Developing the high resolution sea ice forecasting system HAMMER based on regional atmosphere, sea ice and ocean models

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a: www.mi.uni-hamburg.de b: www.ifm.uni-hamburg.de c: www.dkrz.de

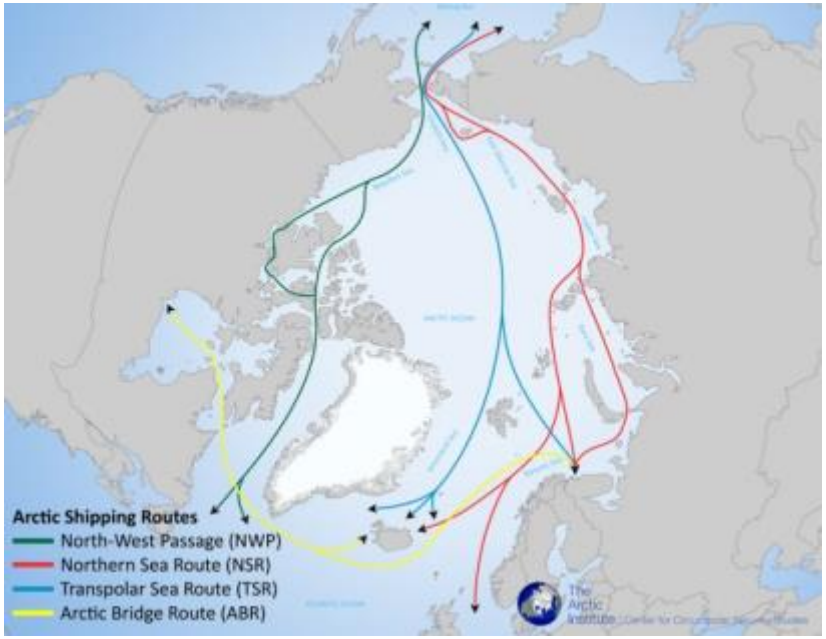
IRO-2: Project team and funding

- 6+1 Project partner
- Team @UHH: MI + IfM
- BMWi 2011-09 / 2014-09
- National Masterplan for Maritime Technologies

FastOpt
O.A.Sys Ocean Atmosphere Systems
HSVA
AWI
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG
Universität Bremen
BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

IRO-2: Mission statement

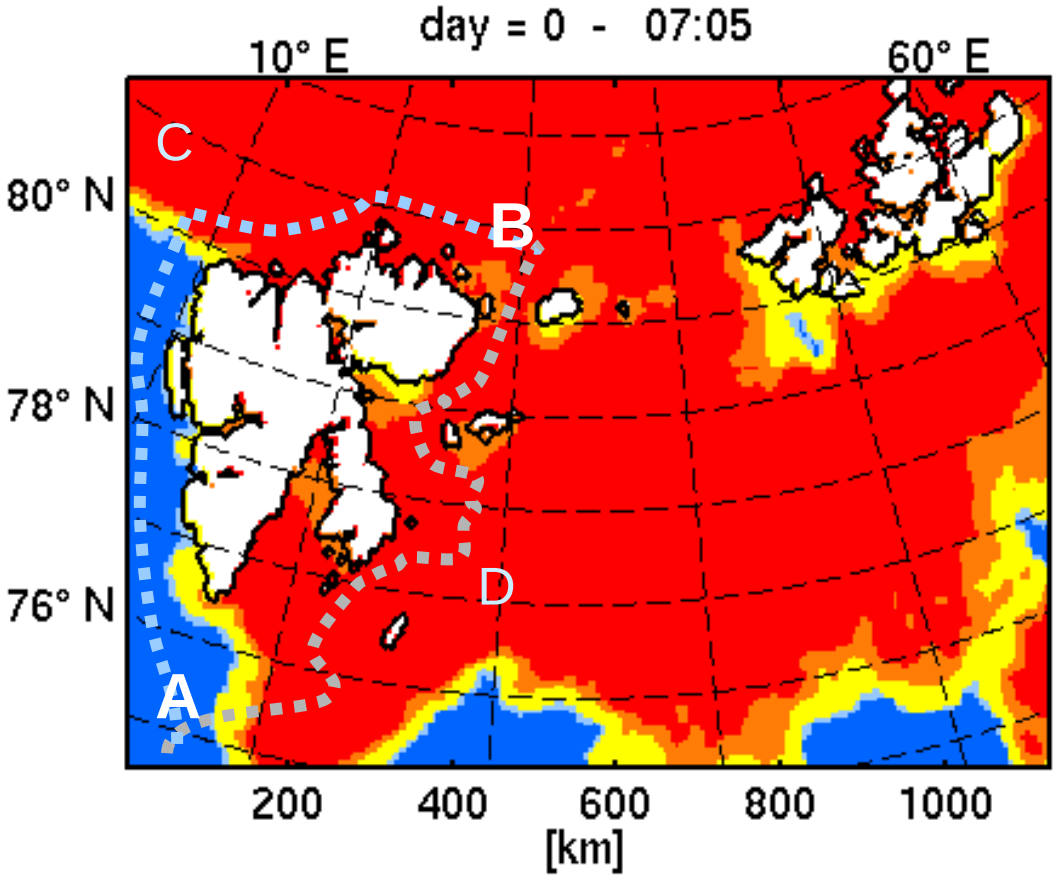
- **Goals**
  - Safe and economic Arctic shipping
    => Ship routing based on current and forecasted sea ice conditions
  - Responsible operation of platforms
    => Forecasts for offshore industry
  - Arctic engineering and product design
    => Virtual reality for ship design, classification, insurance ...
- **Methods**
  - Remote sensing of sea ice
  - Atmosphere/sea-ice/ocean - models
  - Ship speed impact model

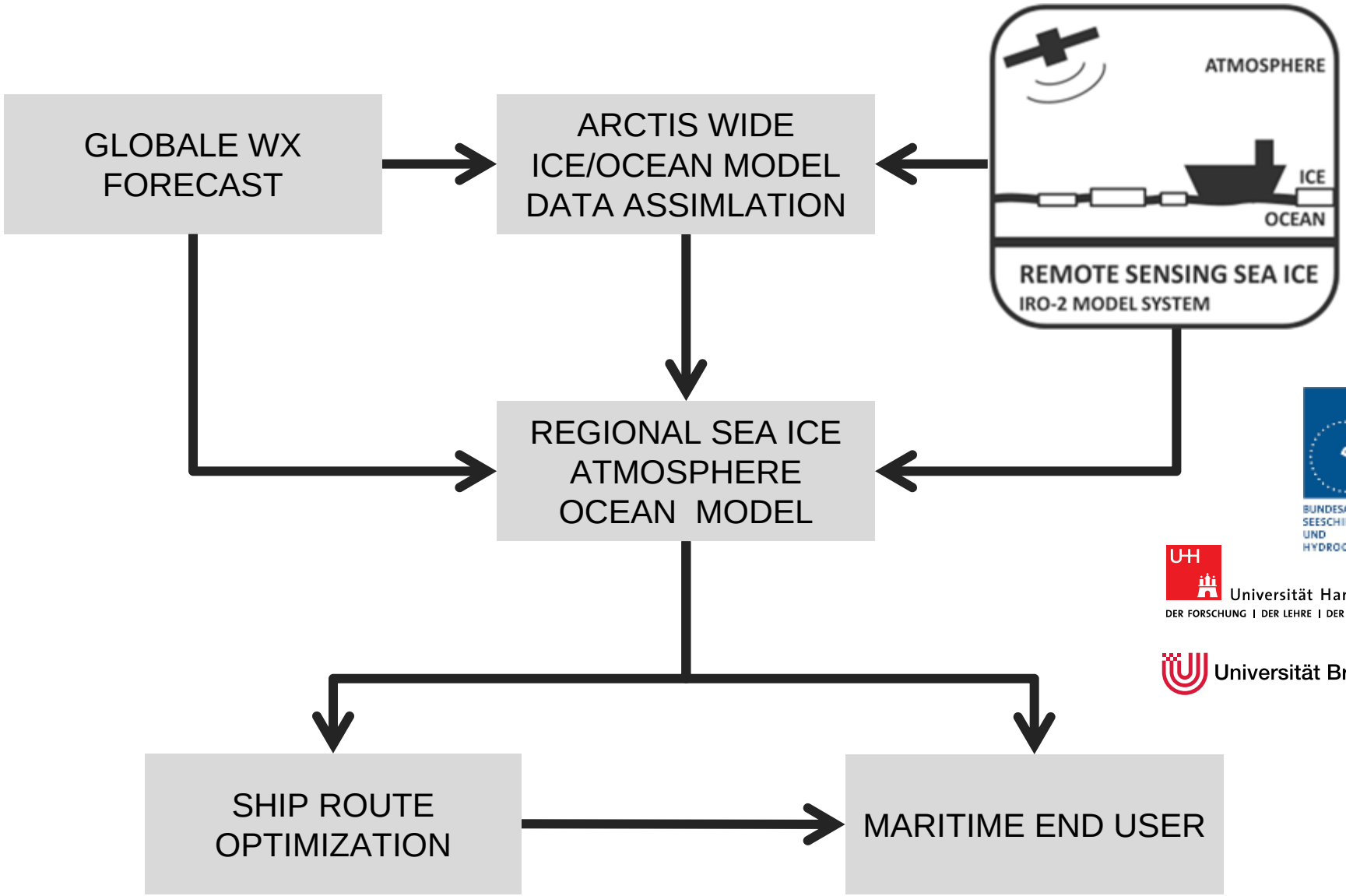


Humpert, M. and Raspotnik, A. (2012): The future of Arctic shipping. The Arctic Institute. http://goo.gl/9Bja3

IRO-2: Practical questions of end users

- Best route form A to B?
- Required ice class of ship?
- Estimated travel speed and fuel consumption?
- Risks for crews, charter schedule, environment?





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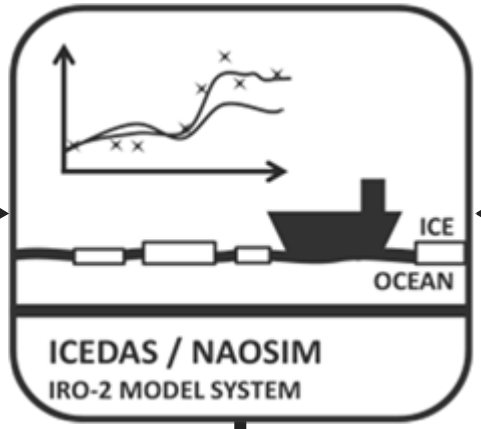


GLOBALE WX FORECAST

REMOTE SENSING

REGIONAL SEA ICE ATMOSPHERE OCEAN MODEL

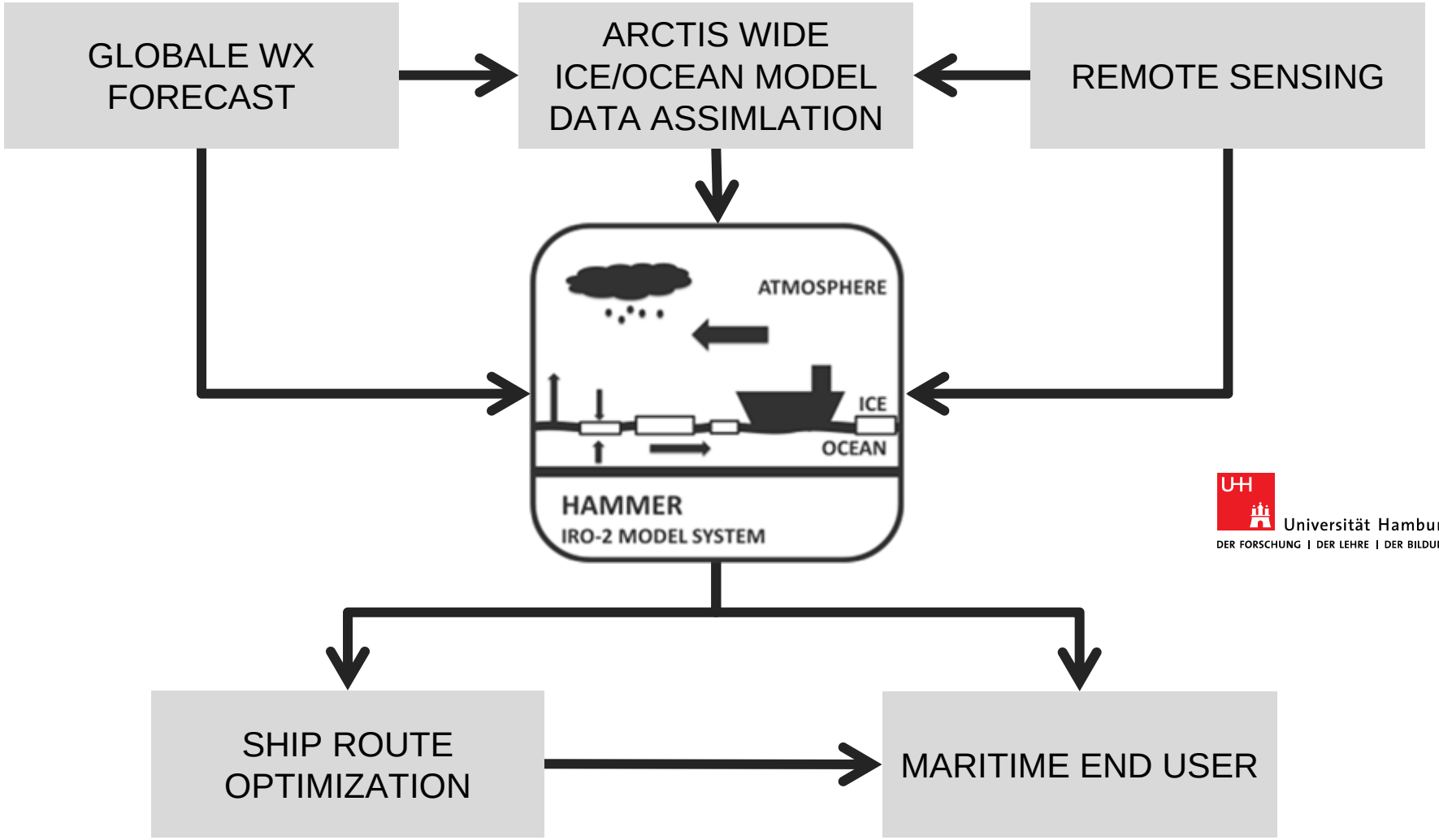
SHIP ROUTE OPTIMIZATION

MARITIME END USER

AWI

O.A.Sys Ocean Atmosphere Systems

FastOpt



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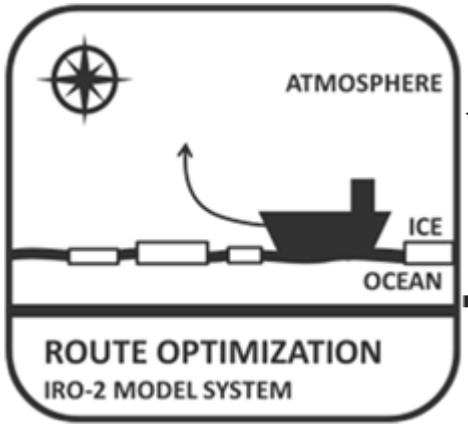
GLOBALE WX FORECAST

ARCTIS WIDE ICE/OCEAN MODEL DATA ASSIMLATION

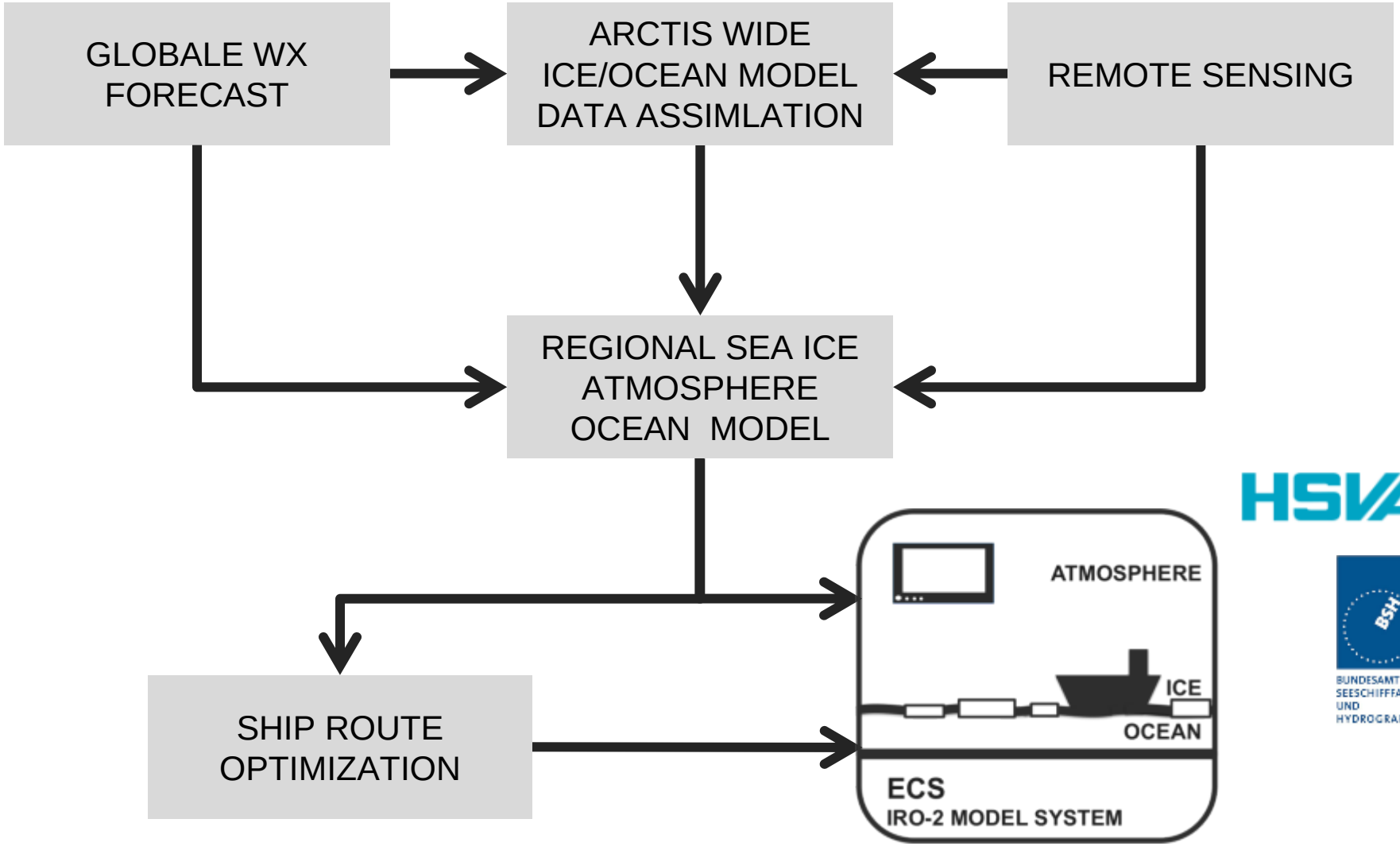
REMOTE SENSING

REGIONAL SEA ICE ATMOSPHERE OCEAN MODEL

HSVA



MARITIME END USER



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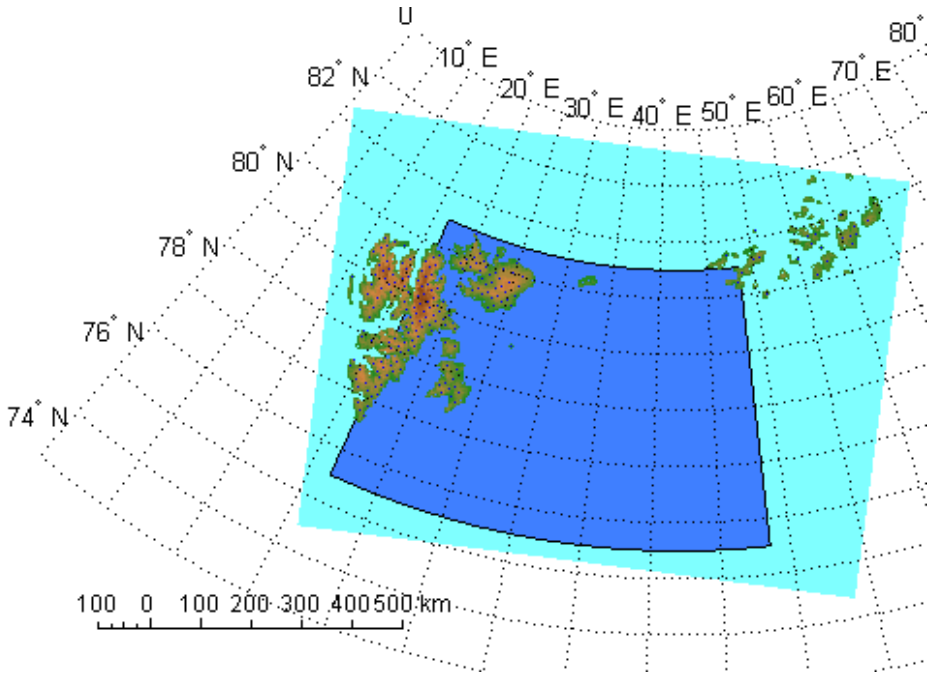
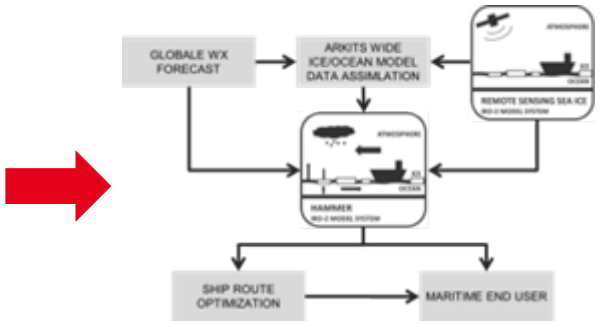
Modelling @ UHH

- Regional IRO-2 model setup in short
  - Test region Barents sea
  - 8.300 x 11.250 km
  - dx = 5 km
  - Few days forecasts
  - Running on one IBM Power 6 node
  - Atmospheric forcing ECMWF HRES
  - Sea ice initial conditions from satellite
  - Additional boundary conditions from ICEDAS/NAOSIM
  - Coupling regional models for sea ice - atmosphere - ocean

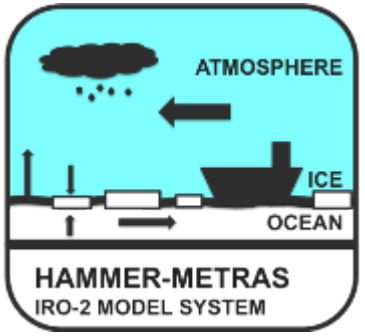


HAMMER: "Hamburger System für mesoskalige Eisvorhersage zur Routenoptimierung"

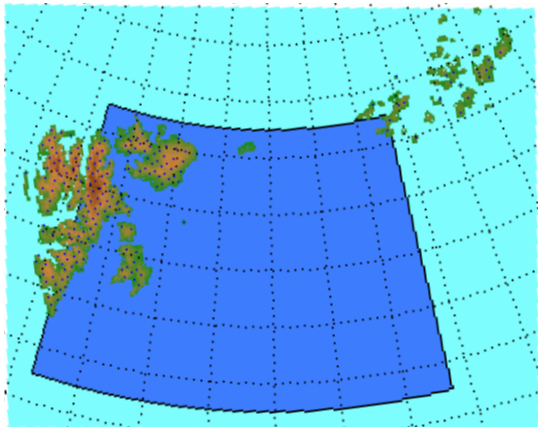


HAMMER MODEL COMPONENTS

- METRAS - atmosphere
  - Anelastic, Boussinesq approximated non hydrostatic atmospheric model
  - Terrain following coordinates
  - Subgrid scale land use
  - Developed at MI UHH based on Schlünzen (1988)

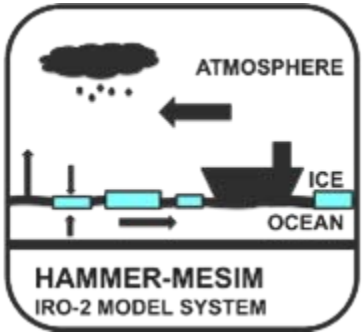


- MESIM – sea ice
  - …

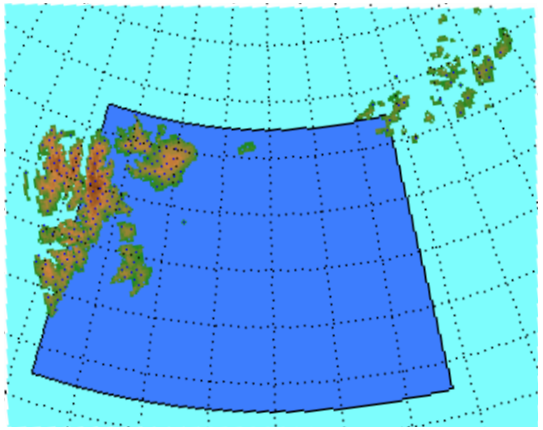


- HAMSOM – ocean
  - ….

HAMMER MODEL COMPONENTS

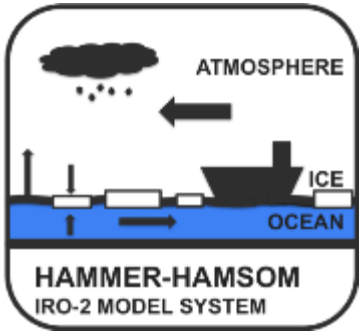


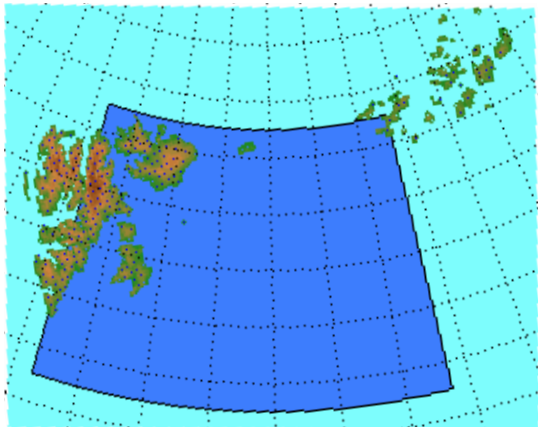
- METRAS - atmosphere
  - …
- MESIM – sea ice
  - Multiclass sea ice physics
  - Multilayer thermodynamics
  - Advection scheme with low diffusion
  - Directly coupled to atmospheric model METRAS
  - Originally ported from an AWI sea ice model (Birnbaum, 1988), since then under development at MI UHH
- HAMSOM - ocean
  - …



HAMMER MODEL COMPONENTS

- METRAS – atmosphere
  - …
- MESIM – sea ice
  - …
- HAMSOM – ocean
  - Shelf ocean model based on primitive equations
  - Free surface including equations for temperature and salinity (Pohlmann, 1996)
  - Z coordinates, regular lon/lat grid
  - Developed at IfM UHH based on Backhaus (1985)



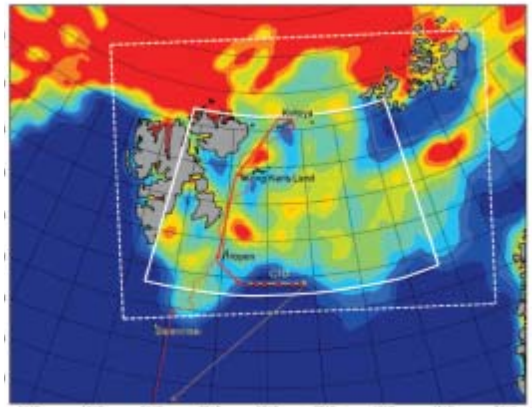


IRO-2 Validation Experiment - 2014-03

- Ship based measurements
  - 10 days test of forecast and routing system on board of an ICE-1A ship in first year ice
  - Collecting ice, ocean, atmosphere and ship data
- Buoy based measurements (CliSAP funding)
  - Approx. 16 buoys to measure ice drift
  - Airplane based deployment in target region
- Forecast experiment
  - Operational forecast of sea ice and route conditions
  - Broadcasting to ship including back communication of route planning

Observation 1970-2011
www.ncdc.noaa.gov/cdo-web

SMOS 2011-04-01

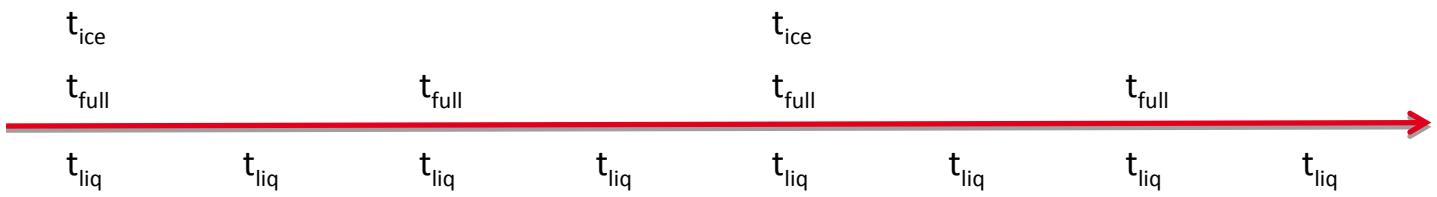


Development of regional model HAMMER

- **Reviewed and improved physics**
  - Improved use of remote sensing data
  - Coupling to ocean (e.g. to get tide influence)
  - Checking sensitivity / required processes
- **Faster numerics**
  - …
- **Technology and model system**
  - …

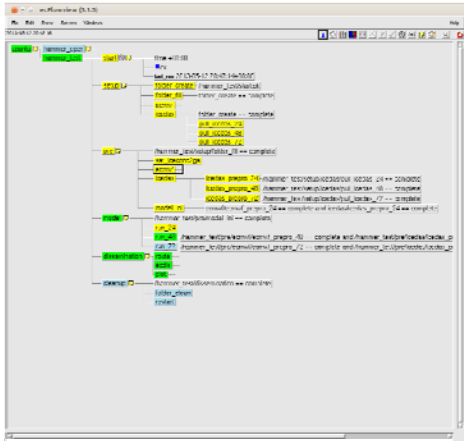
Development of regional model HAMMER

- **Reviewed and improved physics**
  - …
- **Faster numerics**
  - Pressure solver rewritten by DKRZ
  - Process time-split (cloud physics, sea ice, turbulence)
- **Technology and model system**
  - …



Development of regional model HAMMER

- **Reviewed and improved physics**
  - ...
- **Faster numerics**
  - ...
- **Technology and model system**
  - Embedding in IRO-2 Dataflow
  - Development of new operational run suite, useful: https://software.ecmwf.int/ecflow
  - Increase model speed, useful: SCalesTimer Lib https://redmine.dkrz.de/doc/sct/html/

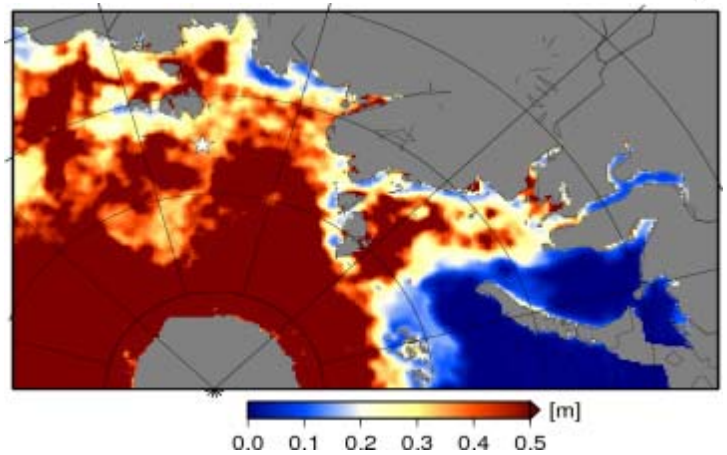


Model setup: Sea ice initialization

Sea ice thickness – SMOS

- 1.4 GHz allows to detect the ocean-ice interface for not too thick ice
- Brightness temperature related to sea ice thickness up to 0.5 m
- Daily coverage with 35 km resolution
- Number of interference sources decreasing
- Data at http://icdc.zmaw.de/smosice.html

2010-11-15



Kaleschke, et al. (2012): Sea ice thickness retrieval from SMOS brightness temperatures during the Arctic freeze-up period, Geophys. Res. Lett. http://doi.org/mgv

Sea ice Concentration – AMSR2

- Current re-forecast tests with SSMIS (dx = 12 km)
- Updating to AMSR2 / AMSR-E (dx = 3.125 km, 4-5 km footprint)

smosice
support to science element

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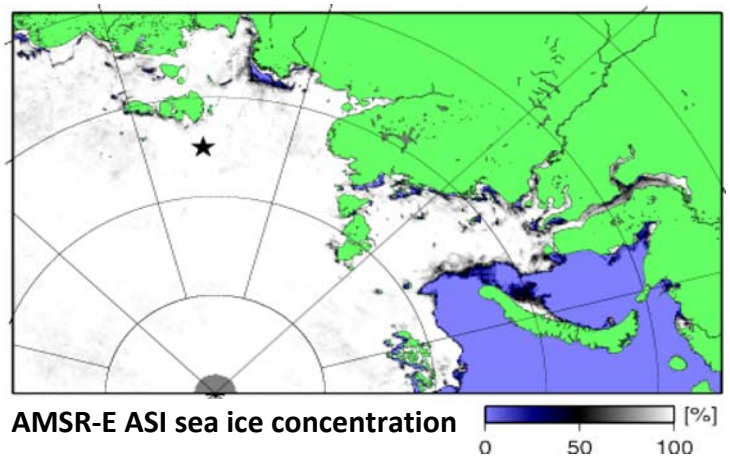

Spreen, G., L. Kaleschke, and G. Heygster (2008): Sea ice remote sensing using AMSR-E 89-GHz channels, J. Geophys. Res., 113, C02S03, http://doi.org/cgfzk8

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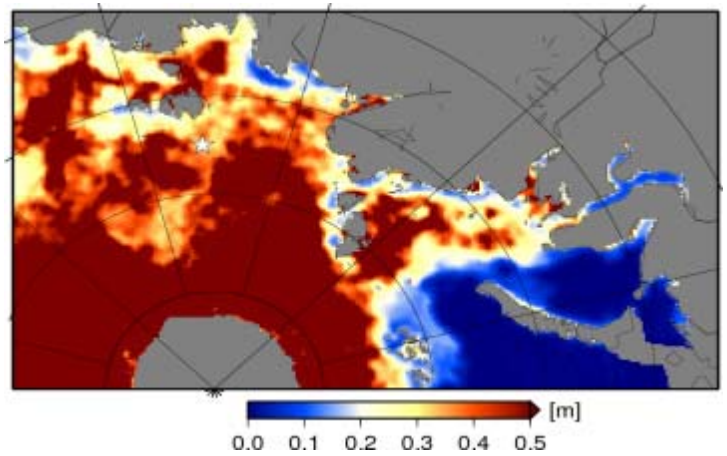
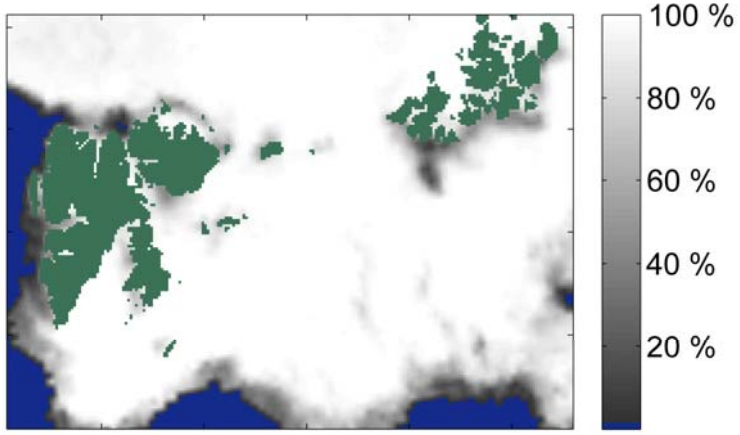


Kaleschke, et al. (2012): Sea ice thickness retrieval from SMOS brightness temperatures during the Arctic freeze-up period, Geophys. Res. Lett. http://doi.org/mgv

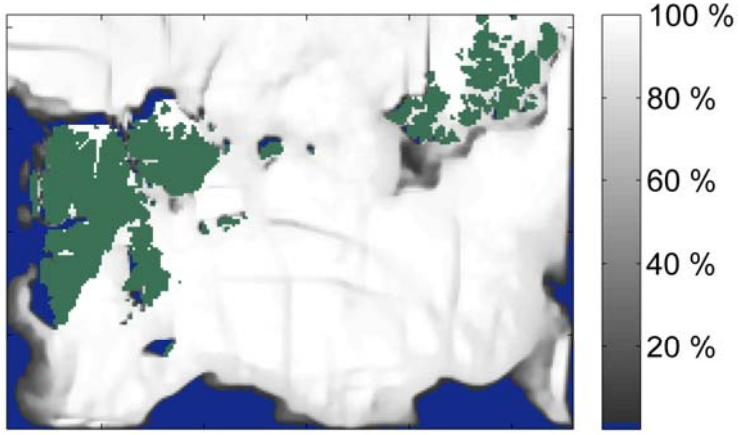
smosice
support to science element

Sea ice concentration: simulation vs. observation

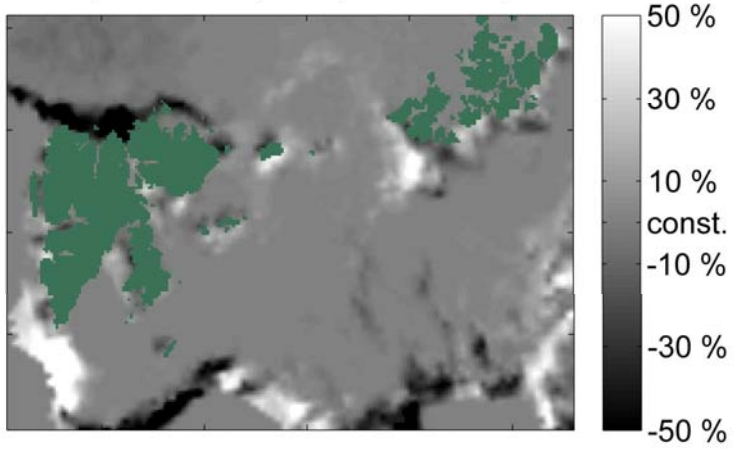
Satellite 2011-04-03



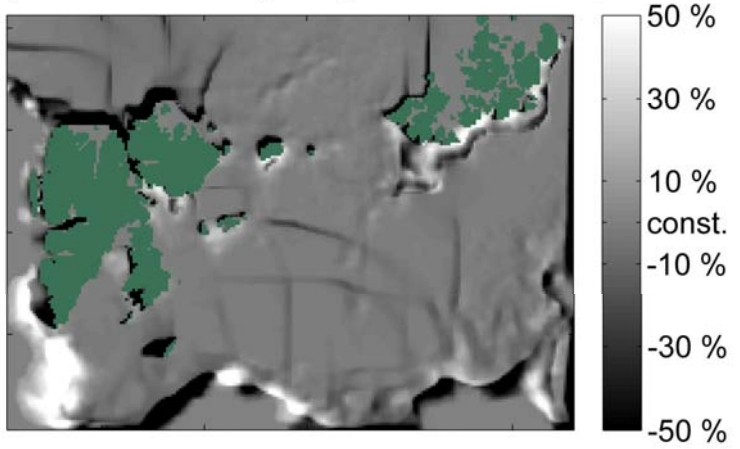
Model 2011-04-03 08:00



S(2011-04-03) - S(2011-04-01)

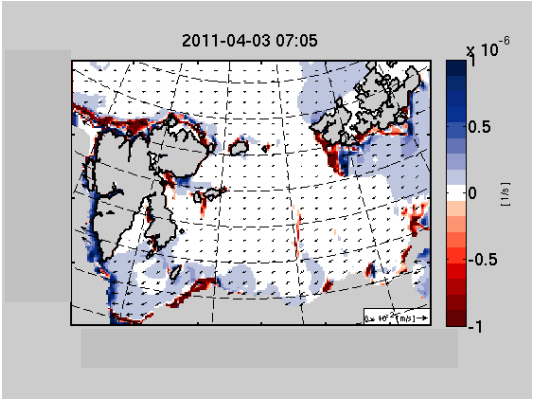


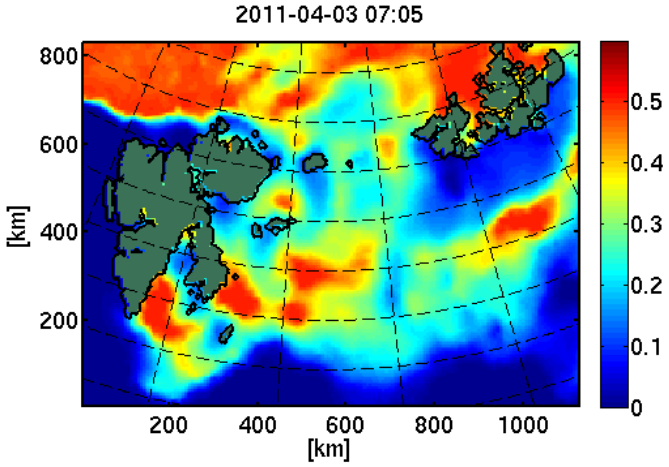
M(2011-04-03 08:00) - M(2011-04-01 08:00)

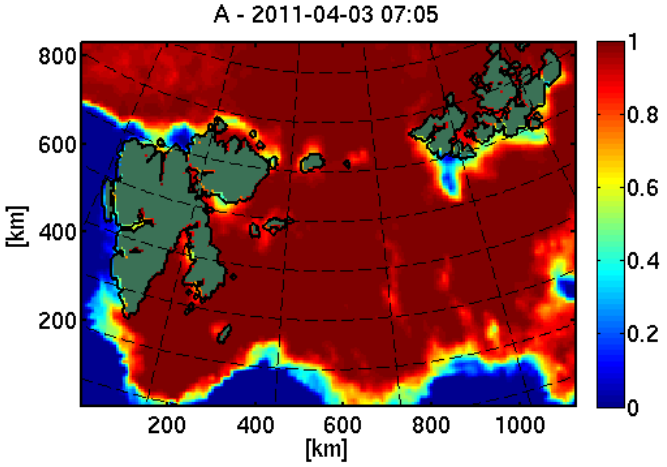


Motion of vessels in ice covered waters

- Data needed from models
  - Weather conditions
  - Sea ice thickness
  - Sea ice concentration
  - Ridges and Leads (sub grid scale)
  - Near surface currents







Known challenges and limits

- Challenges we try to target ourselves
  - Speed to improve possible resolution / domain size / forecast length
  - Robustness and validation of model system
  - Improvement of physical features

- Limitations currently out of our control
  - Limited band width for data transfer to high latitudes
  - Only few observations in the Arctic
  - Dependence on driving models

Summary

- Development HAMMER
  - Regional model based on METRAS, MESIM & HAMSOM
  - Prototype as component for maritime decision support system
  - Main focus on system development by including

- IRO-2
  - Remote sensing of sea ice
  - Arctic wide sea ice / ocean data assimilation
  - Regional atmosphere / sea ice / ocean modeling
  - Ship specific impact model
  - Validation experiment in 2014-03

Discussion on regional sea ice / atmosphere modelling

- Ideas
- Comments
- Questions