with forecasts
- Oil spill modelling
- Support to maritime operations

- Improvement generally based on research funds



Ocean model: HYCOM

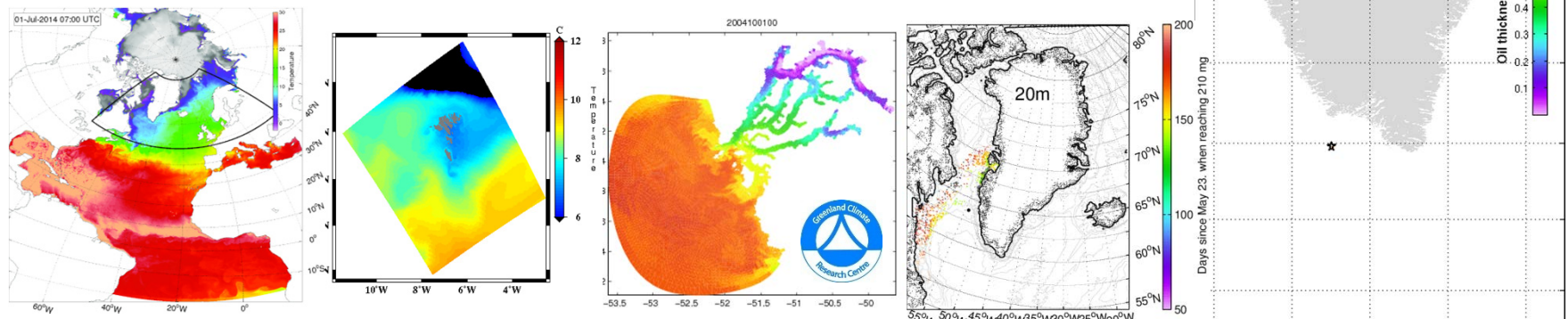
HYCOM 2.2.55 ocean model

- 10 km Arctic and the Atlantic to $\sim 20^\circ\text{S}$, 40 vertical levels (hybrid)
 - 6 days forecast every 12 hours
 - Oil spill module (15 min. response time)

Forcing

- ECMWF atmosphere (Deterministic forecast or ERA-Interim) with possibility for nested high-res data
- Open boundaries: Tides and climatological temperature and salinity
- Body tides
- Rivers from monthly climatology

Possible to set up finer scale areas

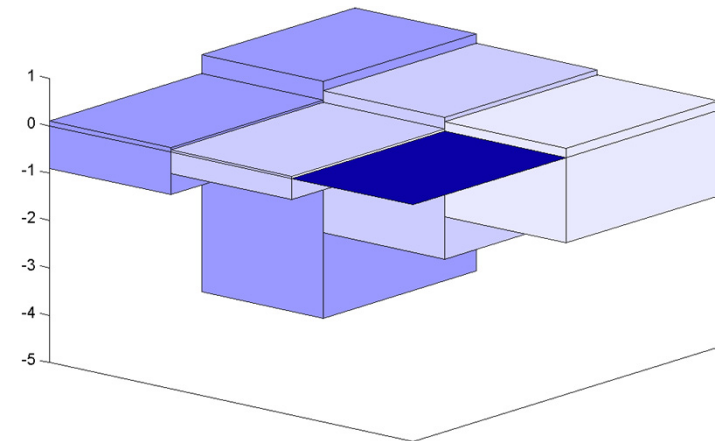


Sea Ice model: CICE

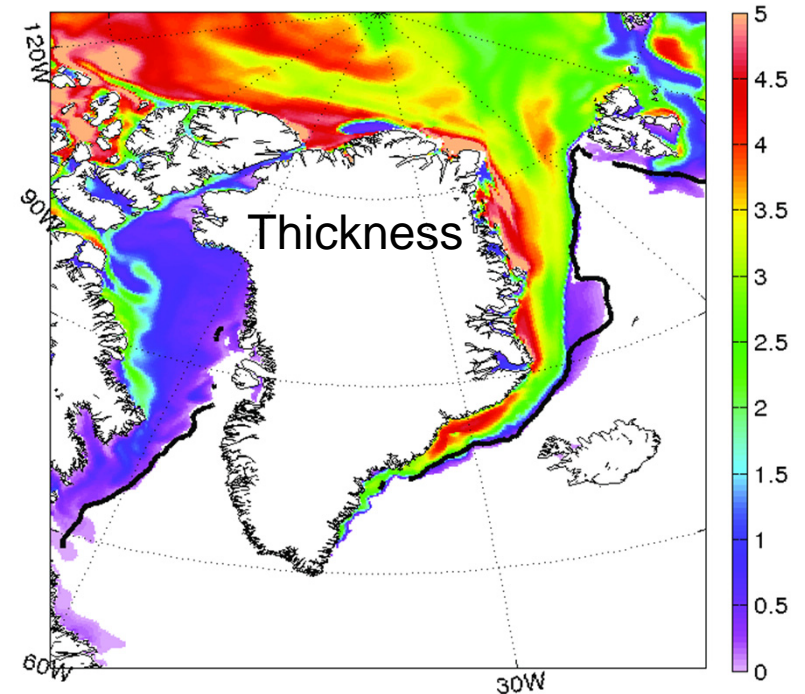
The elastic-viscous-plastic dynamic and thermodynamic sea-ice (CICE) model version 4.0

- 5 ice thickness categories with 4 vertical layers for each, plus one snow layer
- Ice velocities differ significant from ocean surface currents
- Simulates major ridges and cracks

HYCOM and CICE are fully coupled using the ESMF coupler



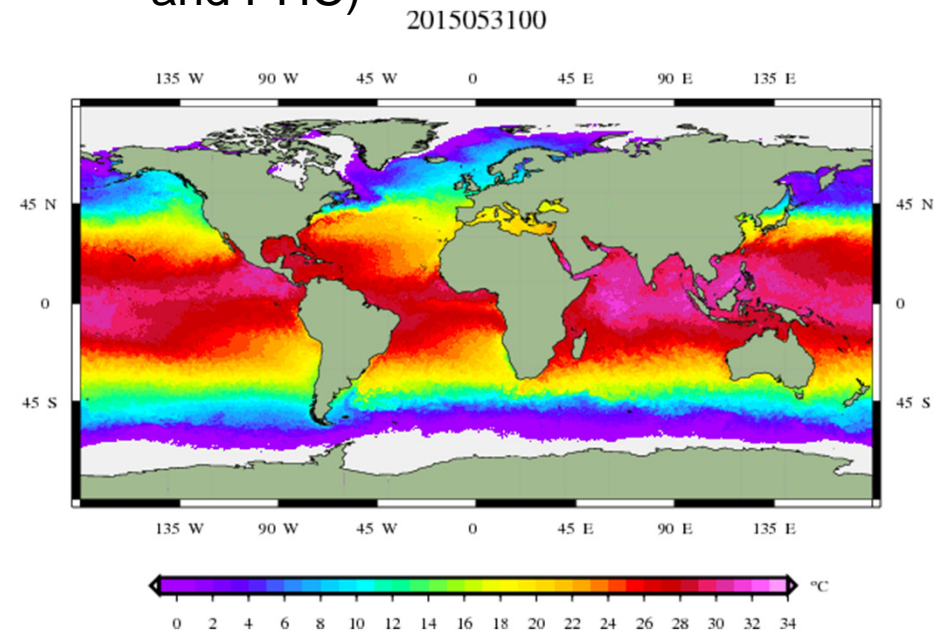
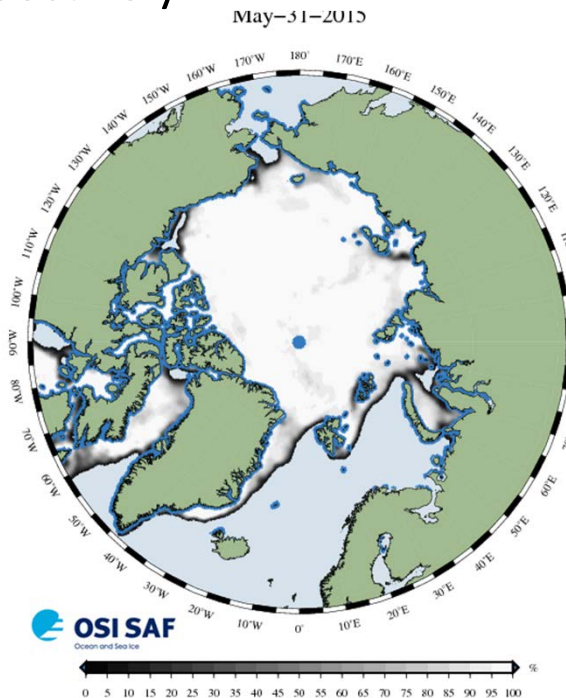
20040101



Assimilation of satellite products

Presently, we nudge towards sea ice concentrations, SST and SSS with 10, 30 and 30 days relaxation time, respectively

- *Sea ice concentration*: OSISAF
- *SST*: GHR SST Level 4 DMI_OI global product (before 2011: OSTIA)
- *SSS*: climatology (combined WOA and PHC)



Sea ice concentration: http://ocean.dmi.dk/arctic/icedrift_anim/index.uk.php
SST: ocean.dmi.dk/satellite/index.uk.php, data through PO.DAAC



Simulation history

Spin-up

- 1997-2003
- ERA-Interim

Hindcast

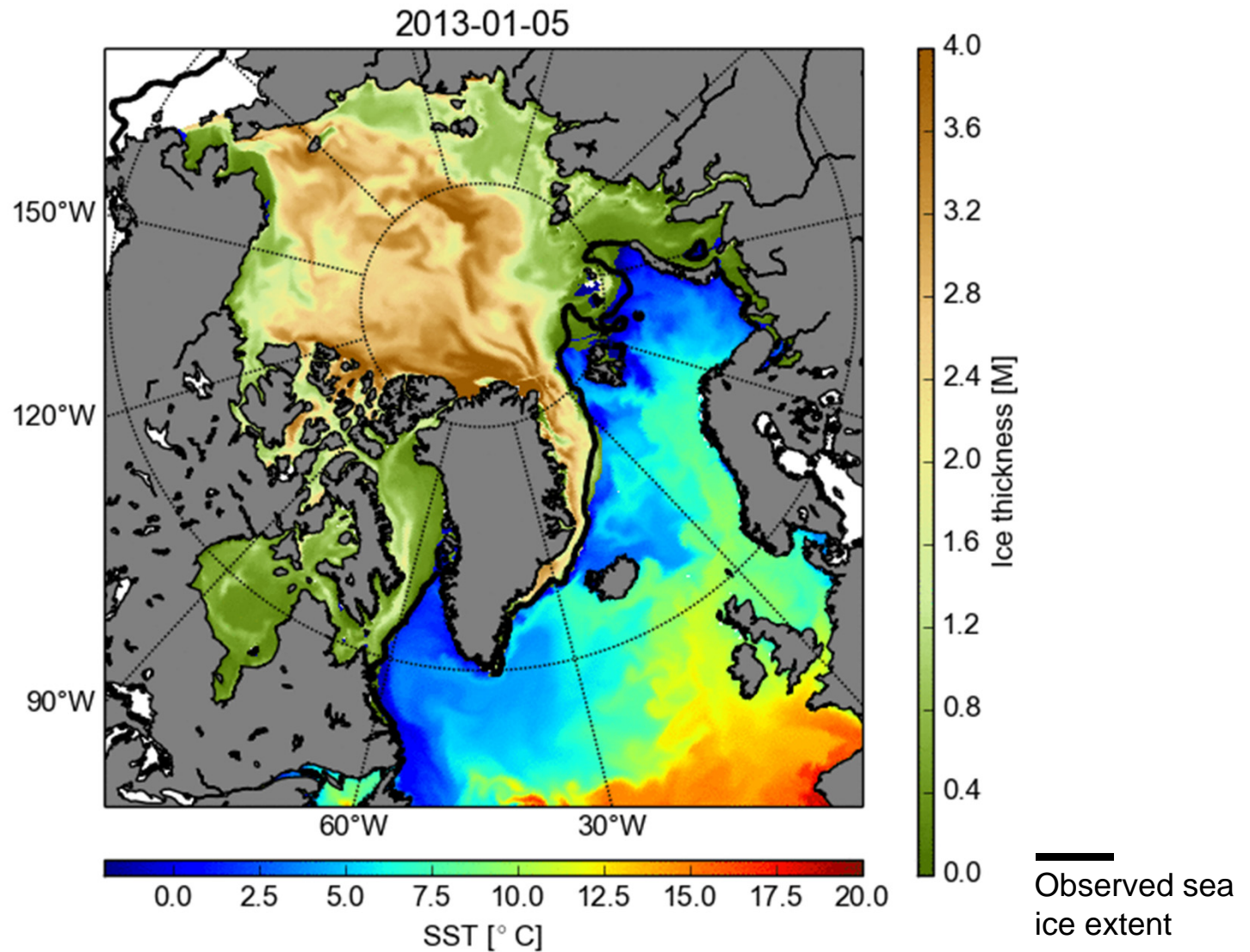
- 2004-2013
- ERA-Interim

Operational

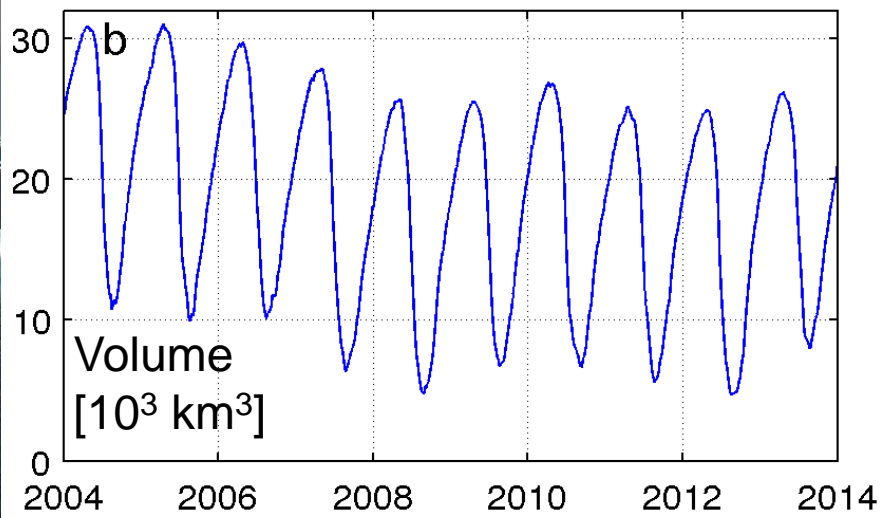
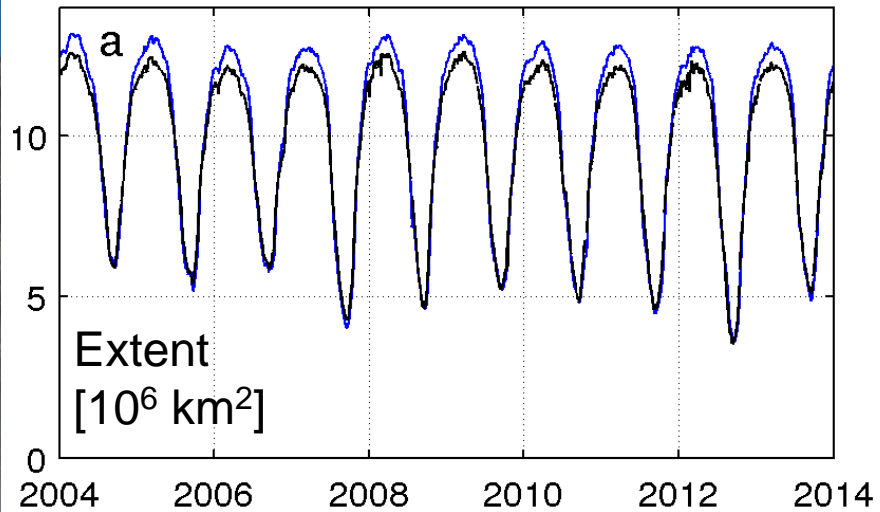
- 2014-present
- ECMWF deterministic forecast



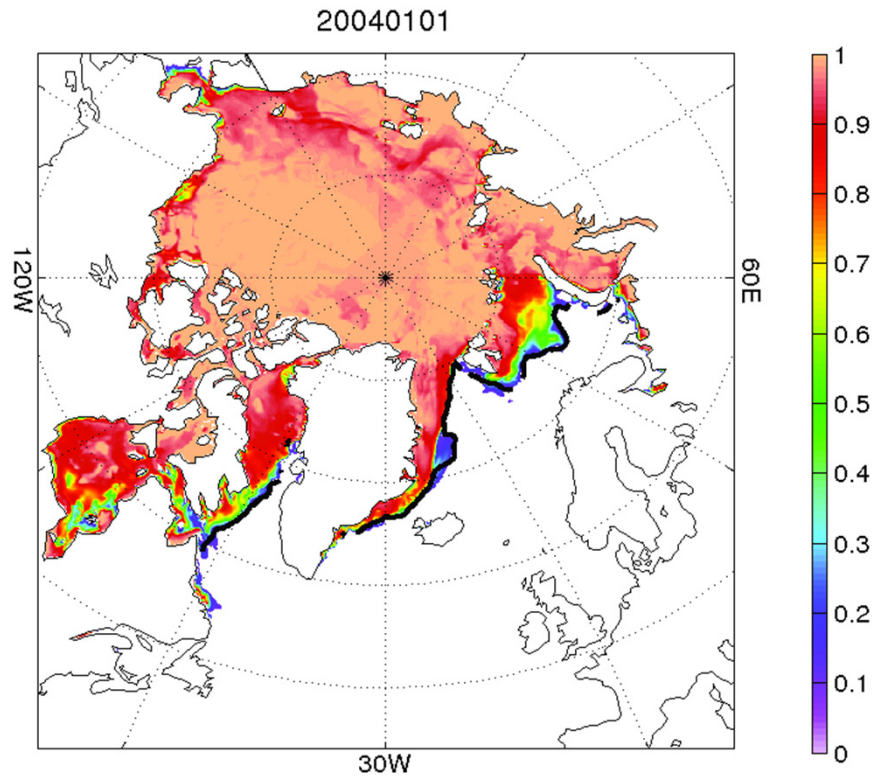
Modelled sea ice thickness and SST 2013



Total extent and volume



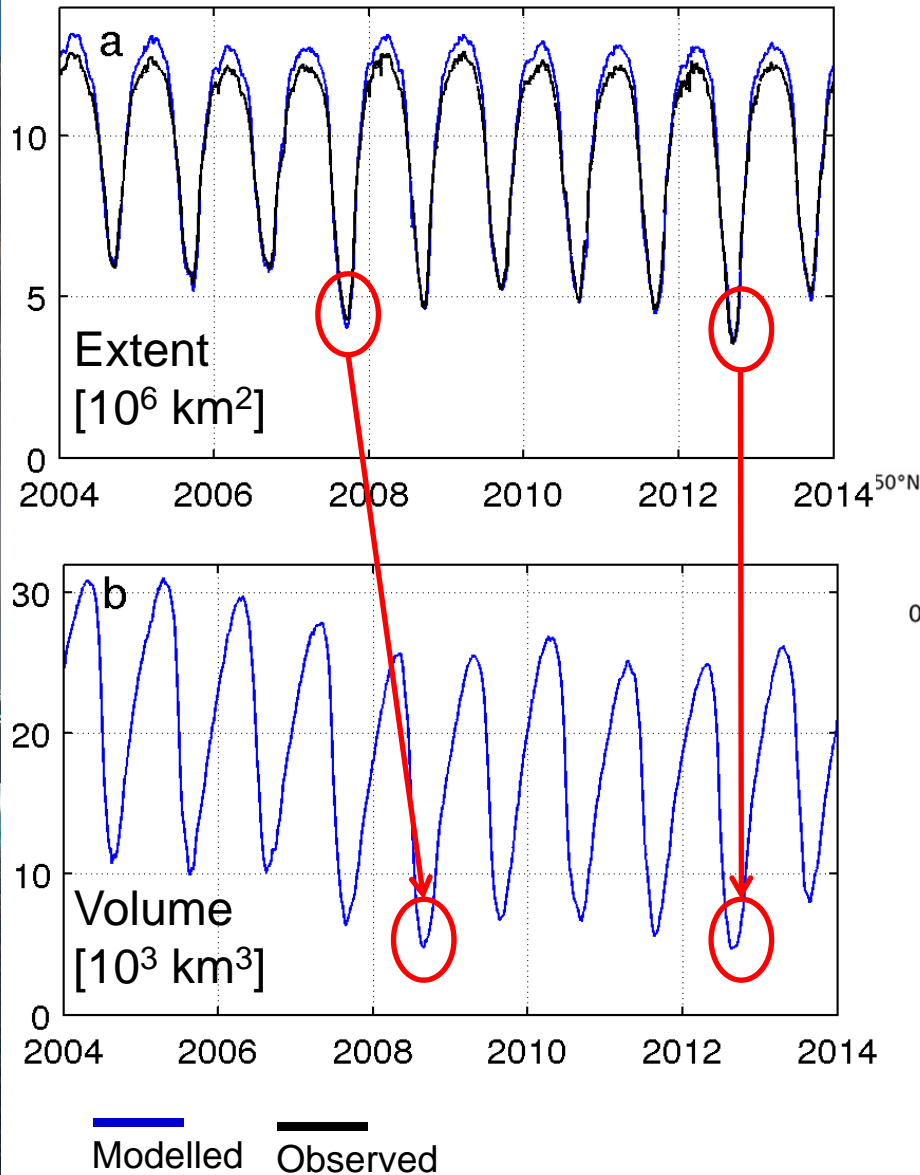
— Modelled — Observed



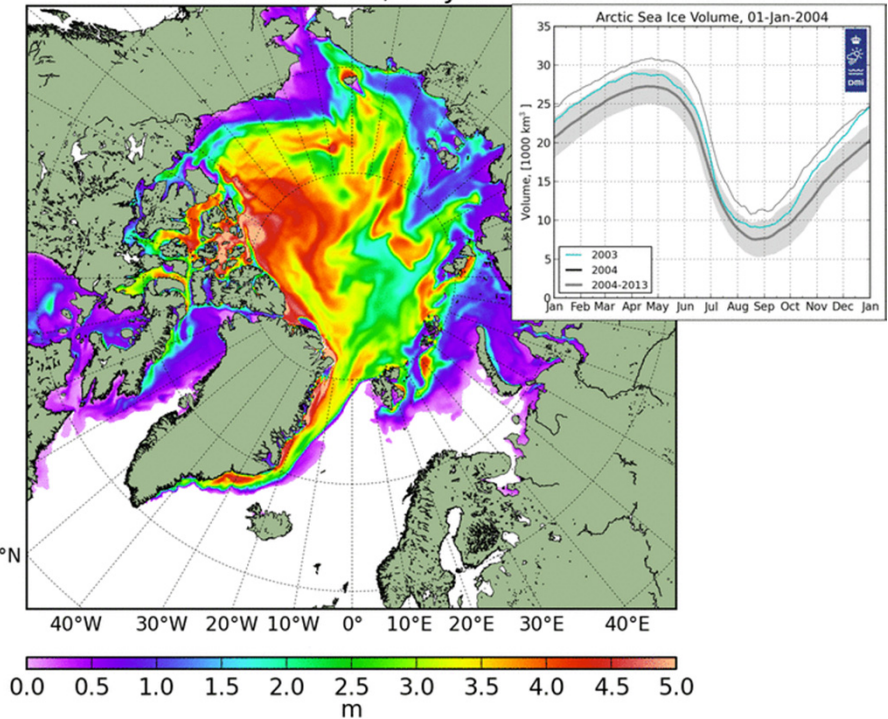
Ice concentration



Total extent and volume



Sea Ice Thickness, 01-Jan-2004



Ice thickness and volume

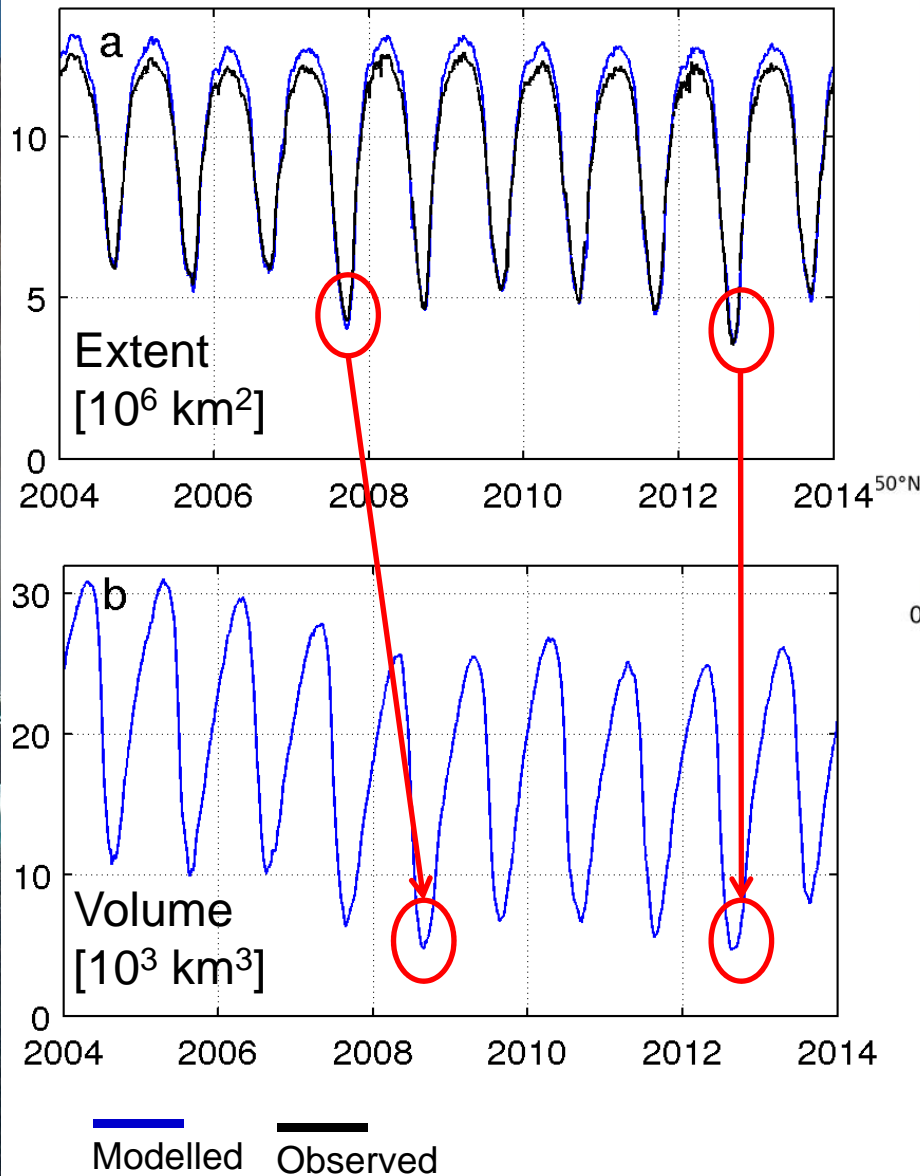
polarportal.dk

ocean.dmi.dk/arctic

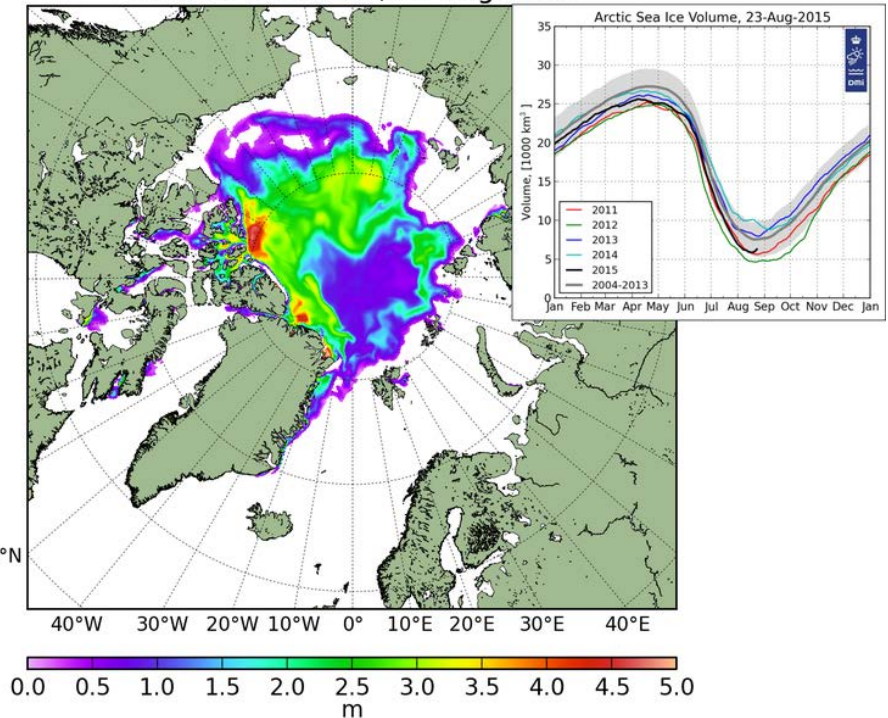
Total sea ice extent and volume do not always follow each other



Total extent and volume



Sea Ice Thickness, 23-Aug-2015



Ice thickness and volume

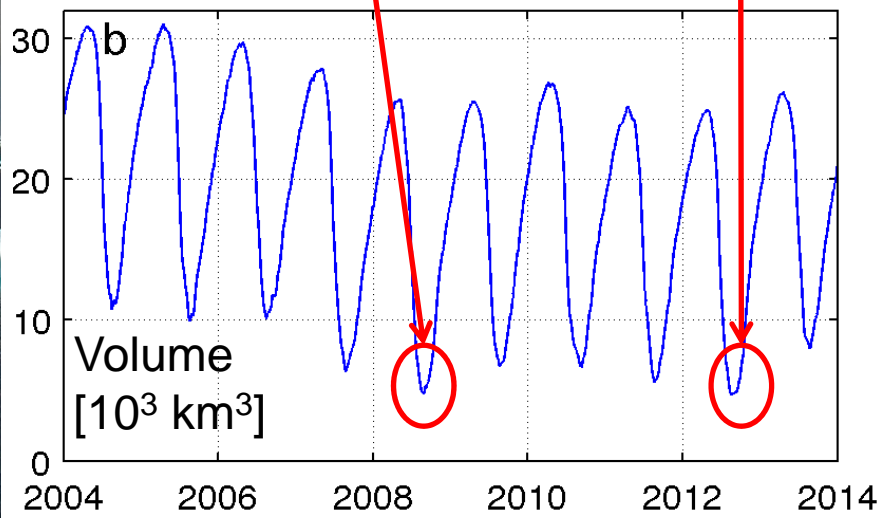
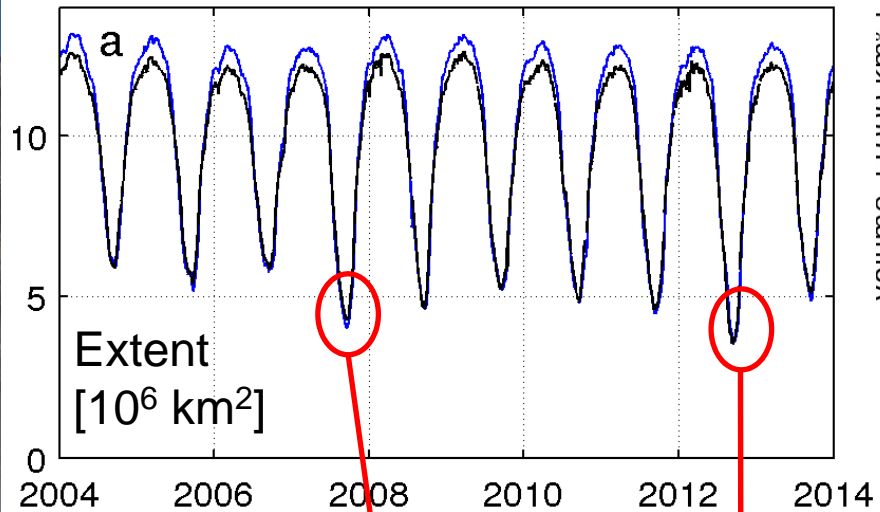
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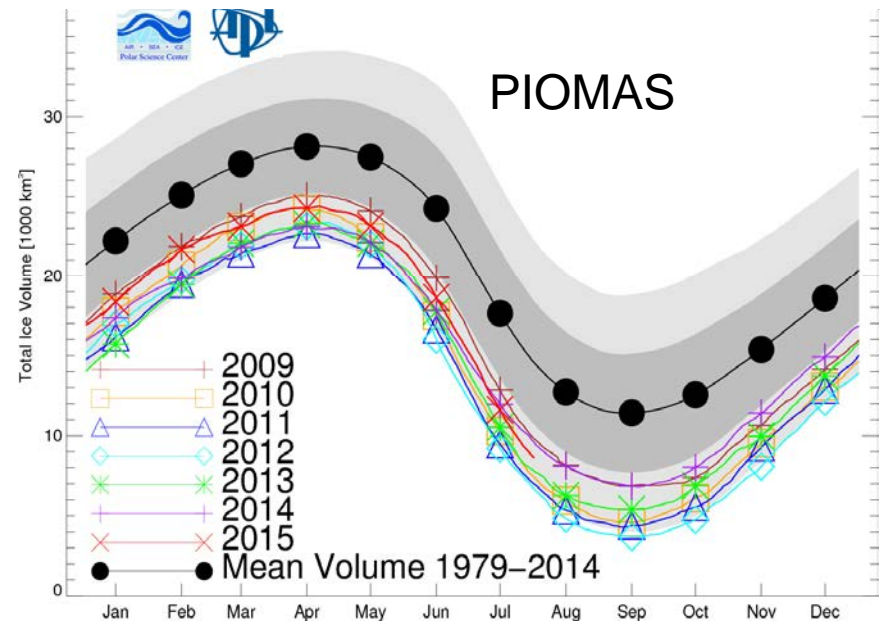
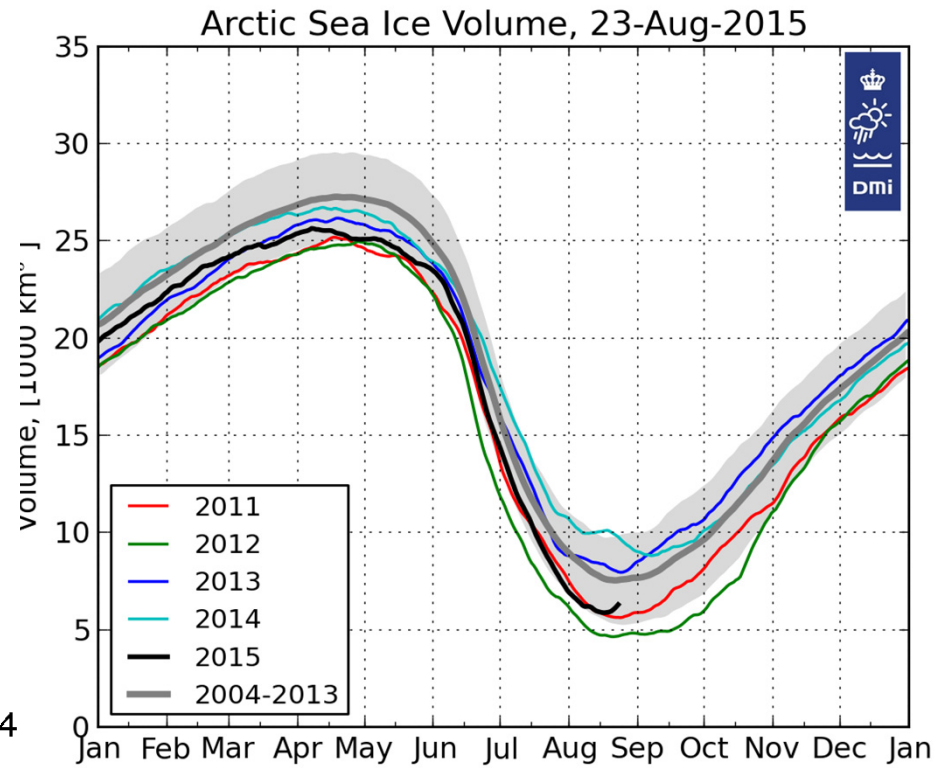
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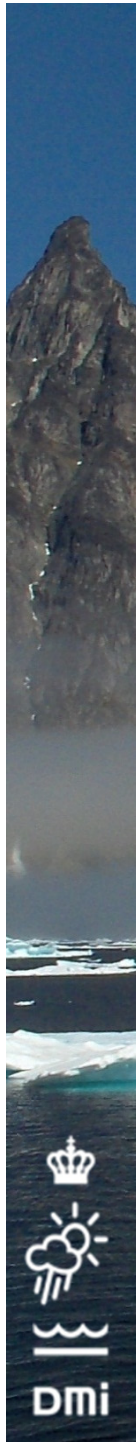
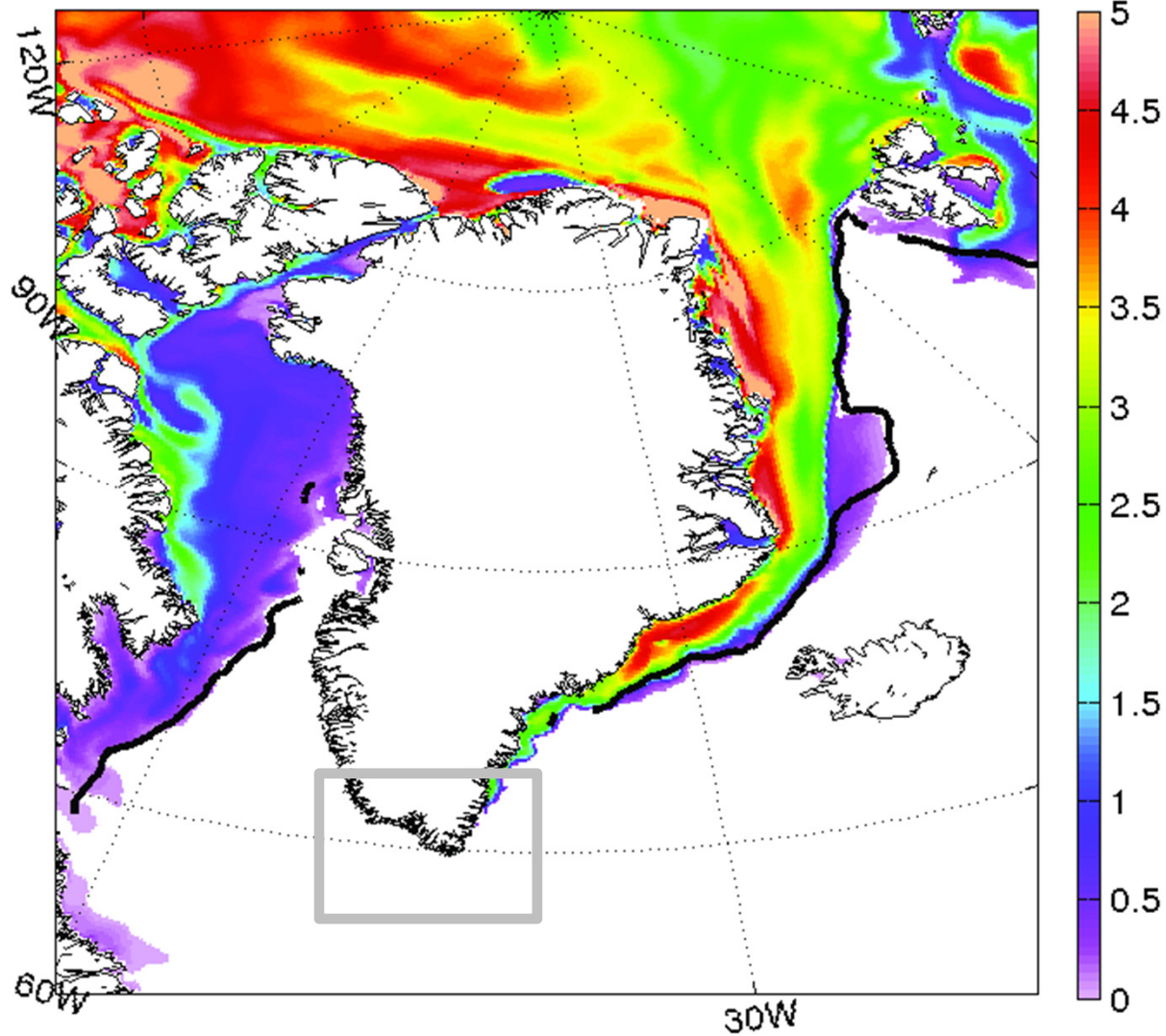


Modelled Observed

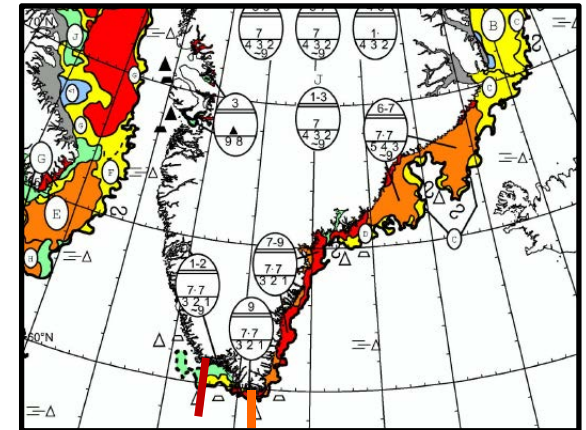
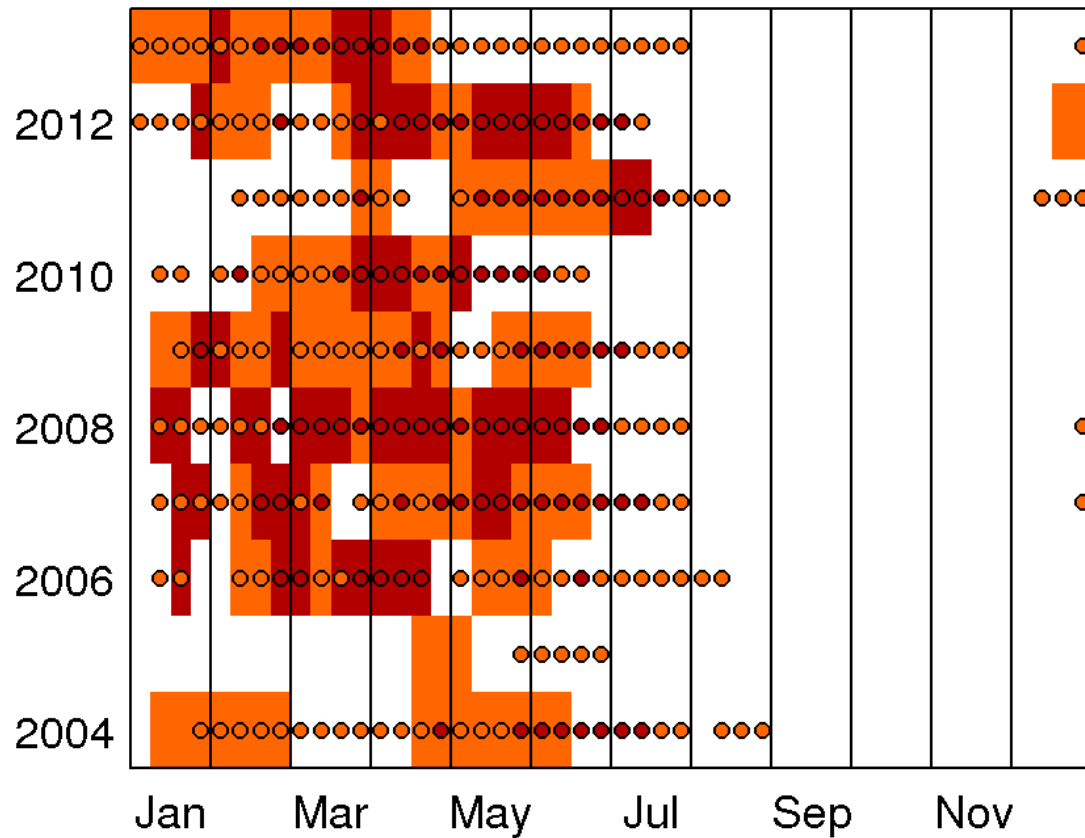


Sea ice at Cape Farewell

20040101



Cape Farewell sea ice index 2004-2013



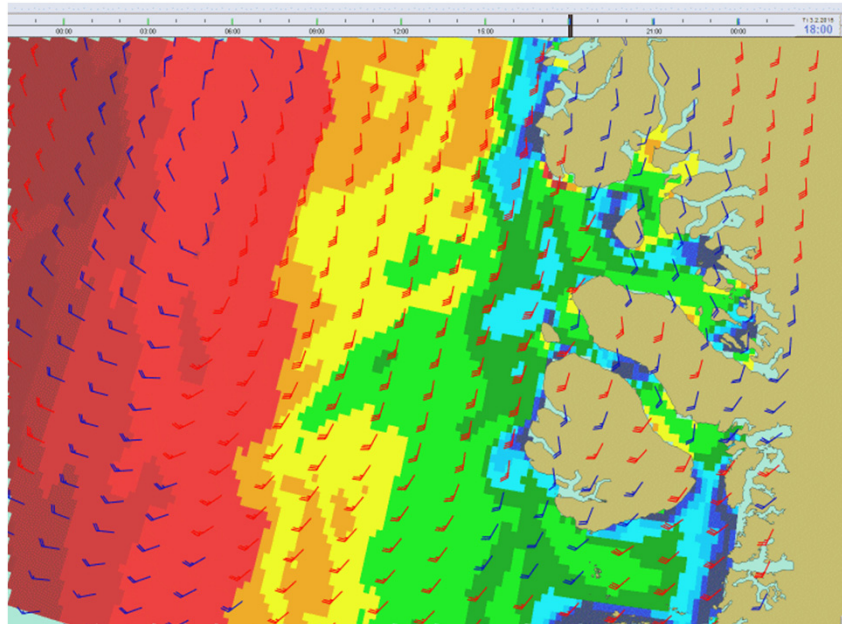
For users: Combine information



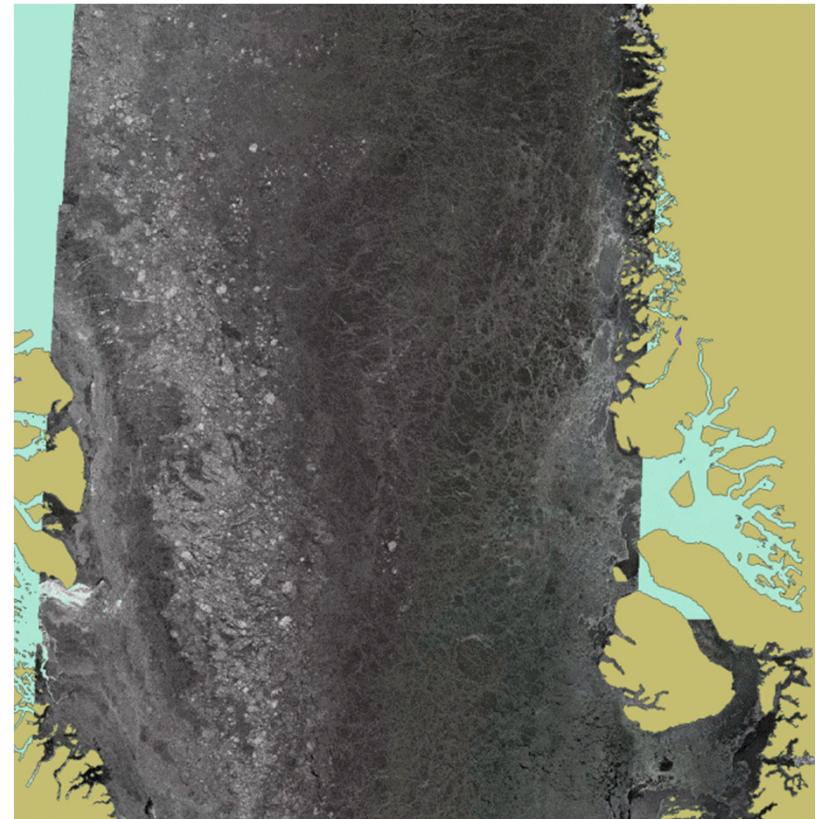
SAR image



For users: Combine information



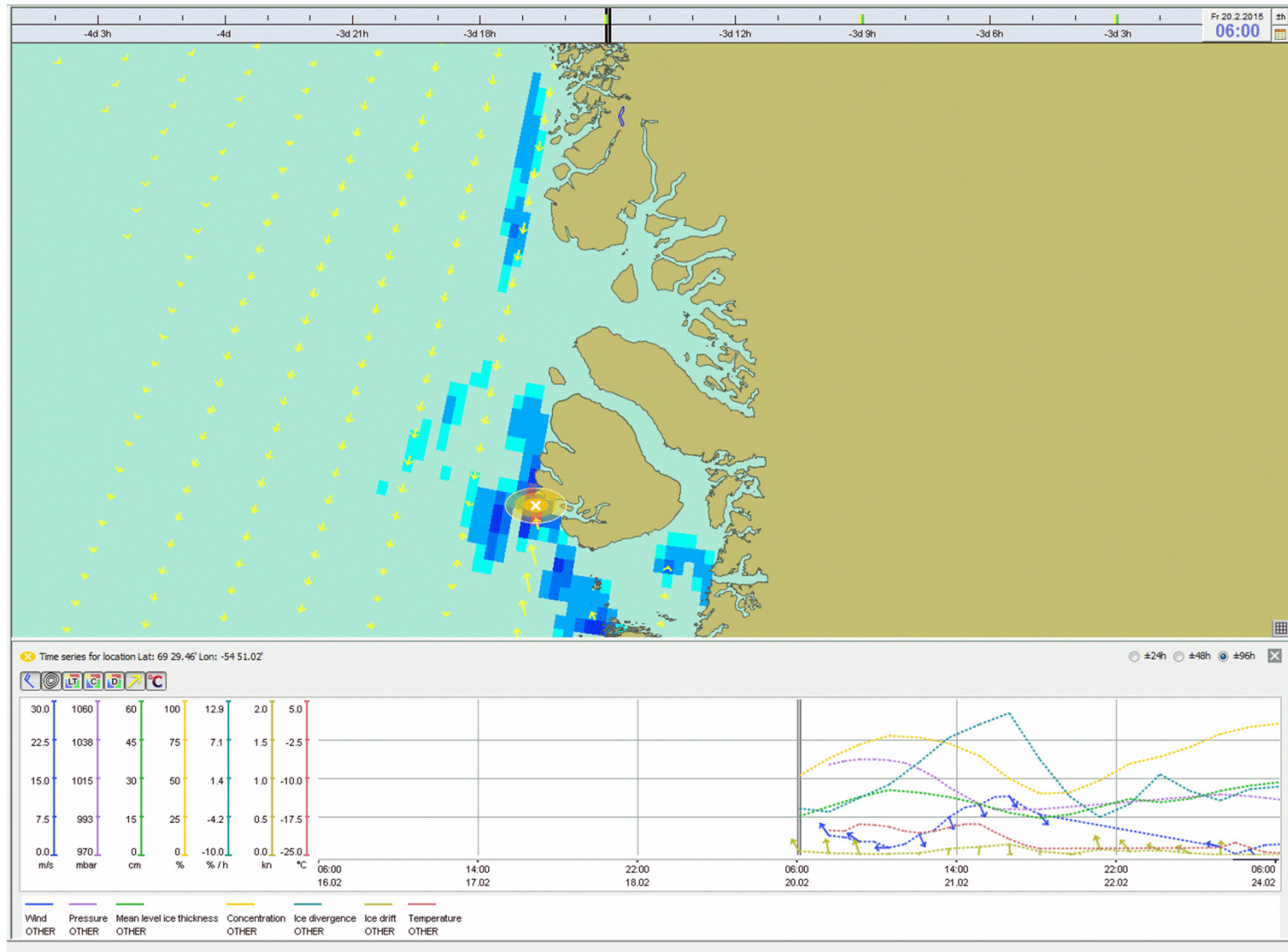
Thickness and wind prognoses in Viewice



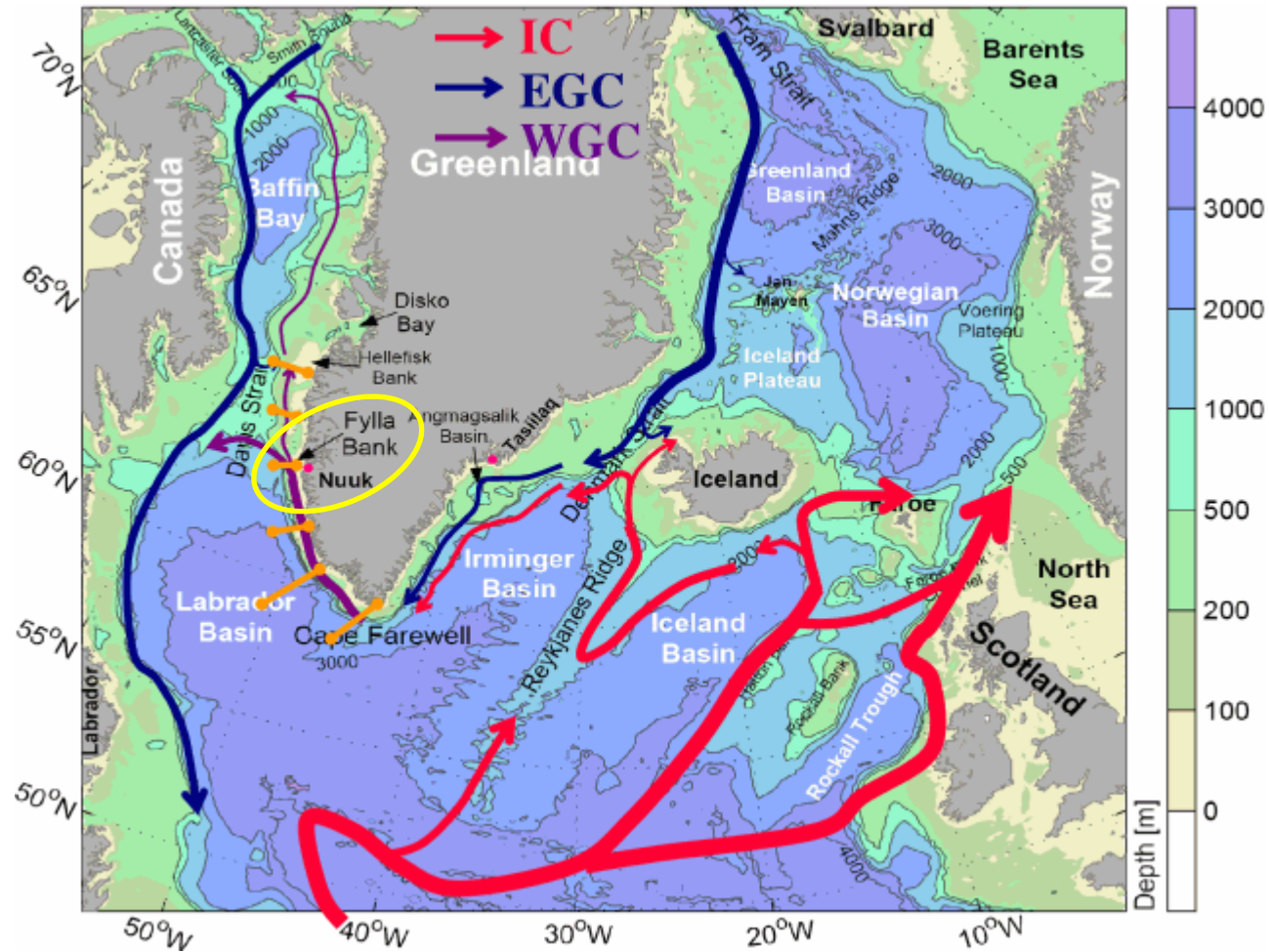
SAR image and forecast thickness



Ice divergence forecast

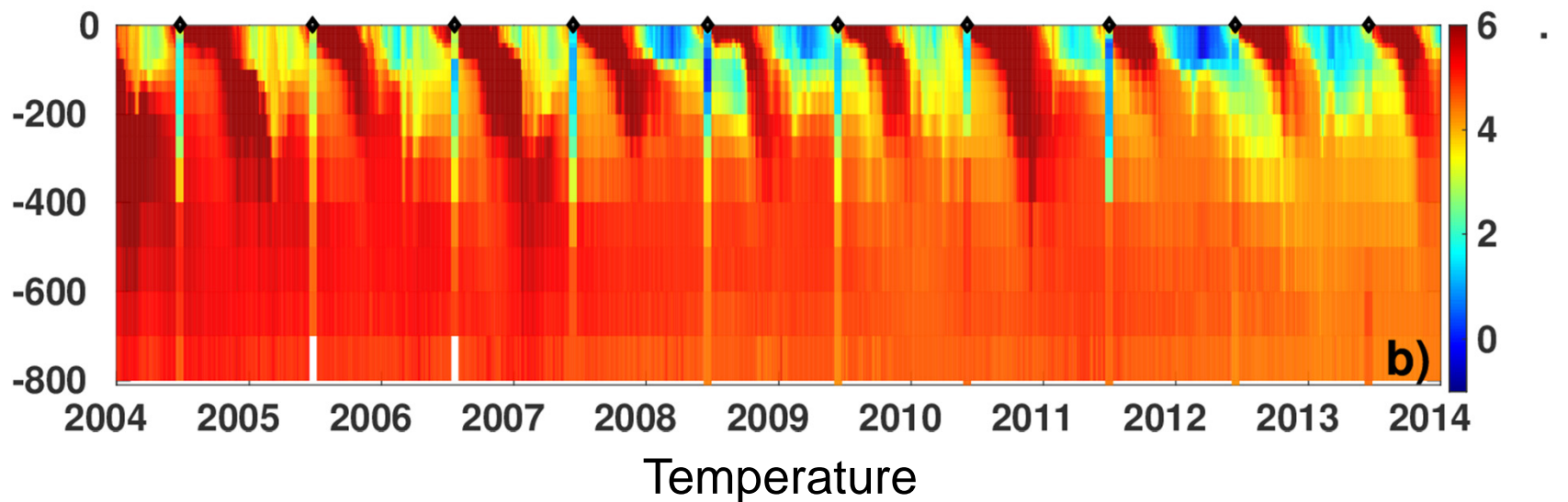
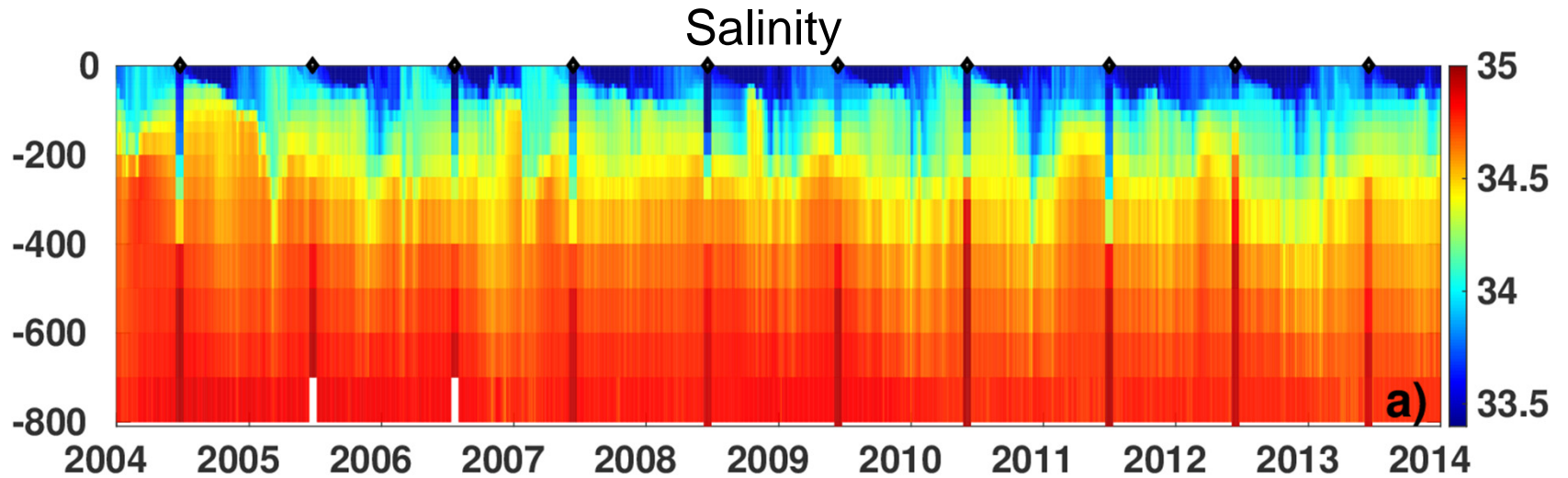


Ocean validation at Fylla Bank Introduction



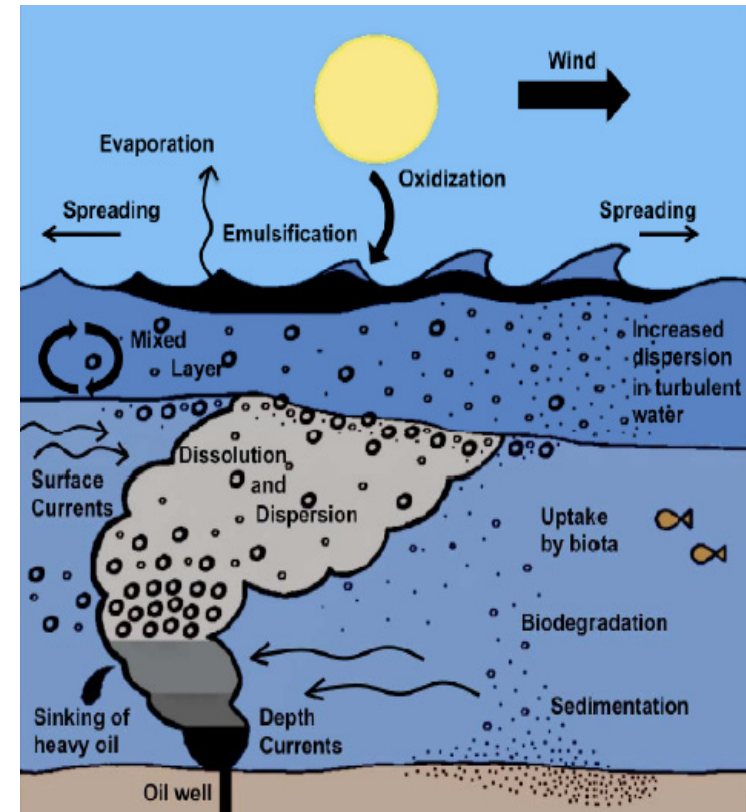
Ocean validation at Fylla Bank

Year-round model results



DMI oil drift module

- Purposes:
 - Oil combating, "Find the sinner",
 - Drifting vessel, Man overboard
- Spillet (**Particle model**)
- Passive **advection with ocean current**
... plus surface **wind** drift (3%)
- Wind speed is **scaled** inverse **with sea ice concentration**
- Surface **currents** is **scaled** inverse with sea ice concentration **towards sea-ice velocities**
- Buoyant rising (or sinking)
- Downward mixing by wind / waves
(scaled by wind speed + random distribution)
- Turbulent spreading
(random walk scaled by current speed)
- Oil weathering
- 8 pre-defined oil-types - based on fractions of 8 hydrocarbons
- Instantaneous or continuous oil spill at any depth
- Runs **operational** with *15 minutes response time 24-7*



Vega Sagittarius (NO Oil pollution)

16 August 2012: Grounding 12 nm from Nuuk near spring tide.

29 August 2012: The ship was safely pulled free and returned to Nuuk and later to Europe to get repaired.

DMI assisted with oil simulations: Select time for pulling the ship free at time with low risk of an oil pollution to enter Godthaabfjorden.



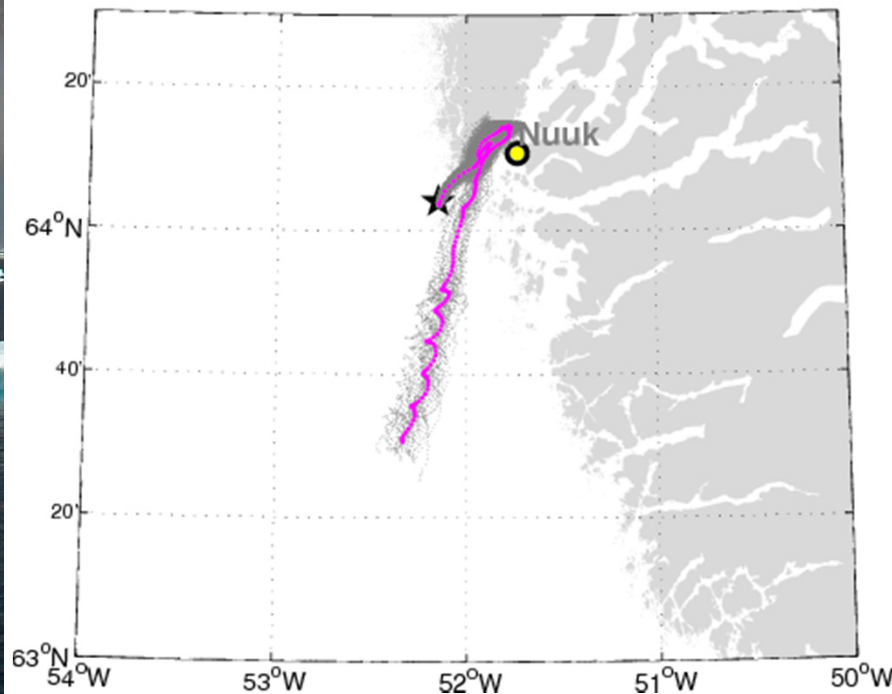
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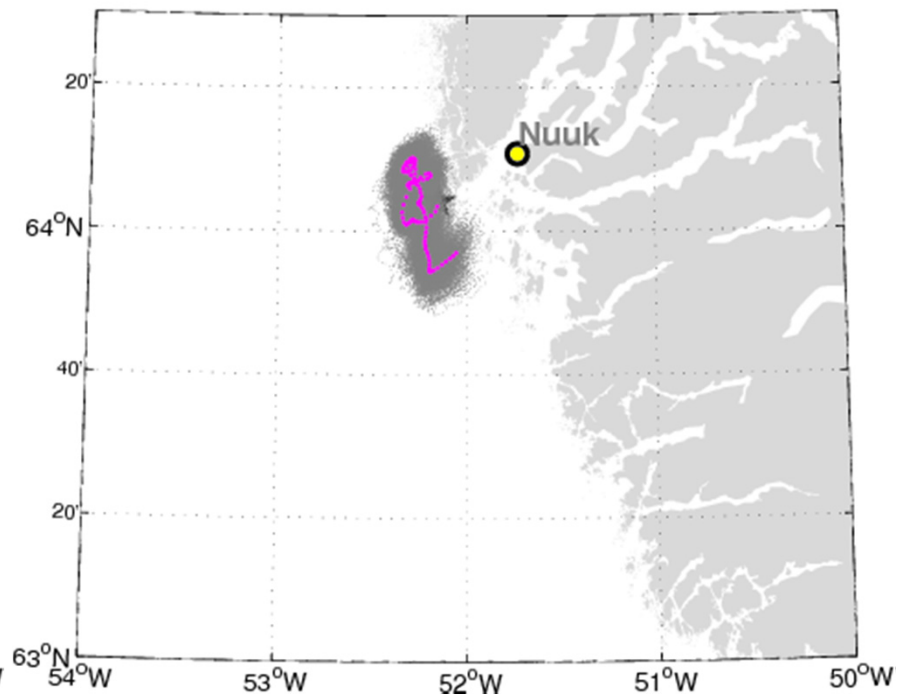
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**Spill: 16 Aug 2012 11:00 UTC
+ 206 hours**



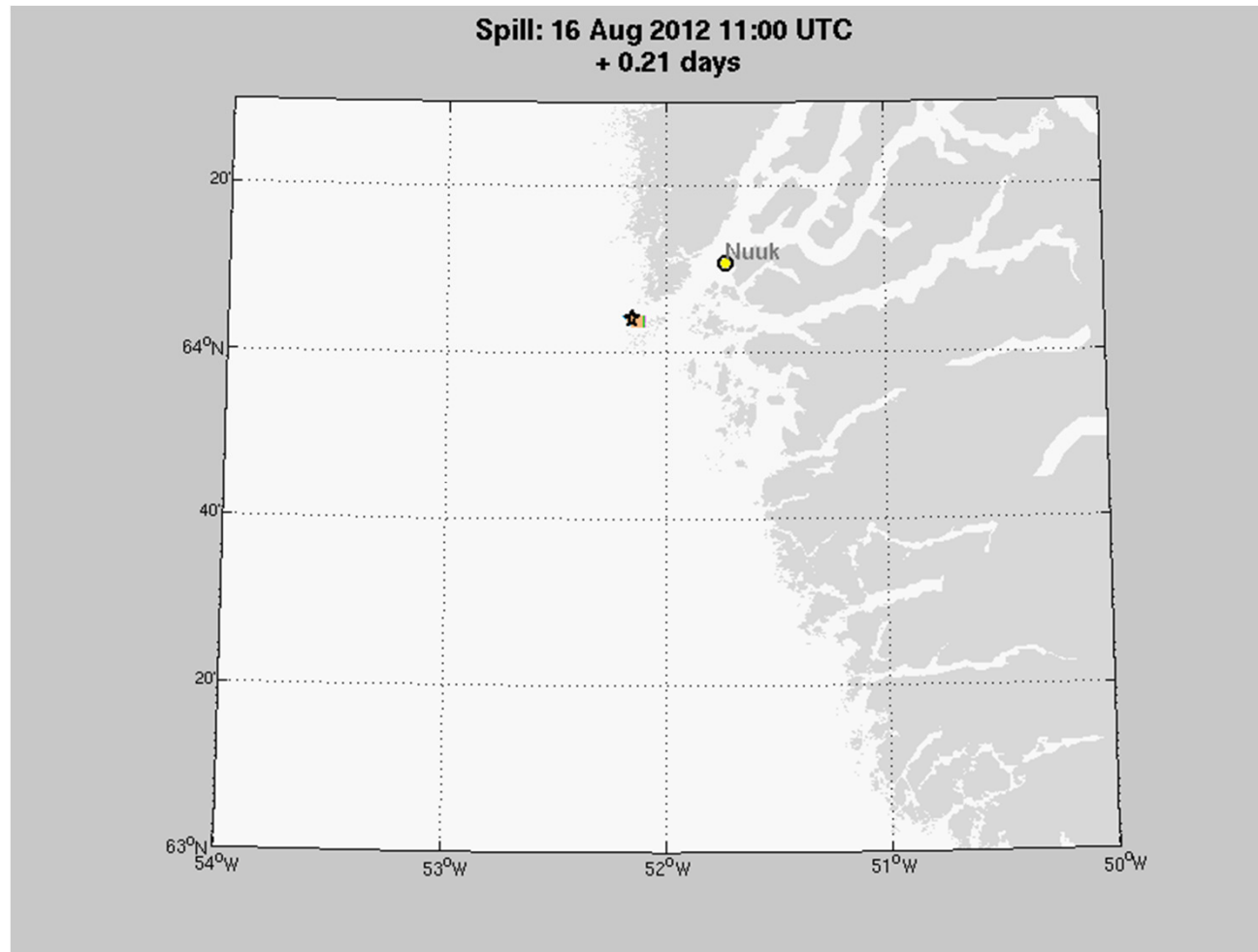
**Spill: 29 Aug 2012 22:00 UTC
+ 99 hours**



Vega Sagittarius

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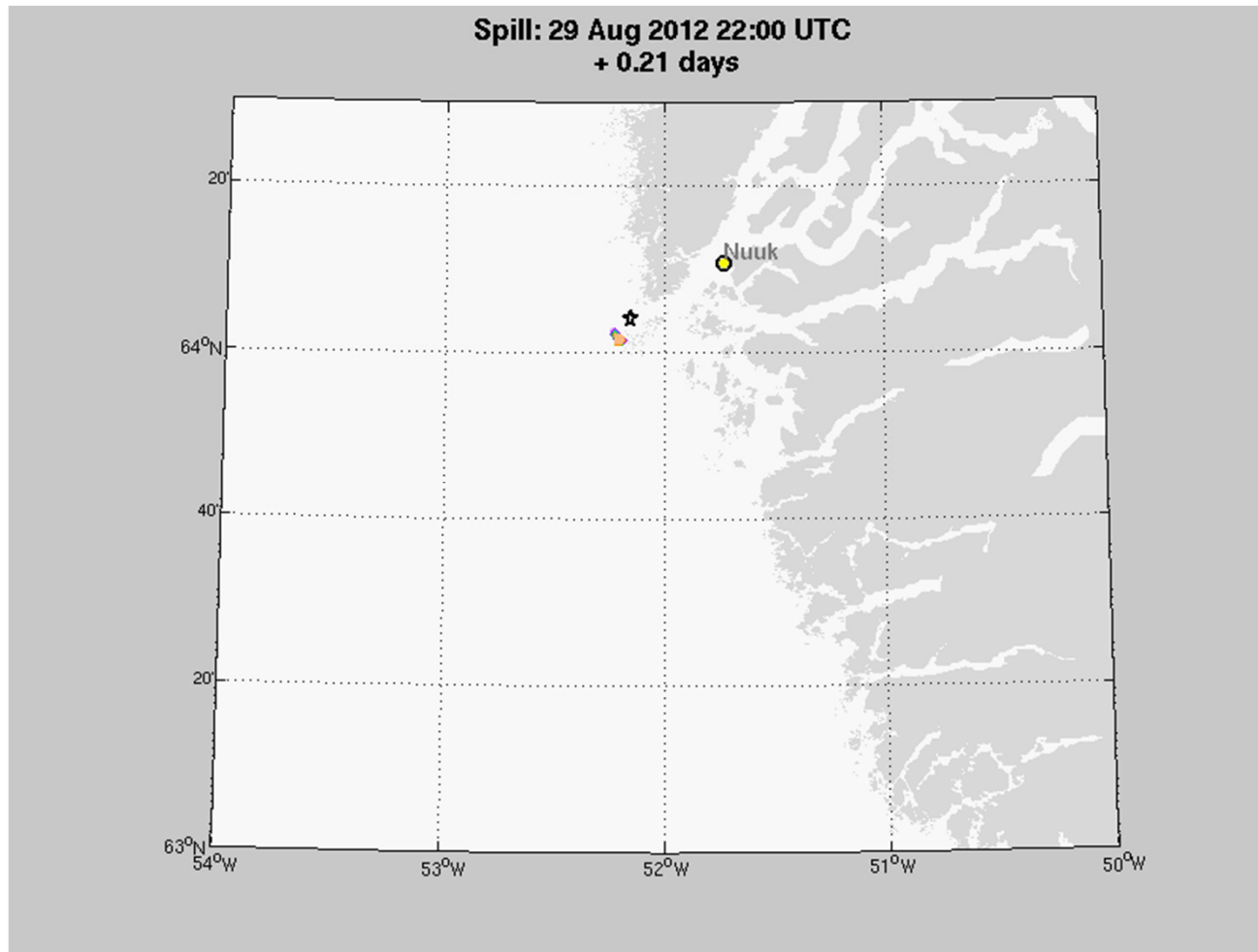
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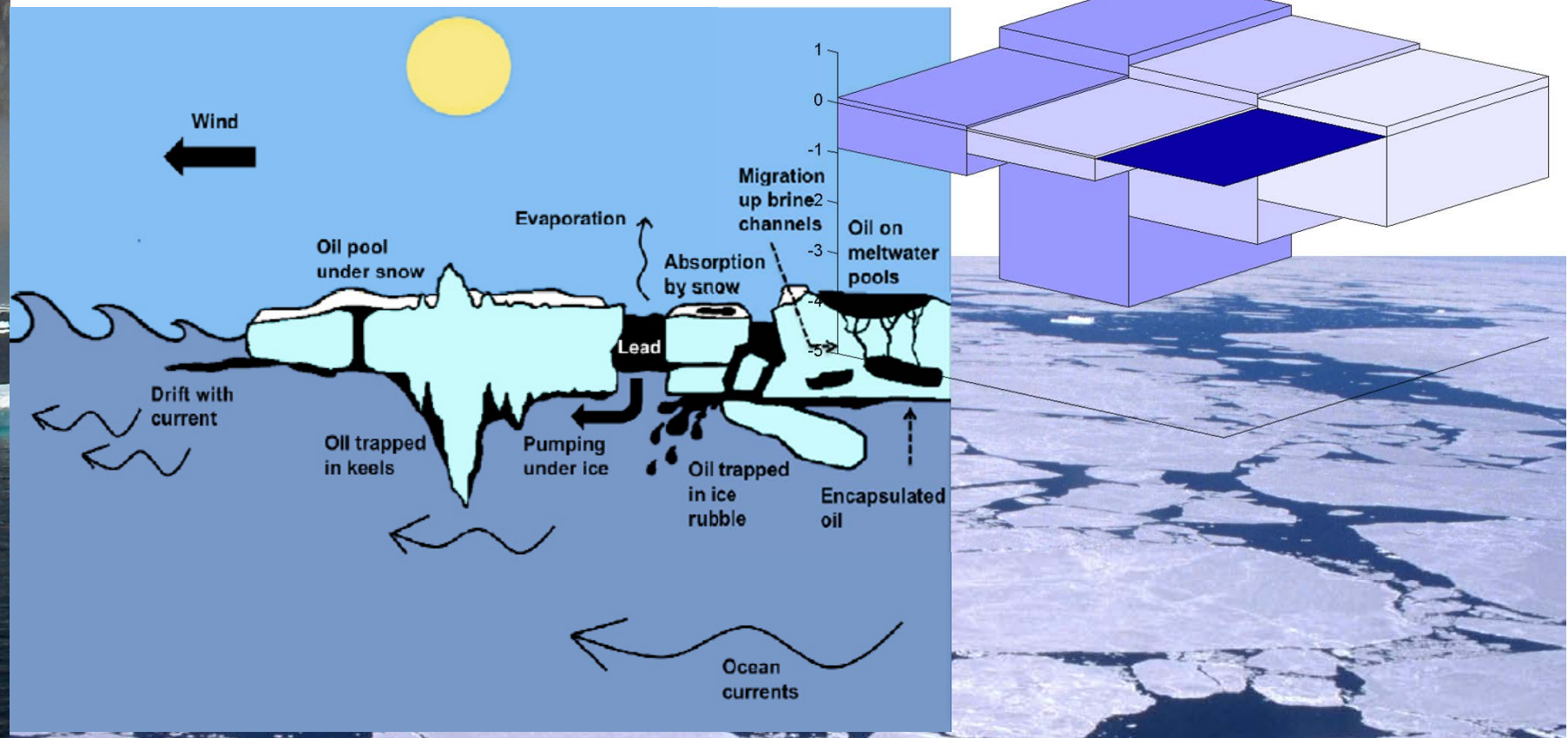
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Oil drift in sea ice affected waters

- Wind drag limited - *implemented*
- Oil will partly drift with the ice - *implemented*
- *Oil will be trapped in pockets under the ice, freeze into the ice etc. – reducing weathering processes*



Summary

- Operational 6 days forecast twice a day with coupled HYCOM-CICE model using ECMWF 16 km forcing
 - Provide ice forecast for the DMI ice service
 - Feed into operational Oil drift model
 - Ocean and ice information for maritime operations
- 10 year hindcast simulation using ERA-Interim forcing
- Sea ice thickness / volume reasonable
- Interannual variability of sea ice at Cape Farewell captured
- Combination of weather, ice forecasts and high res. satellite products is a strong product for Arctic shipping

